AIChE
The Global Home of Chemical Engineers

Body of Knowledge
for Chemical Engineers

Prepared by the American Institute of Chemical Engineers

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This Body of Knowledge is dedicated to the memory of James T. Cobb, Jr. PhD, PE, F.AIChE (1938-2013). A devoted educator, Jim was a dedicated contributor to professional development, AIChE meeting programming and engineering licensure. BOK development was born of his vision and began under his leadership. We are fortunate to follow in his footsteps.

Revision	Date	Purpose
0	6/22/2015	Initial Issue

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1 Executive Summary

The development of a Chemical Engineer (ChE) Body of Knowledge (BOK) has been in the making for more than a decade. The effort was initiated by concerned chemical engineers driven by the need to address changing times and perceptions of Chemical Engineering. They found support in professional organizations dedicated to best practices and the advancement of engineering professionals. This report documents the efforts of these workers, and the professional findings that they prepared. It presents the first formal presentation of a chemical engineering BOK.

1.1 BOK Purpose and Results

The BOK team was charged to prepare a Body of Knowledge that encompasses the range of skills, knowledge, and abilities required of a chemical engineer professional for the purpose of providing guidance information to AIChE continuing education efforts. To achieve the goal, the team had to understand the audience, prepare definitions and a presentation framework, and assess ability at various career stages. The result is a series of Knowledge, Skills and Ability (KSA) matrixes providing industry and role viewpoints at four career stages. Information provided in the KSA matrixes is intended to be interpreted for use by others.

The BOK was developed with the expectations of the stakeholder, AIChE, firmly in mind. The interests of a broader audience were also considered. The audience may use the information in this BOK for personal skills development and career planning and to determine content and competency requirements for education and training programs. The BOK matrixes are structured to provide a cross demographic view that can be filtered to determine which knowledge and skills need to be developed in a chemical engineer's professional career, and which industry and job roles may benefit from programming in these areas. KSA's were evaluate based upon engineers with a major focus on technology. KSA's for management (e.g., more economics and management techniques) and teaching skills were not considered.

The BOK Matrix includes a listing of knowledge and skills that a chemical engineer may possess. The knowledge and skills are arranged in three domain groups: Affective, Cognitive, and Psychomotor following a revised Bloom's Taxonomy format. Detailed definitions are provided for each knowledge and skill describing what knowledge or skill entails and how it is applied.

Ability appears in the matrixes as a number representing the ability level. Each of the three domains, Affective, Cognitive, and Psychomotor has a ranking definition suitable for the knowledge or skills within the domain. This document includes definitions for the ability ranking system. A higher ranking number indicates increased ability level within the domain.

BOK development began with the expectation that KSA requirements would vary depending on the industry where a chemical engineer works and the professional role that they hold. The team prepared a list of 17 industries and 25 professional roles and grouped similar items. Industry definitions describe the characteristics of the industry group and list specific examples. Role definitions indicate what the individual does and characteristics specific to that role. KSA matrixes were developed for the full industry and role list. Once the charts were complete, the team grouped industries and roles together, based on similar characteristics and ranking, and a summary set of matrixes was compiled. The summary charts include seven industry groups and 12 role groups. Note that the industry and roles lists are not all inclusive. The lists focused on the most common industries and roles based upon experience and surveys taken by AIChE. Additional categories may be added in the future.

In order to assess changing ability throughout a career, BOK matrixes were developed for four points in a career. The stages are defined in terms of competency, not years of experience. Most engineer's careers will transition through some subset of the stages. The stage ability level for each knowledge and skill depends upon the engineer's responsibilities and will change with time. The four stages denote:

- Stage 1 - having the minimal experience of a recent graduate or one changing careers. Has collection of knowledge and skills with ability to apply with supervision.
- Stage 2 - having minimal competence in relevant knowledge and skills. Can apply required knowledge and skills with some degree of independence. Level required for acquiring professional licensure.
- Stage 3 – having mature technical competence in relevant knowledge and skills with the addition of management skills. May primarily have supervisory and administrative duties.
- Stage 4 – having expert technical competence in specific knowledge and skills, usually with minimal supervisory and administrative duties. Others seek this engineer's help.

