Making Opportunity Affordable in Texas: A Student Centered Approach

Tuning of Civil Engineering

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Definition of Tuning

Tuning is the effort to put together into a coherent picture the competencies required of a student for a baccalaureate degree in the field, with the purpose of a state-wide understanding of the knowledge skills and attitudes students obtain throughout their education tenure. Tuning emphasizes the need for clarity for non-engineering stakeholders such as high school students and their parents.

Definition of Civil Engineering

Civil engineers are entrusted by society to create a sustainable world and enhance the global quality of life. Civil engineers serve competently, collaboratively, and ethically as:

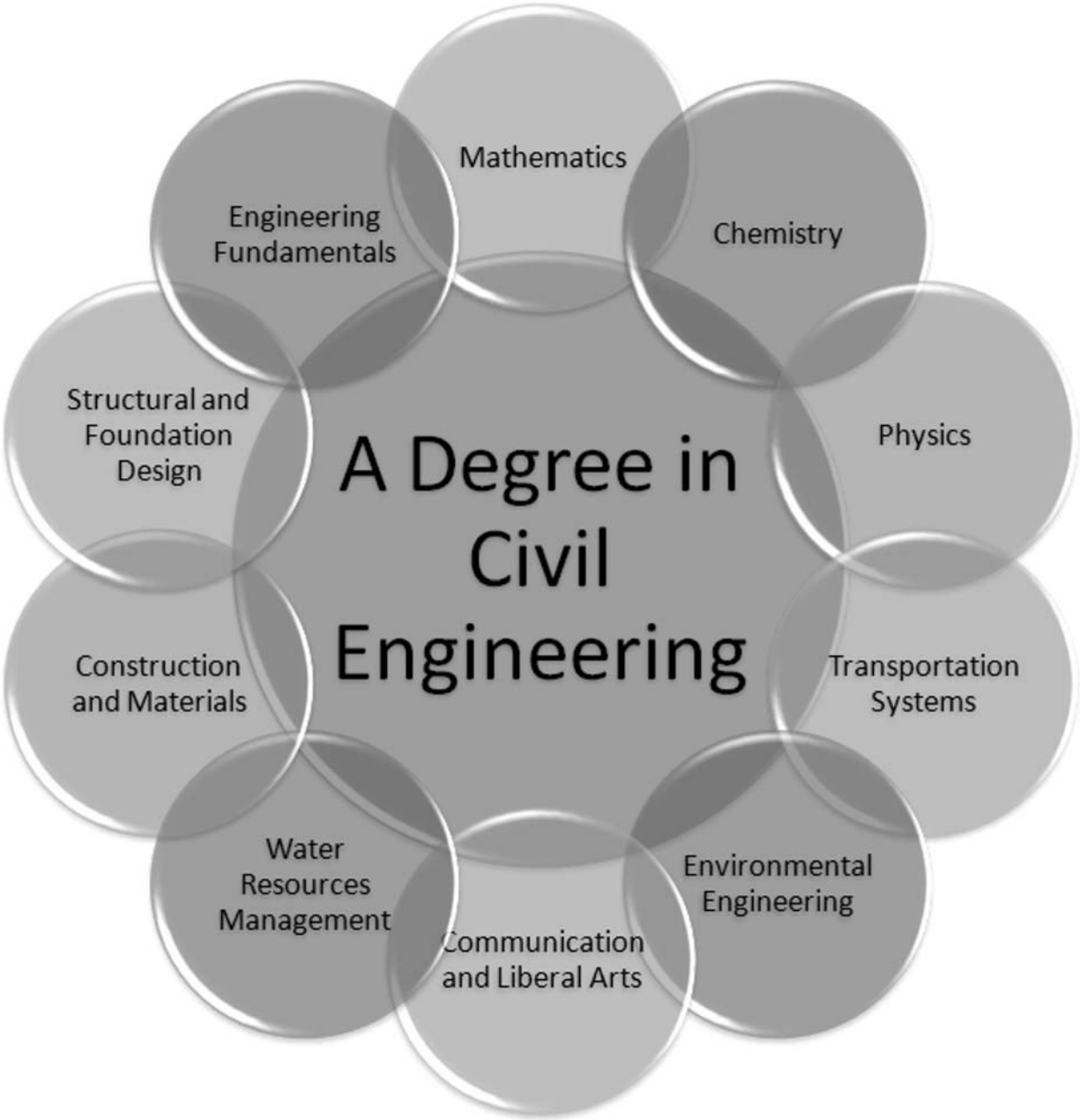
- planners, designers, constructors, and operators of society's economic and social engine, the built environment;
- stewards of the natural environment and its resources;
- innovators and integrators of ideas and technology across the public, private, and academic sectors;
- managers of risk and uncertainty caused by natural events, accidents, and other threats; and
- leaders in discussions and decisions shaping public environmental and infrastructure policy.

