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Educating Civil Engineering Technologist

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Educating Civil Engineering Technologists

Introduction

Civil engineering work has evolved to encompass the distinctive roles and competencies of professional engineers, technologists and technicians. A civil engineering technologist is a specialist trained to work in one or more technical areas within the civil engineering field. Engineering technologists often work under professional engineers, yet they are expected to demonstrate competency for completion of independent activities within their particular area(s) of specialty. In many cases, civil engineering technologists acquire unique skills and knowledge that complement those of a professional engineer. In contrast, civil engineering technicians may be vocationally trained and typically focus on a narrower set of tasks. Whereas professional engineers are entrusted with the highest and most direct level of responsibility to the public, the technologist's responsibilities are commonly tied to those of the professional engineer. American Society of Civil Engineers (ASCE) has defined the roles of professional engineers, technologists, and technicians in ASCE Policy Statement 535, "Defining the Civil Engineering Team."

Objective

The objective of this paper is to explore civil engineering technologists' education in a couple of the South Asian and South East Asian countries based on framework established by ASCE and International Engineering Technologists Agreement (IETA)

ASCE Policy Statement 535

According to ASCE policy statement 535, "Civil Engineering Technologist (CE Technologist) is a person who exerts a high level of judgment in the performance of engineering work, while working under the direct control and personal supervision of a CE Professional. A person initially obtains status as a CE Technologist through the completion of requisite formal education and experience and may include examination and other requirements as specified by a credentialing body. A person working as a CE Technologist can comprehend and apply knowledge of engineering principles in the solution of broadly defined problems."

Civil Engineering Technologists in United States

In contrast to the international acceptance of the term "engineering technologist", unlicensed civil engineering practitioners in the United States have not embraced the term or the concept. Some observations and theories have been put forth to explain this lack of acceptance in this country. Among them is the geographic largeness and diversity of the country; the ethos of "rugged individualism" as opposed to a collective social consciousness; non-recognition or identification with economic classes; and a widely held belief that hard work, creativity, and perseverance are all a person needs to raise their social and economic position. There are probably other explanations, but suffice to say, unlicensed civil engineering practitioners in the United States describe themselves as some derivative of "technician", "engineer", or "engineering", such that the term engineering technologist has not gained acceptance as a position description.

Many licensing boards in the United States have restricted the term "engineer" to describe a licensed practitioner in responsible charge, with a duty to protect the public's health, safety, and welfare. However, a non-licensed practitioner may also see this public safety mission as their role. Graduates of BSET programs typically describe themselves as engineers rather than engineering technologists, whether they are in roughly two-thirds of the states that allow them to become licensed Professional Engineers or the other one-third where the path to licensure is not available to them. Compounding this issue, some state agencies list job descriptions for civil engineering technology while others do not.

One state describes civil engineering technologist duties as, "…may inspect portions of construction projects; take part in field survey work…make and check engineering computations; prepare portions of written reports; assist in the design of highways and buildings including landscaping projects; and conduct complex field and laboratory tests of engineering materials [1]." This agency's job description goes further to state technologists may supervise technicians working for the agency. Although these persons are not in "responsible charge", they have a large degree of responsibility and autonomy in performing their duties.

Civil Engineering Technologist in Industry

ASCE policy statement also acknowledges civil engineering, like other learned professions, consists of a work continuum with varying complexities that is most effectively accomplished by individuals with different ranges of responsibilities, qualifications, and work experience. The civil engineering continuum of work can be segmented into three broad categories: engineering work; technology work; and technician work. However, the roles and titles for CE Professional, CE Technologist, and CE Technician are not well defined in the civil engineering community, making proper assignment of work difficult. Currently CE firms use individuals performing work in these three categories but assign them many different titles and roles. A lack of definition for roles and titles of the team members also makes their support and recognition more difficult. Civil engineering technologists are employed in wide array of industries including construction, inspection, maintenance, facility management, etc. In general, the work of engineering technologists focuses on the applied aspects of engineering principles, whereas the engineering technologists duty as: " ….may inspect portions of construction projects; take part in field survey work including the leading of small project survey parties; make and check engineering computations; prepare portions of written reports; assist in the design of highways and buildings including landscaping projects; and conduct complex field and laboratory tests of engineering materials. …. ... would perform complex and technical activities in support of various engineering projects and/or pro- gram areas. These activities might include preparing written reports and cost estimates of materials, supplies and equipment, and developing or reviewing contract plans and specifications. … may super- vise … technicians in such areas as design, construction inspection, surveying, traffic engineering, maintenance, planning, engineering research, and material testing. Additionally, …. may plan and schedule field and laboratory test work, review test reports, and develop test equipment and procedures. ….. may also be expected to use various computer applications in the performance of your duties [1]."

