Teaching for the Millennium - or for the students?

Jørgen S. Steenfelt

ABSTRACT

Geo-engineering education affects us all. The nature and quality of our graduate intake and the opportunities for continuing education will define the future of our disciplines. In a climate of ever increasing demands for innovation, cost efficiency, fast-tracking and interdisciplinary co-operation it would appear that Society demands more and more in terms of quality and versatility of its professions. Strangely, this is coincident with a worldwide trend for a decrease in funding and an apparent lack of commitment by Society to higher education. The geo-engineering profession and geo-engineering education are not immune from these trends.

The keynote lecture describes this fundamental dilemma, and discusses the influence on geo-engineering education from the different sub-disciplines, the curricula, the teaching language and methods. Furthermore, the impact from the challenges in the new millennium from Society and student body is addressed.

INTRODUCTION

Education and parenting have a lot in common. In a number of cases we feel obliged as educators to say to our students: “Do as I say! – and not as I do”. We also entertain the same worries about the future. Are they sufficiently equipped to conquer the world, will they behave; can we be proud of their exploits?

Like parents educators have different teaching styles and place emphasis and importance on (widely) differing values. And it all falls back on the educator/parent if things go wrong? Parents may adhere to different political/religious beliefs, which colour or guide them in the upbringing of their children.

In the Geo-engineering sciences we have different disciplines and societies/associations which may colour our outlook, methods and understanding of geotechnics.

For better and for worse, geotechnics are represented by three sister societies: The International Society for Soil Mechanics and Geotechnical Engineering (ISSMGE), the International Society for Rock Mechanics (ISRM) and the International Association for Engineering Geology and the Environment (IAEG), together with a number of other international societies, associations and groups. Of the latter, the International Geosynthetics Society (IGS), the International Tunnelling Association (ITA), the International Association of Hydrogeologists (IAH), the International Association of Computer methods and Advances in Geomechanics (IAC-MAG) and the International Commission on Large Dams (ICOLD) are co-sponsoring this conference, GeoEng 2000 – An International Conference on Geotechnical and Geological Engineering.

Already from the name of the conference we get a feeling of the inherent discrepancies and conflicts by comparing it with the names of the societies! Thus, it goes without saying that the field of geotechnics deals with multidisciplinary subjects and problems, which requires input from a broad spectrum of other sciences and disciplines.

The core disciplines are soil mechanics, rock mechanics, engineering geology, geotechnical engineering and the environment.

The ambition with the present presentation was to present a collaborative or multidimensional view of geo-engineering education involving co-authors from the three main sister societies. For various reasons this did not prove possible. Thus, there might be an (unintended) unbalance favouring soil mechanics/ geotechnical engineering reflecting the main background of the author.

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1 Jørgen S. Steenfelt, Technical University of Denmark, Department of Civil Engineering, Diplomvej Building 373, DK-2800 Kgs. Lyngby, Denmark

However, most of the views on Geo-engineering education presented are believed to be equally valid for the whole range although exemplified for one of the disciplines only.

**Preamble**

To actually produce a written version of this lecture in advance proved to be one of the toughest writing jobs ever experienced by the author.

Firstly, the topic is a bitch, as this is a field where everybody is an expert, with ample experience from either or both sides of the rostrum and in part because the subject matter is elusive. We most likely all tacitly know what should be done, despite the fact that few actually do it.

Secondly, the subject matter is a far cry from a good case history where the photos, figures and graphs tell the story almost of its own volition. Hence, I have resorted to insert a few “flies”, by the Danish cartoonist and writer Storm P. (Robert Storm Petersen, 1882-1949), which hopefully invites the smile (copied from Storm P., 1998).

Thirdly, it is humbling to follow in the footsteps of some of the most esteemed colleagues of our profession who by merit of excellence in practice and education are still the basic reference to the subject of education. When I think of impact of geo-engineering I feel belittled and seek solace in one of Storm P.’s “flies”. One vagabond asks the other: “What do you think of the world situation?” Reply: “I don’t know, I have got something in the eye!”

Finally, I have included a few “grooks” by Piet Hein, world famous Danish engineer and writer to help us keep the feet on the ground (Hein, 1966; 1973).

**BRIEF HISTORICAL BACKGROUND FOR GEO-ENGINEERING EDUCATION**

**The Major Geo-engineering Societies**

The current status in terms of numbers for three sister societies formally representing and looking after the development of geo-engineering is shown in Table 1.

<table>
<thead>
<tr>
<th>Society</th>
<th>Founded</th>
<th>Official languages</th>
<th>Current Membership</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Member societies/ National groups</td>
<td>Individual membership</td>
</tr>
<tr>
<td>ISSMGE</td>
<td>1936</td>
<td>English, French</td>
<td>71</td>
</tr>
<tr>
<td>ISRM</td>
<td>1966</td>
<td>English, French, German</td>
<td>43</td>
</tr>
<tr>
<td>IAEG</td>
<td>1964</td>
<td>English, French</td>
<td>66</td>
</tr>
</tbody>
</table>

A number of the member societies/national groups are serving as umbrella organisations for all three sister societies and there is in general a fair amount of multiple membership. This is also very apparent at conferences, symposia etc organised by any of the three societies. Sometimes you have to pinch your arm to see if you are awake and reassure yourself that you have not by “mistake” gone to the “wrong” conference.

