The role of competency-oriented descriptions in geo-engineering

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ABSTRACT
The Joint Technical Committee on Education and Training (JTC-3) has begun the process of assessing the professional competency requirements of specializations within geo-engineering by adapting the process established for civil engineering by the ASCE. Competency profiles based on a unified geo-engineering matrix provide a basis for defining the relative roles of the different specializations. They also show how competency can be achieved through Bachelors and Masters degrees, or by Training/Experience. Thus, individuals can use them to evaluate their own competencies and develop education plans. They can also evaluate the relevance of specialist training courses at the post-Masters level, or the professional qualifications of individuals.

RÉSUMÉ
Le Comité Technique Commun sur Education et l'Entraînement (JTC-3) a commencé le processus d'évaluer les conditions de compétence professionnelles de spécialisations dans la geo-ingénierie en adaptant le processus a établi pour l'ingénierie civile par l'ASCE. Les compétence profiles fondé sur une matrice de geo-ingénierie unifiée fournit une base pour définir les rôles relatifs des spécialisations différentes. Ils montrent aussi comment la compétence peut être atteinte par Célibataires et Maîtrise des degrés, ou par L'Entraînement /Expérience. Ainsi, les individus peuvent les utiliser pour évaluer leurs propres compétences et développer les projets d'éducation. Ils peuvent évaluer aussi la pertinence de cours d'entraînement de spécialiste au niveau de poste-maîtres, ou les qualifications professionnelles d'individus.

1 INTRODUCTION

International consortia are increasingly involved with large civil engineering construction projects. This has promoted mobility of geo-engineering experts, but has also increased the need to understand the qualifications of geo-engineers from different educational and national backgrounds (Morgenstern 2000). Professional expertise of civil engineers and geologists often overlaps; competition, rather than cooperation, results when individuals seek opportunities to perform similar tasks and duties in site-investigation, design, and construction, as well as the identification, evaluation, and mitigation of geo-hazards.

The three principal international professional societies – the International Association of Engineering Geologists (IAEG), the International Society for Rock Mechanics (ISRM), and the International Society for Soil Mechanics and Geotechnical Engineering (ISSMGE) – have responded to these developments by promoting studies of the educational aspects of their professional memberships.

In July 2002, a Joint European Working Group (JEWG) was formally established by the Presidents of ISRM, ISSMGE, and IAEG. In 2004 the JEWG issued a report which recommended further steps be undertaken to develop guidelines for the education of the different disciplines and that "competencies" be used to define their areas of expertise (Bock et al. 2004). This report was subsequently revised in 2008 (JEWG, 2008). The Joint Technical Committee on Education and Training (JTC-3) was established in 2006, under the umbrella of the Federation of International Geo-engineering Societies (FedIGS), with the specific mandate to develop and maintain a "State-of-the Art Report on Education and Training in Engineering Geology, Rock Mechanics, Soil Mechanics and Geotechnical Engineering." A progress report has been prepared by JTC-3 (Turner & Rengers 2010).

2 THE AMERICAN SOCIETY OF CIVIL ENGINEERS APPROACH

The American Society of Civil Engineers (ASCE) has defined the domain of knowledge and experience considered to be essential for a qualified civil engineer as "the ASCE Body of Knowledge (BOK)." It is defined according to 24 outcomes; each outcome defines a distinct and essential part of the domain of knowledge and experience for civil engineering (ASCE 2008). These "outcomes" have the essentially the same meaning as the "competencies" described in the JEWG Report (JEWG, 2008; Bock et al. 2004; Rengers & Bock 2008). Competencies (or outcomes) define the knowledge, skills, and attitudes acquired by individuals through appropriate formal education and experience.

The ASCE has defined how outcomes are mastered in terms of "level of achievement", rather than defining each in terms of the number of educational credits, the approach used by Rengers & Bock (2008) to define their competencies. This ASCE approach is a critically important improvement because it provides a clear basis for international communications and comparisons. Experience with compilations of curricular tabulations from different universities demonstrates their limited utility – typically they merely demonstrate that apparently identical topics are taught in courses with different names, and that two courses with the same name may contain dissimilar subject matter (Higgins & Williams, 1991; Rosenbaum 1997; Manoliu et al. 2000; Manoliu & Radulescu, 2008). In most cases, the relationship between competency and educational credits is very complex.

