ENDURING CONSTITUENTS OF CIVIL ENGINEERING CURRICULA: EDUCATIONAL FIELD TRIPS AND DIPLOMA THESIS

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EXTENDED ABSTRACT

While calls for educational reform are frequent, there is a lack of systematic discussion on the forces that do or should change engineering curricula. Likewise, whereas some time-honored teaching practices, such as lecturing to largely passive audiences, are being questioned, there is a lack of systematic argumentation on the types of traditional educational experiences that are uniquely valuable and, hence, worth preserving. Considering the two issues of what should or should not change to be the two sides of the same coin, this article first describes four categories of potential forces for change relevant to engineering curricula, namely (i) technological advances, (ii) societal demands, (iii) industry needs and (iv) educational good practices and advances, i.e. advances in instructional technology and engineering education research.

Within the fourth category, educational good practices, the article attempts to identify characteristics of curricula constituents of high learning value, which are *not* candidates of replacement by instructional technology. From the educational experiences that fall in the category of “Advance Personalized Learning”, the article focuses on research or research-like experiences, the educational value of which has been documented with evidence. It then presents two such educational experiences from the civil engineering curriculum at the National Technical University of Athens (NTUA), the annual geoengineering field trip and the diploma thesis. The field trip is designed for civil engineering students who need to appreciate the importance of engineering geology in the design decisions concerning civil engineering infrastructure. From the perspective of educational theory, the trip belongs in the tradition of inductive teaching: students are not simply shown the geological features that they should be observing, but instead are presented with a design problem and guided to identify themselves the pertinent geology and rock mechanics data. The diploma thesis helps students develop research skills and exercise autonomy. Data collected at NTUA showed that diploma theses frequently produce original findings, as attested by the number of publications resulting from or including thesis material.

Needs for further work are related to the following observations. The indirect evidence pointing to the success of the two educational experiences notwithstanding, assessment of skills developed by students as a result of engaging in these activities is missing. Hence, it is necessary to gather targeted data, which will enable evidence-based justification of preserving curricular elements on the basis of the skills they promote. In addition, since both educational experiences are faculty-time intensive, their presentation is meant to underscore the need to steer the development of instructional technology towards instructional tools that will free faculty time to be devoted to time-consuming educational activities that technology cannot replace.

KEYWORDS

Engineering education, Engineering curricula, Engineering instruction, Engineering Geology, Undergraduate research

1. INTRODUCTION

1.1 Forces for change in engineering curricula

Engineering is an applied endeavor which interacts with society. As a consequence, engineering education has to change continually, in order both to keep up and to lead. Several forces for change exist, which can be grouped in four categories.

Technological advances, resulting from innovations and research findings, is the category easiest appreciated as a force for change by engineers themselves. One example of this trend is nanotechnology, one of the newest fields being incorporated in civil engineering curricula (Zheng et al., 2011). The same applies to analysis tools, such as finite elements, which gradually become widespread and eventually find their place in engineering curricula (Gilewski, 2010). The agents of change for this category include funding agencies, which selectively support promising or needed research areas, university faculties, when they seek opportunities to expand in new fields, and faculty members trained in these new fields. Typical contested issues regarding implementation of such technology-driven changes include questions as to how central a place these new topics should have in the curriculum and whether they are more appropriate for undergraduate or graduate study programs.

Shifting *societal needs* are perceived as a more indirect force bringing about curricular changes. To a large extent, these needs are related to changes in the perception of the engineering profession by the society. Hence, the resulting curricular modifications address the changing obligations of the profession to society. Typically, these changes are reflected in the continual revisions of codes of professional practice and of engineering curricula, to include “new”, at the time, concerns, such as environmental protection and sustainability. Examples relevant to sustainability include the latest revision to the ASCE code of ethics (ASCE, 2010) and a good number of curricular reforms (Haselbach, 2011).