After the American Society of Civil Engineers (ASCE) 2025 vision for Civil Engineering.

ASCE has a description of Civil Engineering career paths that may help students to fit their professional development with their goals and interests:
http://www.asce.org/uploadedFiles/Leadership_Training_-_New/careerpathfinal.pdf

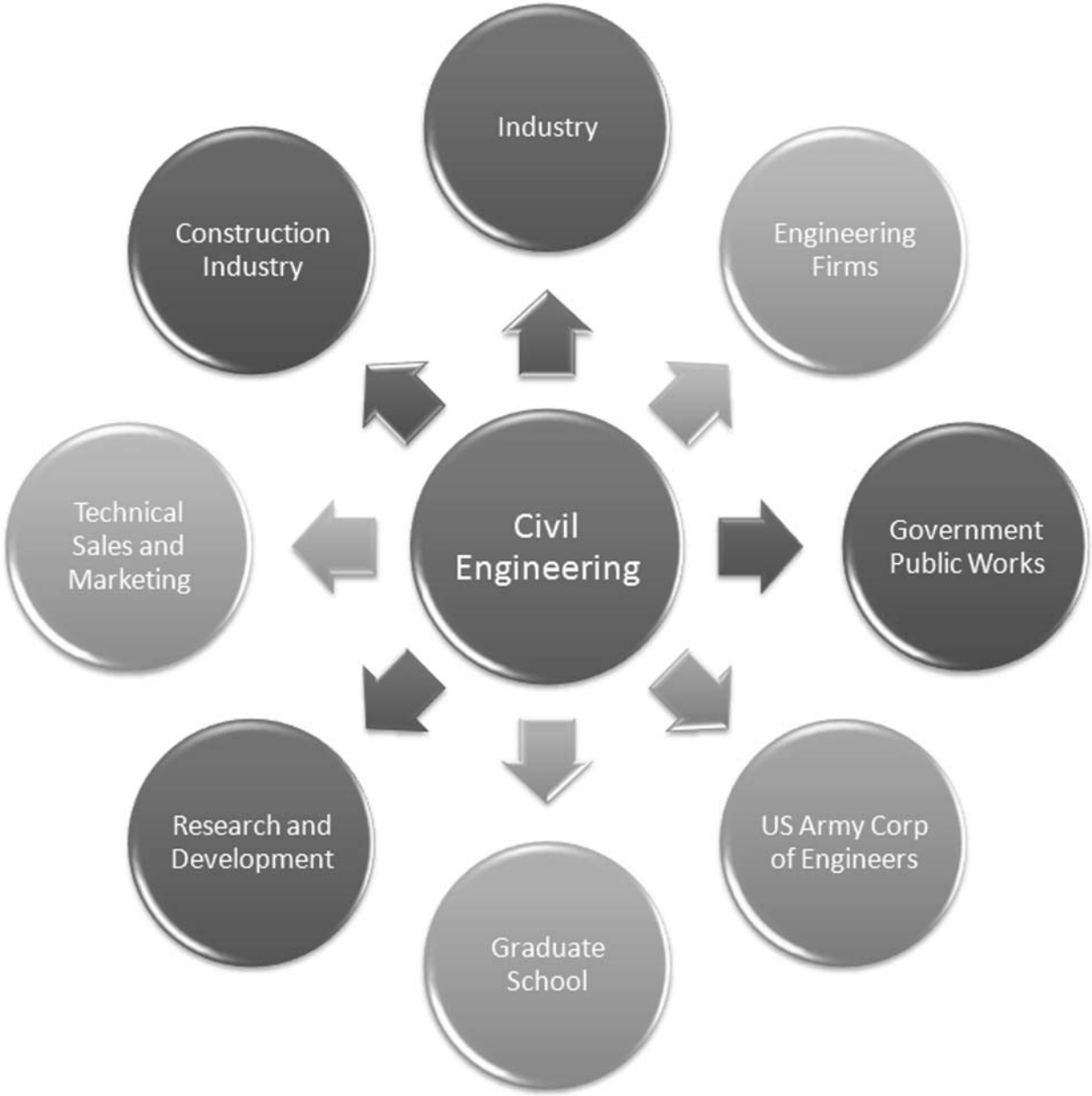
Civil Engineering Expertise Profile

The expertise profile lists ten types of course work necessary for the completion of a baccalaureate degree in civil engineering. Note: general undergraduate degree requirements, i.e., the core curriculum, are not considered for the purpose of tuning civil engineering and this report.



Civil Engineering Employment Profile

The employment profile lists seven types of jobs available for civil engineers.



Civil Engineering Competency Table

The Civil Engineering Tuning Committee's competency table was informed by the American Society of Civil Engineers (ASCEE) Civil Engineering Body of Knowledge for the 21st Century, 2nd Edition, 2008 (BOK2E). However, the Committee focused on current ABET, Inc. driven competency requirements, rather than on ASCEE goals for the future development of the profession.

The Civil Engineering competency table has four learning outcome categories (rows from bottom to top):

1. core competencies needed to enter higher education in civil engineering,
2. pre-engineering competencies gained during first two years of study,
3. baccalaureate level engineering competencies, and
4. post-graduate engineering competencies.

The Civil Engineering competency table has eleven learning outcome titles (columns from left to right):

1. Mathematics
2. Natural Sciences
3. Materials Science
4. Mechanics
5. Experiments
6. Design
7. Teamwork
8. Problem Recognition and Solving
9. Ethics
10. Communication
11. Contemporary Issues and Historical Perspectives

Competencies	Mathematics	Natural Sciences	Materials Science	Mechanics
	A. Mathematics, Science, Engineering			
