Teaching the Big Ideas of the Disciplines: Online Educational Material Accessible to Everyone for Soil Mechanics' Effective Stress

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ABSTRACT: This paper claims that there is a missing type of knowledge that concerns education in all disciplines and belongs in the broader category "pedagogical content knowledge". In order to describe this missing knowledge and give an example, the paper first asks three questions and provides the respective answers: (1) Q: "what is worth being taught to everyone" – A: "the big ideas of the disciplines", (2) Q: "how to motivate the study of a big idea" – "with an essential question, phrased in everyday language" and (3) Q: "how to dress a big idea" – A: "with a lesson accessible to everyone", where "everyone" herein refers to an audience that includes high school students, university students (the main audience) and adults enjoying learning on the internet. In Soil Mechanics, "effective stress" is indisputably a big idea, and the essential question that aims to uncover it is phrased as follows: "what happens when soil compresses". The paper considers resources available to instructors developing online educational material, describes the methodological influences and the approach followed to create an hour-long modular video-lesson that answers the essential question phrased, and discusses comments made by reviewers of the video-lesson and the modifications resulting from these comments.

Keywords: pedagogical content knowledge, conceptual knowledge, design of educational material, geotechnical engineering instruction

1 Introducing the need to identify big ideas in the disciplines

The ultimate claim of this paper is that we need to identify and bring to the public light the core of each discipline, which includes its big ideas. This knowledge exists in a diffused state within the disciplines but, because it requires a concerted effort to give it shape, for practical purposes it is missing. Arguing for the need to somehow condense or distill the disciplines is not a new idea. It reappears periodically, for purposes such as enriching the general education component of tertiary education (Phenix, 1964), creating a unifying multidisciplinary foundation for Science, Technology and Society Studies (Kline, 1995) or better communication among the disciplines (Pantazidou & Nair, 2001).

The present study reintroduces the discipline distillation idea by searching for elements of the core of a thematic field with the help of the question "what is worth being taught to everyone from a thematic field". It differs from the previous conceptions of condensed knowledge in that it considers as main audience for the answer the university students in this *same* thematic field. The core of a thematic field can be identified with fidelity by efforts internal to the thematic field (i.e. not from external disciplines): for example, what belongs in the core of Physics is determined by physics experts, not from experts in the History or Philosophy of Science. This approach can ensure that the identified core of a discipline will have value for the discipline itself, not only for other disciplines or the wider public. At the same time, the involvement of experts with research skills in the Social Sciences and in the Humanities will endow the distillation undertaking with robust methodology and with interdisciplinary linkages helpful for its dissemination.

The broader endeavor motivating the present article seeks to give shape to the overlap between two largely missing bodies of knowledge: (i) the distillates of the disciplines previously discussed and (ii) the category of knowledge introduced in the education literature by Shulman (1986) with the term

“Pedagogical Content Knowledge”, also known in Education with its acronym, PCK. In essence, Shulman (1986) argues for the necessity to build a supplementary body of knowledge for every thematic field X: the pedagogical knowledge of X. This is a foundational realization, which entails a difference between content knowledge (e.g. knowing how to do Mathematics) and pedagogical content knowledge (e.g. knowing how to teach specific topics in Mathematics to specific audiences). Shulman names components of this body of knowledge (“the most powerful analogies, illustrations, examples, explanations and demonstrations”, “understanding of what makes the learning of specific topics easy or difficult”) but does not specify who could produce and record this knowledge. Most instructors carry out parts of the task described by Shulman (1986) for their own teaching, and a few do it systematically and publish about it, but typically for topics taught at early stages of education (e.g. Lampert, 1986).

The intrinsic difficulty to describe convincingly and with adequate detail something that is missing can be handled in two ways: by describing its defining characteristics and by giving examples. Such a combined approach was attempted herein. The defining characteristics are outlined with motivation from three questions, which are stated and answered in Section 2. Then, an example application is described in Section 3 for the thematic field Geotechnical Engineering (and more specifically for Soil Mechanics, its theory base), which is a branch of Civil Engineering. The paper is written for readers from the field of Education, who may want to only skim Section 3.2, and for instructors of Geotechnical Engineering, who may be interested mostly in Section 3.

2 Identifying and presenting a “big idea” with help from three questions

The logic for developing the educational material follows from the answers to three key questions. Sections 2.1 and 2.2 discuss two questions that provide entry points to the core of thematic fields, while Section 2.3 explores, with the help of the third question, ways to make this core widely accessible.

2.1 What is worth being taught to everyone?

The suggested answer is “the big ideas of the disciplines”. The instructional framework Understanding by Design developed by Wiggins and McTighe (2005) provides the connection between the missing knowledge and teaching. Wiggins and McTighe (2005) recommend that instructors plan courses by organizing units of instruction around the “big ideas” the course aims to develop. According to them, the term “big idea” represents “a concept, theme or issue that gives meaning to discrete facts and skills”. Big ideas as presented herein are not powerful ideas thanks to their poignancy or relevance for humans (e.g. Papert, 2000), nor big themes cutting across the material world, e.g. structure of matter (Stevens et al., 2009). They are not headings of textbook chapters either. Big ideas are the major threads that run horizontally through chapters of single-discipline textbooks. They are closer to the organizing principles used by experts in arranging domain knowledge. Or, again in the words of Wiggins and McTighe (2005), “they are the hard won results of inquiry, ways of thinking and perceiving that are the province of the expert”.