The result of the BOK team effort is a series of 16 KSA matrixes demonstrating the ability level for knowledge and skills at four career stages cross referenced with industry or job role. Eight of the matrixes include a detailed list of role and industry. Eight provide a summary viewpoint grouping industries and roles with similar needs. Information presented in these tables is suitable for use by stakeholder and audience to determine continuing education and personnel development needs.

1.2 How to use this document

This BOK records the history of development, establishes basic definitions for analysis criteria, and documents composite analysis from three BOK development teams. Like the subject, the BOK structure is complex and expansive. This document presents the BOK in a structured format that may not be apparently obvious. The following are tips to help the BOK user effectively navigate the information:

- Chapter 2 includes a statement of mission and purpose charge delivered to the workbook development team in 2012. The work of early BOK teams was hindered by diverse concerns and unfocused purpose. The Career and Education Operating Council (CEOC) charge provided the guidance necessary for the team focus effort on a singular objective.
- Chapter 3 includes a summary of BOK development history and a description of concerns that influenced the content of this document. It includes a description of the stakeholder and audience groups and an assessment of how they may use information contained in the BOK.
- Chapter 4 includes a character sketch of chemical engineers. It describes who they are, what they do and where they do it. The KSA impact of differences between mainstream and non-traditional work environments are explored. The perspective gap between academic and industrial concerns are discussed.
- Chapter 5 contains a discussion of the KSA foundation. It defines the parameters knowledge, skills and ability and how they change with experience. This chapter defines four career stages of the BOK.
- Chapter 6 provides a comprehensive description of the BOK structure and presentation. The domain structure for knowledge and skill list is discussed. Detail definitions for the ability level are provided. Summary BOK matrixes are presented by industry and role viewpoints, with trend observations drawn from the charts.
- Chapter 7 includes a summation of the BOK effort to date, and a suggestion of the path forward.
- Appendix 1 is a table defining abbreviations and acronyms.

- Appendix 2 includes knowledge, skill, industry and role definitions used as basis for the BOK categories.
- Appendix 3 includes demographic reference material used by the BOK team to develop KSA lists and assessment structure. It provides statistical background demonstrating the diversity of chemical engineering professionals.
- Appendix 4 includes a 2013 study evaluating the difference between the academic and industrial perspective on new graduate abilities.
- Appendix 5 Includes the detailed industry and role taxonomy charts that forms the basis of the roll up presented in Chapter 6.
- Appendix 6 includes biographical information for contributors demonstrating experiential diversity of the BOK development team.

2 Introduction

The Body of Knowledge (BOK) was developed under the direction of American Institute of Chemical Engineers (AIChE) Career and Education Operating Council (CEOC). Mission and Purpose statements below are direct charge from CEOC to the development task team.

2.1 Mission

To prepare a Body of Knowledge (BOK) that encompasses the range of skills, knowledge, and abilities required of a chemical engineer professional acquired through education and experience.

2.2 Purpose of the BOK

The BOK is geared to the providers of education (academia) and professional training. It will help AIChE effectively act as the bridge between industry, government and academia. The purpose for developing the BOK is to:

- Identify the skills and knowledge required of a chemical engineer working as an engineering professional;
- Guide the education efforts of AIChE, including ChemE on Demand, E-Learning, Webinars, and Instructor-led Courses to keep the chemical engineer professionals current in their fields.

Chemical engineering serves as a common platform for engineers working in the chemical, manufacturing process, pharmaceutical, microelectronics, oil and gas, and petrochemical industries, among many others. Chemical engineers are also increasingly working in non-traditional areas such as healthcare, business, and law. This BOK is aimed at preparing the chemical engineering workforce of the future, trained to move seamlessly into traditional as well as new evolving fields where they can best utilize their chemical engineering skills.

Universities establish their curriculum and ABET establishes accreditation procedures for meeting curriculum goals. The scope of the BOK is not aimed at “intruding” into these activities.

2.3 Complexities of Developing the BOK

Part of the complexity of developing the BOK is due to the many factors influencing this task. One factor is the broad range of interests of the audience. The audience includes stakeholder (investors) and interested users. Stakeholders have a vested interest in the outcome and expect a specific deliverable that supports a predefined purpose. AIChE is the principal stakeholder and defined BOK goals in the Mission and Purpose statements. The balance of the audience are interested users that may draw information from the BOK for purposes not considered during development. The users may include, but are not limited to:

- Chemical engineers seeking options and career development guidance;
- Entities that define academic accreditation criteria and deliver academic education programs;
- Entities that employ chemical engineers and through their technical needs define the KSA requirements for ChEs;
- Entities with interest related to professional licensure and competency evaluation.

