An international initiative on geosynthetic education

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Abstract: An international educational initiative to facilitate the exposure of geosynthetics to undergraduate civil engineering students has been conducted by the International Geosynthetics Society (IGS) for over a decade. Geosynthetics is a comparatively new topic within geotechnical engineering and, consequently, has only been sporadically introduced into undergraduate Civil Engineering curricula. In particular, geotechnical engineering professors themselves may have not been exposed to the basics of geosynthetics to be able to comfortably transfer such knowledge to their students. As part of this educational program, civil engineering professors are invited to take a course on geosynthetics, for which they receive fellowships covering their expenses. The course also includes complementary components such as a workshop consisting of practical demonstrations, pedagogical material, and technical documents. Implementation of the program involves multiple parties, including the IGS, its national chapters, and geosynthetics industry, who are allotted the responsibilities of supporting the program instructors, offering practical project-oriented input. This paper describes the course structure, the educational tools employed, the impact on the program caused by the pandemic, and results from feedback surveys that assessed how the knowledge on geosynthetics acquired by the participants was transferred to their students in terms of new courses on geosynthetics, inclusion of geosynthetics topics in existing undergraduate disciplines, etc. Emphasis is given on the experience of the Brazilian Chapter of IGS, which has already conducted programs. The educational outcomes of the programs currently offered are being evaluated and they suggest excellent acceptance of the course by participants and undergraduate students at the universities.

Keywords: Geosynthetics; Education; Instructor training; Undergraduate education.

1. Introduction

Civil engineering (CE) programs are currently facing increasing technical challenges in relation to the continuously evolving nature of engineering works, which require knowledge of new materials and technologies. However, while CE curricula need to provide such new knowledge to young engineering graduates, they also need to limit the offerings of disciplines in undergraduate civil engineering courses. Accordingly, to ensure that these courses remain relevant and effective, new materials such as geosynthetics must be included but in a way that become integrated into existing syllabi. In this context, geosynthetics are a comparatively new technology in civil engineering, and therefore introducing them into undergraduate courses is a priority but also a challenge for disseminating such knowledge among future civil engineers.

An international training program called "Educate the Educators (EtE)", initiated in 2012 under the auspices of the International Geosynthetics Society (IGS), is addressed to university professors in civil engineering, and aims at providing the content and pedagogical tools necessary for them to teach undergraduate civil engineering students on geosynthetics. An important goal of the EtE program is to provide undergraduate civil engineering students with, at least, a one-hour lesson on geosynthetics. This content should be offered in mandatory disciplines of the fundamental engineering courses, so that every undergraduate engineering student will have received a basic knowledge of geosynthetics before they graduate.

The EtE program provides participants with grants to cover their expenses for a typically two-day-long course. Instructional material from theoretical and practical classes and instructional documents are provided to the participants. The EtE program also includes more advanced modules addressing the design of geotechnical systems using geosynthetics, such as retaining walls, embankments, roads, and waste containment facilities. The educational outcomes of the programs currently offered are being evaluated and they suggest excellent acceptance of the course by participants and undergraduate students at the universities.

2. Timeline

Geosynthetic materials were introduced more than half a century ago and have been widely adopted in engineering applications to fulfill functions such as separation, stabilization, drainage, wastewater and landfill applications (cushions and liners) (Koerner, 1986; Zornberg et al., 2020). Over four decades ago, on November 20th, 1983, the International Geosynthetics Society (IGS) was established (Zornberg 2013) and the first edition of the landmark textbook "Designing with Geosynthetics" (Koerner 1986) was published. The IGS is a learned society dedicated to the scientific and engineering development of geotextiles, geomembranes, related products, and associated technologies. The purpose of the IGS is to provide understanding and promote the appropriate use of geosynthetic technology worldwide.

In the early days of geosynthetic use, applications focused primarily on the use of geotextiles for projects involving drainage, filtration and soil reinforcement and of geomembranes for applications requiring a barrier function. Over the past 50 years, these products have evolved significantly and nowadays there is a wide variety of geosynthetic products from an ever-increasing number of manufacturers, as exemplified in the annual Geosynthetics Specifiers Guide (IFAI 2018). The functions and applications of these materials in geotechnical and environmental protection works have also expanded significantly.

A of using geosynthetics include their speed of installation, ease of deployment in remote areas, comparatively low construction costs, availability of a wide range of products, reduction or elimination of the use of natural construction materials, uniformity of mechanical and hydraulic properties, increasing number of established design methodologies, and reduced environmental impact of geosynthetic solutions compared to conventional alternatives. Research carried out in recent decades has also shown that engineering solutions using geosynthetics result in more sustainable alternatives, having lower impact on the environment than traditional solutions (Palmeira et al., 2021).