However, it should be noted that the actual membership of the three societies at the national level is considerably higher than reflected by Table 1. For political, economical and other reasons some member societies only register a fraction of the actual membership in the international societies. This should concern the Council and Boards of the respective societies, as it may reflect a feeling of not getting enough payback from the societies by the individual members. But more importantly it can seriously deter the societies from actually influencing the development of geo-engineering education and negatively influence the impact on Society.

Although ISSMGE is the oldest and largest society (in terms of numbers) the two other societies at a much earlier stage realised that education should be a priority concern of the societies. On a personal note, it
further seems to me that ISSMGE in some ways fails to come to grip with the realities of the fast changes in the world and stands at risk of being conceived as the tired old men’s society.


Since 1990 the three sister societies have been working together to produce and co-ordinate a set of guidelines for curricula for a wide variety of courses, together with an extensive bibliography of books, journals and videotapes – and lately computer aided learning tools and web sites.

The Major Disciplines of Geo-engineering

The definition of the various disciplines is found in the statutes of the societies, although they differ in clarity and extent.

In the 1992 revised statutes of the International Association for Engineering Geology and the Environment a modern definition of engineering geology is stated as:

“Engineering Geology is the science devoted to the investigation, study and solution of the engineering and environmental problems which may arise as a result of the interaction between geology and the works and activities of man as well as to the prediction of and the development of measures for preservation or remediation of geological hazards”.

The 1999 statutes of the International Society for Rock Mechanics defines the field of activity as:

“The field of rock mechanics is taken to include all studies relative to the physical and mechanical behaviour of rocks and rock masses and the application of this knowledge for a better understanding of geological processes and in the fields of engineering.”

Finally, the International Society for Soil Mechanics and Geotechnical Engineering statutes of 1997 list the aims of the society:

“The aim of the International Society is the promotion of international co-operation amongst engineers and scientists for the advancement of knowledge in the field of geotechnics and its engineering applications.”

It is apparent that the IAEG statutes are the most concise in defining the discipline and ISSMGE by far the vaguest, even using the wording geotechnics. And hence, it is probably not surprising that the separation in the three societies is to some extent promoted. All three societies claim to embrace geotechnical engineering and the environment, and the recent name changes of ISSMGE and IAEG caused very heated debate amongst the councils and member societies of the three societies.

This would be evident from the statement made in the report from the IAEG Commission (Dearman and Oliveira, 1978), namely:

“It should be emphasised that activities related to stability analyses and complex computations of ground behaviour are not within the scope of engineering geology, but are clearly within the province of soil and rock mechanics. What has been stated shows that there is an obvious overlap of engineering geology with soil mechanics and rock mechanics, the three together comprising what is considered more and more in most countries the field of geotechnique.

The border line between engineering geology and each of the other two cannot be sharply defined, many problems being dealt with equally well by a specialist in any of the three disciplines.”

Add to this that there is overwhelming evidence that soils and rocks are not distinctly different materials. Soft soils and hard rocks are extremes in a continuous spectrum with the hard soils and soft rocks occupying the middle ground. Rather than seeing an International Society for Hard Soils Soft Rocks we should strive to combine the current societies – not least in terms of education. In many ways the difference between soils and rocks are not any greater than the difference between sedimentary and residual soils. The latter certainly deserves a more rigorous treatment in education but not a special society!

Haberfield (1998) challenges the artificial separation of soil and rock mechanics and suggests a universal approach to remedy the current situation, including:

undergraduate and graduate courses in geomechanics need to cover all primary aspects of both soil and rock, where (engineering) geology should be fully integrated in the curriculum and not be treated as a separate subject.

- universal systems for classification, logging etc
- integration of laboratory testing standards and Codes of Practice
- more extensive collaboration between the technical societies at both national and international levels – with the ultimate aim to merge the societies in the future.

The co-operation between the commissions on education may serve as a first stepping stone to achieve this universal approach. The merger is de-facto at national level for a number of countries, and to varying extent at universities too. Judging from the names of departments where education in the three disciplines is rooted, there is, however, a very wide spectrum in constellation and emphasis as seen in Table 2.