An ASCE Effort

The Committee on Civil Engineering Technologists (CCET) of ASCE formed the Civil Engineering Technologist Body of Knowledge (CET BOK) task committee to build on the recommendations developed by the Technologist Credentialing Task Committee (TCTC-ASCE). One of the recommendations outlined in the August, 2013 TCTC report is the establishment of the body of knowledge (BOK) for civil engineering technologists (CET). The BOK-CET task committee was formed in spring of 2015. The author was a member of this task committee.

ASCE Methodology

Since formation of the Task Committee (TC) in March of 2015, the TC held three in-person meetings and 11 conference calls. The conference call schedule was approximately monthly. Using data and results from the three previous ASCE Task Committees working on the issues of Civil Engineering Technologists (Paraprofessional Exploratory Task Committee, 18 Sep 2008; Paraprofessional Task Committee, 3 Sep 2010, and Technologist Credentialing Task Committee, 22 Aug 2013), the TC employed a Socratic approach to identify a general framework for a Civil Engineering Technologist's Body of Knowledge. This framework considers the criteria used in the Civil Engineering Body of Knowledge (CE-Bok), but considered the applied nature of technologist's work to add, delete, and shape the Foundational, Technical, and Professional Competency Outcomes. Of significance, the TC felt a technologist would be expected to demonstrate expertise in specific areas, which were captured as Technologist Specialty Outcomes. Each of these "specialty" outcomes is included in the CE- BoK, but as they may represent focus areas for a technologist these were identified individually.

Based on the TC charge, the group deliberated on the skills and prerequisites appropriate for the development of a BoK for civil engineering technologists. The TC developed a rubric in the form of a table to describe the minimum cognitive achievement level for a person to be credentialed as a civil engineering technologist. These findings, based on the application of Bloom's taxonomy, represents the preliminary findings of this TC's effort to develop a BoK. The preliminary CET-BoK includes 18 Technolo- gist Specialty Outcomes. While these outcomes might be considered imbedded components of the Civil Engineering BoK (CE-BoK), they are uniquely identified in this CET-BoK as areas of specialization and in-depth skill that define a CE Technologist's abilities and accomplishments. A similar level of specialized mastery in not explicitly required for the CE-BoK. The CET-BoK also includes 16 Foundational Outcomes as compared to 24 Foundational Outcomes in the CE-BoK. In addition, the level of achievement varies, considerably in some cases, between individual outcomes with similar titles in the CET-BoK and CE- BoK. The most common deviation is in the area of cognitive achievement where most of the civil engineering technologist minimum achievement levels are in "application", where many similar Foundational Outcomes for civil engineers are in "analysis", synthesis", or "evaluation".

The table of rubric is the primary product of the report is shown in the Appendix A .

International Engineering Technologists Agreement (IETA)[2]

The International Engineering Technologists Agreement (IETA) stipulates an engineering technologist shall demonstrate “the competence for independent practice as an engineering technologist as exemplified by the International Engineering Alliance (IEA) competency profile.”

According to IEA, engineering is an activity that is essential in meeting the needs of people, economic development, and the provision of services to society. Engineering involves the purposeful application of mathematical, natural sciences, and a body of engineering knowledge, technology, and techniques. Typical engineering activity

requires several roles including those of the engineer, engineering technologist, and engineering technician. These roles are defined by their distinctive competencies and their level of responsibility to the public. There is a degree of overlap between roles.

IEA stipulated a (civil) engineering technologist’s range of problem solving as encompassing “broadly-defined” engineering problems (as opposed to “complex engineering problems” for engineers). It further expands broadly-defined activities as those which require engineering knowledge at the level of an engineering specialist. Further, a specialist is an individual who possesses the theoretical framework and body of knowledge for an accepted sub-discipline.

IETA (Sydney Accord) describes the knowledge profile for (civil) engineering technologists as incorporating:

1) a systematic, theory-based understanding of the natural sciences applicable to the sub-discipline, conceptually based mathematics, numerical analysis, statistics, and aspects of computer and information science to support analysis and use of models applicable to the sub-discipline;
2) a systematic theory-based formulation of engineering fundamentals required in an accepted sub-discipline; and
3) engineering specialist knowledge that provides theoretical frameworks and bodies of knowledge for an accepted sub-discipline.