The BOK development team was aware of differing interests and that stakeholder and user objectives may not align. The stakeholder goals were clear; however, potential user objectives were unknown and speculation often clouded the discussions.

A major problem in developing a BOK for chemical engineers is the diverse fields where they practice. Formal chemical engineering education provides a basic knowledge rooted in the physical sciences. This gives the chemical engineer the opportunity to work in a wide variety of areas including traditional manufacturing, leading-edge technologies and regulatory fields. Career paths may cause skill sets to broaden, focus or switch to managerial skills. The implications are difficult to capture with basic chemical engineering subjects. A broader view was required to address the breadth of skills and knowledge a chemical engineer can develop and apply in the course of a career.

What factors influenced the BOK development task?

- Differentiating between the stakeholder goals and broader audience interests;
- Identifying the core physical sciences knowledge that need to be developed through education and to what degree are they developed by academia;
- Identifying the application knowledge that is developed through experience and advanced training;
- Understanding how skill and knowledge requirements differ significantly by industries and the many potential career paths (roles) for chemical engineers;
- Assessing the breadth of potential industries where a chemical engineering degree can be applied and how industrial application draws on different knowledge and skills.

3 BOK Development History

The BOK has been developed over roughly a decade, facilitated by three working teams. The original effort to develop a BOK for Chemical Engineering was initiated in the mid 2000s by Jim Cobb PhD, PE. At the time Dr. Cobb was an active member of AIChE's Career and Education Operating Council (CEOC), the National Council for Examiners for Engineering and Surveying (NCEES) Chemical Exam Development committee, NCEES Fundamentals of Engineering Exam Development committee, and NCEES' Examinations for Professional Engineers (EPE) committee. Initial BOK development had no formal written charge from AIChE, but was influenced by three major considerations:

- An expectation that the BOK could help promote discussion between ABET, academics and industry as to what is considered core chemical engineering knowledge for recent graduates;
- A belief that the BOK may serve in helping to identify what AIChE considers essential knowledge for a practicing engineer;
- To address proposals from other professional engineering societies to require a MS degree, or additional course work beyond an ABET accredited BS degree, as a requirement for PE licensure.

Dr. Cobb advocated the value of preparing a BOK, and charged a small team to work under the direction of CEOC. Unfortunately, lack of formal focus and other priorities caused the team to lose direction. In 2009, Freeman Self, PE, was Chair of CEOC and assembled a second BOK team. This team focused the effort by identifying some of the greater benefits to AIChE and the profession. A white paper was prepared and presented to the Board of Directors (BOD) at the 2009 annual meeting. The White Paper established principles and outlined work required to develop a full BOK. The mission and purpose was formalized and in 2013, CEOC prepared a written charge and chartered the third development team.

Denise Chastain-Knight, PE, CFSE, then outgoing chair of the NCEES Chemical Exam Development Committee, was enlisted to lead this final BOK team. She assembled a group that included as many members of the earlier working teams as possible and recruited additional participation to assure balanced industry and academic perspectives. This BOK report incorporates content from the 2009 white paper and communicates documented findings of previous BOK teams. Many people contributed to the content of this report. Appendix 7 provides professional summaries of contributors. The collective biographical sketches demonstrate the efforts that were made to ensure that the BOK was developed with full consideration of chemical engineering demographic diversity and updated to consider core influences. The balance of the report documents the foundation for BOK development and presents a Body of Knowledge.

3.1 BOK Stakeholder

Development of this Body of Knowledge was continuously influenced by direct and indirect interests. The development team's first concern is to achieve the mission and provide information that addresses the purpose for the key stakeholder AIChE. The BOK is expected to provide guidance for the educational and meeting programming activities of AIChE in order to better serve the development needs of members.

