

Enhancing student learning in geotechnical engineering: a study on effective slide design from students' perspective

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ABSTRACT: This paper explores the effectiveness of slides in teaching STEM subjects, particularly geotechnics. While slides are crucial for explaining basic concepts, some can be challenging for both teachers to explain and students to grasp. The study acknowledges that teachers often have favourite images they believe effectively convey key concepts in soil mechanics or geotechnical engineering. However, due to differences in age and learning stage, students may not find these slides as clear or meaningful. The research comprised two parallel surveys: one student-based and one teacher-based, to examine the preferred slide styles for fundamental geotechnical concepts and the motivations. Key geotechnical topics (shear resistance and drained/undrained conditions) were presented using two different slide styles. Using the Wooclap platform, surveys were conducted during lessons with about 80 students from diverse backgrounds in both undergraduate and advanced geotechnics courses. Students were asked to choose their preferred slide and explain their choice. The same was asked to teachers through Google Forms. This study aims to understand students' perspectives on the use of figures in geotechnical engineering slides, potentially serving as a reference for lecturers. The preliminary results have enabled the authors to develop a list of tips for teachers on presenting difficult-to-visualize topics in geotechnics more effectively.

Keywords: Slide design, Smart learning, Student-based

1 Introduction

Teaching has evolved in recent years through the experimentation of new student-teacher interaction methods and technological advancements that have introduced new tools and multimedia aids into classrooms. Regarding this second aspect, particularly in Science, Technology, Engineering and Mathematics (STEM) fields, traditional "chalk-and-talk" lectures have gradually been replaced, first by the use of overhead projector transparencies (OHP) and later by PowerPoint presentations (slideware).

In this evolutionary process, not only has the graphical medium changed (i.e., from analogue to digital), but also the type, quality, and quantity of information conveyed, which have adapted to the new possibilities offered by these tools. Previously, the teacher's spoken explanation was predominant over drawings and diagrams (with more complex figures relegated to textbook readings or handouts distributed in class). Now, however, the graphical component has become increasingly present in PowerPoint slides, incorporating coloured text and objects, static drawings, and photographs, as well as videos and animations.

Throughout this transformation, many researchers have questioned whether and how these tools can be more effective in knowledge transmission. Harknett & Cobane (1997) and Daniels (1999), referring to Information Communication and Technology (ICT) related courses, highlighted the potential of PowerPoint presentations in terms of speech organization, readability of information, and the ability to make lectures more interactive and engaging through animations, as well as the ease with which they can be updated by the teacher.

However, the effectiveness of slideware compared to OHP and blackboard lectures remains uncertain and debated. Study results sometimes favour the use of PowerPoint (Szabo & Hastings, 2000), while other studies find no significant differences (Ahmed, 1998), and some even report negative outcomes (Savoy et al., 2009). As Yilmazel-Sahin (2009) points out, estimating the effectiveness of PowerPoint presentations is challenging due to the variability in styles, content, and contexts, which in turn depend on the individual creating them.

When evaluating effectiveness, it is always important to distinguish between the opinions of teachers and those of students (MacKiewicz, 2008), as well as what comes from students' academic performance (Bartsch and Cobern, 2003). For example, Savoy et al. (2009) measured a 15% decrease in the amount of verbally delivered information retained by students when accompanied by PowerPoint presentations, despite students expressing a preference for PowerPoint over traditional presentations and spoken lectures. In this sense, slides may act as a distraction from the spoken content, especially when there is no clear connection between the two. Masie (2006) argues that many PowerPoint presentations can negatively impact teaching methods, as teachers may tend to present disconnected lists of concepts rather than integrating them into a coherent narrative, which in turn may reduce students' interest in the subject.

Regarding presentation style and content, several studies exist across both STEM and humanities-psychology fields (Johnson & Christensen, J., 2011; Kernbach et al., 2015). Apperson et al. (2008), for instance, conducted a survey on a cohort of psychology students and found that they preferred slides containing key phrases that the teacher then elaborates upon verbally, keeping them actively engaged in the learning process. Similarly, videos can serve as learning prompts if used in a targeted manner (Bartsch & Cobern, 2003). Students also reported a preference for light-coloured backgrounds and suggested dimming the lights during presentations to enhance screen visibility without making it difficult to see their notes or maintain eye contact with the teacher. Additionally, they expressed a preference for receiving slides as handouts. Tangen et al. (2011) found that students performed better when exposed to graphics-rich presentations compared to traditional bullet-point PowerPoint slides. Other authors reached the same conclusions in pilot studies with geology students (Alley et al., 2005) and engineering students (Garner & Alley, 2016), comparing text-only slides (using bullet points) with slides where sentences were supported by graphics. The latter type ("assertion-evidence" style) was preferred by students, who also achieved better performance in quizzes. The criticism that could be raised against this type of comparison is that the text-only slides used by the authors, while containing the necessary information, are text-heavy and stylistically very poor.