Post-Graduate Engineering Competencies	Analyze a complex problem to determine the relevant mathematical principles and then apply that knowledge to solve the problem	Analyze complex problems to determine the relevant physics, chemistry, and/or other areas of natural science principles and then apply that knowledge to solve the problem.	Analyze a complex problem to determine the relevant materials science principles, and then apply that knowledge to solve the problem.	Evaluate the validity of newly created knowledge in mechanics.
Baccalaureate Level Engineering Competencies	Solve problems in mathematics through differential equations and apply this knowledge to the solution of engineering problems	Solve problems in calculus-based physics, chemistry, and one additonal area of natural science and apply this knowledge to the solution of engineering problems	Apply knowledge of materials, such as concrete, steel, soils, and asphalt, used in civil engineering construction	Analyze and solve problems involving solid and fluid mechanics
Pre-Engineering Competencies gained during first two years of study	Explain key concepts and problem-solving processes in mathematics through differential equations	Explain key concepts and problem-solving processes in chemistry, calculus-based physics, and one additional area of natural science	Explain material properties though key concepts in physics and chemistry	Explain key concepts and problem-solving processes in statics, dynamics, and solid and fluid mechanics
Core Competencies needed to enter higher education in civil engineering	Solve problems in mathematics in algebra, plane geometry, trigonometry, and analytical geometry (or pre-calculus), and apply this knowledge to the solution of science and technology problems. Students should be ready to complete calculus I in their first college semester	Explain key concepts in physics, chemistry, and biology and solve related problems	Define material properties though key concepts in physics and chemistry	