3.2 BOK Audience

The BOK development team's primary objective is to satisfy the stakeholder; however, the concerns of influencers, users and broader audience indirectly guide the scope of this document. The BOK team was mindful to provide as much value to these other entities as possible while achieving the goals set for the by AIChE. The broader audience includes:

- Academic accreditation: ABET is concerned with establishment of minimal requirements for chemical engineering education and preparing for future needs. Education topical content need is constantly increasing as demands are made to reduce educational costs. BOK content in assessment of KSAs at the new graduate level (Stage 1) is relative to other career stages.
- Engineering licensure: National Council of Examiners for Engineering and Surveying (NCEES) is concerned with establishment of licensure criteria to assure the protection of public health, safety and welfare. Licensure exam specifications are formulated based on the expected knowledge

performance level of a minimally competent engineer (Stage 2). This BOK drew heavily on Chemical PE exam specification knowledge descriptions to set categories in the taxonomy charts.

- National Society of Engineers (NSPE) is a voice and advocate of engineering licensure. NSPE recently published a general Engineering Body of Knowledge intended to represent concerns common to all engineering disciplines. Built in parallel with the NSPE BOK, this BOK include general concerns and provides additional focus on chemical engineering knowledge requirements.
- Others: There are numerous entities and interests dedicated to professional development, continuing education, industrial development and standards setting. The BOK team is highly sensitive to these many concerns, and labored to provide some differentiating perspectives for the Chemical Engineering population.

4 Chemical Engineering Demographics

Chemical engineering is a particularly diverse discipline because it combines the study and application of chemical and biological processes with physical sciences and creative thought. It may well be the broadest in scope of the engineering fields. The BOK team began the development journey by understanding what makes chemical engineers unique. This chapter provides a character sketch of chemical engineers, and describes key differentiators between them and other engineering disciplines, and how that applies to KSA analysis. Appendix 3 includes demographic information supporting the conclusions drawn in this chapter.

4.1 Who Chemical Engineers Are

Chemical engineering is a branch of engineering that applies the natural sciences (chemistry and physics) and life sciences (biology, microbiology and biochemistry) together with mathematics and economics to produce, transform, transport, and properly use chemicals, materials and energy. It essentially deals with the engineering of chemicals, energy and the processes that create and/or convert them. Chemical engineering influences numerous areas of technology. In broad terms, chemical engineers are responsible for the conception and design of processes for the purpose of production, transformation and transportation of chemicals. Conception and design begins with laboratory experiments, often followed by pilot-plant operations and then full-scale production. Modern chemical engineers are concerned with processes that convert raw materials or chemicals into more useful or valuable forms. In addition, they are concerned with pioneering valuable materials and related techniques, which are often essential to related fields such as nanotechnology and bioengineering.

Like all engineers, chemical engineers use mathematics, physics and economics to solve technical problems. The difference between chemical engineering and other disciplines is that it applies knowledge of chemistry and biology in addition to other engineering principles to solve complex problems. Chemical engineers sometimes are called 'universal engineers' because their scientific and technical mastery is so broad.

To carry out these activities, the chemical engineer requires a complete and quantitative understanding of both the engineering and scientific principles underlying these technological processes. Basic academic curriculums of chemical engineering departments must include the study of applied mathematics, material and energy balances, thermodynamics, fluid mechanics, energy and mass transfer, separation technologies, chemical reaction kinetics, reactor design and process design in order to provide a sound foundation.

The BOK framework attempts to capture the knowledge, skills and abilities of chemical engineers regardless of where or how they apply KSAs. It also recognizes that KSA development will vary with industry and job role.

4.2 Where Chemical Engineers Work

The large number of industries which depend on the synthesis and processing of chemicals and materials place the chemical engineer in great demand. Chemical engineers work in industries such as basic commodity chemical manufacturing, pharmaceuticals, healthcare, design and construction, research, pulp and paper, polymers, resins and synthetic fibers, petroleum and petrochemicals, food processing, specialty chemicals, microelectronics, electronic and advanced materials, business services, biotechnology, fertilizers, consumer products, industrial gases, metals, nuclear energy, catalysts, automotive, aerospace, nanotechnology, and ceramics and glass industries.

In addition, the expertise of chemical engineers is also applied in the areas of law, education, publishing, finance, consulting and government regulation such as process safety management (PSM), Clean Air Act (EPA), worker safety (OSHA) to mention a few. Chemical engineers are frequent participants of standards development committees, code development bodies and accident investigation teams.

The unique set of knowledge and skills gained by the chemical engineer puts them in a position to contribute in any scientific or engineering field; however, the bulk of chemical engineering work falls into one of two industrial groups considered 'traditional' chemical engineering:

- Design, manufacture and operations of processes such as in the commodity chemicals, petroleum production and specialty chemicals sector.
- Development of new and adapted substances and materials such as the engineering design/consulting, research and development and pharmaceutical sectors.