According to Zornberg et al. (2020), despite the aforementioned advantages, geosynthetics continue to be regarded as a new product by many practitioners in the civil engineering industry, mostly due to the lack of familiarity with geosynthetics and their benefits. The adequacy of current design approaches involving geosynthetics has been validated certified through the success of a myriad of existing projects, the availability of numerous standards (ASTM, ISO, CEN, ABNT and others), the increasingly effective quality control in testing procedures, as well as the availability of design manuals and training courses.

A more plausible explanation for the still insufficient adoption of geosynthetics is the lack of education on geosynthetics, as most undergraduate university programs do not include geosynthetics in their curricula. The IGS Council decided in 2010 to set up a program to educate academics about geosynthetics so that they could introduce geosynthetics into their undergraduate courses and thus train future generations of engineers. The objectives of the "Educating the Educators" program were established to assist the educator in introducing geosynthetics as a relatively new and promising technology within civil engineering.

EtE programs result from the initiative of a national chapter IGS, with subsequent involvement from the IGS. The IGS provides financial support to cover travel expenses of the instructors of an EtE event, and also provides educational materials such as a sustainability video, technical handouts, and glossary of geosynthetic terminology. The overall implementation of an EtE event requires a partnership involving the IGS, the local IGS chapter, the local geosynthetics industry, and national civil engineering faculty associations.

To support the IGS mission, an international foundation (the IGS Foundation) was established in 2021 with the objective of collecting donations from different segments of the geosynthetics community for subsequent allocation to important initiatives such as education outreach. For example, a recently supported initiative involved the production of a series of educational videos by two professors from universities in the USA and Brazil. The videos, including basic content on geosynthetics and instructions about practical workshops of the EtE course, were published and are publicly available, for use by undergraduate professors at their universities.

According to Zornberg et al. (2020), The inaugural “Educate the Educators” program was held in May 2013, in Carlos Paz, Cordoba Province, Argentina. This first event was organized by the Argentinian chapter of the IGS, with the support of the International Geosynthetics Society and in cooperation with the Argentinian Society of Geotechnical Engineering. The event brought together 40 professors from 18 different Argentinian universities, representing 19 different cities across the country and the selection criteria involved the professor’s stage in the academic career, experience, maximum academic degree reached and geographic diversity. At least one professor was selected from each university.

From the inaugural program in 2013 to April 2023, a total of 22 additional EtE programs have been conducted. Figure 1 shows the locations of the EtE programs completed to date. As the figure illustrates, 23 EtE programs have already been conducted (Zornberg et al., 2020; IGS 2023). Three more EtE are planned to be held in 2023, reaching 26 events in 15 countries, with over 700 educators trained. Demand for implementation of additional programs has continued to increase. The broad geographical implementation of the EtE program illustrates the significant interest in geosynthetics education worldwide and the motivation of IGS chapters.

However, Figure 1 shows a comparatively higher concentration of EtE in the American continent.