Identifying the big ideas worth being taught to everyone shares characteristics to Kline’s (1995) recommendation to identify materials in the disciplines that every undergraduate should learn. Unlike Kline (1995) though, who recommends the formation of a committee of senior faculty to identify such materials, herein it is recommended that dedicated experts within the disciplines propose the big ideas of their own discipline. Lack of consensus is not prohibitive and will enliven the discussion. In any case, within Soil Mechanics, “effective stress” is indisputably a big idea (further discussed in Section 3.2).

2.2 How to motivate the study of a big idea?

The suggested answer is “with an essential question, phrased in everyday language”. The answer follows again the guidance of Wiggins and McTighe (2005), according to whom essential questions “point to and highlight the big ideas” and “push us to the heart of things – the essence”. Essential questions offer privileged access to big ideas. Essential questions and big ideas have a chicken-and-egg relationship, but for practical purposes it does not matter which one comes first. Questions are always more engaging for learners. Essential questions, whether reconstituted or spontaneous, have the additional advantage that can be phrased without technical jargon. For the big idea “effective stress”, the essential question: “what happens when soil compresses” was deemed to provide a suitable entry point for further inquiry.

2.3 How to dress a big idea?

This question asks how to do justice to the big idea and its answer has two parts, a technical and a methodological. The answer to the technical part depends on the particular characteristics of the thematic field and the specific big idea. The choice made herein for the big idea of effective stress is to highlight the central role of water by considering, in the same frame, the problems of (a) loading soil by a building and (b) pumping groundwater (see Section 3.2). The methodological part is domain-general. Notwithstanding the fact that the main audience for the educational material developed is the undergraduate students of the thematic field, the suggested answer for the question posed is “with a lesson accessible to *everyone*”, where “everyone” herein also includes high school students and adults enjoying learning on the internet. In Section 3.4 it will be argued that the apparent limitations imposed by a wide audience offers opportunities to focus on the essentials, thereby facilitating conceptual understanding. Accessibility is also dually conceived, in the cognitive sense, ensured by widening the target audience, and in the literal sense, which led to choosing the production of an open online video-lesson.

For the author, the biggest opportunity offered by online material is the transformation of the near-private practice of teaching, which involves only instructors and their students, to a public practice, open to review. This opportunity paves the way for teaching to acquire the characteristics that have made research so successful and, hence, affording greater recognition and reward for teaching, as envisioned by Shulman (1993) in his evocatively titled commentary “putting an end to pedagogical solitude”. To make teaching more like research, Shulman (1993) claimed that the academy should “change the status of teaching from private to community property”, giving it thus the value we bestow to research. Shulman stresses that this can happen only from within the disciplines (this notion is echoed in Section 1 herein) and offers two more strategies to elevate the value of teaching: (i) “making teaching visible through artifacts that capture its richness and complexity” and (ii) changing the academy’s mindset to deem teaching valuable so as to assume the responsibility of judging its value. Producing such artifacts is a tall order, which, though, inspires the instructor to strive for quality material (see also Sections 3.3 and 3.5). The element of Shulman’s vision that is deemed herein to be most promising is the academy assuming the responsibility to judge the value of teaching artifacts. This element provided the idea of peer review as an integral part of developing the video-lesson. The different scope of review by peers and evaluation by students should be stressed, considering the research evidence showing that students do not judge accurately what helps them learn (Yadav, 2019).

3 The online educational material developed for the big idea of Soil Mechanics

This part of the paper provides background on some of the main decisions involved when producing online material (Section 3.1), describes the video-lesson produced (Section 3.2), the main comments of the reviewers and the resulting modifications (Section 3.3), discusses envisioned learning environments (Section 3.4) and closes with a summary of good practices considered for the production of education material (Section 3.5).

3.1 Precedents and resources

Many professors aim to emulate examples of good teaching they experienced during their own time as students. But, what would these same professors say is good teaching on the internet? Massive open online courses (MOOCs) offer examples of quality teaching judged by some objective measures. Popularity of MOOCs is one such objective measure, notwithstanding that it is highly affected by the popularity of the MOOC topic. On the interface between education and personal development, the course “Learning how to learn” (Oakley & Sejnowski, 2019) is a star-MOOC with enrolment higher than 1.8 million and subtitles in 22 languages. It is a highly engaging, short MOOC (total playing time: 3 hours, total recommended study time: 12 hours, spread over 4 weeks), with high-quality graphics. It was created by two researchers in the intersection of neuroscience, cognition and instruction. Oakley and Sejnowski (2019) apply their cognition-instruction expertise on the teaching of the topic of their own expertise (this is a rare occasion, as discussed in Section 1: most education researchers address instruction on topics other than their own, i.e. education, such as physics or mathematics).

With MOOCs, instructors have the opportunity to "attend" the classes of other teachers and, as teachers themselves now, to identify their own role-models for a teaching style they want to emulate. Having attended and completed more than ten MOOCs (and quit attending about twice as many), the author of this paper found two rich MOOCs worth emulating, especially regarding their carefully thought out structure: "Writing in the Sciences" (Sainani, 2020) and "Plato" (Kalfas, 2019). These two courses reaffirmed the author's commitment to make visible the logical structure of material presented, which often requires a detailed storyline of a presentation before creating its slides. This storyline is the plot of the video-lesson in Section 3.2.