Competencies	Experiments	Design	Teamwork	Problem Recognition and Solving
	B. Experiments	**C. Design**	**D. Multidisciplinary Teams**	**E. Engineering Problems**
Post-Graduate Engineering Competencies	Specify an experiment to meet a need, conduct the experiment and analyze and evaluate the experiment for effectiveness in meeting a real-world need.	Evaluate design of complex system and assess compliance with standards of practice, user needs, and relevant constraints.	Function effectively as a member of a multidisciplinary team	Synthesize the solution to an engineering problem into a broader public, policy, social impact, or business objective.
Baccalaureate Level Engineering Competencies	Conduct experimetns in civil engineering according to established procedures, report results, and evaluate the accuracy of the results within the known boundaries of the test and materials	Apply the design process to create a solution while meeting the requirements of real-world constraints	Function effectively as a member of an interdisciplinary team	Develop problem statements and solve fundamental civil engineering problems by applying appropriate techniques and tools in at least four technical areas
Pre-Engineering Competencies gained during first two years of study	Explain the purpose, procedures, equipments, and practical applications of experiments in natural sciences	Identify basic purpose and steps of design process as problem solvers	Discuss and demonstrate collaborative learning and team work on class projects	Identify key factual information related to math, science, and basic mechanics problem recognition, problem solving, and applicable techniques and tools
Core Competencies needed to enter higher education in civil engineering	Conduct experiments in natural science courses according to established procedures, report results, and evaluate the accuracy of the results		Have experience in collaborative learning and team work on class projects	Explain key concepts related to problem recognition, problem articulation, and problem solving processes related to math and science applications

Competencies	Ethics	Communication	Contemporary Issues and Historical Perspectives
	F. Ethics and Professional Responsibility	**G. Communication**	**H/J. Impact of Engineering and Contemporary Issues**
Post-Graduate Engineering Competencies	Synthesize studies and experiences to foster professional and ethical conduct	Evaluate the effectiveness of the integrated verbal, written, and graphical communication of a project to technical and nontechnical audiences.	Evaluate the impacts and relationships among engineering and historical, contemporary, and emerging issues.
Baccalaureate Level Engineering Competencies	Analyze a situation and apply standards of professional and ethical responsibility to determine appropriate action	Organize and deliver effective oral, written, virtual, and graphical communication	Understand historical and contemporary issues and apply their impacts in solution of engineering problems
Pre-Engineering Competencies gained during first two years of study	Identify appropriate academic and professional ethical behaviors	Apply the rules of grammar and composition in verbal and written communications, properly cite sources, and use appropriate graphical standards in preparing engineering drawings	Explain the impact of engineering solutions on the economy, environment, public policy, and society
Core Competencies needed to enter higher education in civil engineering		List and use basic elements of oral, written, virtual, and graphical communication	Describe economic, environmental, public policy, and societal aspects of modern history

Civil Engineering Learning Outcome Descriptions

Learning outcome descriptions explain the knowledge skills and attitudes for the eleven learning outcome titles of the competency table.

Mathematics

Mathematics deals with the science of structure, order, and relation that has evolved from counting, measuring, and describing the shapes of objects. It uses logical reasoning and quantitative calculation, and is considered the underlying language of science. The principal branches of mathematics relevant to civil engineering are algebra, analysis, arithmetic, geometry, calculus, numerical analysis, optimization, probability, set theory, statistics, and trigonometry.

The civil engineering graduate solves problems in mathematics through differential equations and *applies* this knowledge to the solution of engineering problems. The mathematics required for civil engineering practice must be learned at the undergraduate level and should prepare students for subsequent courses in engineering.