According to the Cognitive Theory of Multimedia Learning (CTML), learning occurs simultaneously through a verbal channel (for text and narration) and a non-verbal channel (for images and animations). To maximize efficiency, presentations should leverage and carefully structure both channels (Mayer, 2021). Moreover, the audience must be able to absorb information in an organized manner - neither too much at once nor excessively fragmented (limited capacity assumption) - so they can select, organize, and integrate it effectively (active learner assumption). Cavanagh (2023) suggests that, regarding content and style, presentations should follow the principles of proximity, alignment, repetition, and contrast to create visual slide structures that align with the underlying conceptual framework of the presented information.

As a STEM discipline, geotechnical engineering requires presentations that balance textual content, graphics, and spoken explanations. In this context, an important question arises: what is the most effective strategy for conveying key geotechnical concepts, particularly concerning stylistic aspects? To the authors' knowledge, no specific studies have examined these stylistic aspects in geotechnical education.

This study presents the results of a survey conducted on approximately eighty students and twenty teachers, evaluating preferences for two types of presentations on two classic geotechnical topics: soil shear strength and shear behaviour in drained/undrained conditions. These findings aim to offer valuable insights into students' and teachers' preferences for visual presentation of fundamental geotechnical concepts, which could inform future approaches to educational material design in the geotechnical field.

2 Methodology

The authors of this paper prepared two slides with different styles on two fundamental topics of soil mechanics, i.e. shear strength of soils in drained conditions and soil response in drained/undrained conditions. One slide is prepared with a textbook-like style, meaning that there is a long text explaining the content and a black and white figure. Figure 1 and Figure 2 show the slides used for talking about shear strength and drained/undrained conditions respectively. The other is a presentation-like slide with only a few words, more colourful, and with simple figures to remind key definitions. Figure 3 and Figure 4 show the slides we used for this case. Good quality slides can be downloaded here: <https://researchdata.cab.unipd.it/id/eprint/1497>.

Shear conditions

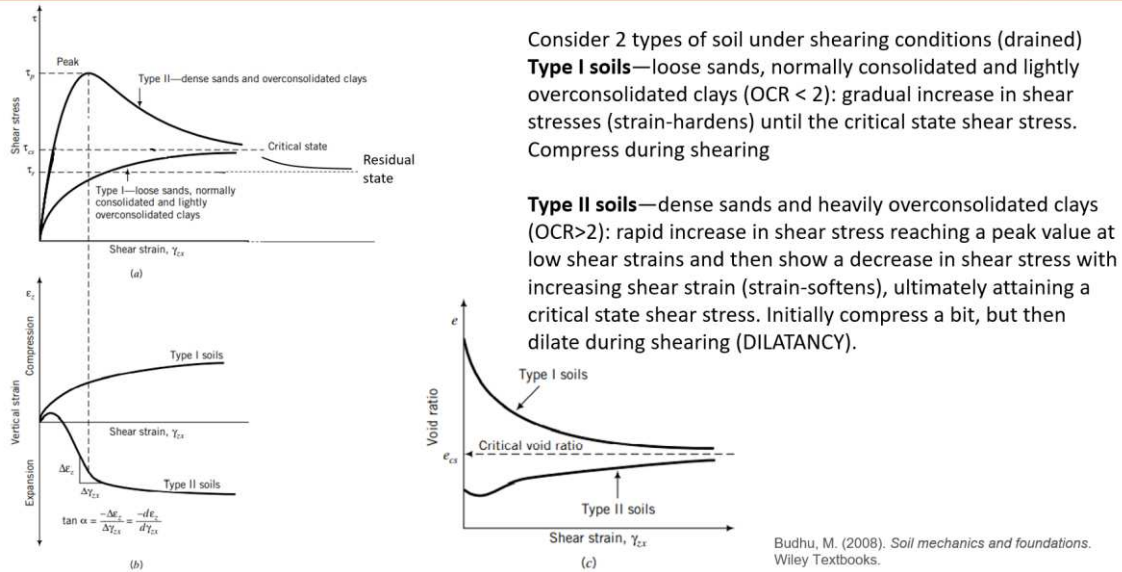


Figure 1. Textbook-like slide style for shear behaviour of soil in drained conditions