Searching for good examples becomes more difficult when leaving the circumscribed space of MOOCs to venture on the internet (Shoufan, 2019). When sharing with colleagues plans about developing online education material for a wider-than-university-student audience, the biggest discouragement is the response "oh, there is so much on the internet". Further asking for recommendations for quality educational material produces websites (e.g. CrashCourse on YouTube) with collections of videos that cover a large variety of topics, including civil engineering topics (e.g. fluid flow), but very rarely recommendations on specific good videos. The author's hesitation about such videos is that they do not provide information on the envisioned audience nor on the goals of the video. In addition, the narration is often very fast, so presumably the implicit goal is transfer of memorable info-bytes (e.g. short science facts) rather than exploration of concepts. Finally, many of these videos have graphics that are beyond the reach of a typical college instructor, so in this respect their viewing can be intimidating.

Other resources available to the educator include guides produced by university centers providing support to instructors interested in producing online materials. Some of this material is a combination of general guidelines and introductions to university facilities and procedures, e.g. for the Technical University of Delft (Mebus et al., 2013), while others are more widely useful, e.g. the description of types of educational video (i.e. videolecture, screencast, pencast, microlecture, event recording) by the University of Twente (2018).

Finally, guidance from the theory of multimedia learning is provided by Mayer (2014), who considers three main instructional goals, namely: 1) managing essential processing (help the learner select relevant information and organize it), 2) fostering generative processing (motivate and guide the learner to integrate presented material with prior knowledge) and 3) reducing extraneous processing (relieve the learner from cognitive overload). Table A1 in the Appendix shows the correspondence between these three goals and the basic principles of multimedia learning that support them.

3.2 Video-lesson description and plot

The video-lesson consists of shorter parts, as recommended for online materials (Choe, 2017), and has a total duration of a little less than 1 hour. A 3-minute introduction presents the logic and the contents of the lesson. A separate introduction is also an opportunity for the viewers to meet the instructor "face-to-face". The remaining videos are videotaped PowerPoint presentations (screencasts): three semi-autonomous parts lasting 13 minutes (the first two) and 21 minutes (the third), and a 4-minute summary. Apart from the videos, viewers have available the PowerPoint slides and the full script of the presentations, slide-by-slide, with some additional explanatory annotations for some slides (see also Section 3.3). The accompanying slides and script facilitate revisions as well as peer review: after watching the video once, it saves time to revisit specific slides in the printed material compared with having to play again the video. The video-lesson has been recorded in Greek and in English and it is available through the website of the International Society for Soil Mechanics and Geotechnical Engineering (ISSMGE) (Pantazidou, 2020a;b).

The introduction asserts that even a thematic field not featured in the media, like Soil Mechanics, has one (at least) topic worth teaching to *everyone*: "what happens when soil compresses" (Figure 1). The plot of the video-lesson complements the "what" of the essential question with the respective "why" (happens what happens) and unfolds in three parts. The plot is summarized below at the simplified level of the videos (i.e. with the minimum of technical terms and the absolutely necessary explanations).

--excerpt from introduction script --

“Say that someone asks: Does Soil Mechanics have something worth teaching to everyone? I would answer: Yes, it does! What happens when soil compresses.

I develop my answer in three parts, three short lessons, and a summary. I prepared the lesson for high-school students, for our students and for all of you who like to understand.”

Figure 1. Introducing the essential question “what happens when soil compresses”

Part 1 considers as an example of compression the settlement of a building and introduces the main “actors” of soil compression (soil grains, soil pores, soil skeleton), as well as the quantities necessary for quantifying settlement (weight, load, pressure, stress) with slides such as those shown in Figure 2. With the aid of a cartoon with magnified grains of dry sand, a first descriptive answer to the motivating question is given as: “when soil compresses, it is the soil skeleton, i.e. the assemblage of soil grains, that compresses: soil grains come closer together, while the volume of the pores decreases”. The importance of the location of the ground water elevation is stressed (while the term “water table” is avoided, so as not to burden the viewers with jargon), as well as that below this level the soil is saturated, i.e. the space of the pores is occupied only by water. The explanation of the term “saturated” is repeated a few times throughout the lesson, because the word has some additional, potentially confusing meanings. The remaining video-lesson deals only with saturated soils, which settle while at the same time the excess water, which does not fit in the tighter configuration of grains, escapes. In a sand, this excess water will leave quickly. But in a clay it will leave slowly, because water flows very slowly through the very small pores of clayey soils. That’s why, in clayey soils, if the settlement of a building is large, we should wait until it is completed before we connect the building to the water and the sewage pipes or, if we cannot wait, we should speed up its completion.