Civil Engineering Technology in South Asia - India

Engineering technologies in India are taught in “Polytechnic” colleges at the post-secondary level. They are usually three-year diploma program under the supervision of respective state board of technical education. These programs are kept outside the purview of university system. Often, they are called Licentiate in Civil Engineering (LCE) or Licentiate in Mechanical Engineering (LME) or licentiate in other disciplines of engineering. A diploma course in engineering involves classes on fundamental engineering concepts. It is a professional course, planned in such a way that students may still take up jobs in the field of engineering once they earn their diplomas. It can allow them to transfer into the second year of the B.Tech. or B.E. course. This, in effect, means the student may not have to take the eleventh and twelfth class exams. So, instead of the last two years of school and four years of the degree engineering course (a total of six years), the same qualification is achieved in the same amount of time with three years of a diploma course and three years of the degree course after the direct transfer. In India, engineering college admissions are controlled by national admission test or statewide admission tests. Engineering entrance exams like Joint Engineering Entrance test or individual state and college Common Entrance Tests can be bypassed by the diploma engineering graduates.

Diploma courses can be of a yearly or semester pattern. Most yearly pattern courses have a duration of three years. The diploma programs that follow a semester pattern have a planned duration of four years, with three years of study and one year for an industrial internship. The minimum qualification required for admission into a diploma course is passing of the Secondary School Leaving Certificate (SSLC)/tenth standard/equivalent examination, with science and mathematics. The state boards of technical education of most of the states in India conduct entrance tests for admission to the diploma programs offered by various polytechnics in the state.

A student who has attained the diploma is usually eligible to enter B.Tech./B.E. programs in the second year under a lateral entry scheme. This fast-track admission is possible only after completing the Lateral Entry Test. If they do well on this test, they can apply to B.Tech./B.E. programs.

The course content of the diploma program and that of the B.Tech./B.E. program may seem very similar, but the level of syllabus content is higher in the latter. Depth of the technical courses and level of use of mathematics in B,Tech/B.E. programs are much higher. However, diploma students may have an advantage, since they are likely to already have solid knowledge of fundamentals engineering courses like engineering graphics, applied mechanics, engineering materials etc. over regular B.Tech./B.E. students who directly enter after their twelfth grade.

Enrollments

According to AICTE[3], in 2016-17 there were 3925 polytechnic or diploma granting institutions in engineering/technology. Enrollments for 2016 were 583.496 males and 113,264 female students. Typically, 70% of the students who enrolls graduate from these programs. There were 121,216 faculty members in the polytechnic system.

Job Prospects for Diploma Engineering Graduates

Graduates from the diploma engineering programs are typically hired as junior engineers in private sector. A few companies have engineering technology and designer designation. Many state governments hire diploma holder as Sub-Assistant Engineer. Majority of the polytechnics claims over 90% of the graduates receive job offer within six month of graduation [4].

Engineering technology education, that is diploma engineering in India, is thriving in the sub-continent. Great influx of technical manpower that was needed to build India’s civil and information infrastructure since mid-nineties has helped the diploma granting polytechnics grow and modernize their programs and facility.

Civil Engineering Technology in South East Asia - Singapore

Civil engineering technology education in Singapore is somewhat similar to India's model. Here also CET is taught in the polytechnic system that is outside of the university system and called Diploma in Civil engineering. The Diploma in Civil Engineering (DCE) is a broad-based and versatile course covering key areas such as Structures, Geotechnics, Transportation, Water Technology and Project Management. The training in DCE prepares the students for the transforming industry and equip them with the essential technical skillset. The graduates build the world, literally speaking. They support civil engineers in the analysis, design, construction, upgrading and maintenance of all forms of infrastructure for better quality of life and sustainable economy.

Conceive-Design-Implement-Operate (CDIO) framework that prepares students to be life-ready, work-ready and world-ready. Take part in competitions, seminars, overseas community service projects, study trips and humanitarian missions Equip students with skillsets that are aligned with the Construction Industry Transformation Map. 22-week Internship Program to apply classroom learning to real projects and develop professional skills.