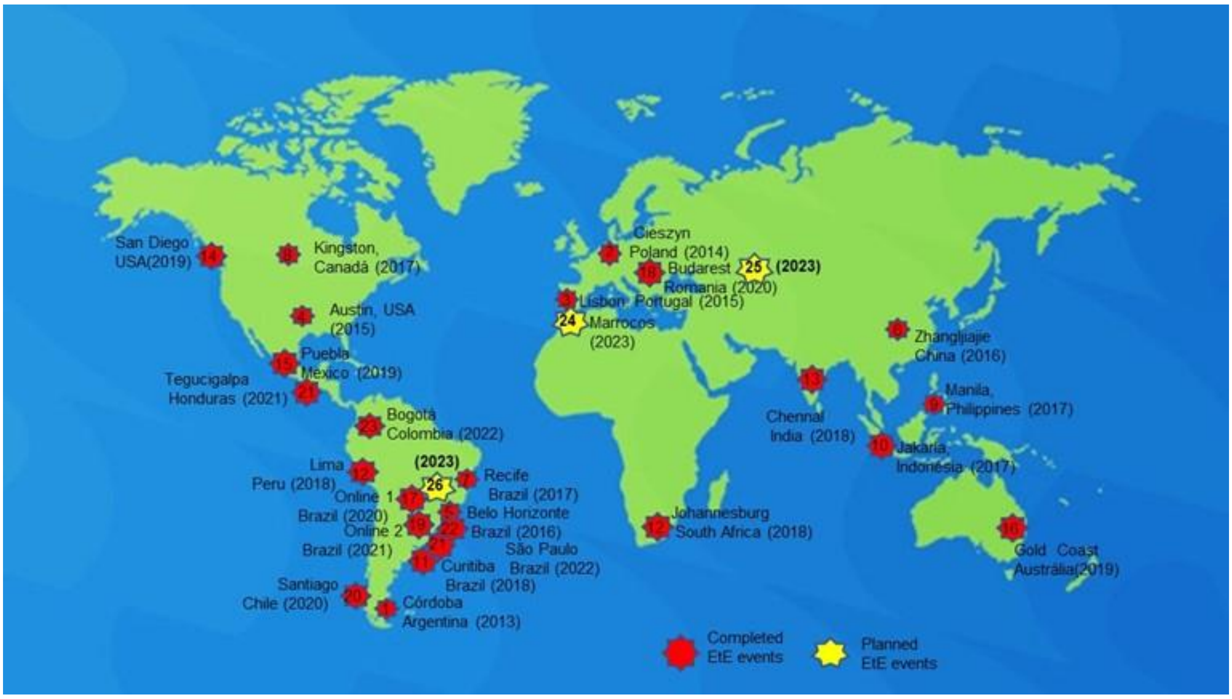

Figure 1. Geographic distribution of Educate the Educators programs conducted up to April 2023 and planned within a 12-month period.

Table 1 presents results from the IGS evaluation of EtE programs conducted from 2015 to 2020 (IGS, 2023). The results show that 17% of the participants from have been able to include geosynthetics in existing disciplines and have created disciplines on geosynthetics.

3. Structure of the EtE Program

3.1. Objectives

As previously mentioned, the overall goal of the EtE program is to provide basic knowledge about geosynthetics to all undergraduate civil engineering students.

The consensus is that the focus on education should involve providing basic information about geosynthetics, even if only a one-hour course within a four-year program, but to all undergraduate civil engineering students. Since they share the same curriculum as civil engineering, geotechnical, structural, environmental, transportation, construction, and hydraulic engineers will also benefit from at least this basic knowledge of geosynthetics before they graduate.

Table 1. Outcomes of the EtE programs conducted from 2015 to 2020 in the world (IGS 2023).

Year	Country	Number of students	Included GSY in existing disciplines (%)	Created a discipline on GSY (%)
2013	ARGENTINA	25 - 50	NA	NA
2015	USA	0 – 24	20	20
		25 – 50	0	20
		51– 100	0	0
		100 - 150	10	0
2017	CANADA	0 – 24	17	0
		25 – 50	0	8.3
		51– 100	17	0
		100 - 150	17	17
2019	USA	0 – 24	8,3	0
	USA	25 – 50	17	0
	AUSTRÁLIA	25 – 50	17	17
	PERÚ	25 - 50	17	17
	AUSTRÁLIA	51– 100	17	7
	MÉXICO	25 -50	NA	NA
2020	TAIWAN	0 – 24	10	0
		25 – 50	0	0
		51– 100	0	0
		100 - 150	0	0

Note: NA = not available; Data on Brazilian EtE's to be presented later in this paper.

Achieving the goal of the EtE initiative may be especially challenging since civil engineering programs are facing increasing challenges from a vastly expanded curriculum base and the need to limit the entry of new disciplines.

With the ultimate beneficiary of the EtE program being the undergraduate student, the effort of this initiative focuses on training the university professor, who will thereafter provide this basic knowledge of geosynthetics to their students. The specific objectives of each EtE course are as follows:

- Provide material for immediate implementation in at least one class on geosynthetics offered to all civil engineering students at the undergraduate level.
- Provide additional information on geosynthetic applications for implementation in upper-level undergraduate courses.
- Offer information that can also be used for advanced classes or graduate courses.
- Offer information that can also be used for advanced classes or graduate courses.
- Evaluate ways to implement the educational material provided in the classroom.
- Outline the basis for curriculum changes that include geosynthetics teaching.

The specific objectives of each EtE program were often tailored to address needs of the country or region of the event.

3.2. Educational Content

The EtE educational program is delivered by geosynthetic engineering experts (usually 3 professors), from universities in the country where the course takes place or invited from other countries. The content of each EtE program is adapted according to the needs of the local chapter in order to facilitate conveying the experience on geosynthetic by the actual experts delivering the program.

The philosophy of the program has been to offer it only as in-person forums to facilitate the experiential nature of the technical content. Such an approach has allowed EtE faculty delivering the course to interact with attendees, facilitating discussion on teaching methodologies and curriculum issues beyond the technical geosynthetics content. However, during the pandemic period, years 2020 and 2021, continuity of the program required that its delivery be conducted. For example, two of the EtE programs implemented by the Brazilian chapter were conducted online. The Chilean chapter has also conducted its EtE program during the Pandemic using an online format.