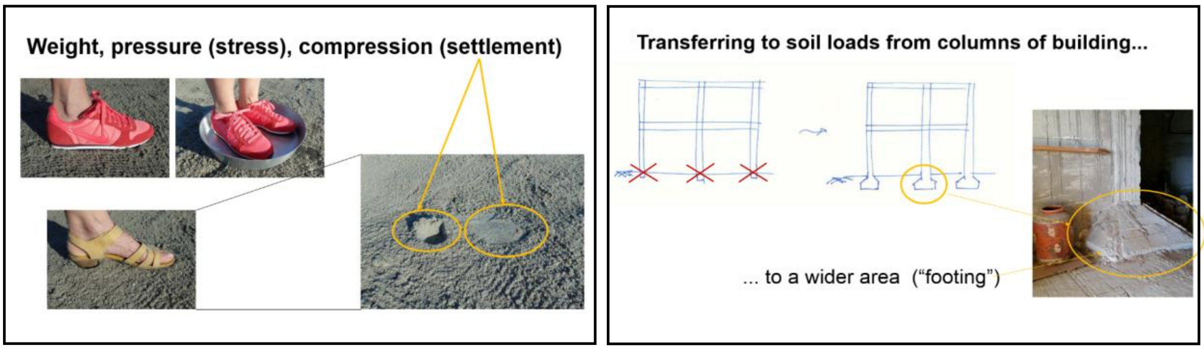

Figure 2. Slides from Part 1: relationship between weight, area of foot support or building foundation (shoe, pan, sandal with heel, footing of a building) and compression

Part 2 deals with pumping water, because pumping also causes settlements. This second part aims to pique the curiosity of the viewers as to why two seemingly unrelated civil engineering projects (construction of a building and pumping groundwater – see Figure 3) have the same result (compression) and to motivate them to watch Part 3, which gives the answer in terms of effective stress, the big idea of Soil Mechanics. Part 2 presents two emblematic cases of settlement due to pumping. Venice, where pumping resulted in settlement of 13 cm: although not a large settlement, it creates problems for Venice where the ground level is very close to the sea level (Carbognin et al., 2005). And Mexico City, where settlements have been as large as 7 to 10 meters (Auvinet, 2016). The comparison of the two cases shows that soils described as loose (sands) or soft (clays, e.g. the Mexico City clay) have large volume of pores (again, Soil Mechanics terms such as porosity and void ratio are avoided), that’s why they can compress a lot.

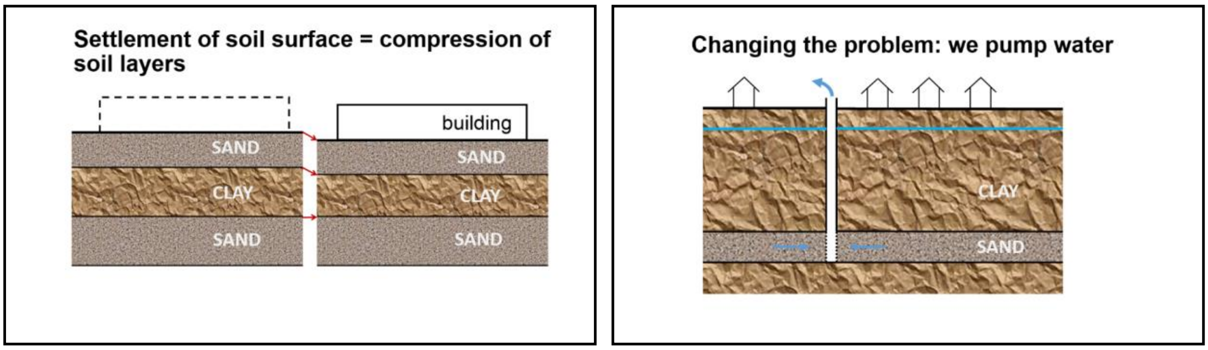

Figure 3. Two civil engineering projects causing settlement: construction of a building (slide from Part 1) and pumping water (slide from Part 2)

The goal of Part 3 is to explain how can Soil Mechanics predict quantitatively the settlement of soil, having defined the foundational concept –the big idea– of effective stress, and to also give some theoretical and historical background (Figure 4). Part 3 asks “how is it possible that water pumping causes settlement, since it does not apply any additional load on the soil, like does the weight of a building?” To answer this question, it is necessary to distinguish between two stresses: the total stress (σ), which is due to the loads applied on soil, and the effective stress (σ′), which expresses what is felt by the soil skeleton. Effective stress (σ′) is equal to total stress (σ) minus the pressure of the water (u) in the soil pores, that is, $\sigma' = \sigma - u$. To understand the role of the water pressure in the expression (i.e. its negative sign), it helps to think of buoyancy, which makes us feel our body lighter in the water. That’s why it is important to know the location of the water level, because it is related to the water pressure and, hence, to effective stress. Since effective stress (σ′) is equal to σ-u, it increases (and, hence, soil compresses) when the total stress (σ) increases, or when the pressure of the pore water (u) *decreases*. This happens when we pump: the water pressure drops, the stress felt by the soil skeleton increases and, hence, soil compresses. For the quantitative prediction of settlement, we need to (1) calculate the effective stress increase and (2) perform experiments in the laboratory to connect the increase of effective stress to the compression of soil samples we have obtained from the area under study.