<table>
<thead>
<tr>
<th>Department of civil engineering</th>
<th>Department of civil and environmental engineering</th>
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<tr>
<td>Department of earth and planetary sciences</td>
<td>Department of geology and geophysics</td>
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<tr>
<td>Department of mineral engineering</td>
<td>Department of civil and offshore engineering</td>
</tr>
<tr>
<td>Underground and mining construction department</td>
<td>Dept. of mining &amp; mineral process engineering</td>
</tr>
<tr>
<td>School of petroleum and geological engineering</td>
<td>Department of geology and geotechnical engineering</td>
</tr>
<tr>
<td>Department of geology engineering</td>
<td>Department of geology</td>
</tr>
<tr>
<td>Institute of hydrogeology and engineering geology</td>
<td>Department of geotechnology</td>
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</table>

There may be a tendency for soil and rock mechanics together with environmental engineering to co-exist in civil engineering departments, where engineering geology in a number of cases are more rooted towards the geology side.

From my own experience the name throwing has no direct scientific meaning, but it can certainly have an effect on the way our fields are perceived by fellow scientists and the general public. In reality the availability of resource and key persons, rather than elaborate scientific arguments, decide how departments are formed and function. Co-operation is often decided at a very personal level depending on the general management structure of the university.

However, the process can be immensely helped by setting out guidelines, as being done by ISSMGE, ISRM and IAEG for curricula, educational material etc.

Whether a lot is in fact gained by a rigorous merger of soil mechanics, rock mechanics, engineering geology and environmental engineering is perhaps questionable. But our efforts must focus on elucidating and exploring similarities and interplay rather than differences.

The geological setting and the stage of economic development of countries/regions will play a very prominent role for universities in deciding the focus areas within geo-engineering. In a climate of an increasing trend for decreasing funding and high demands for efficiency, rationalisation etc, overlapping between the different disciplines should be minimised. But, on the other hand, some overlapping may still prove to be an eye-opener as a major part of the knowledge imparted by education is not strictly topical but of a more general nature. Think of the LaPlace equation. When students meet this in thermodynamics, hydraulics and geotechnical engineering it is not a simple overlap but a reminder that basic mathematics may be useful and the perception can be heightened by the aha-experience.

Science or engineering?

When emphasis is being placed on engineering, both in terms of the theme of this conference and in the topical areas of the three sister societies this is for a very good reason. To meet the challenges that our profession faces in the future for a sustainable development on this planet, we must be good at solving problems. Golder (1948) phrased this very eloquently:

- Everybody knows that this is the truth of the matter – but, hush, don’t tell anyone.
“There are two approaches to a natural problem. They are the approach of the pure scientist and that of the engineer. The pure scientist is interested only in the truth. For him there is only one answer - the right one - no matter how long time it takes to get it. For the engineer, on the other hand, there are many possible answers, all of which are compromises between truth and time, for the engineer must have an answer now; his answer must be sufficient for a given purpose, even if not true. For this reason an engineer must make assumptions - assumptions which in some cases he knows to be not strictly correct - but which will enable him to arrive at an answer which is sufficiently true for the immediate purpose.”

We would do Society and ourselves as educators and employers a big favour by having this in mind and instilling this attitude in our geo-engineering students. From personal experience I have witnessed how the employment of chemists, biologists and other pure scientists in the environmental section of a geotechnical company has been initially very costly and troublesome. The search for “truth” created a multitude of new problems, lead to costly, unnecessary laboratory analyses and created general confusion rather than addressing the client’s problem at hand. Our geotechnical engineers, on the other hand, had already this habit of mind instilled from the teaching.

Geo-engineers should essentially be skilled in synthesising. Engineering is the conceptualisation, design, construction, and administration of products and projects. Hence geo-engineering education must find a balance between analysis and synthesis and find ways to promote creativity and risk taking.

This does of course not mean that we should be immune to the possibility that there may be other problems than the ones immediately foreseen which need to be addressed. I believe a few geo-engineers have red ears by the thought that some 20-25 years ago drilling crews and supervising engineers would think nothing of a faint smell of petrol or oil spills from a borehole! It certainly was not registered on the borehole log!

**CURRICULA IN GEO-ENGINEERING EDUCATION**

Model curricula has been high on the list of the agenda of the commissions on education, see f.inst. Poulos (1984, 1997), Dearman and Oliveira (1978), Manassero and Spanna (2000) and ISRM (2000). Details of curricula for a number of countries and universities, predominantly European, may be found in the proceedings of the recent Sinaia Conference (Manoliu et al., 2000).

While this information is very valuable as inspiration and guides in establishing courses, I concur with Burland (1987), that syllabus is not critical. The key aim of teaching is to provide the students with “sheet anchor points”, whose security and limitations have been clearly established, whether based in experiments, empiricism or theory.

Hamel and Adams (2000) offer 15 fundamentals of geotechnical engineering practice, which may serve as pointers in the actual preparation of curricula:

- Geology
- Observation
- Precedents or Experience
- Diplomacy
- Checking
- Geometry
- Imagination
- Communication
- History
- Redundancy
- Soil and Rock Mechanics (Geomechanics)
- Common sense
- Construction or Constructability
- Field Emphasis
- Flexibility

Their conclusion for geotechnical engineering practice for the 21st century is clear: Stick with the basics. I believe this can equally well be said for geo-engineering education.

