New methodology on Applied Geology and Geology for Engineers education by using practical trip

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***Abstract**: There has been much discussion on the primacy of theory over practice. Today prevails the exaggeration of practice. This idea forgets too that teaching problem is a problem of right balance. The approach of the action lines on the EUROPEAN HIGHER EDUCATION AREA (EHEA) framework provides for such balance. Applied Geology subject represents the first real contact with the physical environment with the practice profession and works. Besides, the situation of the topic in the first trace of Study Plans for many students implies the link to other subjects and topics of the career.*

This work analyses in depth the justification of such practical trips only on Applied Geology. This methodology could be usual in Study Plans of pure sciences career, Geology or Biology, but not in Civil Engineering like teaching method. It shows the criteria and methods of planning and the result which manifests itself in pupils. Therefore, work shows a methodology taking in account the engineering perspective, the practical point of view and the learning process inside students and their evaluation and, hence, their marks.

Introduction

Geology and geomorphology have always had an important role on applied studies in Civil Engineering, which is in the shallow part of the Earth crust where support infrastructure works. It has been from second half of the 20th century where a great development of the applied studies has been reached: natural hazards, water and wind erosion, flooding, landslides, risks linked to the karst and the coast, etc. They also include Geology and climate aspects related to the relief and related to environmental aspects, even anthropogenic and environmental impacts. However, the teaching is applied in the civil engineering career. For example, Bachelor's degree of Territorial and Civil Engineer relates specifically the study of Climate and Geology jointly and from the point of view of their application. This implies a practical knowledge of Physical Geography. All this complicates the course programme of Applied Geology and teaching activities. The term "Geology applied" is the name of the main subject from which they derive others. It is considering geological matters that are necessary to the engineer for the development of works. The applied nature necessarily implies teaching methods that transfer experimental, engineering and scientific, knowledge at the same time. The Applied Geology is the application of the principles and methods of Geology to Civil Engineering needs.

Context and background

The engineer is required to have the following skills:

1. Engineer must have a sufficient theoretical knowledge so that they can be applied to solve specific problems, the capacity of criterion to simplify these one, and taking into account factors such as speed, simplicity, quality and economy.
2. Engineer must take advantage of pre-existing data, know where they are, how to find them, how to select them and avoiding repetitions.
3. Engineer must get sufficient skills in order to analyze and asses sample of data or results, with regards to reality and, finally, reach a satisfactory resolution.

4. Engineer must find solutions, although they are approximate but always successful.

But Geology has another object. His ultimate goal is the exploration of the history of the geological events through observation, deduction and reasoning and, in exceptional cases by direct underground exploration or experimentation. Experimentation is very limited in Geology; reproduction in the laboratory of certain phenomena or processes geological, among other things is difficult because both the time and space acquire a great magnitude. For this reason, some aspects of the Geology are close to descriptive sciences, whereas others, closer to techniques, such as geophysics and geochemistry, have assimilated advances experienced by the physics and chemistry.

Geology is studied in all about Civil Engineering. We believe that the engineer should have a general but no detailed geological formation. Attention will focus on those aspects of the Geology which are full of particular practical importance to the Civil Engineering: External Geodynamics, Structural Geology, Petrology or Stratigraphy.

Research questions

Work shows a new methodology to teach and learn Applied Geology attending particular circumstances mentioned: teamwork, Applied Geology like practical subject, teachers and students.

The teamwork of the civil engineer

The engineer has to know how to use the services of specialists, in our case a geologist specialist. And, generally speaking, teamwork: geologist-engineer in coordination. Geologist analyzes the conditions as they are, and the engineer considers the conditions can be changed so that they will serve for a certain purpose, i.e. to overcome the difficulties that the geologist he predicts. Geologists should take into account that what the civil engineer needs not a complete geological survey, but enough information to be sure about terrain expected conditions: lithostratigraphy, plain language, separation of real issues from interpretable ones, etc.