Shaping engineering curricula to respond to *industry needs* may be considered as unwelcome commercialization of education (Bok, 2006). Granted, such an orientation cannot be made independently of the aims of education, an issue on which society has a saying, especially when it concerns higher institutions accepting public funds. However, for students who choose to study an applied field such as engineering, it makes sense that their educational program is informed by the practice and the future challenges of the profession (Sheppard et al., 2009). To this end, accreditation boards contribute significantly, by supporting the development of a breadth of skills, including both subject-matter and horizontal skills (e.g. communication skills) by the graduates of engineering programs (EUR-ACE, 2008; ABET, 2010). When gathering evidence of successful developments of such skills is not stipulated by national law, the main agent of change having the power to respond to the needs of the industry is university administration.

The fourth category, *advances in engineering education*, has yet to be recognized on a par with the rest. This state of affairs is somewhat puzzling, considering the first category of the forces for change: all engineers recognize that progress in *engineering research* should affect both engineering practice and *engineering education*. In contrast, most instructors apparently do not recognize that the same relationship exists between progress in *education research* and *instruction* (Bok, 2006). If we consider this lack of recognition to be not a failure but a lag, then it may partly be due to the slowness of disciplinary networks in providing dissemination avenues (Borrego et al., 2010). For research on engineering education in particular, there is an additional difficulty that must be accommodated: the fundamental methodological differences between engineering disciplines and education, which shares characteristics of academic fields such as social sciences and humanities (Borrego, 2007). In any case, even faculty who do appreciate the relationship between research on education and instruction, they may believe that educational advances influence the "how" but not the "what" questions of education. It appears then, that advances in engineering education are not forces for change of engineering curricula, at least not at present. Before we probe more into this tentative assertion, we first pose the antithetical question of what is better *not* to change.

1.2 What, if anything, should remain the same?

This question can be analyzed from two perspectives: in terms of (i) subject matter and (ii) instructional approach. In this paper, we adopt the latter perspective. It may sound counter-intuitive, but we will claim that it is the advances in engineering education research that point to the invariant elements of an engineering curriculum. More specifically, we believe that advances in engineering instruction make possible to secure places in the curriculum for "what instructional technology cannot replace" (in the logic of "what money can't buy"). We are not the only ones making this claim.

In a recent workshop of the Committee on Engineering Education of the National Academy of Engineering (NAE), which explored how engineering curricula could be enhanced to better prepare future engineers (NAE, 2010), the concept of "Advanced Personalized Learning" was proposed. Specifically, it was claimed that faculty members may now be able to focus on the big challenges of education (e.g. learning to design), if they can use computerized media for routine tasks (e.g. learning computer-aided design packages). This is not an entirely new concept but, rather, the natural evolution of earlier ideas on the sound use of educational technology. The characteristics of effective teaching media resemble the elements of human communication and according to Laurillard (1993) can be grouped in four categories: discursive, adaptive, interactive and reflective. The most challenging is the last one, whereby, in Laurillard's words, "the teacher must support the process by which students link experience to descriptions of experience".

Hence, as instructional technology and research on engineering education progress, engineering instructors have to decide which aspects of training are better suited for computer-aided instruction, which elements of their teaching can be enhanced by instructional technology and, finally, which constituents of the curriculum belong in the invariant category of elements that cannot be substituted with the aid of instructional technology. The remaining of this paper describes two such constituents of the undergraduate civil engineering curriculum at the National Technical University of Athens (NTUA), Greece.

1.3 The goal of the paper

The goal of this article is two-fold. First, to start a systematic discussion on the dynamic balance between invariant and changing elements of civil engineering curricula. Second, to highlight examples of the former category in the integrated 5-year civil engineering curriculum at NTUA, in a way that instructors from other institutions may benefit and NTUA instructors may appreciate opportunities for improvement. Two such examples are described herein: a 12-day long geoengineering field trip, which takes place during the 6th semester, and the diploma thesis carried out during the last semester of studies. Each example has at least one unique characteristic that places the particular curricular constituent in the "irreplaceable" category. For the field trip, these characteristics include direct experience with the rock material itself, appreciation of spatial scale, guided descriptions of qualitative observations of the rock structure in a quantitative way. For the diploma thesis, these characteristics cover the entire spectrum of the apprentice-master interaction, typical of supervised research.