**Back to Basics**

Many, if not most, of the problems and difficulties experienced in geo-engineering practice result from failure to apply the quintessential or basic concepts of the geosciences. Failure to observe and apply the genesis and layout of the ground cannot be replaced by precise analysis, use of sophisticated computer programmes or any other of the latest cutting edge research results. In his acclaimed Nash lecture, Burland (1987) quoted Ingliss on the essence of education:

“...the soul and spirit of education is that habit of mind which remains when a student has completely forgotten everything he has ever been taught.” Or in Burland’s version “...that habit of mind which remains when everything a student has ever been taught has changed.” True words of wisdom.

On Problems

Our choicest plans have fallen through, our airiest castles tumbled over, because of lines we neatly drew and later neatly stumbled over.
In the late 70ties it was estimated that the time for 100% obsolescence of acquired knowledge through the engineering degree was 25 years in 1950, 10 years in 1975 and 4 years in 2000! We may note that the change of technical material in civil engineering is slower than in faster moving fields as electronic engineering. This, however, still reiterates the need to first and foremost teach *that habit of mind* to our students and to pay attention to the basics, which will not be obsolete.

To illustrate the essence of soil mechanics, Burland (1987) introduced the soil mechanics triangle. As pointed out in his follow-up lecture in Sinaia 2000 (Burland, 2000), it can be generalised into a geo-engineering triangle. It displays (see Figure 1) the four interlinked but essential components of our craft:

- The ground profile
- Material behaviour
- Modelling
- Empiricism

Each of the activities in the triangle has its own distinct methodology and rigour, but the aspects are interlinked. For geo-engineering to be successful the geo-engineering triangle should be kept in balance and all aspects should be considered properly.

The geo-engineering triangle should be considered as an aide in developing courses assisting both students and teachers to get an overview and the right perspective. By observing the tacit wisdom in the triangle, we also address the problems and challenges of the spectrum of disciplines in geo-engineering.

To ensure the balance in the triangle, it is a prerequisite that the students acquire a sound understanding of fundamental engineering mechanics (statics, dynamics, mechanics of materials, fluid mechanics) coupled with hydraulics and hydrology. Were this in our power we should add the need for common sense and imagination, both of which are very difficult to teach. One can only hope that the educational process serves to stimulate those qualities.

The triangle also illustrates one of the very real problems of education, i.e. the teaching of the practice of geo-engineering. The value of precedents and experience cannot be overemphasised. In many cases the theories play subordinate roles in many practical projects and problems. Figure 2 illustrates this and the components of the geo-engineering triangle by looking at the key elements in the geotechnical decision process. Due to the current recruitment, and faculty award systems together with the differences between salaries...
in academia and practice, a number of universities find it difficult to offer this aspect for real to the students. This will be treated in more detail later.

**Importance and Impact of Languages in Education**

English is for all practical purposes the de-facto world language today. And those who doubt it should just surf briefly on the Internet. As seen in Table 1, the three geo-engineering societies all have English as the primary language but despite heated confrontations at several council meetings it has not been possible to make the societies mono-lingual. In a recent report from the ISRM President, Sakurai (1999) states that language is one of the most pressing issues facing our Society (i.e. ISRM) today. Although not daring to do away with the idea of three official languages he pleads for English as the basic, international language to be applied at all conferences, symposia etc. One very valid argument is the unavailability of translators for the other languages, particularly outside Europe and the exorbitant costs of translation in general. Even with a cursory grasp of the other two languages the audience is far better off than if they listen to the translation. The language issue is really a political issue.

This also means we have to take it very seriously, not least in connection with geo-engineering education (attendance at conferences etc qualifies as continuing education, hopefully!). It is however, thought provoking, that in California, which is often considered the demographic forerunner of USA, whites will be a minority in a few years and Hispanics and Asians are both expected to outnumber whites in some 20 years.

Despite this development and the formidable growth in population worldwide, English will attain the role of Medieval Latin as the world’s scientific language. Does this mean that we should change our educational language in countries such as Denmark where English is not the mother tongue? Had I been asked this question shortly after my first appointment at university, the answer would have been a cocksure yes, in particular with reference to textbooks. But over the years, strangely enough coincident with a better personal command of English, I have changed to a definite no, particularly for undergraduate education. I have come to realise the absolute importance of a thorough understanding of the basics, an understanding it is very difficult to acquire in a foreign language.

Concepts, analogies etc are much more easily appreciated in your mother tongue than one immediately realises. Try cursing in a foreign language. It leaves you completely cold, whereas the same abuse in your own language would be a major embarrassment.

At graduate, and particularly postgraduate level, teaching in another language is on the other hand a must for a more balanced perception of our profession and the world the students are going to practice in.

This of course raises the question, whether students from English speaking countries should not be required to (1) learn at least one other language and (2) be encouraged (forced) to use it as part of the education? In twenty years time it might be a serious shortcoming for American geo-engineers not to be conversant in Spanish.