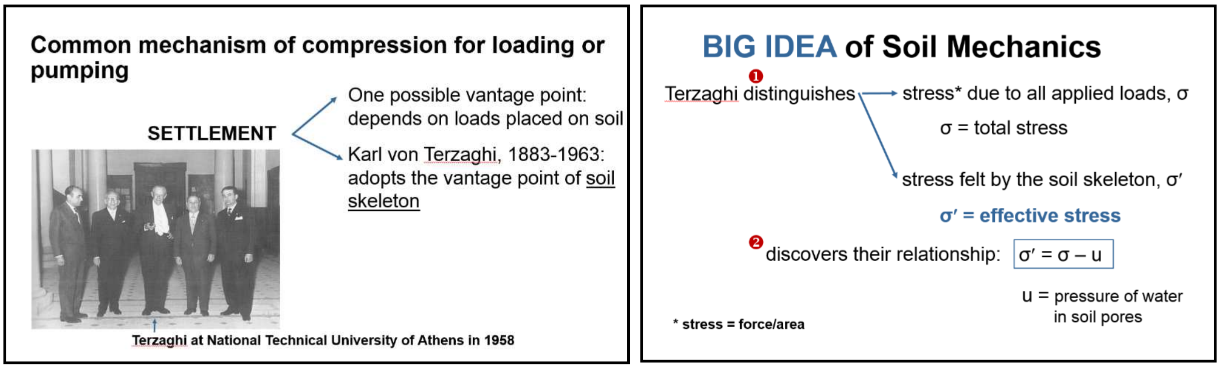

Figure 4. Slides from Part 3 guiding the viewer to follow the conception of the big idea “effective stress” by the founder of Soil Mechanics, Karl Terzaghi

Part 3 concludes with another example of settlement of ground at low elevation, in fact below sea level, in Holland. In Holland too, pumping of water resulted in settlement. However, the settlement in Holland is primarily a result of a chemical phenomenon, the oxidation of organic soil, which shrinks and compresses when it comes into contact with the oxygen in the air entering the pores, due to the drop of groundwater *level*. So, it would be wrong to conclude that since pumping caused settlement in Holland as well, settlement was also due to a mechanical phenomenon, like the increase of effective stress due to the drop of the *pressure* of groundwater.

Finally, the 4-minute summary gathers (i) in one slide the answer to the question “what happens when soil compresses” (Figure 5a) and uses the study of soil compression (ii) in a second slide as an example of prediction of how engineering projects may impact natural processes, and (iii) in a third and final slide as an opportunity to generalize the way the applied engineering sciences work (Figure 5b).

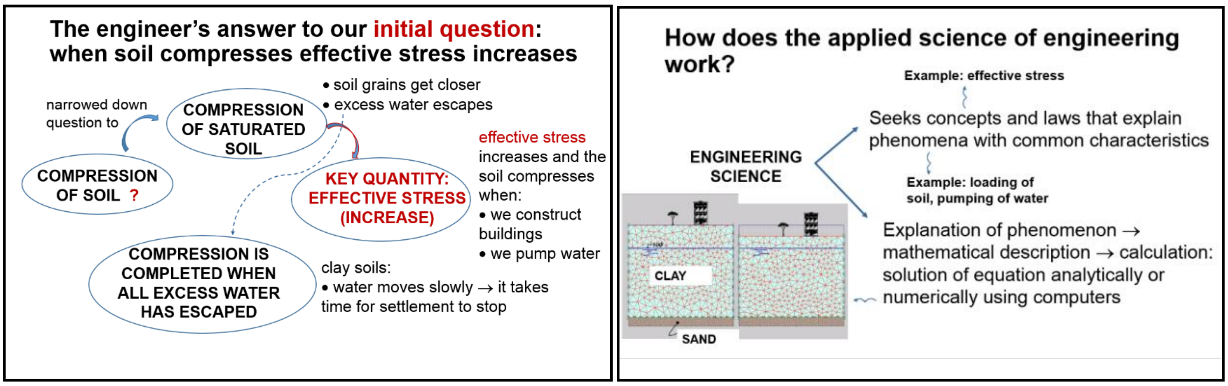

Figure 5. Slides from the Summary: (a) synopsis of answer to essential question (slide is presented in animation mode, starting from "COMPRESSION OF SOIL ?" and proceeding clock-wise) and (b) generalizing the methodology followed to answer the question (figure from Auvinet, 2016)

3.3 Review comments & modifications

The videos were first recorded in Greek and then comments were sought from four reviewers. Their comments resulted in modifications of the presentation slides and the script, which were then translated in English and the videos were recorded again (in English only). The reviewers were three professors in Departments of Civil Engineering in Greece, two with a specialization in Geotechnical Engineering and one with a specialization in Environmental Engineering and prior experience with attending and completing MOOCs. Comments were also offered by a representative of the wider public, who was sought in the personal circle of the author, with criteria to have (a) prior experience with attending and completing MOOCs and (b) non-engineering background (the reviewer had a background in the Humanities). The types of comments provided by the four reviewers grouped their input into two categories which were different than those originally anticipated by the author (i.e. the three engineering professors and the representative of the wider public): reviewers with or without geotechnical engineering background, regardless of university affiliation or engineering background.