Undrained conditions



- Drained condition occurs when the excess pore water pressure developed during loading of a soil dissipates, i.e., $\Delta u = 0$. (typical of sand, and clay at long term)
- Undrained condition occurs when the excess pore water pressure cannot drain, at least quickly, from the soil, $\Delta u \neq 0$. (typical of clay at short term)

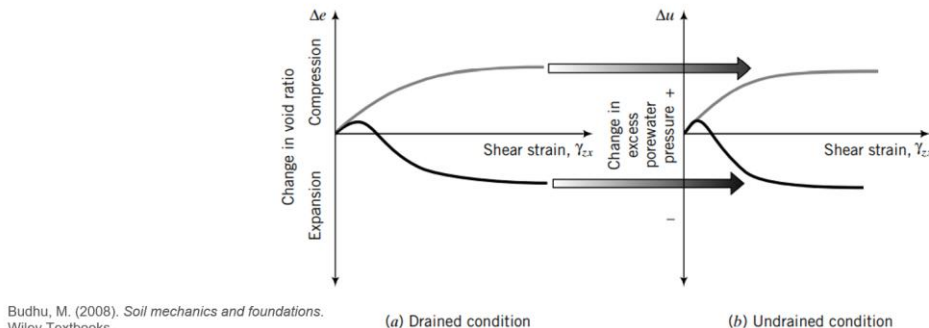


Figure 2. Textbook-like slide style for drained and undrained conditions

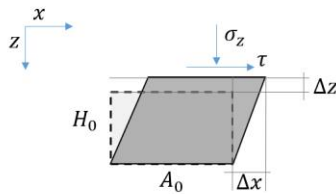
The textbook-like slide can be prepared very easily re-using, with permission, figures and text from a soil mechanics book, requiring limited effort for the teacher. During the lesson the teacher can read the text and add additional explanations and content to enrich the slide. The presentation-like slide

requires more effort both to prepare graphs and drawings using Power-Point and to explain the content during the lesson, i.e. the teacher will explain the topic describing the figures, whereas the text is only used to highlight key concepts.

Shear conditions



Shear deformation of soil:



$$\gamma_{zx} = \frac{\Delta x}{H_0} \quad \text{Shear strain}$$

$$\varepsilon_v = \frac{\Delta V}{V_0} = \frac{A_0 \Delta z}{A_0 H_0} = \frac{\Delta z}{H_0} \quad \text{Volumetric strain (compression is positive)}$$

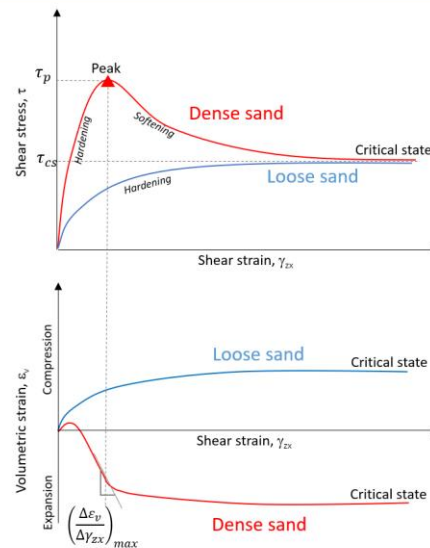


Figure 3. Presentation-like slide for shear behaviour of soil in drained conditions