The knowledge, skills and abilities of a chemical engineer are applicable in many non-traditional industries and these applications must be explored in the BOK framework to produce a comprehensive KSA analysis.

4.3 What Chemical Engineers Do

Chemical engineers rely on their knowledge of mathematics and science, particularly chemistry, to safely and economically solve technical challenges they encounter. Some chemical engineers make designs and invent new processes. Some construct instruments and build facilities. Others plan and operate manufacturing facilities. Chemical engineers have helped develop atomic science, polymers, paper dyes, drugs, plastics, fertilizers, foods, petrochemicals… pretty much everything. They devise ways to make products from raw materials and ways to convert one material into another useful form. Chemical engineers make processes more cost-effective, more environmentally friendly and/or more efficient.

Chemical engineers design processes and products to solve problems and to supply vital materials for our technology-based society. Their work ranges from making clean energy, to producing more-affordable medicine, to streamlining semiconductor manufacturing – and even ways to improve food production and processing.

They also construct the synthetic fibers that make clothes more comfortable and water resistant; develop methods to mass-produce drugs, making them more affordable; and they create safer, more efficient methods of refining petroleum products, making energy and chemical sources more productive and cost-effective. Chemical engineers also develop solutions to environmental problems, such as pollution control and remediation.

Chemical engineers are found in traditional manufacturing industries and production plants. They are also a significant presence in research laboratories working at the molecular level to create new synthetic materials. Molecular level work also involves life sciences to look for ways to prevent disease and to improve diagnostics and therapeutic methods such as improved drug delivery.

The majority of chemical engineers assume similar roles regardless of the industry where they work. Some of the roles where chemical engineers work include:

- Process Design Engineer
- Technical Service
- Process Controls Engineer
- Project Engineer/Manager
- Industrial Research Engineer
- Educator
- Environmental Engineer
- Technical Staff Manager
- Production Engineer
- Process Safety Engineer
- Consultant
- Regulator

4.4 Persons Not Directly Performing as 'Traditional' Chemical Engineers

Historically more than 70% of chemical engineering graduates get jobs immediately on graduation, while the rest either obtain jobs in other sectors or are not certain of their plans. (See surveys Appendix 3.) Many are hired into the traditional industries like chemicals, petrochemicals, plastics and rubber. Others work in less traditional industries such as electronics, nuclear energy, and business services. The reason chemical engineers can work outside traditional chemical engineering fields is because chemical engineering education emphasizes conceptual instruction, modeling skills, analytical situation assessment and creative problem solving skills.

Non-traditional application of chemical engineering skills is becoming increasingly more important to AIChE as the Institute addresses complex new global challenges, with broad social and ethical implications. Examples of the issues include worker and community safety, production efficiency and waste management, inconsistencies in global standards and practices, and sustainability. Chemical engineers possess the right type of technical skills to work on complex global problems and are well prepared to participate in developing solutions.

The 2013 AIChE salary survey includes respondent industry demographics (Appendix 3, Table A.3.2). 52% of chemical engineers worked in 20% of the industry categories. 89% of the industry categories employ less than 5% of the population. Conversely, 95% of ChEs are represented in 11% of industries. About 60% of the respondents work in traditional chemical process industries. Because chemical engineers are scattered amongst many different industries/employers, capturing the skills they use and how they apply their expertise is a challenge. As a result, the ChEs performing in a non-traditional industry group is small and may be poorly represented in this BOK. The basic fundamental undergraduate chemical engineering education provides numerous valuable skills that can be useful to almost any field of endeavor. This BOK focuses most heavily on the knowledge, skills and attribute requirements for traditional chemical engineering fields and may not address the concerns of every industry where ChEs work.

4.5 Differences in Academic and Industrial Perspective

Academia and industry should, and do hold different perspectives. Academia is primarily interested in education and developing “leading edge” technologies through sponsored research. Industry conducts research and training, but is much more focused on utilizing technologies in practical application for more immediate commercial benefit. This issue is also termed “theoretical versus practical”. Often these differences are driven by academia’s need for funding research and by industry’s need to compete in the corporate world.

