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INFUSE TEACHING WITH RESEARCH PRACTICES: A PILOT PROJECT – WELCOME PRESENTATION FOR FIRST-YEAR STUDENTS ON TIME SCALES IN CIVIL ENGINEERING PROJECTS

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ABSTRACT

The seed motivation behind this paper is the realization that time is not given its due as a concept in Civil Engineering. The corresponding education need is expressed with the question "what educational material can stress the importance of time and how can it be produced?". The approach chosen to answer the first part of the question was to juxtapose smaller and larger time scales and highlight their relevance to civil engineering projects in a video-presentation with the title "Earth, Water, Time and We, the civil engineers". The project described in the paper consists of two products: the video-presentation and the methodology, which addresses the second part of the question motivating the work. The methodology infuses teaching with the research practices of teamwork and peer review, hence the production of the educational material can serve as a pilot for other endeavors to raise the standing of education relative to research.

1. INTRODUCTION

This paper and the accompanying video-presentation address different thematic fields of knowledge and different physical perspectives within the civil engineering domain and its specializations, such as structural, geotechnical and hydraulic engineering. The scientific focus of the paper is time and time scales, notions known to pose perceptual difficulties as discussed in Section 3.5. The paper has a complementary target, namely, to outline a procedure of teamwork for the production of peer-reviewed educational material. The framework of the study is Civil Engineering Education, and hence the educational material developed concerns civil engineering projects. The paper belongs also in the interface of Philosophy of Science and Philosophy of Civil Engineering, since it focuses on the concept of time, a major topic in Philosophy, and its manifestations through civil engineering projects. The paper was written for an audience spanning the aforementioned thematic fields, aiming to attract instructors in departments of civil engineering as main interlocutors for the exchange of ideas.

The methodology followed for the production of peer-reviewed educational material, i.e. the video-presentation, involves three main steps: first choosing to focus on the general concept of time scales in Civil Engineering, then dressing it with a lecture, and finally executing the video-presentation following good practices. An analogy from literature would be to first choose the theme of a novel

(e.g. for Anna Karenina: the relative power of romantic love against unshakable social conventions), then dress the theme with the plot and the characters, and finally write the novel [1]. Using the video-presentation as an example, the paper aims to: (1) propose an alternative way to choose content, i.e. not among topics of individual courses but, instead, to follow threads running through the entire curriculum, (2) demonstrate the practice of developing educational material that incorporates peer review and (3) prove the feasibility of teamwork for the production of quality educational material with an effort that can be accommodated in the busy schedule of a university instructor without remuneration.

2. EDUCATION PERSPECTIVE

Almost three decades ago, the renowned educator Lee Shulman [2] published his article "Putting an end to pedagogical solitude", in the suitably named journal *Change*. Shulman calls for an end to the solitary practices of most educators and the concomitant low respect commanded by education when compared to research. Shulman's main message to all educators is simple: *do education as we do research,* thus changing teaching from private to community property. Specifically, Shulman [2] suggests three strategies that can guide educators in this transformation. (1) Educators need to reconnect teaching to the disciplines (corollary: domain-general education tips will not command high respect). (2) If teaching is going to be community property, it must be made visible through artifacts that capture its richness and complexity. (3) If something is community property in the academy, and is thus deemed valuable, then educators will view it as something whose value they have an obligation to judge.

Guided by the three tenets put forth by Shulman [2], we produced a presentation with these characteristics: (1) a topic that unites different civil engineering subfields and highlights the omnipresence of the concept of time; (2) a product that is an artifact, captured in its final form in video format following rehearsals; (3) a procedure based on multiple peer reviews, as explained in detail in the paper.

3. DEVELOPMENT OF EDUCATION MATERIAL

The production of the video-presentation had a trajectory with several iterations and some zigzags. Four important factors made possible the collaborative work of the authors on a project that was not an explicit part of their duties.

(1) The core of the presentation was partially founded on pre-existing material (see Section 3.1 and Table 1: Section 5 of the Presentation) and the research interests of the second author, the more senior of the group, who was the instigator of thinking deeply about suitable time scales to study physical phenomena relevant to civil engineering projects.

(2) The first author, who has a publication record in Engineering Education, had prior experience in successfully drawing engineering faculty in engineering education projects.

(3) The occasion to deliver the presentation was offered by the 1st-year class of civil engineering students at the National Technical University of Athens (NTUA), who would start their studies online in the fall of 2020, without being physically together with their fellow class mates and their

professors. Since freshmen have just graduated from high school, the target audience also includes high school students in their final year. To this end, team members deliberately abstained (more or less successfully) from the use of specialized technical language (see also Section 3.5), in order for the presentation to be informative and, hopefully, attractive also for high school students contemplating studies in civil engineering.