While conceivably one competency could encompass an entire course, typically a single competency involves topics that appear in multiple courses. Conversely, a single course may contribute to many competencies. Many competencies can only be fulfilled with post-graduation experience.

Some competencies are more important than others; so a definition is required of the level at which each competency has to be mastered. The ASCE defines a “level of achievement” according to “Bloom’s Taxonomy” – an international standard used worldwide by educational specialists (Bloom, et al. 1956). Although more than 50 years old, Bloom’s taxonomy remains highly relevant. The current ASCE efforts focus on the cognitive domain because that domain addresses many conventional learning outcomes associated with engineering. Bloom’s taxonomy assesses the cognitive domain according to six levels of achievement, which range from the basic Level 1 “Knowledge” (the ability to recall a wide range of previously learned material) to the advanced Level 6 “Evaluation” (the ability to judge the value of material for a given purpose).

The ASCE BOK2 Committee developed a matrix composed of 24 rows - one for each competency - and 6 columns - one for each “level of achievement” in Bloom’s taxonomy. The 24 competencies are categorized as foundational, technical, and professional and, within each category, are organized in approximate pedagogical order, and not relative importance. To complete the matrix, the ASCE BOK2 Committee first evaluated and defined each matrix cell. Then the committee made decisions concerning the recommended level of achievement that an individual must demonstrate for each competency to practice civil engineering. Only with a third step did the committee identify the roles of bachelors and masters degrees, and experience, in achieving each competency.

Figure 1 illustrates the resulting “Competency profile” for Civil Engineering which was developed by the ASCE following their prescribed analysis procedures. It shows the 24 outcomes, each with its necessary level of achievement and a code that explains when, and how – through formal teaching and training or by experience – the competency may be developed.

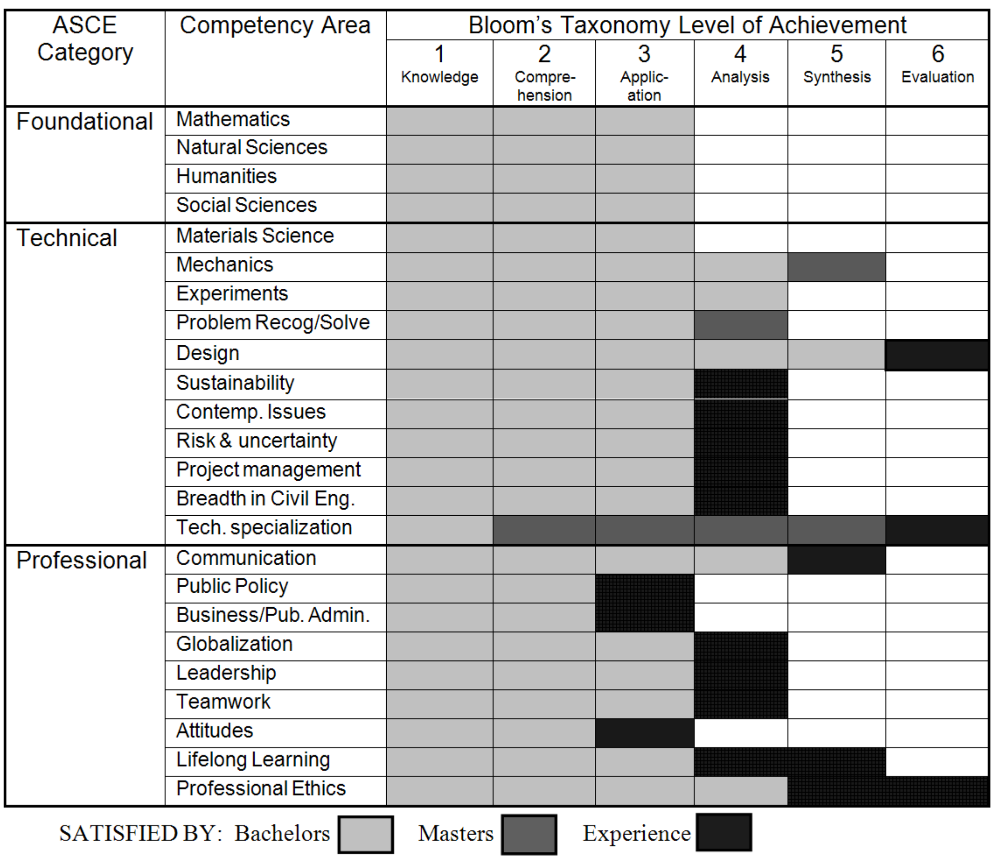

Figure 1. ASCE “Competency Profile” showing essential competencies for a qualified expert in civil engineering. (ASCE, 2008)