Undrained conditions

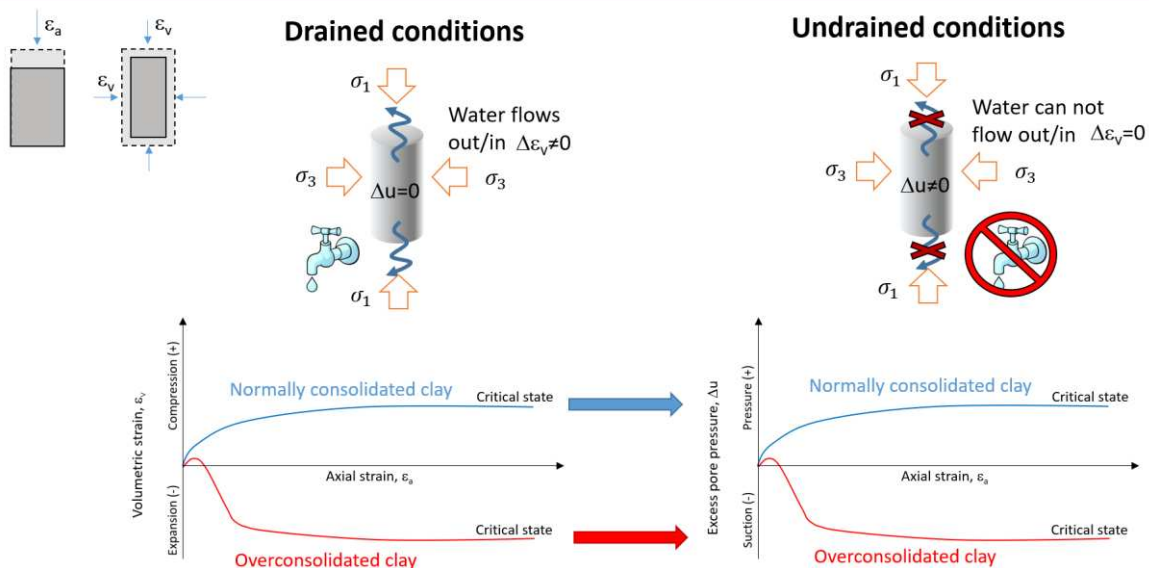


Figure 4. Presentation-like slide for drained and undrained conditions

For the purpose of this study, the two slides of the same topic were shown one after the other to the students without additional explanations by the teacher, who then asked, “what slide do you prefer?” (2 alternative options) and “why?” (short text answer). Replies were collected using Wooclap, an on-line interactive questioning platform.

From the analysis of the short text answers, the reasons why the prefer one type of slide with respect to the other were grouped in five classes from the authors:

1. Comprehensive information through more writing: a group of students felt that in textbook-like slide more text made the content more complete and easier to understand, reducing dependence on the teacher's teaching style.

2. More writing for at-home study: some students preferred text-heavy slides for independent study, expressing a written desire for the teacher's interpretation of plots and diagrams.
3. Less writing for in-class engagement: some students preferred slides with less text (presentation-style slide) during lectures, citing increased incentive to listen and more space for notetaking on the slide.
4. Preference for colourful/intuitive graphics: students favoured slides with visually appealing and easy-to-understand graphics (presentation-style slide).
5. Clarity through less writing: a portion of students found that less text made the slides clearer and more schematic, which they considered beneficial for revision purposes (presentation-style slide).

Replies from students of the University of Padua (Italy) were collected during the first semester of the academic year 2024/2025. A part of them (about 40%) are students from master's degree (graduate students, GS) in Civil Engineering and Water and Geological Risk Engineering (<https://www.dicea.unipd.it/corsi-di-studio>) and the slides have been shown during a lesson dedicated to a recap of soil mechanics. The slides were first shown to students asking to recall in their mind the concepts and then the teacher lead the recap. These students followed the course of geotechnics a few years earlier, but these topics may not be fresh in their minds.

The remaining (about 60%) are bachelor students (undergraduate students, US) in Civil Engineering (<https://www.dicea.unipd.it/IC>), following the course of geotechnics for the first time, and they received a detailed theoretical explanation on the topic a few days earlier, using different slides. In this case, the surveyed slides were both briefly explained by the teacher, to recap the principles learned before. After the presentation, the students were surveyed.

To minimize potential bias in student responses, the order of slide presentation was varied across topics for both groups of students. For the first topic, the presentation-like slide was shown before the textbook-like slide, while this order was reversed for the second topic. The specific sequence of slide presentation was as follows: Figure 3, Figure 1, Figure 2, and Figure 4.

In the following, the answers of the two groups of students are processed separately.