The duration of EtE programs is usually two days, with at least 16 hours of instructor contact time. Other durations, such as 2.5 days and 3 days, have been implemented, at least by the Brazilian Chapter, but a duration of two days is deemed the best suited. Each EtE event involves a partnership between the international society and its national chapter, the local geosynthetics industry, and national associations of civil engineering professors.

IGS provides funds to cover travel expenses for program instructors. The responsibilities of the local IGS Chapter are to coordinate activities and funding related to the venue, compilation of educational material (e.g., geosynthetic samples), promotion of the event, and design and execution of the application process and selection of event attendees. The local IGS Chapter, along with industry sponsors, fund local travel expenses (e.g., hotels, meals) for the attending university professors, with only the transportation costs being paid by the participants.

The structure of the different EtE programs has been reasonably similar. For example, the program conducted in Austin, Texas (USA), in 2015, consisted of four modules, which considered four typical undergraduate CE courses (Zornberg, 2020). Table 2 presents the structure of EtE 2015, Austin, Texas, USA (Zornberg, 2020).

- Module 1: A typical “Geotechnical Engineering I” core class
- Module 2: A typical “Geotechnical Design” technical elective class
- Module 3: A typical “Pavement Design” technical elective class
- Module 4: A typical “Environmental Design” technical elective class

In the EtE programs, introductory topics were presented to illustrate the didactics and level of detail expected in undergraduate civil engineering courses. The advanced topics were presented at a higher level with a focus on technical content and should illustrate the level of complexity that designers of systems using geosynthetics must achieve. Discussions were focused on the theoretical content delivered and the implementation of basic and advanced topics in undergraduate courses.

Table 2. Typical structure of an EtE program

Introductory Topics	1. Introductory class on types and functions of geosynthetics materials 2. Introductory class on geosynthetics in soil reinforcement applications 3. Introductory class on geosynthetics in roadway systems 4. Introductory class on geosynthetics for environmental protection
Topics	1. Fundamental properties and related tests on geosynthetics materials 2. Advanced topics on geosynthetics-reinforced soil walls 3. Geosynthetics-reinforced steep slopes 4. Geosynthetics for stabilization of unpaved roads 5. Geosynthetics for stabilization of paved roads 6. Prediction of leakage through geosynthetic liners 7. Factors affecting the service life of geosynthetic liners
Support Activities	Workshops Case histories Discussions

EtE Brazil introduced several innovations, such as an initial class on pedagogical tools for participants to use in their disciplines; two practical workshops presenting different engineering projects to be analyzed using geosynthetics; and the development of the Pedagogical Plan for the discipline of geosynthetics, which was developed during EtE and delivered at the last class by each of the participants. Another interesting innovation introduced by EtE Brasil was the creation of a Mutual Support Network (MSN), with the aim of integrating the participants with each other, with the teachers, and with the IGS Brasil secretariat, during and after the course.

The MSN would grow with each EtE held and interconnect participants from all regions of Brazil.

4. EtE Programs in Brazil

4.1. General description

To satisfy the demand for the program, a total of six EtE courses were implemented in Brazil (2016, 2017, 2018, 2020, 2021 and 2022). Figure 2 illustrates the origin of the attendees throughout the Brazilian territory (modified from Zornberg et al., 2020). The events implemented by the Brazilian Chapter of the IGS are described in this paper as a case study to explain the metrics collected from the participants and the overall outcomes of the EtE programs. The first EtE event in Brazil was held in 2016 in the city of Belo Horizonte (southeastern region of Brazil) and included participants from the entire country. Considering the vast territorial extension of Brazil, it was decided to organize the subsequent EtE's courses in different geographic regions to facilitate outreach to a high number of professors. The regional events included: North and Northeast, Midwest, Southeast, and South. Specifically, the 2017 event was held in the city of Recife (north and northeastern regions); the 2018 edition took place in the city of Curitiba (southern region); the 2020 event, which was the first online EtE (due to the COVID 19 pandemics), aimed at participation from the Midwest region; the 2021, which was also an online event, aimed at participation from the Southeast region. The most recent (2022) event was held in São Paulo and included participants from the entire country. Table 3 summarizes information from the six Brazilian EtE courses, the regions where they were held, and the number of participants in each one.

Despite the country's significant size and the wide distribution of its population, a relatively diverse distribution of participants' origins can be observed in Figure 2, with a greater number of attendees coming from the southeastern and southern regions of Brazil. The organization of such courses has had a major impact on the dissemination of geosynthetics among undergraduate students in Brazil, as will be detailed below.