(4) While working on the presentation, all authors became aware that the omnipresent time is often given secondary status as a concept in civil engineering. This realization strengthened their resolve to create a presentation worth attending for civil engineering instructors as well, since it highlights cross cutting aspects of time scales relevant to many civil engineering subfields (Shulman's first strategy). Standards were thus set high in order to have an educational product worth the time of peers offering review and worth writing a paper about (Shulman's second and third strategies). The ultimate goal is that this pilot project can serve as an example for other teams of civil engineering faculty to produce additional presentations on topics from the core of Civil Engineering, accessible to audiences broader than the students enrolled in the specific civil engineering courses.

3.1. Theme development and team formation

The title of the presentation is "Earth, Water, Time and We, the civil engineers" and its subtitle is "Time scales in civil engineering projects and their relevance in Geology for Engineers (1st semester) and Engineering Hydrology (5th semester)". The reference to specific courses of the civil engineering curriculum at NTUA and corresponding semesters is meant to offer freshmen a preview of their studies. However, the presentation is not tied to specific courses. If the presentation were a play, its main actor would be time. The choice of the theme was prompted by a presentation given for a broad audience of scientists and engineers by the second author, which included observations of earth temperatures as far back in time as measurement and proxy records go. The decision to focus on time followed from discussions between the first and the second author. "Time and change" was also a theme discussed by the first and third author in a previous collaboration for the production of educational material. The third and fourth authors are co-instructors of the course "Geology for Engineers" taught in the 1st semester of the civil engineering curriculum at NTUA. But, the presentation is not meant as part of a geology course. The representation of diverse subfields of civil engineering within the author team made possible to showcase the relevance of one theme (time & time scales) to different areas within Civil Engineering, thus offering to novice students a semblance of a bird's eye view of their chosen field. Figure 1 contrasts the unifying approach to content followed herein to the frequent practice of presenting concepts in individual courses without drawing attention to connections to other courses of the same curriculum.

3.2. Content development and review

To ensure that the separate contributions form a coherent whole, the authors developed the presentation by gradually dressing the theme with layers of garments, so to speak. To this end, authors proposed ideas highlighting the theme in their area of expertise. Some ideas had to be pruned, both to keep the duration of the presentation to about forty minutes, and to ensure flow between the sections of the presentation and create a coherent plot. With the plot more or less fixed, the next step was the creation of a storyboard, in the form of titles of PowerPoint Slides and rough descriptions of each

slide. Finally, once the storyboard was finalized, the PowerPoint Slides were produced and a full script was written by two authors.