Geologists, engineering geologists and civil engineers have to work as a team. If they ignore each other, there is a permanent risk which has its origin in the different training received. The risk of lack of connection can fill with the degrees of engineering geologist, where in one person, met two aspects: geological and engineering. However, these two aspects are real in civil engineers with training and experience in Applied Geology.

Importance of the practice in Applied Geology

We could define the Applied Geology like the application of the principles and methods of Geology to the needs of Civil Engineering. It is, therefore, based on geological knowledge. We might call them basic or theoretical. They can be acquired both scientifically and empirically. This knowledge will be transferred like application to the infrastructure works.

A long time, and increasingly, Applied Geology is becoming more important because the works are larger and more complex and have more impact on the ground: tunnels and large works, greater demand for industrial rock, better use of all water resources, including the subways, preponderance of the environmental aspects etc. The new works require greater demands with respect to the knowledge of the terrain (surface and in depth)

On the other hand, the geology perhaps is the part most random and difficult to analyze in projects or in constructions In infrastructure works, terrain is showed in very different geological processes. The most of the problems and uncertainties lies on this. And their economic consequences may be very significant, like it has been observed in the frequent amendments to projects. The history of large buildings and structures is full of effects of geological origin. Therefore, we must stress the importance of the geology, both basic and applied.

Students roll

The teaching of geology and related subjects is adjusted to a curriculum that supports few variations (material limitations and teachers). Also, teaching is adapted to the degree of knowledge of geology that high school students bring. The most part of new students in Escuela de Caminos de Madrid

comes from high school. They know poorly Geology. The Geology is an optional subject for those who follow the option for engineering. There are very few who choose it, certainly below the 10%. They prefer Technical Drawing, subject of preparation to the first year in university.

There is another added difficulty, perhaps with secondary order, and it is that by placing the Geology in the initial courses, students still not has got explanations if different types of infrastructures and works. The application of Geology requires each one of them. For this reason, must be taught basic concepts of different projects and their interaction with the terrain.

There are other characteristics of the students who are in initial courses of engineering. The have been taught in an atmosphere of inductive and deductive rigor that predominates on the rote study. Also there is an utilitarian and practical attitude that elude unnecessary efforts. The geology is for them the first subject of a nature highly qualitative rather than quantitative. Geology does not conform exactly to the frames of mathematical rigour. It is appropriate to insist that the nature and terrain present very changing situations, and with big uncertainties which do not conform to simple geometric models.

Teachers roll

Teachers must know the subject and feel it. Having enthusiasm for teaching and research and then, motivate the student and convey the desire to know and love profession. We must always encourage and make pleasant the subject, but also with demand. This is closely related with the professional vocation to geology, to teaching and research, and with the personality of each teacher.

Teachers dedicate many hours to other educational activities, such as the preparation of classes, tutoring, test preparation and its correction, drafting of texts, participation in thesis courts, coordination of courses, etc. The teacher is the primary subject on the programme. He directs its realization (in part, also he runs it) and controls its results. Without the teacher would not be possible teaching as conceived today.

For the exercise of their profession, teachers, must be improved continuously. The improvement becomes from reflection on their experience and progress in pedagogy and science that he teaches. Keep up to date, in this regard, requires, by today, many hours of study and reading. Geology has experienced a spectacular development in recent years. Publishers take to the market translations of general works of this matter and reissues, each year. At only one particular field of geology, the abundance of publications is overwhelming

As the teaching takes place in an engineering career and not a Faculty of Science, would have to take into account non-decoupling of the professional world, because it would be incomprehensible that we were teaching a discipline in a practical career without parallel experience with the world of business or, at least, know or be aware about methods of the Geology for engineers.

Pedagogical Principles

For searching how focus our teaching under these circumstances, it has been designed a teaching experience based on practical trip. This information has been gathered by experience, as said, and by application of pedagogical principles. Years of teaching show us how and when student motivation is higher and how and when knowledge and competences are solid and reliable. We also attend to the very common pedagogical principles which support and explain in some way the collected experience. As discussed, these facts are set in the beginning:

1. Applied nature of the geology for engineers.
2. Level of knowledge of the student.
3. Degree of participation of the teacher and real experience.
4. Team work and multidisciplinary team.
5. Motivation of the student and the teacher given their profile and their origin.