2. GEOENGINEERING FIELD TRIP

The geoengineering trip is an integral part of the Engineering Geology course taught in the 6th semester of the civil engineering curriculum at NTUA. Engineering Geology belongs in the group of core geotechnical courses in the civil engineering curriculum, which also includes in earlier semesters Geology for Engineers, in the 1st semester, as well as Soil Mechanics I and II, in the 5th and 6th semester, respectively.

The trip takes up a week of regular semester time and half a week from the Easter break. Most of the sites visited during the trip are in the French, Swiss and Italian Alps; hence such a trip can be organized by a good number of universities in nearby countries. The subsections that follow discuss the considerable logistics of the trip, give an overview of sites visited and the educational materials assembled, and attempt to sketch the educational philosophy of the trip through the presentation of its educational objectives.

2.1 Logistics

The trip has been attended by about 200 students on average each year. The second author of this article has designed the trip (Marinos, 2011) and led it for the last 20 years, assisted in organizational matters by a department secretary and a committee of volunteer student participants. A total of four engineering geology faculty members or teaching staff are needed for the trip, which is also attended by invited visitors from academia, consulting and construction, some of whom have recorded their impressions of the trip and their interactions with the student participants (e.g. Medley, 2010).

The cost of the trip in 2011 was 750 euros per student. This cost covers 4 coaches, 1 emergency coach, a doctor, special insurance and half board accommodation in good hotels. The School of Civil Engineering has been contributing, depending on the year, with 40,000 to 60,000 euros. The rest is covered partly by sponsorships, and the remaining by the students. Through the years, sponsors have included the Technical Chamber of Greece, major public corporations, construction companies and corporations and civil engineering consulting companies. The field trip leader has initiated exploratory contacts with potential sponsors and prepared a letter addressed to them. The letter explains the educational goal of the trip, includes an endorsing statement by the field trip leader and is signed by the student committee. Students are encouraged to take initiative and contact additional sponsors, provided they have a positive public profile. Every year, it is the responsibility of the student committee to contact old and new sponsors in order to cover as much as possible of the total cost. The sponsors are not offered any advertisement advantages; they only receive an appreciation letter.

2.2 Itinerary

Figure 1 shows the major sites of interest of the trip, which includes ferry rides between Patras and Ancona. The 2011 trip had overnight stays at Venice (2 nights), Florence area (1 night), Nice (2 nights), Gap (1 night), Geneva (2 nights) and Torino (1 night). From the ten days of the trip (excluding the ferry rides), only one whole day (9th day), in Geneva, is completely free, as well as one afternoon in Florence (4th day). The remaining time is fully covered by educational activities; nevertheless culture, behaviors and social issues are also discussed with the unfolding of the trip along the different places and countries crossed.