The advent of the Internet and Web-based teaching possibilities also place the language problem or challenge at the forefront. Will the fact that a major part of the frontrunners among the universities and educational institutions are in English speaking countries have a negative impact? Or will this act as a catalyst, where translation and adaptation to regional needs makes it possible to be abreast with the whole range of possibilities even in developing countries where funding is criminally lower than in the rest of the world? There are no certain answers, but we will need to address these issues both in Society and as geo-engineers.
TEACHING STYLES, LEARNING METHODS AND AIDS

Project oriented Problem Based teaching

The Boyer Commission on Educating Undergraduates in the Research University (Boyer Commission, 1998) recommends the following “ten ways to change undergraduate education:”

- Make research-based learning the standard
- Build on the freshman foundation
- Link communication skills and course work
- Culminate with capstone experience
- Change faculty reward systems
- Construct an inquiry-based freshman year
- Remove barriers to interdisciplinary education
- Use information technology creatively
- Educate graduate students as apprentice teachers
- Cultivate a sense of community

Furthermore, the Commission asserts the “students bill of rights”, as follows:

- Opportunities to learn through inquiry rather than simple transmission of knowledge
- Training in skills necessary for oral and written communications
- Appreciation of arts, humanities, sciences and social sciences
- Preparation for graduate school, professional school or first professional position

Although based on American experience and educational system, the advice has universal bearing. The evidence clearly shows that student learning is greatly enhanced through collaboration and teamwork. An educational paradigm based on project-oriented, problem-based learning has proven very efficient. However, before it becomes ubiquitous throughout the learning communities at universities it must be realised that this is not a cheap way out. It is very demanding, albeit rewarding for faculty and students, but huge savings compared with the traditional chalk and classroom teaching, as anticipated by university management, is not in the offing.

To be effective it requires a large number of group rooms with access to student-net and internet, and proviso for ventilation etc to accommodate the ubiquitous computers, scanners, printers etc.

At Aalborg University, Denmark, where I was employed from 1995-99 we faced considerable problems due to the inherent system of project-oriented, problem-based teaching. Due to the very nature of the project work, with groups of 6-8 students at undergraduate level, the utilisation ratio of lecture rooms dropped from close to 100% down to near zero in the last quarter of the semester. This is incomprehensible to bureaucracy, when the newly imposed standard rate is 70% from 8 am to 5 pm throughout the semester for educational institutions based on traditional teaching methods! Moreover, the group rooms were designed at a time when a pocket calculator had recently replaced the slide ruler as the most advanced piece of equipment in the student satchel.

Demonstration Models

The challenge to “install that habit of mind”, rather than perishable facts, can be immensely helped by demonstration models. Some of the possibilities are f.inst. described by Burland (1987), Bucher (2000), Kodikara (2000).

An inventory of the demonstration models would be extremely valuable across the board of geo-engineering. It would be well worth the effort for the commissions on education to include this task in the terms of reference. A

Fig 3: Demonstration of the effect of suction and reinforcement on the capacity of an ordinary beach sand using a 50 kg weight

British information pack on teaching models (15) was announced by Orr (1992), but has not been traceable. It would serve as inspiration for individual educators and also reduce the amount of re-invention of the same experiments.

The particular attraction of the models is the aha-experience and the possibility for hands-on-activities. An added benefit is the possibility to demonstrate the models to the general public in order to stimulate interest in and respect for geo-engineering. In response to the declining interest in natural science and engineering, an annual Natural Science Festival (www.dnf2000.dk) has been initiated in Denmark. As an element of the festival a hands-on-exhibition is organised at the exhibition pavilion for the Øresund Link (the fixed link between Denmark and Sweden inaugurated 1 July 2000; www.natvid.dtu.dk). A large number of school kids and their parents will here have the opportunity to hear about and feel the sciences required establishing a “bridge”. As an example the beach experience of the difference between sandcastles built of dry, wet and reinforced sand may be experienced, cf. Figure 3.

The general trend at research universities for overemphasis on research and lack of rewards for faculty devoting time to teaching is seen very clearly in terms of demonstration models. Compared to the costs of research facilities we are talking peanuts – and yet most of us regretfully confess to not utilising this powerful feature of teaching to its full potential.

Computer Aided Learning (CAL)

Computer Aided Learning (CAL) or Computer Based Instruction (CBI) have come of age as an integral part of the ITC-revolution. It is very likely that CAL/CBI will play a prominent rule in the future teaching of geo-engineering if the basic rules of the geo-engineering triangle are kept in mind in the preparation of courses using this medium. The access to the World Wide Web, within the Internet, will allow distance learning at an unprecedented rate.

This rapidly emerging technology is f.inst described by Massarch (2000), Sharma (2000) and Jaksa et al (2000). In the latter an extensive list of available CAL resources in geo-engineering is listed and described.

Figure 4: Will computers find their way into the laboratory and the home?
The resources vary from stand-alone PC-based programs to multimedia CD-ROMs and web-based simulations and courseware. A number of relevant web addresses are given in the paper.