Entrance requirements include passing at a minimum "O" level examination that is usually taken after tenth grade (again, similar to Indian model). There are some seats reserved for highly competitive civil engineering baccalaureate programs for graduates of diploma civil engineering programs. However, they do not get any advance standing as it is given in the Indian system.

Conclusion

Educating civil engineering technologists in United States is not defined and confusing. South Asian and South East Asian countries education model for civil engineering technologists are well defined and follow IEA framework.

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APENDIX

Initial Framework for Body of Knowledge (BOK) for Civil Engineering Technologists

Outcome Number and Title	OUTCOME
Foundational Outcomes	
1 Mathematics	**Solve** problems in application of integral and differential calculus or other mathematics above the level of algebra and trigonometry and apply this knowledge to the solution of engineering problems.
2 Natural Sciences	**Solve** problems in algebra based physics and/or chemistry and apply this knowledge to the solution of engineering problems.
3 Humanities	**Demonstrate** the importance of the humanities in the practice of engineer-ing
4 Social Sciences	**Demonstrate** the incorporation of social sciences knowledge into the prac-tice of engineering
Technical Outcomes	
5 Material Science	**Demonstrate** knowledge of materials science to solve problems appropriate to civil engineering sub-discipline
6 Mechanics	**Analyze** and solve problems in statics, strength of materials, and applied fluid mechanics

7 Experiments	**Conduct** investigations of broadly-defined engineering problems; locate, search, and select relevant data from codes, data bases and literature, design and conduct experiments to provide valid conclusions.
8 Problem recognition and solving	**Identify and formulate** research literature to analyze broadly-defined engineering problems reaching substantiated conclusions using analytical tools appropriate to the discipline or area of specialization
9 Design	**Conduct** design solutions for broadly –defined engineering problems and contribute to the design of systems, components or processes to meet specified needs with appropriate consideration for public health and safety
10 Sustainability	**Demonstrate** understanding of sustainability and impact of engineering technology work in the solution of broadly defined engineering problems in societal and environmental contexts
11 Contemporary issues and historical perspectives	**Demonstrate** understanding of impact of historical and contemporary issues on the identifications, formulations, and solution broadly defined engineering problems
12 Project Management	**Demonstrate** knowledge and understanding of engineering management principles and apply these to one's work, as a member or leader in a team and to manage projects in multidisciplinary environments
13 Breadth in civil engineering areas	**Solve** well defined engineering problems in at least three technical areas appropriate to civil engineering
14 Technical Specialization	**Analyze** and solve broadly defined engineering problems in a specialized technical area appropriate to civil engineering
Professional Competency Outcomes	
15 Communication	**Compose** the verbal, written, virtual and graphical communication of a project to technical and non-technical audiences
16 Business and public administration	**Apply** public policy process techniques to simple public policy problems related broadly defined civil engineering works
17 Globalization	**Analyze** broadly defined engineering works and services in order to function at a basic level in a global context
18 Leadership	**Organize** and **direct** the efforts of a group
19 Teamwork	**Function** effectively as a member of a multidisciplinary team
20 Attitude	**Demonstrate** attitudes supportive of the practice of civil engineering
21 Lifelong Learning	**Recognize** the need for and have the ability to engage in life-long learning in specialist technologies
22 Professional and ethical responsibility	**Demonstrate** understanding of commitment to professional ethics, responsibilities , and norms of civil engineering practice

CET-BoK Outcomes Rubric

Outcome title	*Level of cognitive achievement*					
	1 Knowlede	*2 Comprehension*	*3 Application*	*4 Analysis*	*5 Synthesis*	*6 Evaluation*
Foundational Outcomes						
1 Mathematics			**Demonstrate** an ability to apply integral anddifferential calculus to the solution of engineering problems.			
2 Natural Sciences			**Demonstrate** an ability to understand the application of physics and as appropriate other natural sciences such as chemistry, biology, or geology			
3 Humanities		**Relate** humanities to the practice of civil engineering technology				

4 Social Sciences		**Relate** social sciences to the practice of civil engi- neering technol- ogy				
5 Material Sci-			**Apply** knowledge of material types and			

Outcometitl	*Level of cognitive achievement*					
	1 Knowledge	*2 Comprehension*	*3 Application*	*4 Analysis*	*5 Synthesis*	*6 Evaluation*
11 Business acumen		**Follow** efficient and effective business				
12 Leadership				**Plan, Organize,** and **Direct** the efforts of a group and self		
13 Public Policy		**Understand** public policy applicable within an area of specialization				
14 Teamwork			**Apply** knowledge of roles and responsibilities of team members in a multidisciplinary environment and **Operate** effectively as a member of a multidisciplinary team			
15 Lifelong Learning					**Develop**enhanced understanding appropriate to one's area(s) of	