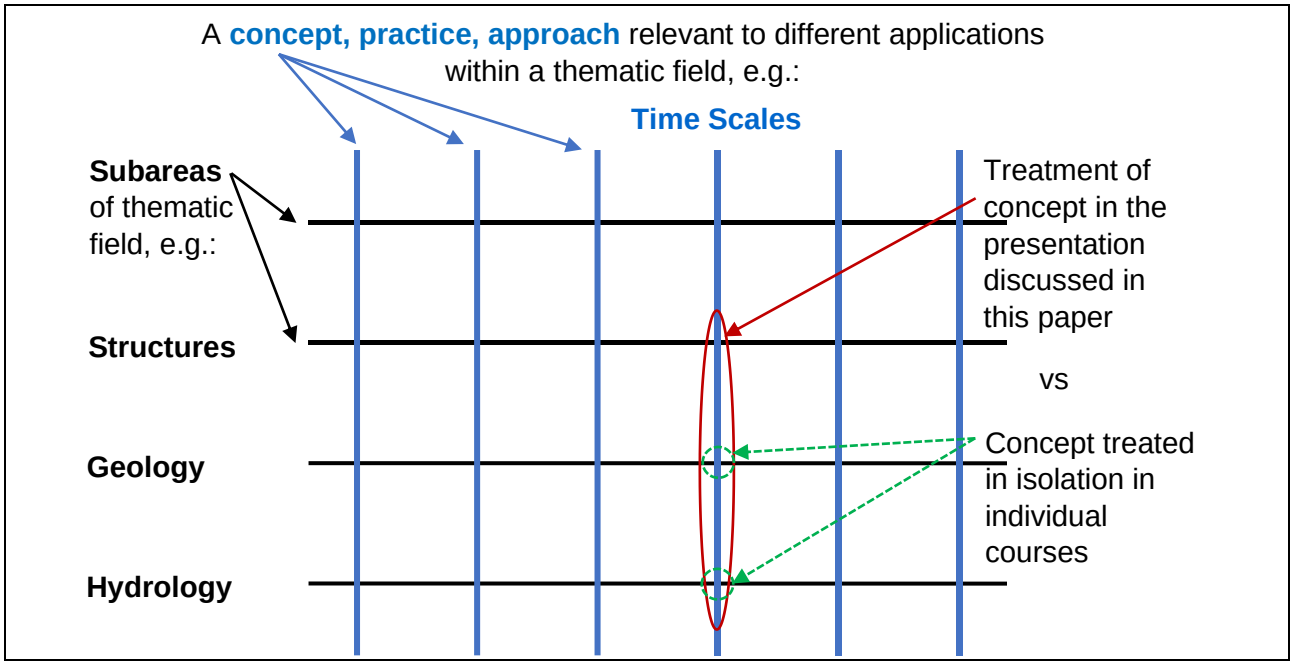

Fig. 1: Presenting a general concept in the thematic field of Civil Engineering (e.g. Time Scales) spanning different subareas of the field vs discussing the same concept in apparent isolation in individual courses (e.g. Structures, Geology, Hydrology).

Review was a structural component of the methodology for content development. Internal review (within the team) was done according to the three musketeers' motto "One for all, all for one". The first four authors commented on each author's contribution at two stages of the development of the presentation: at the storyboard stage and at the stage of the PowerPoint presentation. Only the final script was reviewed solely by the first author. This close collaboration between the authors made them responsible for the entire presentation, so that each one could deliver the entire presentation.

External review from civil engineering faculty was sought during the first delivery of the presentation on October 29, 2020, through an online platform. Reviewers were asked the following questions: (1) Does the presentation have an authentic "civil engineering taste"? (2) Did you spot in the presentation elements offering to high school students – candidate students in our program a preview of their studies? (3) Do you disagree with some technical content, or do you have a modification to propose? Comments were received from two colleagues who were generally positive about (1) and (2) and had no disagreement with technical content. An important comment was that it would be desirable to make the presentation less conceptual and more applied, in order to make it more attractive to high school students. In response to this comment, the second author invited the fifth author, who was responsible for (i) identifying a suitable case study for the hydrology part of the presentation (flood protection work at Spercheios River: Section 5 in Table 1), (ii) writing the full script for Sections 4 and 5 of the presentation (see Table 1) and (iii) producing the video for the last three sections (Sections

4, 5 and Epilogue). The video-taped lecture of October 29, 2020, was reviewed one last time by all the authors before recording the final video-presentation.

3.3. Final video-presentation

The presentation consists of five main sections, demarcated by slides with the titles of each section (Table 1), preceded by an introduction and followed by an epilogue. The final presentation was produced by joining separately recorded videos and has a total duration of 42 minutes. The video is in Greek and is available at this link. The supplementary files (slide titles with full script, and presentation, in Greek, with slide-by-slide references are available at this link). The section titles and main points of the final presentation are included in Table 1 and its plot is summarized below.

The Introduction familiarizes students with the faces of the instructors, who are not visible during the presentations, and prepares them to attend an extended trailer of their future studies. The subtheme of Section 1, "Age of contemporary civil engineering works", was chosen as a student-accessible introduction to the notions of time and time scales. It draws content from Structures and invites students to guess "how long civil engineering structures live" before introducing the concept of useful life of a civil engineering work (of the same order of magnitude as human life). At this point, students are encouraged to (i) search –after the presentation– for civil engineering projects in Greece that interest them, (ii) choose one and note its actual age and (iii) submit this information as an optional assignment (see Section 3.4). Section 1 ends by juxtaposing the age of the buildings and the age of the earth they are built on, thus providing a segue to Section 2. The main idea of Section 2 is that "the earth is alive". However, we often need to speed up time to perceive the changes of geological environment, whether these changes are fast or slow (in a geological sense) in more or less active geologic environments, respectively. Soil- and rock-forming processes and rates are mentioned as specific examples of gradual changes and as an introduction for students to guess the soil vs rock coverage of the land surface in Greece. Section 3 alerts students to the possibility of rapid changes of the geologic environment with the subtheme "Civil engineering works and their dynamic relationship with geologic time". Section 3 showcases the challenges posed by geological environments to infrastructure projects and concludes with the Vajont Dam catastrophe. Following the discussion of time scale issues relevant to earth, Section 4 provides a pivot point for the presentation with its general theme "We study the past to predict the future", in particular different elements of the future that will affect different civil engineering works, e.g. flood flow for a bridge. Then, Section 5 alerts students to the possibly unanticipated finding that we observe "different trends of temperature-sea level & rainfall at different time scales". Finally, the Epilogue encourages students to be unafraid of change, since civil engineers have become quite adept at counteracting the effects of natural phenomena, hence the subtitle of the Epilogue is "Sanctus for engineers".