The same questions were posed to geotechnical teachers in Italy by contacting them via e-mail and asking to fill a Google Form (in Italian). 21 teachers of different age (from 31 to 70) replied to the survey. We asked them which of the two slides they prefer to use for one of their geotechnical classes and why. The motivations can be chosen between the following options, but they can also suggest alternative answers:

- 1) If they prefer the presentation-like slide:
 - a) Fewer words make the slide clearer/more schematic.
 - b) Fewer words help the student review at home.
 - c) Fewer words are more useful in class, the student focuses on what I'm saying.
 - d) With lots of text, the student is encouraged to get distracted from my explanations while reading the slides.
 - e) Few words so the student can take notes directly on the slides.
 - f) Few words "force" the student to attend class.
 - g) Few words require the student to pay attention to explanations in the classroom.
 - h) Few words so the student is 100% focused on my words.
 - i) Drawings help the student internalize concepts better than words.
- 2) If they prefer the textbook-like style:
 - a) Lots of text helps the student study at home.
 - b) Content in the slides helps the student if they are absent from class.
 - c) Written concepts make the explanation more complete and easier to understand.
 - d) Lots of text helps me as a teacher to cover all the important things in the lesson.
 - e) Better to prefer text and avoid colourful drawings that distract.
 - f) Lots of text so the student doesn't feel obligated to take notes and can concentrate on my words.
 - g) Lots of text because it's better to be redundant between oral explanation and written concepts (repetition helps).
 - h) Words help the student internalize concepts better than diagrams and drawings.

For the following elaboration of the results these answers are grouped into 6 classes:

1. Comprehensive information through more writing: 2c, 2d, 2g.

2. More writing for at-home study: 2a, 2b.
3. Less writing for in-class engagement: 1c, 1d, 1e, 1f, 1g, 1h.
4. Preference for colourful/intuitive graphics: 1i.
5. Clarity through less writing: 1a, 1b
6. More writing for clarity and in-class engagement: 2e, 2f, 2h.

3 Results and discussion

In this section the data regarding student and teachers' preferences for different slide styles are examined. The two key topics evaluated are indicated in the graphs as "shear strength" (Figure 1 and 3), and "drained/undrained conditions" (Figure 2 and 4).

For the shear strength topic, a total of 80 responses were collected (52 US and 28 GS). The survey asked students to indicate their preferred slide style for presenting this concept and revealed that 32 students (40% of the total population) preferred the presentation-like style and 48 of them (60%) preferred the textbook-like style for this concept. Notably, this preference is not equally distributed across the two groups, with 18 undergraduate students (35% among the US, see Figure 5.a) and 14 graduate students (50% among the GS, see Figure 5.c) selecting the presentation-like. These findings indicate a clear preference among undergraduate students for the textbook-like style when learning about shear strength. The great majority (65%) of undergraduates favoured this approach, suggesting that for this topic, they find more detailed, text-heavy slides beneficial. In contrast, graduate students showed no clear preference between the two styles for this topic. The even split (50% for each style) among graduate students might indicate greater adaptability to different presentation formats or a more diverse set of learning preferences at this academic level, highlighting the importance of considering the target audience when designing educational materials. While undergraduate students seem to benefit from more comprehensive, textbook-like presentations for topics like shear strength, graduate students appear equally comfortable with both detailed and more schematic presentation styles.

Regarding the drained/undrained conditions topic, 75 responses were obtained (41 US and 34 GS). The slight difference in response rates between the two questions (80 vs. 75) is because the two topics were presented in different days. Students were again asked to select their preferred slide style for this concept and 40 students (53% of the total) favoured the presentation-like style, while 35 students (47%) preferred the textbook-like style. In detail, 18 undergraduate students (44% among the US, see Figure 5.b), and 22 graduate students (35% of the GS, Figure 5.d) preferred the presentation-like style for this topic. This preference may be attributed to the inclusion of visual representations of the sample and sink in the presentation-like slide (Figure 4), elements which were absent in the textbook-like version (Figure 2).

Beyond preference, students were asked to provide motivation for their choices (Figure 6). Most of US, having more writing was more useful for having comprehensive information, whereas for GS less writing is more important for clarity. This may be due to GS' more extensive knowledge on the topics and their higher visual literacy and ability in taking notes.

It should be considered that there are possible biases in reading these results, the effect of which is difficult to assess. Specifically, (i) the culture of teaching at the University of Padua, as most people are more comfortable with what they are used to; (ii) whether students read the textbook before class; (iii) cultural differences among students.

In addition to surveying students, the same questions were posed to teachers to evaluate their preferences and compare them with those of students. The results revealed a notable contrast in approach and motivation. Teachers demonstrated a remarkably consistent preference in their slide style choices. Unlike the diverse opinions observed among students, 86% of the surveyed teachers (18 out of 21) expressed a clear preference for the presentation-like style (Figure 7a,b). Their primary motivation for this choice was focused on capturing and maintaining student attention during class sessions. Teachers aim to push students to pay attention and interpret the figures while they are being discussed in class by taking notes, to actively involve them in the cognitive process.