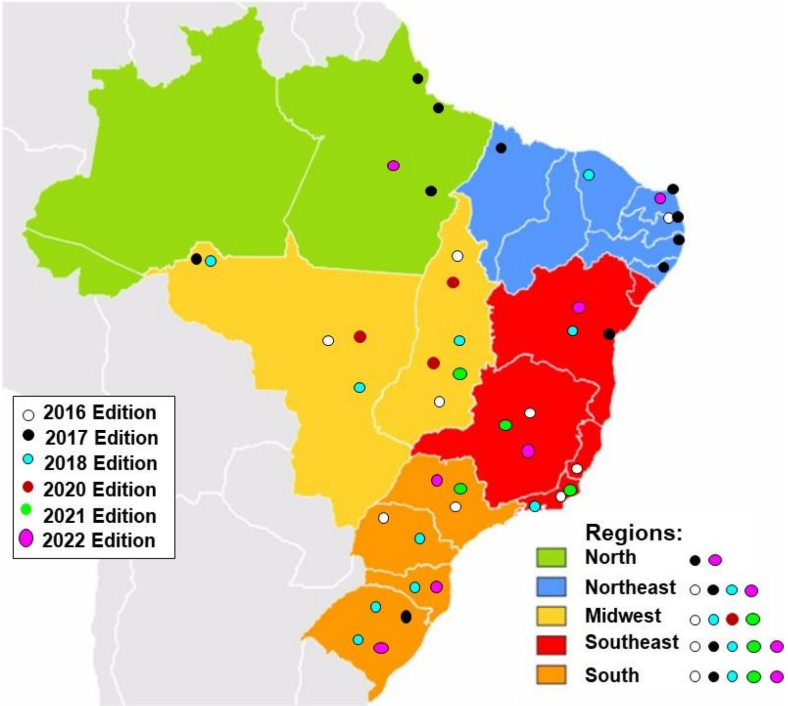

Figure 2. Origin of the attendees to the EtE programs implemented in Brazil.

Table 3. EtE held by region in Brazil and number of attendees.

EtE date	Region	City	Number of attendees
2016	All regions	Belo Horizonte	27
2017	Noth/Northeast	Recife	27
2018	South	Curitiba	30
2020	Midwest	Online	34
2021	Southeast	Online	28
2022	All regions	São Paulo	24

Consistent with the technical content previously described for the EtE program, the EtE courses given in Brazil examined different aspects of geosynthetics applications in civil and environmental engineering works. Overall, the following topics were addressed:

- Introduction to the teaching of geosynthetics at the undergraduate level; objectives of the “Educating the Educators” program; course methodology, pedagogical techniques.

- Geosynthetic types and functions.
- Geosynthetic properties and testing.
- Geosynthetics in filtration and drainage.
- Geosynthetic-reinforced walls.
- Geosynthetic-reinforced steep slopes.
- Reinforced embankments on soft soils.
- Geosynthetics in roadway applications.
- Environmental applications of geosynthetics.
- Hydraulic applications of geosynthetics.

Following core sessions on a given theme, sessions focusing on case histories of engineering works involving geosynthetics were presented to provide additional context involving recent projects. Pedagogical workshops with groups of activities were also conducted, including integrated panels, workshops on recognition of geosynthetic samples, customer and supplier exercises, and a pedagogical workshop for the preparation of the geosynthetics course plan (Masetto, 2003, Coelho, 2012, Coelho, 2016 and Gardoni & Coelho, 2016).

The workshops involve the application of teaching techniques and group dynamics, followed by a discussion of the pedagogical knowledge that underpins class planning, learning evaluation, and the relationship between the teacher, the students, and knowledge. This pedagogical setup is better aligned with the practical learning outcomes associated with geosynthetic materials in engineering, such as the selection of types and functions that the geosynthetics can fulfill, as well as their properties. Participants are also exposed to project challenges during the course to better prepare their undergraduate students for the project challenges they will encounter during their careers.

The Pedagogical Workshop reviews the pedagogical techniques experienced during the course (Integrated Panel, Client and Supplier), the pre-planning of teaching for the subject based on the knowledge acquired in the course, and the Mutual Support Network proposal for continued interaction among attendees, instructors and manufacturers.