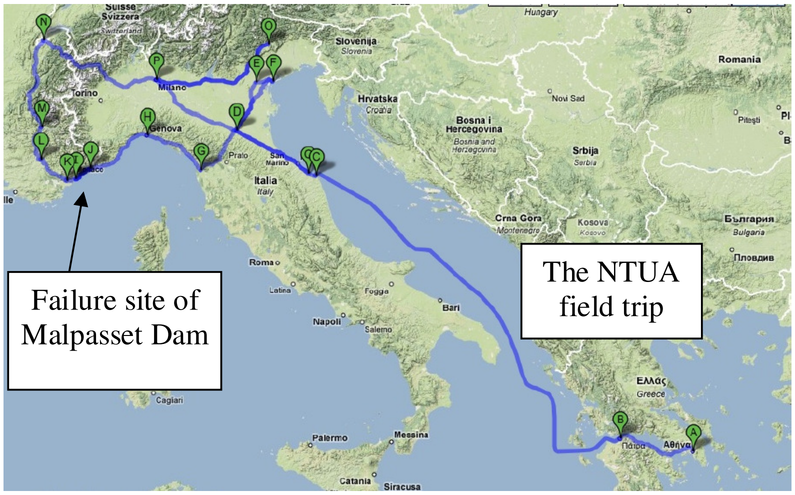

Figure 1. Itinerary of the 2009 field trip and location of Malpasset Dam discussed in Section 2.4.

2.3 Educational materials

The educational materials supporting the trip are summarized in Table 1. It is important to note that materials produced take into account the practical constraints at the field. Thus, students have both a brief handout for site visits and a thick volume (Marinos et al., 2011) with detailed information to consult while at the bus, later in the semester during report writing, and much later in their professional lives, as a reference source. The volume includes material written specifically for the trip and a selection of key publications for each site. Beyond the strictly technical content, the volume also includes personal stories related to the sites visited, as well as contributions of students participating in past trips. Some of these contributions consist of trip-specific lyrics written by students during the trip and fitted to the music of various popular Greek songs. The lyrics are mostly meant to be humorous, however, they also show very eloquently how much students enjoy the field trip.

Table 1. Summary of educational materials supporting the field trip.

Type	**Content**	**Purpose**
Program & advice: student handout	Day by day technical topics & topics of general interest. Advice is geared towards raising team morale, assuaging discomfort and addressing emergencies.	Students know very well what to expect each day. Advice is meant to prepare them for the physically demanding nature of the trip.
Site information: student handout	Key features of site visits.	Students have a handy reference on site.
Rock classification charts: instructor tool in a plasticized menu-like form	Major classification charts and systematic descriptions of rock structure and discontinuities.	Instructors can demonstrate in situ the use of charts under any weather conditions.
Field trip supporting volume: reference source (Marinos et al., 2011)	Extensive information and references for 25 topics pertaining to geotechnical engineering and civil engineering infrastructure.	Students consult during the field trip and while preparing trip reports.

Topics covered in the 600-page volume include problems with landslides and fault activity along the way from Athens to Patras, the subsidence of Venice, the tragic huge landslide in the Vajont reservoir (1963), the catastrophic flooding of Florence (1966), the stabilizing measures taken at the tower of Pisa (1993-2005), the sliding rock mass at Clapière under surveillance since 1982, issues specific to tunnels in urban settings (Monaco), the failure of the Malpasset Dam (1959), the tunnels crossing the Alps and the tunnels of the Torino Metro. Apart from Marinos et al. (2011), key references to some of these topics are also given in Marinos (2009).

2.4 Learning objectives and assessment

The overall educational goal of the trip is tailored to civil engineering students who need to appreciate the importance of engineering geology. The trip is designed so that students perceive the spatial scale of geological features and use the sites as the “laboratory of nature”. Visits emphasize that site selection, safety, cost, construction pace and performance of major civil engineering structures depend to a large extent on geological features of the foundation material and on the surrounding subsurface conditions. Hence, sites are chosen to represent large-scale, well-known case studies of failures, some catastrophic, caused by geologic features either overlooked during the design phase (e.g. Malpasset Dam) or the role of which was underestimated (e.g. Vajont Dam). In terms of educational philosophy, students are not told what they are supposed to be observing but instead are guided to discover it themselves. This is achieved by following an inductive approach to learning, whereby students are given an open-ended question and asked to come up with a recommendation. The visit to the area of the failed Malpasset Dam (Figure 2) is a good example of this approach.