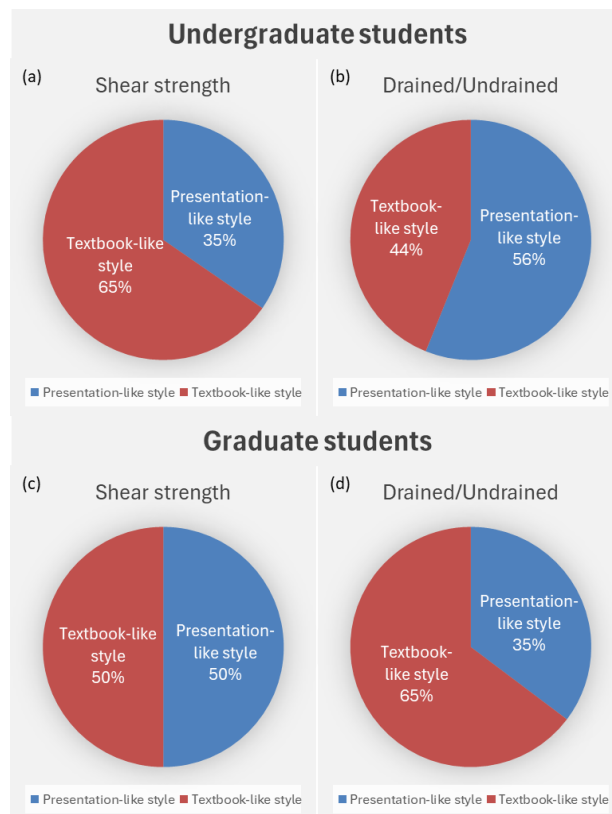


Figure 5. Preferences for slide style from: undergraduate students on (a) shear strength and (b) drained/undrained; and graduate students on (c) shear strength and (d) drained/undrained topics