The two geotechnical engineering professors asked mainly for clarifications so as to avoid possible misunderstandings. Such examples included a suggestion that when saying "in general, sands compress less than clays", we should stress that this is true for the same applied load. Or that it may be confusing for the students to hear about soil underneath a building and see a 2-dimensional (2D) sketch. They also asked for additional information on topics outside the geotechnical engineering domain (e.g. why does the sea rise in the Adriatic region close to Venice). These comments led mainly to adding annotations to the script, in the respective slides. In one instance, where the first 2D cross-section appears (Part 1, Slide 5), a figure was added to the script, explaining the correspondence between 2D and 3D, and a note was added to the narrative, inviting the viewers to check the script for additional explanations. The two geotechnical reviewers were also more demanding on quality issues (clearer pictures, animations instead of still pictures): these comments were taken into account to the technical degree possible, e.g. a simple animation was added in Slide 8, Part 1. The initial plan for the preparation of graphics used in the slides was that the author would make first sketches from which a professional would produce the final versions: such professional help could not be procured in Greece (despite contacts with graphic design schools, publishers of engineering textbooks and with faculty members at education departments), so the author ended up producing everything herself.

One of the two geotechnical reviewers found rather tiring the discussion of potential ideas for exploring the mechanism of settlement discussed in Part 3, before arriving at effective stress. In response to this comment, the English version of Part 3 is shorter by two slides, since indeed this exploratory part could be made shorter while preserving some references to how engineering proceeds with solving theoretical problems. The same reviewer did not see value in the historical reference to the founder of Soil Mechanics, Karl Terzaghi, and also thought that the discussion of the settlement in Holland is off topic. These two comments did not result in changes, each for a different reason. The historical reference to Terzaghi remained because it is more vivid (apart from being true) to explain that one particular person made the key realization that permitted the application of Mechanics to soils and, thus, created Soil Mechanics. The reference to the settlement due to pumping in Holland remained because it serves two purposes. First, it contributes to the broader discussion on engineering at the beginning of Part 3 (Slide 5: engineers often extend the use of existing tools for new problems with suitable modifications) and then in the summary (Slide 3: discussion of unanticipated impacts of engineering projects). Second, it alerts the viewer against always associating the settlement resulting by pumping to the mechanical phenomenon caused by the decrease of pore water pressure, which was the author's first impression when she started reading on the internet about Holland. In fact, after reading an article about the settlement in Mexico City in the New York Times (Kimmelman, 2017) and recent publications discussing cracks appearing on the soil surface in the Mexico City area (Auvinet et al., 2017), the author finds it more probable that in Mexico City as well settlements nowadays are due to two mechanisms, soil shrinkage and increase of effective stress. Unfortunately, she was unable to have the authors of the relevant publications to comment, but she is hopeful that when the video-lesson and this paper are published, comments are bound to materialize. As mentioned in Section 3.3, instructors who widen the scope of a lesson and make connections to real-life cases end up spending more time because (i) they venture outside their zone of expertise (e.g. having to look up eustacy) and (ii) real life seldom conforms 100% to principles presented in theory. This orders-of-magnitude higher time involvement can be compensated by involving the geotechnics community (Shulman, 1993).

On the contrary, the two reviewers without geotechnical engineering background focused on difficult key points and commented on their efforts to address these difficulties of understanding. Sample comments included misunderstandings ("how come we calculate stresses and pressures only at the lower point of soil layer but then we talk about the settlement of the entire layer?"), uncertainties created by the video ("we only talk about saturated clay, so are we to conclude that dry clay does not settle?") and attempts to understand effective stress as a physical quantity (which is not a productive idea, it is better to think of effective stress as a concept, a useful tool to describe the behavior of soil). The buoyancy analogy, included in the English version, is meant to help the viewers who might go beyond following the material presented and attempt to create their own understanding of the big idea of effective stress.

Comments made by non-expert reviewers are invaluable for the instructor, because they are close to comments students would have made, if they had the metacognitive abilities of the reviewers, who would be classified as highly experienced learners. Domain experts often find it difficult to anticipate learning difficulties of novices, a characteristic known in the education literature as "the expert's blind spot" (Ambrose et al., 2010). Since the video-lesson in Greek was not recorded again, the comments of the non-geotechnical reviewers were addressed in annotations to the script. For the video-lesson in English, their comments helped with (i) modifying the narrative itself (i.e. the script) to provide additional explanations (ii) adding small clarifications to the slides (e.g. notifying the viewers that the scripts include annotations as already mentioned), as well as (iii) providing additional explanations as annotations to the slides. Annotations were deemed to be very useful and convenient because they allow some side notes without interrupting the presentation flow and increasing the duration of the video.

3.4 Intended and suggested audiences and learning environments

As already mentioned, the primary audience of the video is university students in civil engineering departments; targeting such an audience ensures the technical fidelity of content (yes, simplifications are made, but not to the point of altering the essence). The educational material will be used by the author in a Soil Mechanics course at the National Technical University of Athens. Before recording the video, selected slides from Part 2 were included in the lecture on consolidation, when students already know of the importance of effective stress: as mentioned, the point was to unite, in a single frame, soil loading and pumping. In class, the description of the slightly compressible clayey silt in Venice and the highly compressible Mexico City clay is accompanied with the respective values of their compression indices, C_c=0.1-0.29 in Venice, and C_c=3-8 in Mexico City.

With the video available now, students will be asked to watch it on their own, after the lecture on determining 1D settlement and before the lecture on the evolution with time of settlement due to consolidation. Then, the discussion in class will focus on what more can civil engineering students say about the material presented in the video. This discussion can be motivated with the aid of some questions at a level suitable for civil engineering students, e.g. if we stop pumping, will the soil surface return to its pre-pumping levels?