Natural Sciences

Underlying the professional role of the civil engineer as the master integrator and technical leader is a firm foundation in the natural sciences. Physics and chemistry are two disciplines of the natural sciences that have historically served as basic foundations. Additional disciplines of natural science are also assuming stronger roles within civil engineering.

Physics is concerned with understanding the structure of the natural world and explaining natural phenomena in a fundamental way in terms of elementary principles and laws. Mechanics is concerned with the equilibrium and motion of particles or bodies under the action of given forces. Many areas of civil engineering rely on physics for understanding the underlying governing principles and for obtaining solutions to problems.

Chemistry is the science that deals with the properties, composition, and structure of substances (elements and compounds), the reactions and transformations they undergo, and the energy released or absorbed during those processes. Chemistry is concerned with atoms as building blocks, everything in the material world, and all living things. Some areas of civil engineering—especially environmental engineering and construction materials— rely on chemistry for explaining phenomena and obtaining solutions to problems.

Additional breadth in such natural science disciplines as biology, ecology, geology and geomorphology will eventually be required to prepare the civil engineer of the future. Civil engineers should have the basic scientific literacy that will enable them to be conversant with technical issues pertaining to environmental systems, public health and safety, durability of construction materials, and other such subjects.

The civil engineering graduate solves problems in calculus-based physics, chemistry, and one additional area of natural science and *applies* this knowledge to the solution of engineering problems. The physics, chemistry, and breadth in natural sciences required for civil engineering practice must be learned at the undergraduate level and should prepare students for subsequent courses in engineering and engineering practice.

Materials Science

Civil engineering includes elements of materials science. Construction materials with broad applications in civil engineering include ceramics like Portland cement concrete and hot mix asphalt concrete, metals like steel and aluminum, as well as polymers and fibers. An understanding of materials science also is required for the treatment of hazardous wastes utilizing membranes and filtration. Infrastructure often requires repair, rehabilitation, or replacement due to degradation of materials.

The civil engineer is responsible for specifying appropriate materials. The civil engineer should have knowledge of how materials systems interact with the environment so that durable materials that can withstand aggressive environments can be specified as needed. This includes the understanding of materials at the macroscopic and microscopic levels.

The civil engineering graduate uses knowledge of materials science to *solve* problems appropriate to civil engineering. The materials science required for civil engineering practice must be learned at the undergraduate level and should prepare students for subsequent courses in engineering curricula.

Mechanics

In its original sense, mechanics refers to the study of the behavior of systems under the action of forces. Mechanics is subdivided according to the types of systems and phenomena involved. An important distinction is based on the size of the system. The Newtonian laws of classical mechanics can adequately describe those systems that are encountered in most civil engineering areas.

Mechanics in civil engineering encompasses the mechanics of continuous and particulate solids subjected to load, and the mechanics of fluid flow through pipes, channels, and porous media. Areas of civil engineering that rely heavily on mechanics are structural engineering, geotechnical engineering, pavement engineering, and water resource systems.

The civil engineering graduate analyzes and solves problems in solid and fluid mechanics. The mechanics required for civil engineering practice must be learned at the undergraduate level and should prepare students for subsequent courses in engineering curricula.

Experiments

Experiment can be defined as "an operation or procedure carried out under controlled conditions in order to discover an unknown effect or law, to test or establish a hypothesis, or to illustrate a known law."

Civil engineers frequently design and conduct field and laboratory studies, gather data, create numerical simulations and other models, and then analyze and interpret the results. Individuals should be familiar with the purpose, procedures, equipment, and practical applications of experiments spanning more than one of the technical areas of civil engineering. They should be able to conduct experiments, report results, and analyze results in accordance with the applicable standards in or across more than one technical area. In this context, experiments may include field and laboratory studies, virtual experiments, and numerical simulations.

The civil engineering graduate analyzes the results of experiments and evaluates the accuracy of the results within the known boundaries of the tests and materials in or across more than one of the technical areas of civil engineering.