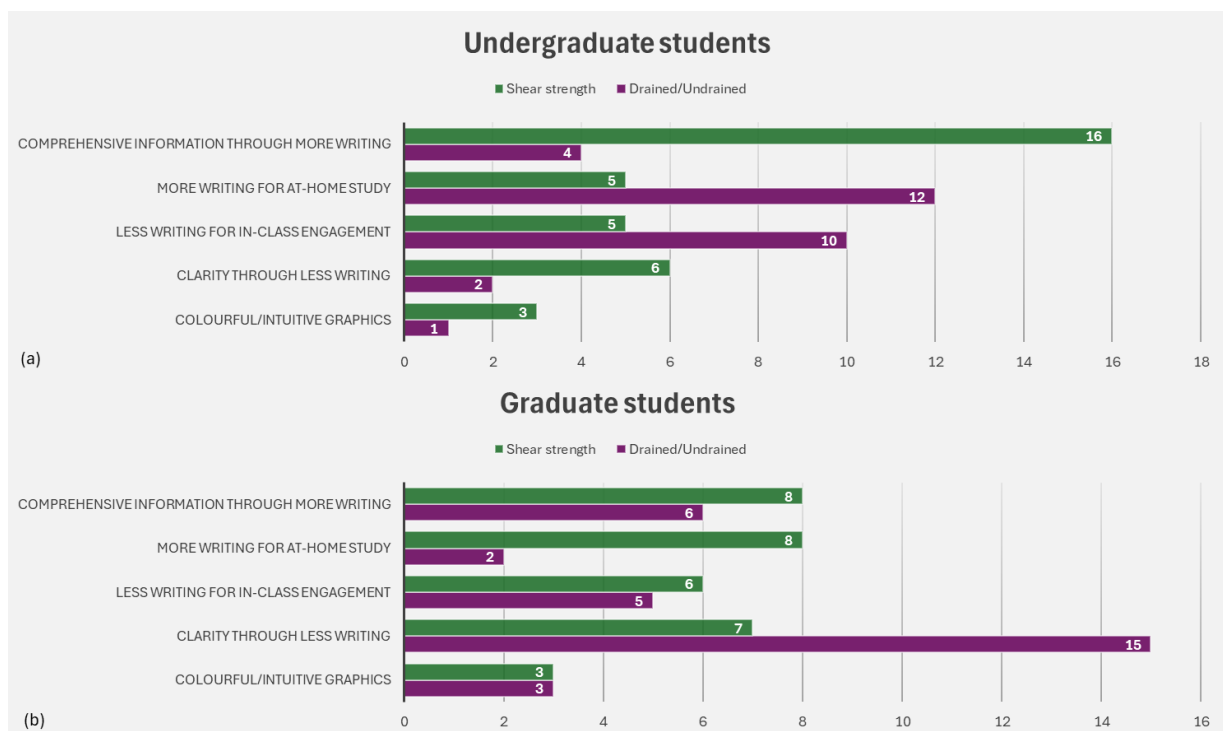


Figure 6. Number of students grouped for motivation for shear strength and drained/undrained topics: (a) undergraduate students; (b) graduate students

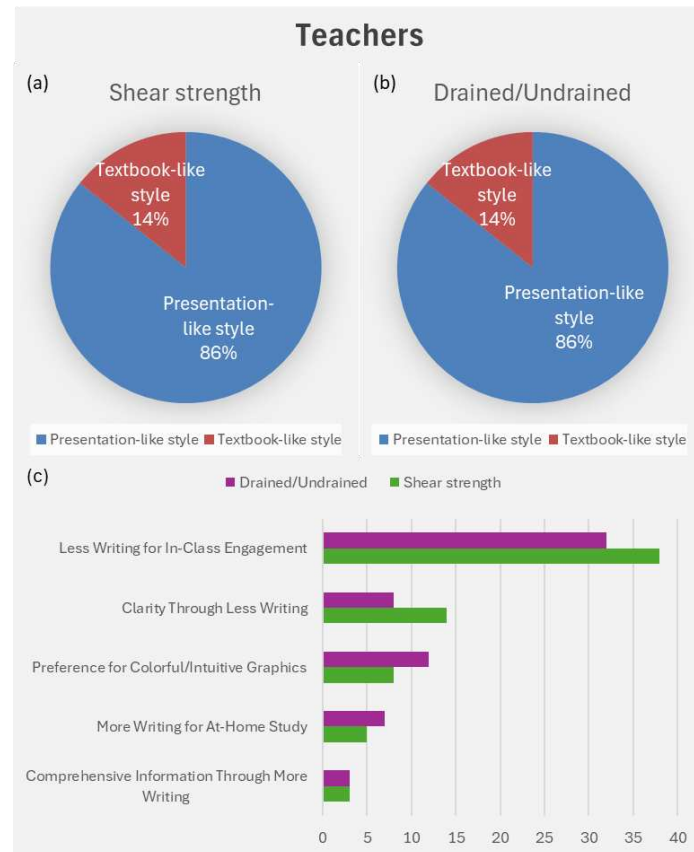


Figure 7. Teachers' preferences for slide style for (a) shear strength and (b) drained/undrained topic. (c) Number of teachers grouped for motivation

In Figure 7c the comments made by teachers have been categorized into the six main categories (see Sec. 2). The last category (More writing for clarity and in-class engagement) was not selected by anyone, so it is missing from the figure. It is important to note that the total number of comments exceeds the number of teachers surveyed because each participant had the opportunity to express multiple preferences or provide several comments related to the same category.

Also, the results from teachers might have biases difficult to quantify, such as the teaching experience, personality, and cultural background.

This uniformity in teacher preferences stands in stark contrast to the more varied preferences observed among students. While students' preferences fluctuated based on factors such as academic level and specific topic (depending on their previous personal knowledge; their ability in writing notes during lessons and their personal study methodology), teachers consistently prioritized engagement and attention-grabbing elements in their slide design choices. This alignment of all teachers towards the presentation-like style may not fully address the diverse learning preferences expressed by students, particularly undergraduates who often favoured more detailed, textbook-like slides for certain topics.

Possible causes of textbook-like style preference among students may lay on:

- the fact that, with this type of slide, the influence of the teacher's ability in explaining the proposed concept and catching the audience is less important.
- students' and teachers' ability to understand graphs and figures can be very different. Usually, teachers have higher visual literacy (Christidou, 2020). The slides without written parts make the graphs/images central to the lesson and the student may not feel able to fully understand the concept.

Only few teachers preferred textbook-like slides, and the main reason is that text can better support the home study, providing the most important concepts to acquire. In addition, textbook-like slides can be very useful in conveying the subject proper language, in particular, in case there is not a reference textbook for self-study at home.