Civil engineering students have much to gain by viewing and discussing a simplified version of material presented in class. For the specific topic under study, the video-lesson offers to civil engineering students an opportunity to contrast sand-clays and dense/hard-loose/soft soils. More generally, simplified versions of adequate fidelity afford opportunities for students to (1) place emphasis on concepts and think qualitatively of the implications of the quantities they use in calculations (e.g. the void ratio) and (2) reactivate their own knowledge through the invitation to enrich the simpler version, thus getting a glimpse of expertise. Perhaps it would be a good idea for the university student to watch the video-lesson with a high school student and have the responsibility to answer any questions.

Another option would be to use the video-lesson in an introductory lecture for Soil Mechanics, for a mixed audience consisting of civil engineering students and some invited high school students contemplating studies in Civil Engineering. The instructor could make the presentation using the actual slides or can show the video in parts, and having a discussion after each part. The goal for the high school students is to see their future self, and for the civil engineering students to see the subject of Soil Mechanics in a context broader than typically allowed in weekly lectures. At the semester's completion, civil engineering students will be asked to watch the video again and, with the semester's knowledge, answer more advanced questions.

One additional learning environment, at the high school level, concerns the broadening of knowledge useful for career guidance. A future extension of this work will add video-lessons for big ideas from other civil engineering thematic fields (e.g. Structural Engineering, Transportation Engineering, Hydraulic Engineering). These video-lessons will help high school students interested in civil engineering studies become familiar not only with projects involving civil engineers, but also with the types of problems they will deal with as students in a civil engineering department.

Finally, the video-lesson may be of interest to those who find attractive using their free time to learn university-level material. In this more unstructured environment, the video-lesson offers the viewers (1) mental exercise for explanations requiring several steps (layered understanding requires more time than info-bytes) and (2) some appreciation of impacts of engineering projects and the work method of engineering.

3.5 Good practices followed (or not)

As with all educational material developed by teachers for the benefit of their students, it is difficult to tell whether the video-lesson helps students learn better. As mentioned, self-assessments of students have little value with respect to what helps them learn (Yadav, 2019), so it takes a research project to answer convincingly the question "did they learn better". In the absence of results from such a project, this section lists some of the good practices followed (or not) in developing the video-lesson. As mentioned, the video-lesson was designed in shorter, semi-autonomous parts conforming to the guideline to keep videos short to keep the viewers engaged (Choe, 2017). This guideline could not be followed in Part 3, which was broken down into parts A and B, so as to at least create a break point. The guideline to keep slides sparse (Grob, 2015) was not followed in the slides where the viewers need to follow separate steps of an explanation. But even in these slides, animation is used to present to viewers the material is smaller chunks and, thus, guide their attention (Grob, 2015). The guideline for inserting quiz questions in the presentations, which is the norm in MOOCs, was not followed due to limited functionalities of the free version of the recording software used (Active Presenter). Finally, from a content point of view, the video-lesson includes elements viewers can easily connect with, such as everyday experiences (from sand beaches) and real case studies. In terms of Mayer's (2014) multimedia design principles (see Table A1 in Appendix), most of the principles were followed to a varying degree, with the exception of: the redundacy principle (at several slides, the same information was both printed and narrated – this was done so that the student can pause the presentation and see the text) and the voice principle (the video-lesson in English is narrated by the foreign-accented voice of the author).

4 Concluding remarks

This paper aimed to present a pilot for the production of future stand-alone video-lessons. To this end, it devoted equal space to the description of the developed material in geotechnical engineering and the methodological underpinnings of the undertaking. The hope is that some instructors will find some idea(s) useful for their teaching, while some others will be inspired to produce something better. In terms of methodology, the paper (i) argued that addressing an audience larger than only university students helps the instructors focus on the more fundamental aspects of their discipline and (ii) placed emphasis on the public character of online teaching, which makes possible peer teaching reviews. Beyond geotechnical engineering, the ultimate goal is that domain experts will be challenged to identify the big ideas and essential questions of their own domain and write about them.

Acknowledgements

The author is grateful to the reviewers of the video-lesson, Alexandra Katsiri, Eva Pantazidou, Achilleas Papadimitriou and Theodora Tika, for their insightful comments, to Kostis Tsantilas for assistance with recording the videos, to Peter de Vries for sharing TU Delft material, to Olga Mavrouli for recommending material from U of Twente, to Tina Pitsaki for suggesting CrashCourse, and to Kyriakos Kandris for starting her on the right foot with MOOCs by recommending an excellent MOOC early in 2013. The thoughtful and meticulous comments by the two reviewers of the paper are greatly appreciated.

References

Ambrose, S.A., Bridges, M.W., DiPietro, M., Lovett, M.C., Norman, M.K. (2010). How learning works: 7 researched-based principles for smart teaching. Jossey-Bass, San Francisco, CA, USA, 301 p.

Auvinet, G. (2016). Geotechnical challenges in Mexico City clay. International Society for Soil Mechanics and Geotechnical Engineering (ISSMGE) webinar, https://www.issmge.org/education/recorded-webinars/geotechnical-challenges-in-mexico-city-clay (accessed March 3, 2020).

Auvinet, G., Méndez, E., Juárez M. (2017). Recent information on Mexico City subsidence. Proc. of the 19th Int. Conf. on Soil Mechanics and Geotechnical Engineering, Seoul, South Korea, pp. 3295-3298.