4.2. Analysis and results

The benefits derived from the various courses implemented in Brazil were assessed by interviewing attendees at the end of the event and two years thereafter to evaluate if the major course objectives had been achieved. Figures 3(a) to 3(f) present evaluations at the end of the event by the attendees of the six events in Brazil (from 2016 to 2022) (Zornberg et al., 2020). Specifically, the attendees evaluated the courses by assigning a grade ranging from zero (poor) to 5 (excellent) regarding quality of learning, quality of course content and overall satisfaction. As indicated by the ratings shown in Figure 3, the attendees thought very highly of the course in the different categories and in the various events. The evaluations of the three types show increasing scores for EtE 2022 compared with previous years. However, for "Quality of learning" and "Satisfaction with the course", the rating reached 100% compared to the last years.

As part of the evaluation process of the benefits brough by the EtE program, the participants were also interviewed two years after course completion to assess if the main course objectives were accomplished. Approximately 60% of the participants in the 2016 to 2022 courses responded to a questionnaire aimed at evaluating the influence of the course on encouraging them to disseminate the knowledge acquired.

Figure 4 shows that geosynthetics topics had been incorporated to existing disciplines in undergraduate courses by 62% of the 2016 course attendees; elective disciplines on geosynthetics had been created by 15% of them; geosynthetics were included in routine academic events at their institutions by 54% of the attendees. In addition to coursework activities, 15% of the attendees indicated having delivered keynote addresses; and 15% indicated having participated in the offering of geosynthetics short courses. Inspection of the information in Figure 4 reveals some notable highlights, including the fact that geosynthetics topics were included in existing disciplines in undergraduate courses by 90% of the 2017 course attendees (See Figure 4(b)); 54% included geosynthetics in academic events; 10% created a discipline on geosynthetics; 11% delivered keynote addresses and 6% offered geosynthetics short courses.