4 Conclusions

This study presented the results of a survey conducted on both students and teachers to investigate their preferences in slide styles for two classic geotechnical topics: soil shear strength and drained/undrained conditions. Even though the sample sizes for both questions are substantial (80-75 students and 21 teachers), to provide a more robust basis for analysis, larger samples should be considered.

The findings showed that depending on the topic presented and their academic level, students tend to prefer textbook-like style, whereas teachers are less likely to put a lot of text on slides. The divergence between teacher and student preferences highlights an important consideration in educational material design. While teachers prioritize in-class engagement, students' preferences often reflect their needs for both in-class learning and independent study. This difference underscores the challenge of creating educational materials that balance immediate classroom engagement with comprehensive content for later review and study.

In conclusion, few tips for teachers preparing PowerPoint slides for geotechnical topics can be derived from this study.

- 1) Thinking about the scope of the material you are preparing:
 - a) Are the slides replacing a textbook?
 - b) Are the slides made to take notes on them?
- 2) Think about background and abilities of the audience:
 - a) What is the academic level?
 - b) What could be their visual literacy?

The key is perhaps to balance written text, graphics, images, and narration without being too concise in the text (as teachers would prefer) or, on the other hand, too verbose (as students might desire).

The findings offered a valuable insight into student and teachers' preferences for visual presentation of complex geotechnical concepts, which could inform future approaches to educational material design in the geotechnical field.

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Authors' bios

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Dr. Viviana Mangraviti is a Civil Engineer and Researcher in Geotechnics at the University of Padova, Italy. She earned her PhD cum laude in "Structural, Seismic and Geotechnical Engineering" from Politecnico di Milano in 2021, specializing in Geosynthetic-Reinforced and Pile-Supported embankments. Her postdoctoral work at Chalmers University of Technology, Sweden, focused on developing fully-coupled numerical analyses for slope stability under extreme climate events. Dr. Mangraviti's current research explores methodologies to evaluate levee system stability during floods, reflecting her expertise in geotechnical engineering and natural hazard mitigation. She currently serves as the chair of the International Geosynthetics Society (IGS) Young Members Committee, contributing to create connections among next-generation geotechnical engineers worldwide.

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Dr. Lorenzo Brezzi is Assistant Professor in Geotechnical Engineering at the University of Padova (Italy), where he teaches courses on foundations, environmental geotechnics, and geotechnical monitoring. His research focuses on landslide risk assessment, the interaction between geohazards and infrastructure, and innovative monitoring techniques such as fiber optic sensing and drone-based photogrammetry. He has contributed to the numerical modelling of both slow and rapid landslides, and to the development of risk assessment methodologies for bridges and viaducts within the FABRE framework. Dr. Brezzi is a member of the National Group for Geotechnical Engineering (GNIG), where he serves as the representative of Italian early-career researchers. He actively participates in public outreach activities, such as Science4All. Internationally, he serves as lecturer in the Erasmus Mundus Master "NoRISK" and in the national Master on the safety assessment of existing infrastructures (FABRE Master), and he is involved in academic cooperation with ENSTP in Cameroon. In 2024, he was invited as a guest lecturer at the China University of Geosciences (Wuhan), presenting his research on landslide–infrastructure interaction.

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Giorgia Dalla Santa is a Researcher (RtdB) at the University of Padua (Italy). Her research focuses on soil characterization as well as levee monitoring and stability assessment. Additionally, she specializes in energy geostructures and shallow geothermal systems for building conditioning. Regarding teaching, she is responsible for the courses "Geotechnics" and "Safety in Excavations" in the master's programs at the Department of Geosciences, and the course entitled "Geothermal Systems for a Sustainable Environment" in the Environmental Engineering master's program. She has also been involved in the international teaching program Engineering for Africa, a collaboration between the University of Padua (Italy) and the École Nationale des Travaux Publics (Cameroon).

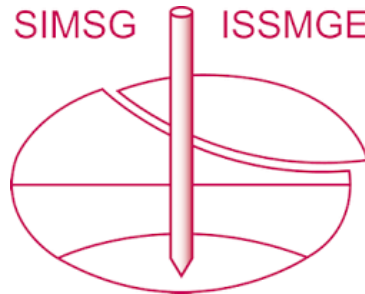
Fabio Gabrieli, University of Padua (Italy)

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