Carbognin, L., Teatini, P., Tosi, L. (2005). Land Subsidence in the Venetian area: known and recent aspects. Giornale di Geologia Applicata, doi:10.1474/GGA.2005-01.0-01.0001

Choe, E. (2017). Optimizing video for learning: A case study-based primer of informal, educational, digital video best practices. Social Science Research Network, https://ssrn.com/abstract=2909769 (accessed March 3, 2020).

Grob, M. (2015). Do's and don'ts when designing an educational video, https://www.youtube.com/watch?v=ZdlpqO2RIwc&feature=youtu.be (accessed March 3, 2020).

Kalfas, V. (2019). Plato. Mathesis open online course (in Greek), https://mathesis.cup.gr/courses/course-v1:Philosophy+PHL3+19C/about (accessed March 3, 2020).

Kimmelman, M. (2017). Mexico City, Parched and Sinking, Faces a Water Crisis. New York Times, Feb.17, 2017, https://www.nytimes.com/interactive/2017/02/17/world/americas/mexico-city-sinking.html (accessed Oct. 13, 2019).

Kline, S.J. (1995). Conceptual foundations for multidisciplinary thinking. Stanford University Press, Stanford, CA, USA.

Lampert, M. (1986). Knowing, doing, and teaching multiplication. Cognition and Instruction, 3(4), pp. 305-342.

Mebus, L., Ouwehand, M., van Zijl, R. (2013). Step-by-step plan for producing video for online distance learning. TU Delft Online, https://www.slideshare.net/LindaMebus/step-bystepvideo-for-online-distance-learningv20130724/1 (accessed March 3, 2020).

Mayer, R. E. (2014). Cognitive Theory of Multimedia Learning. In R. E. Mayer (Ed.), The Cambridge handbook of multimedia learning (2nd ed.) (pp. 43–71), Cambridge University Press, Cambridge, UK.

Oakley, B., Sejnowski, T. (2019). Learning How to Learn: Powerful mental tools to help you master tough subjects. Coursera open online course, https://www.coursera.org/learn/learning-how-to-learn (accessed Oct. 5, 2019).

Pantazidou, M. (2020a). What happens when soil compresses (in Greek). ISSMGE webinar, https://www.issmge.org/education/recorded-webinars/what-happens-when-soil-compresses-greek (accessed March 3, 2020).

Pantazidou, M. (2020b). What happens when soil compresses. ISSMGE webinar, https://www.issmge.org/education/recorded-webinars/what-happens-when-soil-compresses (accessed March 3, 2020).

Pantazidou, M., Nair, I. (2001). Academe vs. Babel. Organization, 8(2), pp. 341-348.

Papert, S. (2000). What's a big idea? Toward a pedagogy of idea power. IBM Systems Journal, 39(3&4): 720-729.

Phenix, P.H. (1964). Realms of meaning. McGraw Hill, New York, NY, USA.

Sainani, K. (2020). Writing in the Sciences. Coursera open online course, https://www.coursera.org/learn/sciwrite (accessed Feb. 16, 2020).

Shoufan, A. (2019). Estimating the cognitive value of YouTube's educational videos: A learning analysis approach. Computers in Human Behavior, 92, pp. 450-458.

Shulman, L.S. (1986). Those who understand: Knowledge growth in teaching. Educational Researcher, 15(2), pp. 4-14.

Shulman, L.S. (1993). Putting an End to Pedagogical Solitude. Change, 25(6), pp. 6-7.

Stevens, S.Y., Sutherland, L.M., Krajcik, J.S. (2009). The big ideas of nanoscale in Science and Engineering. National Science Teachers Association (NSTA) Press, Arlington, VA, USA.

University of Twente (2019). Video in Education: Types of Videos, Technology Enhanced Learning & Teaching (TELT), https://www.utwente.nl/en/telt/themes/Videoproduction/#types-of-video (accessed Oct. 7, 2019)

Wiggins, G., McTighe, J. (2005). Understanding by design, Expanded 2nd edition. Association for Supervision and Curriculum Development, Alexandria, VA, USA.

Yadav, A., Alexander, V., Mehta, S. (2019). Case-based Instruction in Undergraduate Engineering: Does Student Confidence Predict Learning? Int. J. of Engineering Education, 35(1A), pp. 25-34.

Appendix

Table A1. Basic principles for designing multimedia environments and respective instructional goals (from Mayer, 2014)

Instructional Goal	Name of Principle	Description of Principle: People learn better …
Manage Essential Processing	Multimedia	… from words and pictures than from pictures alone
	Modality	…from graphics and narration than from graphics and printed text
	Segmenting	…when a multimedia message is presented in learner-paced segments rather than as a continuous unit
	Pre-training	…when they know the names and characteristics of the main concepts
Foster Generative Processing (motivation - related)	Personalization	…when the words are in a conversational style rather than formal style
	Voice	…when the words are spoken in a standard-accented human voice rather than a machine voice or foreign-accented human voice
	Embodiment	…when on-screen agents display human-like gestures[1]
Reduce Extraneous Processing	Spatial & Temporal Contiguity	…when words and pictures are integrated in space and time
	Redundancy	…when the same information in not presented in more than one format
	Signaling	…when cues are added that highlight the key information and its organization
	Coherence	…when extraneous material is excluded

[1]…but not necessarily when the speaker's image is on the screen

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