There is no doubt that CAL/CBI has a very direct appeal to the modern students as this resource in many ways emulate the familiar MTV and computer games. The downside of the resource is the “Microsoft effect” with the possible dominance of a few universities worldwide and the financial consequences in terms of licence costs in countries with limited economic possibilities.

THE FUTURE

In the words of Storm P.: “It is difficult to prophesise – in particular about the future. This profound statement is borne out by the development in the computer industry.

When computers were first created, T.J. Watson founder of IBM, predicted, “We may need six computers world-wide, for government, etc”. In 1977, Ken Olson, the founder of Digital Equipment Corporation, said, “There is no reason for any individual to have a computer in their home.” And as recently as 1981, Bill Gates himself was quoted as saying, “640 K ought to be enough for anybody”. The last statement certainly puts the old saying, ”The best way to predict the future is to create it”, into perspective.

Challenges for Geo-engineers in the New Millennium

World news of mudflows, landslides, earthquakes, floods and other natural hazards with thousands of fatalities and millions affected are more or less the order of the day. One of the reasons is the increasing and extensive use of marginal lands and overcrowding in coastal zones. This predicament is only made worse as we also face the challenge of housing another 3 billion people within the next 50 years, compared to the present population of 6 billion in the world. The trend of megacity formation and general migration of people to the cities will continue, particularly in the developing countries.

The foreseeable desperate lack of clean water, utilisation of marginal land at risk for natural hazards, housing of the exploding population, and establishment of a working infrastructure are tall orders in the developing countries.

In the developed countries a decaying urban infrastructure, traffic congestion, general pollution, waste management problems, environmental deterioration and effects from possible global warming are very real threats to our civilisation.

Thus, there is a bright future for the geo-engineering profession, albeit on a very dire background. This emphasises the need for education of young engineers equipped with basic skills of science, abilities for lateral thinking and creative problem solving.

Oliveira (2000) offers advice on the role geotechnics or geo-engineering can play in order to help a balanced evolution of Mankind through a sustainable development and the protection of the environment.

Another pointer is offered in the Geotechnical Services File 2000 (Ground Engineering June issue). The results of a questionnaire sent to 750 UK companies are summarised as follows:

Main concerns

• Lack of suitably qualified and experienced geotechnical personnel
• Uncertainty about the future of postgraduate vocational training
• Tight margins and late payments
• Continued reluctance to invest in site investigations and desk studies, driving down rates and quality
• Lack of coherence on contaminated land legislation and no clear framework for risk assessment of brown-field sites
• Short and unrealistic timescales
• Clients not aware of ground risk and lack of appreciation of the value of geotechnics
• Reliance on professional indemnity insurance and warranties instead of sufficient ground investigation
• Under-use of brown-field sites

Main trends

- Contaminated land/brownfield development work continues to increase
- Skills shortage
- Move towards risk-based assessment especially for remediation
- Increase in geotechnical design and build contracts
- Rail and housing sectors still strong
- Information technology leading to faster data transfer
- Trend toward larger multi-disciplinary and global companies.

Increase in number of smaller independent geotechnical firms
- Fast-track investigations and reporting becoming the norm
- Environmental issues are moving up the corporate agenda as awareness increases
- Innovative solutions such as bio-remediation are finding increased acceptance

The survey in general confirms the trend of optimism in terms of job opportunities, and the lack of general acceptance of the geo-engineering profession.

Perception of Geo-engineering – by Educators and the Public

To engineer something is conceived positively by the general public, but the problem is, that very few know exactly what engineers do. Where the architects regularly capture the interest of the media, the engineering achievements are neglected. Or others are given the credit. Doctors bury their mistakes, geo-engineers their successes! The discovery of bacteria and the importance of hygiene are common knowledge. But very few realise that the real lifesavers were the engineers who provided the networks of conduits, reservoirs and filters to deliver pure water, and the sewers to get rid of the contaminated.

If we take pride in our profession as geo-engineers it is our duty to educate the public and the media in order to regain the former status (in the developed countries) in order to be able to attract the best of the student. This is needed to match the challenges of the future for a sustainable development, where geo-engineers must play a vital role.

Pennoni (1998) indicates some of the perceived requirements for civil engineers: “The engineers of the next millennium must possess a bachelor’s degree, master’s degree in an area of speciality, experience, licensing, leadership qualities and be bi- or multi-lingual. He or she must be capable of working in a team environment, be a good communicator and possess excellent people skills. In addition to possessing up-to-date technical knowledge, civil engineers must know how to do things right as well as the right things to do”.

The latter corresponds to the motto of the founder of Maersk (the world’s largest container shipping company): Punctual care.

Geo-engineers possessing these skills will be in a position to effectively take charge and change the public’s perception of geo-engineers for the better. The key question is whether we as educators are prepared to accomplish this educational task?