Design

Design is an iterative process that is often creative and involves discovery and the acquisition of knowledge. Such activities as problem definition, the selection or development of design options, analysis, detailed design, performance prediction, implementation, observation, and testing are parts of the engineering design process.

Design problems are often ill-defined, so defining the scope and design objectives and identifying the constraints governing a particular problem are essential to the design process. The design process is open-ended and involves a number of likely correct solutions, including innovative approaches. Successful design requires critical thinking, an appreciation of the uncertainties involved, and the use of engineering judgment. Consideration of risk assessment, societal and environmental impact, standards, codes, regulations, safety, security, sustainability, constructability, and operability are integrated at various stages of the design process.

The civil engineering graduate designs a system or process to meet desired needs within such realistic constraints as economic, environmental, social, political, ethical, health and safety, constructability, and sustainability.

Teamwork

Licensed civil engineers must be able to function as members of a team. This cooperation requires understanding team formation and evolution, personality profiles, team dynamics, collaboration among diverse disciplines, problem solving, and time management and being able to foster and integrate diversity of perspectives, knowledge, and experiences.

A civil engineer will eventually work within two different types of teams. The first is intra-disciplinary and consists of members from within the civil engineering sub-discipline—for example, a structural engineer working with a geotechnical engineer. The second is multidisciplinary and is a team composed of members of different professions—for example, a civil engineer working with an economist on the financial implications of a project or a civil engineer working with local elected officials on a public planning board. Multidisciplinary also includes a team consisting of members from different engineering sub-disciplines—sometimes referred to as a cross-disciplinary team—for example, a civil engineer working with a mechanical engineer.

The civil engineering graduate functions effectively as a member of an intra-disciplinary team. At the undergraduate level, the focus is primarily on working as members of an intra-disciplinary team—that is, a team within the civil engineering sub-discipline. Examples of opportunities for students to work in teams include design projects and laboratory exercises within a course and during a capstone design experience.

Problem Recognition and Solving

Civil engineering problem solving consists of identifying engineering problems, obtaining background knowledge, understanding existing requirements and/ or constraints, articulating the problem through technical communication, formulating alternative solutions—both routine and creative—and recommending feasible solutions.

Appropriate techniques and tools— including information technology, contemporary analysis and design methods, and design codes and standards to complement knowledge of fundamental concepts—are required to solve engineering problems. Problem solving also involves the ability to select the appropriate tools as a method to promote or increase the future learning ability of individuals.

The civil engineering graduate develops problem statements and *solves* well-defined fundamental civil engineering problems by *applying* appropriate techniques and tools. Civil engineers should be familiar with factual information related to engineering problem recognition and problem-solving processes. Additionally, civil engineers should be able to explain key concepts related to engineering problem recognition, articulation, and solving.

Ethics

Civil engineers in professional practice have a privileged position in society, affording the profession exclusivity in the design of the public's infrastructure. This position requires each of its members to adhere to a doctrine of professionalism and ethical responsibility. This doctrine is set forth in the seven fundamental canons in the American Society of Civil Engineer's (ASCE) Code of Ethics. The first canon states that civil engineers "...shall hold paramount the safety, health, and welfare of the public...." By meeting this responsibility, which puts the public interest above all else, the profession earns society's trust.

Civil engineers aspire to be "entrusted by society to create a sustainable world and enhance the global quality of life." Therefore, current and future civil engineers, whether employed in public or private organizations or self-employed, will increasingly hold privileged and responsible positions.

The civil engineering graduate analyzes a situation involving multiple conflicting professional and ethical interests to determine an appropriate course of action. The undergraduate experience should introduce and illustrate the impact of the civil engineer's work on society and the environment. This experience naturally leads to the importance of meeting such professional responsibilities as maintaining competency and the need for ethical behavior.