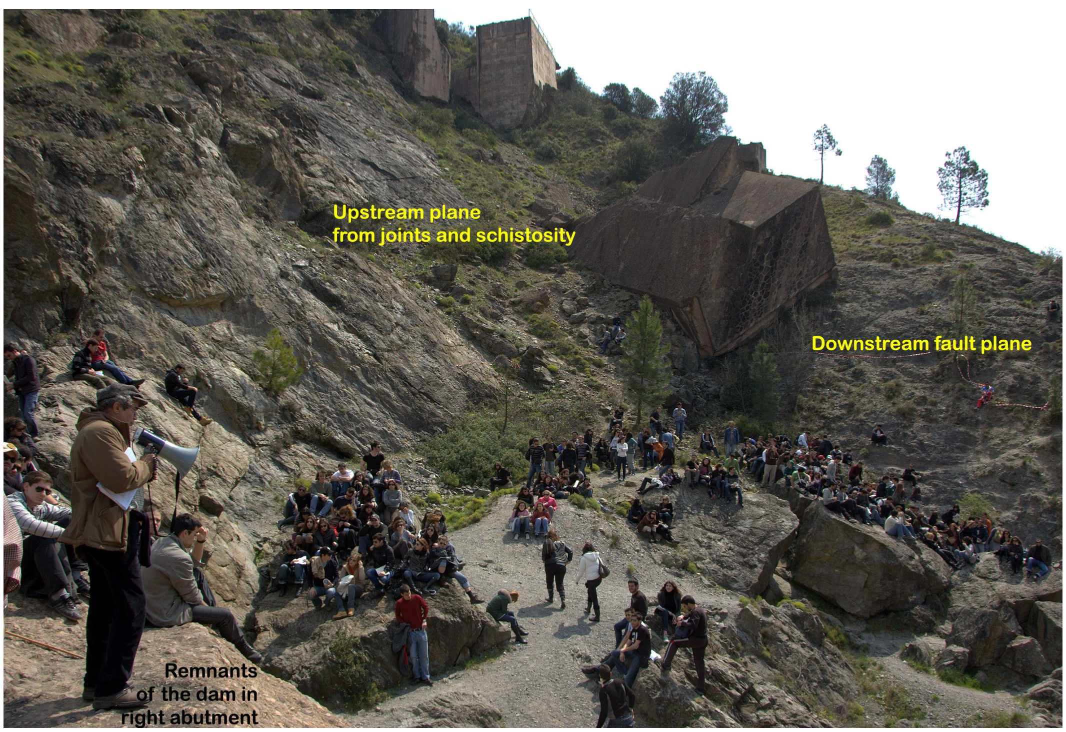

Figure 2. Malpasset Dam failure: The civil engineering students inside the dihedron, in left abutment, removed, together with the dam, by the uplift pressure.

Students are divided in four groups for the visit of the Malpasset Dam area. Each group is led by one of the four instructors on a 1.5 km hike in the gorge of the Reyran creek dammed by Malpasset. The students know of the leading explanation for the failure of the arch dam due to hydraulic uplift exacerbated by the unanticipated presence of a fault. But this is not the main focus of the visit. Instead, even for this well publicized case, students are invited to start thinking with a clean slate. Specifically, they are asked what type of dam they would build and at which location, considering the different rock types along the gorge. In order to make this recommendation, students must synthesize prior information on the importance of geologic conditions on the selection of dam type (also included in the volume) and their own evaluation of the rock types in the vicinity. As they walk along the gorge, they evaluate the strength of the intact rock using the geologic hammer. Then, they have to classify the discontinuities and estimate the overall strength of the rock mass. Students have some prior experience doing this in tutorials and homework assignments using photographs. The visit of the Malpasset Dam locale gives them the opportunity to refine this skill in a natural laboratory. Thus, borrowing once more Laurillard's (1993) words, "students link experience to descriptions of experience".

For the purposes of final assessment, students form small working groups. Each group is assigned one topic from the field trip and prepares a written report upon returning to Athens. Examination also includes group presentations of the reports. These reports are not assigned a grade, but they contribute to rounding up the final grade for the course.