Table 1: Structure of presentation "Earth, water, time and we, the civil engineers"

Section title	**Section Main Points**
Introduction	• Introduction of instructors with photographs at their offices • Scope of the talk: a cohesive preview (trailer) of civil engineering studies
1. Age of contemporary civil engineering works	• The concept of useful life of civil engineering works (50 – 100 y), of the same order of magnitude as human life • A prompt for attendees to search for civil engineering works and their age • The need to consider longer time scales since civil engineering works are constructed on earth and earth is very old (how old?)
2. The earth is alive – the geological environment and its changes through time	• Difficult to perceive geologic changes in our lifetime, impressive changes in fast forward (180 million years ago $\rightarrow$ today) • Contrast of more and less active geologic environments at the present geologic time • Rates of soil formation through rock disintegration and rock formation through soil diagenesis • How much soil vs rock on the land surface of Greece?
3. Civil engineering works and their dynamic relationship with geologic time	• Section overview: ongoing geologic changes due to earthquakes, fast geologic changes due to rapid sedimentation and landslides • Kakia Skala, West Attica, Greece: the need to accommodate active faults in the design of transportation works • Thermopylae, Spercheios river Delta, Central Greece: narrows in 480 BC, soft sediment flatland today • Vajont Dam, North Italy: a rock slide of 270 x10^6 m^3 earth material creates overflow of 30 x10^6 m^3 water, killing 2000 people
4. We study the past to predict the future	• We need long time series of measurements to design our structures, e.g. of flood flow for a bridge, of wind velocity for a skyscraper • Based on past measurements, we use probability theory to construct potential future loadings for our structures
5. Different trends of temperature-sea level & rainfall at different time scales	• Trend of temperature increase in the last decades? How big is it? How does it compare with past temperature trends? • Estimates of global temperatures based on Ice Cores from Greenland correlate well with estimates of global sea levels and go back to 20 000 BC. • Over the last 10 000 years, i.e. the span of human civilization, temperatures have been, compared to the past, elevated and relatively constant. • Rainfall measurements in the last 70 years reveal no trend. A 150-year record of rainfall peaks shows increased frequency of such events in 1960-1980. • How do civil engineers manage such peaks? By lessening their consequences with structures like the flood protection works for the Spercheios River.
Epilogue – Sanctus for engineers	• By going far back in time, we understand better natural phenomena and can make better predictions. • Earth is ever changing, but change is not necessarily bad, especially considering civil engineering achievements since 1900: deaths from droughts and floods have dropped drastically. • By choosing to study civil engineering, you follow on this great tradition, which you can further improve.

3.4. Intended audience and learning activities

A lecture with an unusual subject requires explicit mention of the main and secondary audiences envisioned for the video-presentation, the respective purposes for the different audiences and the desired activities resulting from attending the presentation. The primary audience is freshmen at the School of Civil Engineering at NTUA. By attending the presentation early in the first semester, the students get a preview of their studies, as already mentioned. More than that, they also get a glimpse of the philosophy of the School: the pride in being and becoming a civil engineer (see Epilogue in Table 1) and the opportunities given to the students for closer involvement with the School (even a welcome talk has optional homework). From about 100 freshmen attending the presentation in the Fall of 2020, seven submitted the optional homework assignment (their names are included in the acknowledgements). The care students took in describing their favorite project made clear their enthusiasm for their chosen field of study. In a virtuous feedback loop, submitted homework motivated the first author to broadcast this enthusiasm back to the School, by creating a 3-page "bouquet of civil engineering works" that was uploaded to the School's webpage. The bouquet consists of the following notable projects: a 465 m-long concrete box girder bridge built in 1970 over an artificial lake created by a dam, a 490 m-long steel bridge built in 2016, a 3580 m-long tunnel built in 2009, a 910 m-long underwater tunnel built in 2002, a complex of cylindrical apartment buildings built in 1974, a 103 m high rise building built in 1972 (the tallest building in Athens, and one of its very few high rises, known affectionately as "the Tower of Athens"), and the monumental building of the Academy of Athens built in 1885.

Another envisioned audience for the video-presentation is high school students contemplating studies in Civil Engineering. These students can watch the video in their own time, or together with one of the authors, or with any other civil engineering faculty willing to discuss the contents of the presentation with students and answer questions they may have about civil engineering studies and the profession.

Lastly, a very small but very important audience for the video-presentation is civil engineering faculty considering the possibility to create additional stand-alone video-presentations for audiences broader than the students enrolled in specific civil engineering courses.