Applied or Applicable Geo-engineering Education

When I was a student at university we used to joke about the difference between applied and applicable mathematics. The geo-engineering education must be applicable. Here we face a major problem in the developed countries in the post-industrial era. Despite the drop in birth rate the universities still see record high numbers in admission – although not in engineering. It is, however, number magic as the increase is due to short-duration studies. We live in times where the garbage collector is a Sanitary Engineer, a shipping agent a Transport Logistician etc.

The natural sciences and engineering see a decrease in applicants, whereas studies with clear competence-profession profiled aspects like Law, Medicine and IT, Business and Media are booming. Both within and outside the university sector the students are primarily looking for competencies – i.e. formalised abilities – not dedicated knowledge. However, the consequence ought to be different. Inside the universities focus should be on knowledge, and outside on abilities.

The reason for the radical change in the pattern of interest from the students must be in the radical changes in Society in the late part of the 20th Century. Back in the 50-60ties boys full of beans wanted to be engineers. Taking part in the rebuilding after World War II was prestigious. The humanities were for sissies. Engineering had tough admission limits – it was the seal of manliness of the elite. Today both boys

and girls want to explore human relations, media or marketing. And engineers are being replaced by hordes of bookkeepers, IT or ITC candidates. Human management to the tune of global work sharing is replacing industrial management.

At a national scale the mass demand for qualifications in civil engineering, ship and machine technologies has changed to health, service and behavioural technologies. The elite among the young have jumped on the wagon and reinforced the trend. The employers want the brightest even if the educational profile does not exactly match the job. That was not the case when boys wanted to be civil engineers but it is today when girls do not. Main stream education is the order of the day.

The youngsters want education with instant applicability. Thus, in Europe and USA where the post-industrial information society is a reality it is first and foremost about gaining competence – not about acquiring a specific amount of applicable knowledge. No knowledge is of course unacceptable, but if it is not process-oriented, the knowledge –so to speak- at first comes second. To remedy the situation the current thinking goes in the direction of adopting the Anglo Saxon three tier model of Bachelor, Master and Ph.D. degrees. Information on the current structure, recent trends and possible avenues for change in the architecture of higher education systems in Europe may be found in Haug (1999). The document is a follow up to the notorious Sorbonne declaration (http://www.europedu.org/gb/vert/declaration.html)

In a sense we are probably talking about a different kind of packaging of the curricula, where universities respond to the students’ quest for competencies. It is the duty of the universities to direct the quest after abilities towards a self realisation by the students of the need for and benefit of knowledge assimilation - in order to posses the ability to generate new knowledge.

The attempts using problem oriented project based learning could play a significant part in this transition where a broad multidisciplinary basic education is a must. At Aalborg University, Denmark this has been practised from the inauguration of the university 25 years ago. As a result we have seen a decline in the number of Bachelors in civil engineering. The students have taken to the assimilation of knowledge as demonstrated by the projects and wanted to stay on for a Masters degree (the passing unemployment in the 70ties has no doubt also contributed to this trend). At the same time the university can brag about a higher rate of passed degrees compared with the Technical University of Denmark, where this transition in teaching style is only now about to be fully realised.

While the current, politically based trend in Europe seems to favour the Anglo-Saxon model - albeit with considerable variation and some resistance from universities - the trend in USA points towards making the Masters degree the first degree in engineering.

If the students at their own volition arrive at the conclusion that they need knowledge besides competence or ability and stay on to receive a masters degree in geo-engineering (or even a Ph.D.), we would probably find that it is because we have changed our teaching methods and made the university a more exciting place of education and learning.

**IT’s Now or Never**

The advent of affordable information and communication technology (ITC) has had a formidable impact on society – and we are only at the starting point. In particular the Internet has begun to change the way of life, also in the education sector.

This poses many challenges to students, educators, universities and governments. ITC should be seen as the most powerful potential and supplement to education and not necessarily as a threat to existing well-win-nowed types of education. Changes are necessary and will be made. ITC will mean a whole new set of opportunities and possibilities, which will make it much more fun and challenging to be educators and learners.

The changes in opportunities will, however, also mean that less viable educational offers will be deselected and new ones will appear. The mere fact that out of town, out of country or even out of planet courses at other universities or institutions are offered will invite solid competition.

In all probability this will result in better quality teaching and a possibility for more diversified and personalised education if due respect is still paid to regional and cultural multiplicity. As already implemented
at a number of universities (notably in USA) ITC-literacy is now a major factor at admission to college and ITC-proficiency will be an integrated part in the passing of exams.

The mantra of the future will be flexibility and adaptability in particular regarding continuing education. This, however, will place an even higher importance on basics (the geo-engineering triangle) as these will be prerequisites for knowledge accumulation and lateral thinking. The exchange and updating of information will be an asset in itself.