Outcome	*Level of cognitive achievement*					
	1 Knowledge	*2 Comprehension*	*3 Application*	*4 Analysis*	*5 Synthesis*	*6 Evaluation*
16 Professional and ethical responsibility				**Analyze** situations involving conflicting professional and ethical interests to **Formulate** an appropriate course of action		

Note --- This information was based on the following assumptions:

1) No mandatory formal education beyond a high school diploma or equivalent
2) No specific type of college degree required
3) Applies to an individual practicing in civil engineering field
4) Does not apply to individuals operating in a position of responsible charge
5) Applies to individuals operating in design, construction, testing and measurements, or research
6) Describes a minimum level of competency as a civil engineering technologist

CET-BoK Specialty Outcomes Rubric

Out-come ti-	*Design*	*Construction*	*Testing and Measurement*	*Research*	*Level of cognitive achievement* *1 Knowledge*	*2 Comprehension*	*3 Application*	*4 Analysis*	*5 Synthesis*	*6 Evalua-tion*
					Technologist Specialty Outcomes					
a – Survey	**X**	**X**		**X**			**Produce** route and topographic surveys, and			
b – Field Data Col-lection		**X**	**X**	**X**			**Choose** appropri-ate sensors and field data collec-tion equipment			
c – Data Processing	**X**		**X**	**X**			**Organize** tech-nical field data collection ef-forts to **Pro-duce** infor-			
d – Produc-tivity Soft-ware	**X**	**X**					**Use** productivity software for en-gineering design and/or construc-			

Outcome	*Design*	*Construction*	*Testing and Measurement*	*Research*	*1 Knowledge*	*2 Comprehension*	*3 Application*	*4 Analysis*	*5 Synthesis*	*6 Evaluation*
					Level of cognitive achievement					
					Technologist Specialty Out-					
e – Testing Standards			**X**				**Demonstrate** familiarity with relevant testing stand-			
f – Cods and Standards	**X**	**X**					**Apply** codes and standards to routine design and construction planning			
g – Quantity Estimating	**X**	**X**					**Prepare** quantity takeoffs from plans and specifications			
h – Permitting	**X**	**X**					**Prepare** and submit permit applications, oversee per-			
i – Health and Safety	**X**	**X**	**X**	**X**			**Develop**, implement, and /or monitor health and safety plans			
j – Standard Calculations	**X**						**Prepare** standard and routine design calculations			

Outcome	Design	Construction	Testing and Measurement	Research	Level of cognitive achievement 1 Knowledge	2 Comprehension	3 Application	4 Analysis	5 Synthesis	6 Evaluation
					Technologist Specialty Out-					
k – Cost Estimating	**X**	**X**					**Produce** cost estimates for materials, labor, equipment, and overhead			
l – Plans and Specifications	**X**	**X**					**Prepare** engineering and construction documents, such as drawings, plan sets, and **s**pecifications			
m – Contracts	**X**	**X**					**Prepare** and **Organize** form contracts for construction and procurement			
n – QA/QC	**X**	**X**	**X**				**Implement** Quality Assurance and Quality Control programs			
o – Contractor Performance		**X**	**X**	**X**			**Conduct** coordination with contractors and **Prepare** reports			
p – Tech-	**X**		**X**	**X**			**Prepare** and **Edit** technical			

Out- co me ti-	*Design*	*Construction*	*Testing and Measurement*	*Research*	*Level of cognitive achievement* *1* *Knowledge*	*2* *Comprehen-*	*3* *Application*	*4* *Analysis*	*5* *Synthesis*	*6* *Evalua-*
					Technologist Specialty Outcomes					
q – Civil Engi-neering Soft-ware	**X**	**X**	**X**	**X**			**Use** specialized civil engineering software for analysis, design, reporting, and/or project scheduling.			
r – Project Manage-ment	**X**	**X**	**X**	**X**			**Apply** manage-ment skills for the successful delivery of a pro-ject.			

Note --- This information was based on the following assumptions:

1) No mandatory formal education beyond a high school diploma or equivalent
2) No specific type of college degree required
3) Applies to an individual practicing in civil engineering field
4) Does not apply to individuals operating in a position of responsible charge
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