3.5. Good practices followed and lessons learned

The presentation consists of short sections, as recommended for online materials [3]. The total duration of the video-presentation is 42 minutes, but the sections are self-contained and the separate slides introducing the subtheme of each section are suitable break points for watching the video in segments.

As already mentioned, technical terminology (jargon) was avoided to the extent possible. Technical terms, with their proper definition, serve the purpose of scientific accuracy and precision and are crucial for experts in a thematic field, also facilitating communication among them. As a result, experts often do not realize the extra cognitive effort required by non-specialists to follow texts and presentations including technical terms, especially if their meaning is not transparent. This frequent inability of experts to recognize the learning difficulties of novices is described in the education literature with the very transparent term "the expert blind spot" [4].

When the presentation was first delivered with streaming, it included four multiple-choice quiz questions, three of which were presented as poll questions. To save time, one question was presented as a "guessing question", followed by a pause for the students to make a note of their answer (although not asked to respond, quite a few students answered anyway using the chat function). Research has shown that short quiz questions strengthen learning [5]. Self-quizzing also has beneficial effects on learning [6]. In the final static version of the presentation, all four quiz questions are delivered as guessing questions, followed by short pauses and discussion of the answers.

The last piece of good practice concerns full attribution of sources, in order to set an example for the habits students are expected to develop during their studies. Full references of all sources used in the slides are included, slide by slide, at the end of the presentation, for every third-party material used in the presentation, including creative works (videos, photographs). Creative works used are either accompanied by a Creative Commons license or, if not, permission was asked and granted by the copyright owner, and the permission is acknowledged.

Lessons learned include the practical realization that quality education materials produced collaboratively require significant production and coordination time. What is more, the focus of the presentation on time highlights a perennial difficulty of the human brain to perceive time. According to a major synthesis study on learning of science and engineering topics, students have incorrect understandings about fundamental concepts, particularly those that involve very large or very small temporal and spatial scales [7]. The philosopher Aristotle, following on the footsteps of Plato and differentiating himself from his teacher, stated that without perceiving some movement or some change, humans cannot perceive time. Or, more succinctly, "without change, there is no time" [8]. This cognitive limitation is very relevant to slow-moving processes, as is the case in geology: time is passing but we humans often do not see change in our life time. When the human brain cannot reconcile seemingly non fitting entities, it discards those that do not fit and are easiest to discard. So it discards change. This need to better understand change may be more salient for Civil Engineering, where dynamic processes are often analyzed with pseudo-static models.

4. CONCLUDING REMARKS

The work described in this paper was motivated by the two-part question "what educational material can stress the importance of time in Civil Engineering and how can it be produced?". The first part of the question is answered by an example, the video-presentation described herein, while the second part of the question is answered by offering a methodology that can be adapted for the production of similar material.

- The video-presentation was produced as a transferable educational product, i.e. a product usable by instructors other than those developing it. To enable transferability, the open access video-presentation is accompanied by (i) the statement of the educational need it addresses (to offer a trailer for civil engineering studies and to highlight a cross-cutting theme) and (ii) condensed descriptions of the product. To this end, we codified the structure and the content of the presentation in a table format so that, in conjunction with the full list of the slide titles, PowerPoint Slides (in Greek) and references provided (online), any part of the presentation can be used by other instructors.

- The main elements of the methodology are (i) close teamwork, (ii) selection of an important theme, (iii) development of the presentation in stages, starting from the theme and progressing to the ideas (subthemes) supporting the theme, to the storyboard, to the plot and finally to the full script, (iv) peer reviews, provided by each team member at intermediate stages and by external reviewers for the final presentation, and (v) the incentives of visibility and recognition, within the School of Civil Engineering at NTUA (announcement through the School's webpage and permanent links for the video and the accompanying files) and within the civil engineering education community (publication of this paper).
- Freed of the constraints of individual courses, the authors were able to choose as a theme an eternal big idea and frame it with civil engineering projects. The collaborative production of educational material on the cross-cutting theme of time gave the authors the opportunity to ponder at an abstract level its nature and to realize the perceptual difficulties posed by time, already recognized at the beginning of the philosophy as an organized discipline by Plato and Aristotle and, more recently, by researchers on education in science and engineering.
- The recognition of difficulties in perceiving widely varying time scales and their relevance to civil engineering instruction guided the authors to mitigate these difficulties by talking about the essence of time effects mostly with examples familiar to students and without using jargon.
- By showcasing a methodology employing the research practices of teamwork and peer review, we propose that the project presented herein serve as a pilot for the production of peer-reviewed educational artifacts.

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