The ASCE BOK2 Report (ASCE 2008) emphasizes that acquiring competencies with the appropriate levels of achievement is generally not a quick or simple process, and certainly is not a process that is restricted to formal education in a baccalaureate program of study. While some basic competencies are typically fulfilled through formal study in a baccalaureate program, other more advanced competencies require the master's degree or equivalent instruction, and some competencies can only be gained through practical field experience. The assumption is that experience is needed, in addition to formal education, to enter the practice of civil engineering at the professional level.

3 ADAPTING THE ASCE APPROACH TO GEO-ENGINEERING

The JTC-3 Committee has begun the process of investigating how the ASCE process may be adapted to represent the geo-engineering field. The JTC-3 prepared a progress report in 2010 that began to frame the necessary steps (Turner & Rengers 2010). The report recommends the development of a geo-engineering competency matrix with the same 6 levels of achievement as in the ASCE BOK; but with competency descriptions that reflect principles of geo-engineering (Fookes 1997; Morgenstern 2000; Knill 2002) and additional relationships and characteristics of professionalism reflecting the needs of the geo-engineering community.

The need for specializations within the broader context of geo-engineering largely results from the increasing complexity of many civil engineering projects and the demands posed by enhanced environmental regulations, technological advances, and economic forces. In recent decades, bridges and tunnels have become larger and longer, high-speed transportation links have become common, and population growth has pushed developments into more complex geological locations where site conditions are less optimal and geohazards more likely.

Additional factors become important at the international level. Because geo-engineering practitioners are increasing likely to become involved in litigation, professional liability and professional recognition is becoming an important concern in many countries. The issues surrounding the professional recognition of geo-engineers are complex and often specific to each country, as the legal basis for professional recognition varies from country to country. Part of the complexity arises because aspects of geo-engineering practice frequently involve scientific studies and engineering design topics to varying degrees. In many countries, there are long-standing legal separations that divide engineering and scientific activities. Tepel (2009) provides views on the situation within the USA. Turner (2004; 2008) discusses the underlying rationale for the specialization of "geological engineering" in the USA and Canada. The situation in other countries is often quite different. Bock (2009) provides some details of the contrasting situations in several European countries, including Germany, the Netherlands, and Austria. The recent report by the Joint Commission on Professional Practice (JTC4 2009) provides additional perspectives.

3.1 How Many Specializations?

The JTC-3 began its deliberations by reviewing the roles and interactions among geo-engineering specializations. This initial step has been followed by most other individuals or organizations when attempting to assess the educational needs or responsibilities of geo-engineers (Higgins & Williams 1991; Manoliu et al. 2000; Manoliu & Radulescu 2008; Bock 2009; JTC4 2009; Tepel 2009). The three principal international professional societies – IAEG, ISRM, and ISSMGE – broadly correspond to the specializations of engineering geology, rock mechanics, and soil mechanics. Consequently, the JEWG focused on these specializations and prepared a list of competencies for them in 2008 (JEWG, 2008). Rengers & Bock (2008) and Bock (2009) discuss the concepts developed by the JEWG.

As noted previously, the situation in various countries or regions of the world sometimes produces additional specializations, or markedly modifies the simple three-fold classification of the JEWG. For example, some countries favor the term "geotechnical engineer" while others avoid the term. In many countries there are long-standing separations between engineers and scientists; while in others there are cordial and collaborative relationships (bock 2009; Tepel 2009). Geological engineering has developed as a specialty field within the broader engineering professions in the USA and Canada, where it first became established in response to a combination of existing legal and technological conditions (Turner 2004; 2008). Similar geological engineering specializations, and educational programs to support them, exist in Portugal, Spain, and Turkey.

Thus the initial JTC-3 progress report discussed the requirement to evaluate more than three geo-engineering specializations; and began to address four specializations – Engineering Geology, Geological Engineering, Geotechnical Engineering, and Rock Engineering. In reality, there is potentially a need to address closely-related specializations such as hydrogeology and environmental geology that have considerable relevance to many projects and have considerable numbers of practitioners. There has been a considerable debate within the JTC-3 as what is the best approach, since an increase in the number of specializations being considered results in much more complex coordination efforts with professional societies and increased consultation and review procedures.