Lateral thinking as opposed to traditional, vertical thinking, was very appropriately illustrated by deBono (1971) by considering the process of digging a hole:

“It is not possible to dig a hole in a different place by digging the same hole deeper. Logic is the tool that is used to dig holes deeper and bigger, to make them altogether better holes. But if the hole is in the wrong place, then no amount of improvement is going to put it in the right place. No matter how obvious this may seem to every digger, it is still easier to go on digging the same hole than to start all over again in a new place. Vertical thinking is digging the same hole deeper; lateral thinking is trying again elsewhere”.

The employers of geo-engineering candidates will likewise face tremendous changes. Rather than spending weeks or months on external courses the employees will be expected to take part in video conferences, CAL (Computer aided learning) courses via the internet etc. Supervisors may for all purposes be on a different planet.

In my view, however, Society and the educational sector will also need to place a demand on companies to actively interact in the process, by participating in education a much more proactive way than seen so far. How else will we be able to enjoy the benefits of real and relevant case histories in exchange for free access to the research results produced on the expense of Society at the Ivory Towers?

The development of a Society is very much reflected by its level of infrastructure – where roads, sewers, electric cables are supplied by Society for the greater benefit of the populace (Add to that hospitals, libraries etc.). However, cars loose all sense if no roads are provided. And likewise the transformation to a viable ITC-society requires a similarly well functioning infrastructure in the shape of high-speed transmission lines (light conductor cables or wireless satellite connections).

The universities will have to take this very seriously if they want to stay in business and provide extensive student-nets. This is implemented at my own university this summer and a number of other universities worldwide have already risen to the challenge. This places a very heavy additional burden on universities in developing countries. But at the same time it might be a short cut to resources otherwise only dreamt of by possible access to laboratory facilities, demonstrations, lectures and libraries made available via the Internet from universities in the developed world.

With extensive and fast student-nets the over crowded classroom, databars etc could be a thing of the past. Despite a day in bed today’s lecture, the lecture series from last week or from far away is no more than a mouse click away. Educators will need to rise to this challenge, as the students are way ahead – and very demanding.

The revolution on the Internet – fact or fallacy?

If we estimate the existence of some 10-20 millions web sites today the forecast is 100 million in the year 2010 with 1 billion Internet users! At that time the ultimate status symbol may well be to afford to be offline – without reach of mobile phone and portable computer – and Tonga will be the richest country in the world as host to most extensive and successful websites? Believable or not, that is the prediction by the Danish-American internet guru Nielsen (2000). According to him newspapers and books will exist in the same way as old-fashioned vinyl records do today. He envisages an ultra thin wireless screen, sized as a book, with touch or voice recognition capabilities and available in different sizes meeting different tastes and demands. If that isn’t scary in terms of producing educational materials? Maybe we will all be obsolete, except for a few really ITC-literate young super professors mastering the changes in hyper-space – or maybe there is still room for more direct human instruction and interaction?
No matter what, we will definitely have to change teaching and learning habits in the new Millennium. In this endeavour we must be extremely careful not to fall in the trap of Disneyfication of education or entertainment. We must likewise be wary of the possible dominance by multinational conglomerates usurping power on the internet and supplying “universal” education. Hopefully such strategies will prove untenable on the lines of the current trend where the truly international labels like Coca Cola, Lewis etc find that the all embracing (American) way of marketing packaging etc results in dropping market shares. National and regional tastes and preferences must be obeyed and diversification is the order of the day.

CONCLUDING REMARKS

The new millennium presents a full plate of challenges and opportunities for the geo-engineer. The prospects for meaningful jobs are favourable, albeit on a dire background of imminent natural hazards and needs of remediation of the sins of the past.

Successful geo-engineering education in the new millennium will therefore depend on a fruitful cross-pollination of research, teaching and practice. All three components are important and this necessitates positive action from funding bodies and university administrations to resist a downgrading of the teaching part.

To meet the challenges from the ubiquitous information society, the different sub-disciplines of geo-engineering must come together in positive exchange with emphasis on similarities, with the goal of ensuring a better and safer all-round understanding of the behaviour and interplay of geomaterials.

The students are not immune from the radical changes in society and the way engineering in general escapes the attention of the media. It is our duty as educators to strike the right balance. We must be subservient to Society and bring our abilities to bear on a sustainable development for the good of mankind. In this sense we are working for the millennium.

At the same token, this requires the best possible education of the prospective geo-engineers. Thus, the question: Teaching for the Millennium – or for the students, is not an either or. We must do both.

As closure and food for thought, one might ponder the following question posed by one of my students at the University of Petroleum and Minerals in Saudi Arabia just before finals:

“Sir, are the questions going to be straightforward, or do we have to think?”

Considering the complex tasks and challenges we face in the new millennium, we are not at liberty to expect questions or problems to be straightforward. It is imperative that we instil that notion in our students: Think, think and think again!

The geo-engineering educators have a tall order to match, but the rewards are out there to be reaped. By combining the advances of ITC with a thorough understanding and respect for the basics and fundamentals of engineering in the broadest sense and the multidisciplinary nature of geo-engineering, I have high hopes for the geo-engineers of the 21st century.

REFERENCES