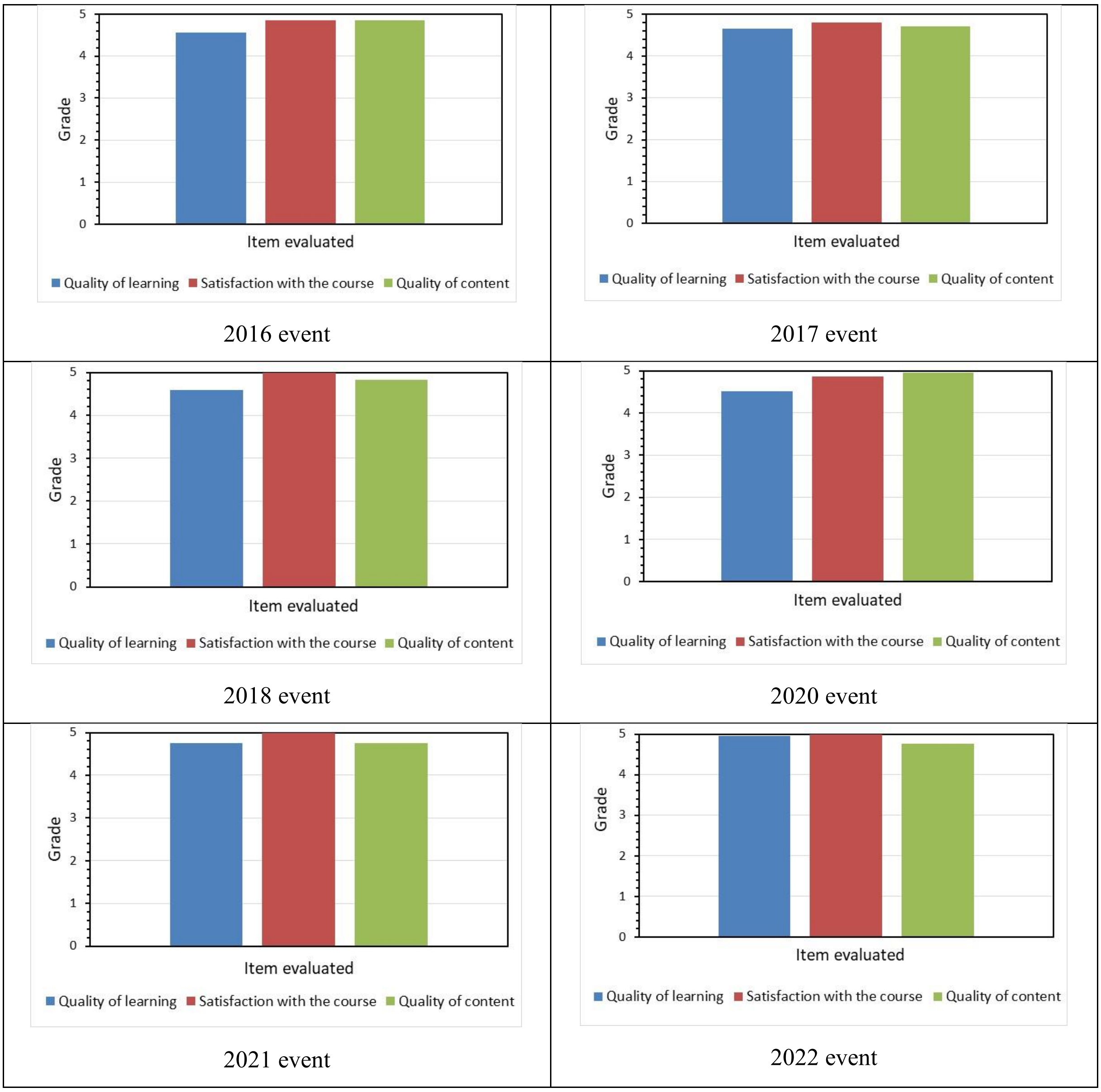

Figure 3. Evaluation of EtE course by attendees.

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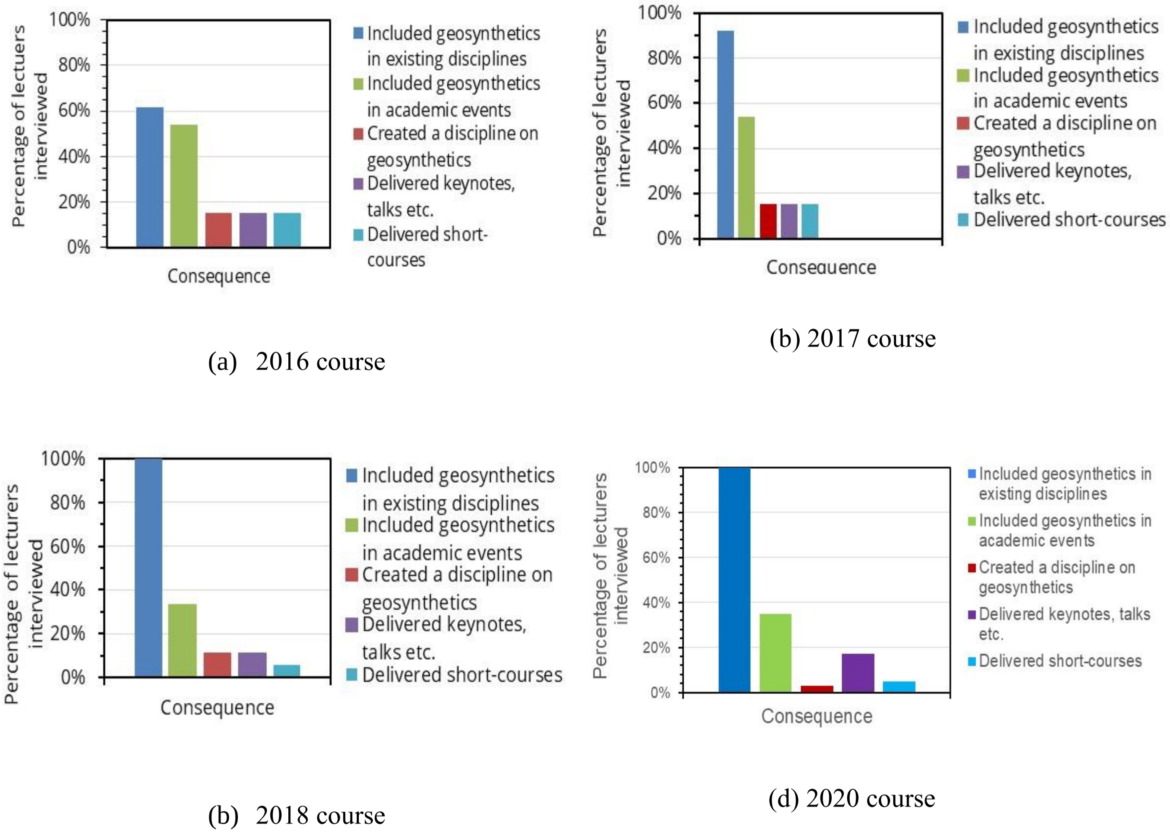
An important achievement regarding the percentage of lecturers who successfully introduced the subject of geosynthetics into existing disciplines was observed. While the 2016 EtE showed 62% of the course attendees having this initiative, for 2018 and 2020 EtE that percentage reached 100%. While the objective of the EtE program was not necessarily to support the creation of a new discipline, it was interesting to observe that 15% of the attendees to the 2016 and 2017 events reported affirmatively to the question "have you created a discipline on geosynthetics?". However, some decrease in this specific outcome was observed in the outcomes of the subsequent EtE events. Yet, the reason for such decrease in this ambitious outcome may have been the determination of the Brazilian Ministry of Education to reduce the number of disciplines in undergraduate courses. In fact, the results of the EtE program in Brazil so far can be clearly qualified as a huge success since a survey pre-dating the EtE program (of the year 2000) had shown that only two universities in the country with disciplines on or incorporating geosynthetics in the curricula of undergraduate courses (Palmeira 2000).