3. DIPLOMA THESIS

Civil engineering students at NTUA have to pass about 65 courses taught in nine semesters. These courses are taught primarily by members of the civil engineering faculty, while there is a sizeable fraction of courses taught by members of other NTUA faculties, specializing in mathematics, mechanics, architecture, humanities, economics etc. The 10th semester of the 5-year program is devoted to the preparation of diploma thesis, which culminates in a formal presentation and oral examination by a committee of three faculty members. Often students elect to take more time than a semester: it is common for students to work both during the spring semester and the summer and present their thesis in early fall. Admittedly, civil engineering students at NTUA have a "very full plate". Still, 30% graduate within the nominal study time of five years, while 74% have completed their studies within six years (Caroni, 2011).

For the diploma thesis, each student works under the close supervision of a faculty member on a topic relevant to any of the courses included in the civil engineering curriculum. A sizeable number of theses are practice-oriented and address some civil engineering design problem. Others involve extensive literature reviews and original research. Those are often independent elements of larger research projects, whereby students interact not only with their faculty supervisor but also work as members of larger research teams. The anecdotal evidence suggesting that the number of diploma theses published in the peer reviewed literature was sizeable motivated the systematic gathering of data presented in the following section.

3.1 Statistical data (2004-2010)

Data collected by the central administration office of the Civil Engineering School included a total of 1520 theses carried out in seven academic years, from 2003-2004 to 2009-2010. Data analysis showed the distribution of theses supervised by (i) faculty members of civil engineering, (ii) faculties of neighboring thematic fields, i.e. mechanics and architecture, and (iii) faculties of thematic fields other than engineering, such as humanities, economics and law. For the data included in Table 2, the calculated average percentages are 81.5%, 12% and 6.5%, respectively. Within the School of Civil Engineering, data are further broken down by its five departments: structural engineering, water resources & environmental engineering, transportation planning & engineering, geotechnical engineering and planning & construction management.

Table 2. Distribution of thesis topics from 2003-04 to 2009-10.

Academic year	Theses supervised within the School of Civil Engineering					Theses supervised outside the School of Civil Engineering			
	Structural Eng.	Hydraulics & Environ-mental	Trans-portation Eng.	Geo-technical Eng.	Construct. Manage-ment	Mechanics	Archi-tecture	Humanities, Economics, Law	Other
03-04	72	12	26	31	12	14	15	10	1
04-05	124	27	25	27	16	11	16	11	2
05-06	100	28	28	27	6	10	17	17	0
06-07	87	19	12	40	1	8	15	13	0
07-08	96	19	13	32	5	4	23	6	0
08-09	100	16	14	23	6	3	23	19	1
09-10	115	21	20	37	2	3	18	20	0
Average	**99**	**20**	**20**	**31**	**7**	**8**	**18**	**14**	**0**

For the subset of theses supervised by civil engineering faculty, a separate spreadsheet file was created for each of the 65 faculty members who have supervised 1148 theses in the 2004-2010 period and were not retired as of the spring semester of 2011. The file included the title and year of each supervised thesis and was sent with a personalized e-mail to each faculty member. The e-mail referred to the writing of the present article and asked each faculty to mark in the appropriate column of the spreadsheet if material from a thesis was presented at a conference or published in a journal, Greek or international or if the thesis was awarded a distinction, such as a NTUA thesis award or any other prize given by professional associations at a national or international level.