The pedagogical principles applied are:

1. You learn by doing. Development of a model based on the master and apprentice.
2. Learning in a team. The team goes further in the knowledge that the individual.
3. Student-centred learning. Student is active and not passive within the group. The ability is individual.

4. The student must observe, formulate hypotheses, verify them, execute them and defend their criteria. Competencies are individual.
5. The teacher uses his leadership in a democratic way. He is not authoritarian nor frees the student. He transfers with good sense and ability his knowledge and experience to the student.
6. Knowledge has value by itself. It is not just useful to be evaluated or pass an exam, but the interest of knowledge lies in the professional interest, in the power to do, and in the pleasure.

Methodology Framework

Trying to summarize and clarify the used methodology in the real practical trip framework, this methodology is based on the following application of pedagogical situations and objectives. The following table shows methods according to the educational objectives and pedagogical situations required under teaching of engineering environment. This methodology would be applied during practical trip. It was showed under programme framework. It was developed by the authors based on their experience and on mentioned pedagogical principles.

Objectives	**Pedagogical situation**			
	Knowledge	**Training**	**Obtained Experience**	**Reflection of experience**
To know	Theory before visits works on site and places	n.a.	Personal work and team work	
To know how	Practical work showed and taught on site			n.a.
Way to do	n.a.	Practical work showed and taught on site. Interactive dialogue between professionals, teachers and students		
Attitude	n.a.	Professional experience transferred by professionals and teachers on site and places. Interactive dialogue between professionals, teachers and students		

Figure 1: Statement of pedagogical situation for practical trips

Discussion

At this point, it is showed our new proposed methodology which has been applied for last ten years. Every year it was improved adapting variable circumstances (teachers and students) through the preparation and design of the trip.

The choice of itinerary, works to visit, teachers and the geology are important. Before set these variables teacher must be programme stops during trip, cities and places to visit, works under construction, important geological places and points to visit, etc. This programme should be including: dates, times, places in order to facilitate logistic and supporting.

Programme is including proposed learning targets. These ones are included in the course of Applied Geology at Escuela de Caminos de Madrid. In example:

1. Learn main types of minerals and rocks, their identification and training, as well as the processes that affect the rocks: tectonics, weathering and erosion.
2. Know the properties of the soil and rocks on the basis of their origin.
3. Management of geological concepts, with ease and skill that reveal the importance of the interaction of the geological environment with infrastructures works in its feasibility, design, construction and operation phases.
4. Predict and reason behaviours and responses of the terrain and works in their interaction.
5. Analyze geological for every type of civil work conditions.

6. Develop a sufficient confidence in the concepts acquired in the course to link with the rest of the subjects of subsequent courses of a purely technical nature, understanding conditions technicians that can bring the knowledge of the geological characteristics of the environment.
7. Understand and reason around of geological reconnaissance in Geology for Civil Engineering.
8. Experimental and realistic understanding of the geological problems in public, mainly Spanish works.

Result is a programme which integrates and gathers: restrictions and conditions, learning objectives, and pedagogical principles. Methodology is showed with these main points of a practical trip programme:

1. Brief Explanations during trip. Using microphone and papers. Its objective is to underline the importance of knowledge and practice to develop later at the works on site and the countryside. Basic theoretical knowledge is presupposed like learned already, however, must be clarified the most difficult concepts. It aimed to the student towards planned goals.
2. Practical classes during the itineraries with their corresponding stops in the teaching and previously established points of interest. Contact the student with the practical aspects of Geology and Applied Geology to infrastructures works is achieved through practical classes in field and on site. They constitute an essential piece in the subject. And theory can not meet it. Also, it leads an attractive environment that stimulates questions and the dialogue between teacher and student. This is in the interests of the student.
3. Transfer of experience in the visited works and sites of geological interest. The experience on field and on sites, even if minimal, has fundamental importance in all training of a science of nature, such as geology. No course of Geology for the Engineers can be considered complete without well planned field trips, where the student can get in touch with the field and see what is explained in classroom. Visits to works can provide him an insight into relationship between Geology and Civil Engineering.
4. Discussion and analysis around the visited works. The purpose of discussion and analysis is to understand design, construction, operation, problems, solutions, etc. Passage through the course of Geology represents the first real contact with the physical environment, the profession and works for many students. These debates are directed in such way. These debates also illustrate different types of phenomena and generally not very complex geological structures. The intervention of professionals linked to the works built or under construction, and who have been related to geology, is essential.

Learning Results Evaluation

The assessment of their knowledge is delivered through the production of a trip report or statement structured according to the programme of the same trip. For years we were collecting this report and it is part of exams and questions. Part of subject can be asked and evaluated by this mean, as far as, site are part of the real life of civil engineering. Teacher only must adapt the complexity of problems to the friendly and simpler environment. Students can be evaluated better and they recognise it by specific survey (see next point). Marks are significantly better. Over 10% students are failed in questions related with practical trip which is 3 times less than usual questions.

This report is drawn up in team of students. It details the most important conclusions and it should reflect the results of the learning. All of the students show a good enough report. They collect the main ideas and concepts. Graphics and photographs are representative. It is true that learning outcomes are achieved with sufficiency. These learning results are as follows.

1. Knows and understands the Geological Sciences in a sufficiently deep way, mainly in the fields of Geodynamics Internal and External, Mineralogy and Palaeontology, Historical Geology and Climatology.
2. Applies concepts and principles of Geology and Geomorphology and Climate Science to engineering problems.
3. Applies the relevant experimental methods of Geology in Civil Engineering.
4. Develops a sufficient confidence in the concepts acquired in the course, to link with the rest of the subjects of subsequent courses of a purely technical nature, understanding technical conditions.

5. Predicts and rationally manages geological constraints that the geological environment imposes on the feasibility, design, construction and operation of infrastructure works, from the interaction of these with terrain.
6. Understands, from a realistic and experimental point of view, the geological problems with regards to infrastructure works, mainly Spanish.

Students Motivation.

Motivation of students is one of the basic pillars to check if practical trip is helping them. Once practical trip experience is developed, we try to know about results and changes on student's motivation in learning perspective. This is done regardless of the outcome of their knowledge achievements assessed properly.

For this, it has been designed a survey about their motivation after trip. Survey was made by the Unidad Docente de Geología Aplicada of the Departamento de Ingeniería y Morfología del Terreno (Escuela Técnica Superior de Ingenieros de Caminos, Canales y Puertos, Universidad Politécnica de Madrid). It was completely anonymous. Its objective was to collect the opinion of the student as a key agent of learning and teaching of the subject. It takes place under new teaching/learning criteria approach at the European framework in Higher Education. The results are exceptionally good with 90% of student's participation and with very high scores in a number of questions as the itineraries, teachers and visited places (range of 4.5 to 4.2 in a 5 points scale). The majority of students are very satisfied (average of 4.5 in a 5 points scale). In general, student's motivation is moderately high (average score over 4.0), the best valued aspects are about learning and teaching.

Conclusions and recommendations

Once analyzed the results of the evaluations and data from the survey can be said that:

- Practical trip is a teaching tool that joins teamwork, the application of geology to the engineering and the transfer of professional experience.
- The results of learning of the Applied Geology are widely achieved by students.
- It is complex to base a full programme of Applied Geology teaching exclusively on practical trips, however, they teach to know for the professional interest rather than for the interest in passing an examination.
- Practical trip links motivation, learning, innovation and teaching
- Motivation is not only a question of student inside but question of team, professional utility and realistic approach.
- Logistics can largely damage motivation. Balance between itinerary and logistics is required,
- Practical trip needs to be adapted, under EHEA criteria, to Earth Sciences in Engineering.

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