3.2 Developments in North America

In recent years, in both the USA and Canada, there has been considerable interest in better defining core competencies and related educational requirements for both geoscientists and geo-engineers. The efforts by the ASCE have already been described. In 2008, the Geological Society of America undertook an extensive survey to determine the interest in establishing some type of formal accreditation process for bachelors degrees in the geosciences (GSA Ad Hoc Committee on Accreditation 2008). Currently there is no formal accreditation process for the geosciences, although engineering education has a long-standing formal accreditation process. There has since been a spirited debate on the merits of establishing accreditation for geoscientists (Bralower et al. 2008; Schmitz 2009). Currently the American Geological Institute is planning to lead further discussions. In contrast, many geoscience departments at Canadian universities have voluntarily adapted their programs to match the basic educational requirements specified by the Canadian Council of Professional Geoscientists (2008). While this is not a formal accreditation program, it accomplishes many of the same objectives.

3.3 Demonstrating the Concept

In order to provide some guidance in establishing appropriate competencies for geo-engineering by adapting the ASCE civil engineering process, the JTC-3 progress report developed a sequence of four conceptual competency profiles. They were developed solely to provide an example of how the competency-based approach can provide benefits to the assessment of educational and training needs for sub-disciplines within geo-engineering

Figure 2 shows these conceptual four profiles – for Engineering Geology, Geological Engineering, Geotechnical Engineering, and Rock Engineering. These profiles are conceptual only. They should not be construed as representing definitive descriptions of these sub-disciplines, nor of providing answers to educational and training issues that must still be resolved in the future after a fully-developed geo-engineering assessment matrix has been developed.