Table 3 includes data that correspond to a sample size equal to about 1/3 of the faculty members (22 responses out of 65 requests) and the theses (366 out of 1148). It is apparent that a sizeable number of graduating students are coauthors of conference or journal publications that include material from their diploma thesis. Even with the 1/3 response rate, the percentage of the 1148 diploma theses that contributed material to papers in international conferences and journals is 6.5% and 4%, respectively. This recognition attests to both the dedicated supervision of the civil engineering faculty and the talent of the students, which have entered the civil engineering program after having excelled in very competitive university entry examinations. At the same time, the importance of the 5-year integrated curriculum, which enables many students to mature and be productively involved in research on their last year, should not be overlooked. These very encouraging data also strengthen the belief that diploma thesis is a valuable element of the civil engineering curriculum at NTUA. What is more, they indicate that diploma thesis preparation is worth to be supported and improved further.

Table 3. Publications and distinctions related to 366 diploma theses completed from 2003-2004 to 2009-2010 and supervised by civil engineering faculty.

Number of publications and distinctions				
Conferences		Journals		Awards
Greek	International	Greek	International	
63	76	5	49	10

3.2 Further work

To further improve average thesis quality, the School of Civil Engineering has submitted a proposal to secure funds for the development of three web-based modules supporting thesis writing, with the collaboration of a language and information specialist. The three modules will address 1) technical writing, 2) expectations for a NTUA thesis (goal, audience, abstract writing, structure of thesis, use of tables, use of figures, format, references, glossaries with key terms) and 3) systematic literature searches (databases, deontological issues) & technical terminology (glossaries, multilingual resources). While the first module will be to a large extent specific to the Greek language, the other two modules are of broad relevance and will be made available in English as well. The developed modules will build on material from existing technical and science writing guides in Greek and English (e.g. Agioutantis and Mertikas, 2003; Montgomery, 2003). The first two modules will follow the approach adopted by Montgomery (2003), whereby excerpts from texts are presented at several subsequent editing stages. To this end, authentic texts written by civil engineering students have been collected; module users will first be given an opportunity to comment on them and suggest changes, before they are given access to the edited versions.

4. DISCUSSION

In the absence of systematic assessment data, this section gives some anecdotal evidence of the impact of the two educational activities presented herein, together with some supporting evidence from the literature. On the part of the students, the first author has been recipient of numerous comments regarding the value students themselves give to their experience of the field trip. Many students have commented that their resolve to become geotechnical engineers has its origins in the geoengineering field trip. Other comments highlight how stimulating is for them to approach real civil engineering as active participants instead of as passive onlookers. Among the most telling comments is the following: “when we returned to Athens, if only I could take a shower, I would be ready to start the trip all over again”.

Another feature that contributes to the value of the experiences is their research element, direct or indirect. The debate concerning the research-teaching relationship (i.e. whether research activities of faculty members add value to their teaching) already had a long history, before Prince et al. (2007) showed that, whereas research has clearly the potential to support teaching, data collected so far do not substantiate this broad claim. Regarding the possibility of bringing research into the classroom, Prince et al. (2007) question the potential of integrating research content into instruction. However, they are very positive about the potential of introducing elements of the research process in instruction. Accordingly, they highlight inductive teaching as an instructional strategy that emulates research: such was the approach for the visit at the Malpasset Dam locale described in Section 2.4. When it comes to evidence substantiating the various claimed gains from the research-teaching connection, Prince et al. (2007) found that currently only undergraduate research can be supported by several documented educational benefits.

5. CONCLUDING REMARKS

In breaking with tradition of highlighting innovations in education, this article presented two lasting components of a civil engineering program deemed by the authors of unique educational value because of their “Advanced Personalized Learning” aspect. Although no direct assessment has been made of skills developed by the students as a consequence of the two learning experiences, the hypothesized value is consistent with literature findings that show concrete gains for undergraduate students engaged in research or research-like experiences. At a conceptual level, the article takes the discussion on distinguishing logistical from pedagogical contributions of instructional technology one step further: recognizing the forces for change of engineering curricula, it starts delineating the dividing line which instructional technology cannot cross (as of yet). At a practical level, the article offers material for a geoengineering field trip that can readily be adapted by institutions in many European countries and provides motivation for the development of educational material for undergraduate thesis preparation.

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