Table 4 shows the number of students enrolled in courses including geosynthetics that the participants in the four EtE programs had delivered by year 2021 in their institutions. Differences between the results of the EtE courses are likely a consequence of differences in academic conditions, curricula, and facilities of the host institutions in different regions of the country.



(a) 2016 course

(b) 2017 course

(b) 2018 course

(d) 2020 course

Figure 4. Percentage of Respondents of EtE programs conducted in Brazil, after two years.

Analysing the results obtained in the online EtE's in relation to the face-to-face EtE's, immediately after the end of the course, they remained practically the same for both, with an increase in "Satisfaction with the course and "Quality of the content. However, in relation to "Inclusion of geosynthetics in existing subjects" there was a significant increase in EtE2020 online compared to the previous in-person courses, but the other items evaluated showed decreasing results. This can be explained by the pandemic that occurred in Brazil in 2020 and 2021.

Table 4. Number of students enrolled in classes on geosynthetics because of EtE programs in Brazil.

Number of Students	2016 (%)	2017 (%)	2018 (%)	2020 (%)	2021 (%)
5 – 20	8	8	6	17	33
20 – 70	31	38	50	58	34
70 – 150	23	23	28	17	33
Over 150	15	8	17	8	0

5. Conclusion.

An international educational program to facilitate the exposure of geosynthetics to undergraduate civil engineering students, Educate the Educator has been introduced by the International Geosynthetics Society (IGS). Some conclusions that can be reached from the evaluations on this initiative are:

- The EtE initiative has been successfully implemented throughout the world, as evidenced by the 23 EtE events conducted so far, which took place in 14 countries, providing access to geosynthetics knowledge to a geographically diverse number of undergraduate students

- The demand for EtE worldwide has been continuously increasing, which attests to the program's effectiveness.

- Brazil has conducted 6 EtE with 161 participants from various universities from all regions of the country. The evaluations carried out after the course and two years after its completion show that teaching activities such as introduction of the subject in existing disciplines, creation of optional subjects, academic events, lectures and mini courses were implemented in all the universities that attended the program,

- The participants of EtE Brazil have been continuously interacting through the Internet in a Mutual Support Network, helping each other with materials, suggestions for classes, practical workshops etc.

- Regarding the online EtE, IGS Brazil adapted the online version of the practical classes so that could be reproduced online. Several adaptations were necessary for the course to work. One of them was the sending of geosynthetics samples by mail one week before the start of the course and the students received the photos of the samples that they were supposed to separate from the box before the practical class.

- Despite the excellent evaluations received from the online EtE participants, the course coordinators and instructors have concluded that the in-person format is the most suitable and that it best meets the EtE's objectives. There are several reasons for this, such as: the dedication of the participants is much greater in the in-person EtE, since they are totally immersed in the course, while in the online version they continue to carry out their university activities. The participant's contact with the instructors is so important as is the student's contact with the teacher in the classroom. The practical activities were greatly affected in the online version since there was no connection between the students during the project discussions. In conclusion, the Brazilian experience has shown that for a course with the philosophy of EtE, th in-person version is essential.

Bearing in mind the significant size of the Brazilian territory, it may be concluded that the EtE program in Brazil has been a great success for dissemination of the geosynthetics knowledge in the country, serving as example for successful implementation of similar initiatives by other countries.

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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

Maria das Graças Gardoni Almeida: Conceptualization, Data curation, Formal Analysis, Methodology, Visualization, Writing – original draft. Jorge G. Zornberg: Conceptualization, Data curation, Supervision, Validation, Writing – original draft. Ennio Marques Palmeira: Formal Analysis, Conceptualization, Data curation, Supervision, Validation, Writing – original draft. Nathalie Touze Foltz: Data curation, Supervision, Validation, Writing – original draft.

6. Data availability

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

Abbreviations

ABNT	Brazilian Association of Technical Standards
ASTM	American Society of Testing Materials
CE	civil engineering
EtE	educate the educator
IFAI	Industrial Fabrics Association
IGS	International Geosynthetics Society
IGS-Brazil	Brazilian Chapter of the International Geosynthetics Society
ISO	International Standards Organization
NA	not available

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