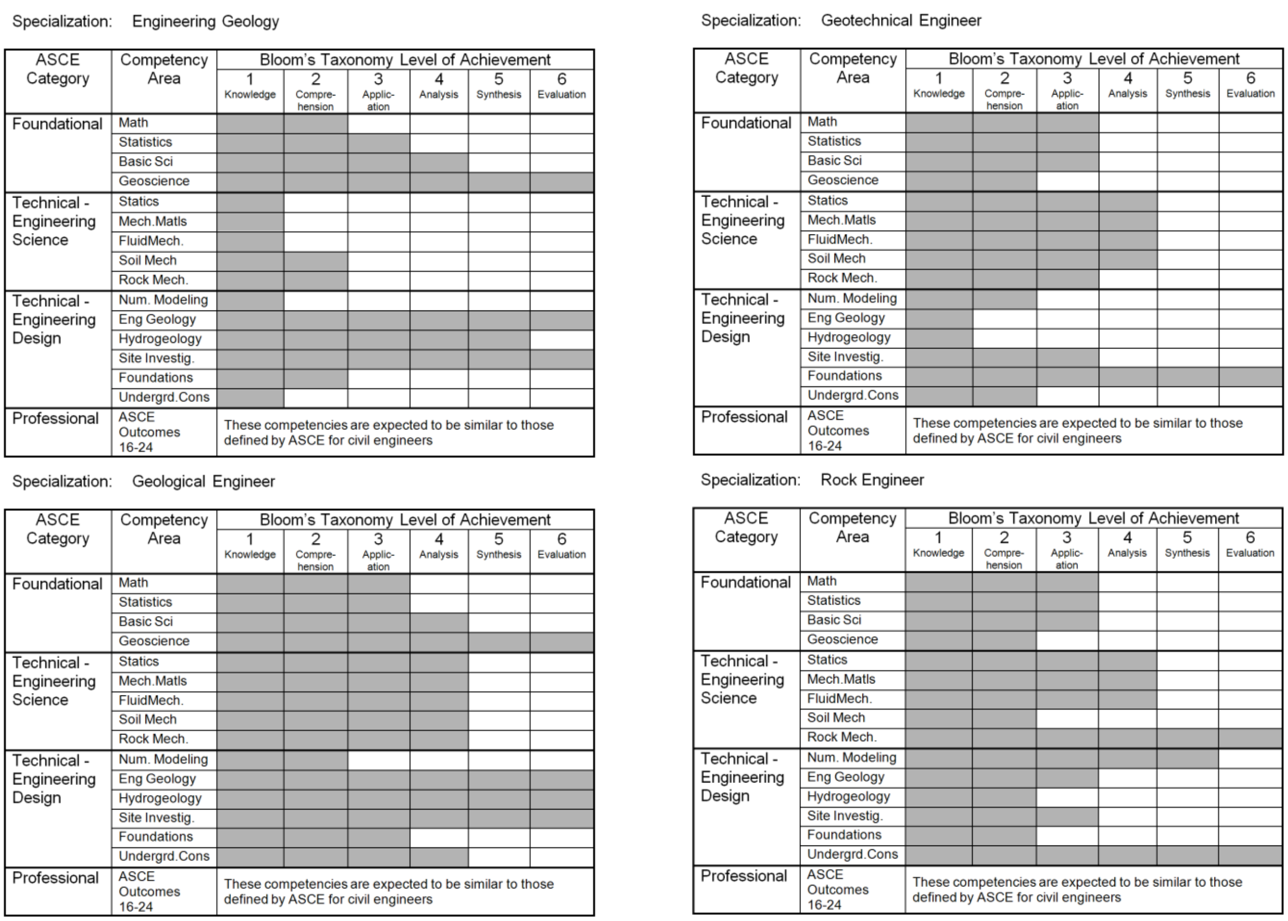

Figure 2. Four conceptual competency profiles for geo-engineering specializations demonstrate their distinctive required competencies.

The profiles were developed in the following manner:

1. A representative, but temporary, set of competency categories was developed because competencies defined for civil engineering by the ASCE BOK2 Report were not considered entirely appropriate for assessing the competencies of geo-engineering sub-disciplines, and a full set of such competencies has yet to be established,
2. Thus, a series of 15 competency classes was established that approximated the ASCE Foundational and Technical categories. “Engineering Science” and “Engineering Design” classifications, formerly used to assess engineering curricula in the USA, were used to define the Technical category.
3. The resulting sequence of competencies thus neither entirely conforms to existing assessment criteria, nor is expected to be the selection developed in the future.
4. The 6 levels of achievement defined by Bloom’s taxonomy were used to form the columns of the matrix.
5. Guidance in establishing the profiles was obtained by using the competency profile for civil engineering developed by ASCE (Fig. 1) as a base case against which the levels of achievement for each geo-engineering sub-discipline could be raised or lowered.

In spite of the limitations imposed by the fact that these are preliminary conceptual representations, the four profiles show distinct patterns of strength and specialization for each sub-discipline. Accordingly, they demonstrate, on a conceptual level, some of the advantages of a competency-based assessment approach applied to geo-engineering with its several sub-disciplines.

4 CONCLUSIONS

Competency profiles for the specialties within geo-engineering can provide a basis for defining the relative roles of various specific professions, such as Engineering Geologists, Geotechnical Engineers, Rock Engineers, Environmental Geologists, and Hydro-geologists. Comparison of these profiles provides a basis for defining the relative roles of the different specializations. They also show how competency can be achieved through Bachelors and Masters degrees, or by Training/Experience; thus, an individual can use them to evaluate his/her competencies. They may also allow for:

- Developing individual life-long-learning plans,
- Establishing the relevance of specialist training courses at the post-Masters level, or
- Evaluating professional qualifications of individuals wanting to work at certain levels within the Eurocode structures, or seeking professional licensure.

Competency profiles should be produced by analyzing a single matrix of competency topics and levels of achievement – the development of this matrix for geo-engineering is currently the major task remaining to be undertaken cooperatively by the geo-engineering community. The size and complexity of this matrix, the number of columns and rows comprising it, should be similar to the existing matrix (or rubic) developed by the ASCE for civil engineering.

Once such a matrix is agreed to, it can also form the basis for evaluating regional variations in the competency profiles of individual specializations, or of geo-engineering in its entirety. For instance, how do the desired competencies for Engineering Geologists in South America compare to those in Europe, or in Asia? Such competency profiles are likely to show differences among the various regions due to the presence/absence of geohazards, and the relative importance of several economic factors, such as large urban centers, groundwater resources or flooding, and mining or underground construction. The availability of such international comparisons will provide the basis for communicating and understanding the role and importance of education and training issues. They may also assist in promoting appropriate professional recognition of geo-engineering specializations within nations, regions, and internationally.

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