Communication

Means of communication include listening, observing, reading, speaking, writing, and graphics. The civil engineer must communicate effectively with technical and nontechnical individuals and audiences in a variety of settings. Use of these means of communication by civil engineers requires an understanding of communication within professional practice. Fundamentals of communication should be acquired during formal education. Pre-licensure experience should build on these fundamentals to solidify the civil engineer's communication skills.

Within the scope of their practice civil engineers prepare and/or use calculations, spreadsheets, equations, computer models, graphics, and drawings—all of which are integral to a typically complex analysis and design process. Implementation of the results of this sophisticated work requires that civil engineers communicate the essence of their findings and recommendations.

The civil engineering graduate organizes and *delivers* effective verbal, written, virtual, and graphical communications. Communication can be taught and learned across the curriculum—that is, over all years of formal education and in most courses.

Contemporary Issues and Historical Perspectives

To be effective, professional civil engineers should draw upon their broad education to analyze the impacts of historical and contemporary issues on engineering and analyze the impact of engineering on the world. The engineering design cycle illustrates the dual nature of this outcome. In defining, formulating, and solving an engineering problem, engineers must consider the impacts of historical events and contemporary issues.

Examples of contemporary issues that could impact engineering include the multicultural globalization of engineering practice; raising the quality of life around the world; the importance of sustainability; the growing diversity of society; and the technical, environmental, societal, political, legal, aesthetic, economic, and financial implications of engineering projects. When generating and comparing alternatives and assessing performance, engineers must also consider the impact that engineering solutions have on the economy, environment, political landscape, and society.

The civil engineering graduate draws upon a broad education, *explains* the impact of historical and contemporary issues on the identification, formulation, and solution of engineering problems and *explains* the impact of engineering solutions on the economy, environment, political landscape, and society.

Civil Engineering Key Competencies Profile

The key competencies profile is a schematic diagram that is derived from the competency table. It lists for each learning outcome (columns) the required competency levels according to Bloom's taxonomy (rows) that have to be gained at each of four educational levels:

1. secondary education competencies, marked "HS,"
2. pre-engineering competencies, marked "CC,"
3. baccalaureate level competencies, marked "BS," and
4. post-graduate competencies, marked "G."

The six competency levels according to Bloom's taxonomy are:

1. knowledge,
2. comprehension,
3. application,
4. analysis,
5. synthesis, and
6. evaluation.

The level of response for each of the Bloom's taxonomy levels are described through active verbs, for example (http://www.teach-nology.com/worksheets/time_savers/bloom/):

Knowledge	count, define, describe, draw, find, identify, label, list, match, name, quote, recall, recite, sequence, tell, write
Comprehension	conclude, demonstrate, discuss, explain, generalize, identify, illustrate, interpret, paraphrase, predict, report, restate, review, summarize, tell
Application	apply, change, choose, compute, dramatize, interview, prepare, produce, role-play, select, show, transfer, use
Analysis	analyze, characterize, classify, compare, contrast, debate, deduce, diagram, differentiate, discriminate, distinguish, examine, outline, relate, research, separate,
Synthesis	compose, construct, create, design, develop, integrate, invent, make, organize, perform, plan, produce, propose, rewrite
Evaluation	appraise, argue, assess, choose, conclude, critic, decide, evaluate, judge, justify, predict, prioritize, prove, rank, rate, select,

	Mathematics	Natural Sciences	Materials Science	Mechanics	Experiments	Design	Teamwork	Problem Recognition and Solving	Ethics	Communication	Contemporary Issues and Historical Perspectives
Evaluations				G	G	G				G	G
Synthesis				G	G	BS		G	G	G	G
Analysis	G	G	G	BS	BS	BS	G	G	BS	BS	G
Application	BS	BS	BS	BS	BS	BS	BS	BS	BS	CC	BS
Comprehension	CC	CC	CC	CC	CC	BS	CC	CC	BS	SH	CC
Knowledge	HS	HS	HS	CC	HS	CC	HS	HS	CC	HS	HS

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