State and private funding has substantially declined over the years for our educational institutions and has forced colleges and universities to seek the needed funding from research grants and programs. This shift has resulted in some university programs placing a higher emphasis on funding and conducting R&D than educating undergraduate. In fact, tenure for new faculty is often tied to the amount of research dollars and university prestige that these professors can procure. Certainly, curriculum must continue to provide the technical skills that new graduates require in the workplace and as well as grow curriculum to include new technologies. Financial pressures drive educational institutions to reduce costs. Academia must continue to address education fundamentals while still allowing for the introduction of new technology elements. One challenge of the BOK was to frame the taxonomy structure so that both perspectives are addressed.

For the most part, chemical engineering faculty of the past had industrial experience either by employment in the chemical process industries or as consultants to industry. Consulting plays a lesser role for today’s faculty. A recent survey of chemical engineering faculty teaching process design revealed that 22% of these instructors had no industrial experience. This percentage is expected to substantially increase as more senior faculty approach retirement age.

In a survey conducted by the late Dr. John Chen of 93 industry representatives, the three top rated skills by these industries were unit operations, reaction engineering and analysis and modeling. All of these skills received a 4.0 rating or above on a scale of 1 to 5. By contrast, academics rated these skills at 3 or below. This is but one example from the study that suggests a lack of alignment between research in core chemical processing areas and the quality of instruction in those essential fundamentals. Causes for this shift include difficulty in obtaining research funding for projects relating to the skills and the desire to attract students. A copy of the April 2014 Chemical Engineering Progress (CEP) article summarizing results of Dr. Chen’s survey can be found in Appendix 4. AIChE will continue to explore and define this gap.

5 Career Foundation and Growth

In order to develop the BOK, the team first had to settle on a discussion framework. This chapter provides an overview of the knowledge, skills and abilities (KSA) a chemical engineer may develop throughout their career. Detailed definitions for each KSA used in the BOK matrices are given in Appendix 2. The team also recognized that KSAs change with time in a career and career path. Technical knowledge may become focused as one becomes more expert, or diminish as one acquires management skills. This section also describes four milestone experience levels (stages) used as a basis for BOK development.

5.1 Knowledge and Skills

To be productive in society chemical engineers require a broad range of knowledge, skills and abilities. Classifications of knowledge include Affective, Cognitive and Psychomotor domains. A detailed knowledge list organized by domain is given in Appendix 2 with detailed definitions for each knowledge and skill. Arrangement within the taxonomy structure is described in section 6.1.

It is important to remember that the various knowledge sets are itemized in the BOK to make the BOK more useful. In the real world multiple types of knowledge are used together. An example would be members of a team working together and exchanging ideas on a technical project. Another would be an engineer addressing the sustainability questions on the design of a new plant. Knowledge is described as follows:

- Fundamental knowledge provides the foundation for all of the other types of knowledge. Nontechnical fundamentals include communications, humanities and social sciences. They also include other important non-engineering material such as accounting, foreign languages, history, cultural training, psychology, management theory and law. Technical fundamentals provide the underlying tools to the sciences and include mathematics, statistics, physics, chemistry, and biology.
- Technical knowledge is the basis of the chemical engineering sciences which productively applies physics, chemistry, and biology to the real world. Fluid flow, heat transfer and mass transfer are obvious types of knowledge and are addressed specifically within the matrix. The matrix also includes cross functional knowledge sets which combine several technical and/or fundamental knowledge areas such as sustainability and safety.
- Professional knowledge facilitates the application of engineering knowledge. These include teamwork, performing experiments, project management, leadership, and problem solving.
- Human knowledge includes the skills and experiences that influence the effectiveness of delivery to other knowledge groups. These include speaking, listening, interpreting body language, adjusting communication style, identifying optimum delivery media and cultural factors

5.2 Ability

Ability is a word used to describe execution competency. Knowledge and skill requirements evolve with career stage. Competency may increase, or decrease by role, industry or stage. The ability requirements for an engineer are heavily dependent on the role in which the engineer works. Chapter 6.2 provides a detailed discussion of the ability levels used within this BOK. This section of the BOK provides more detail on ability level definition. It is not all inclusive, but rather given so that one can understand what should be expected of a person performing at each level for a given knowledge. A major challenge to BOK development was coping with the infinite possibilities in describing knowledge, skill, ability, tools, techniques, role, etc. The following are examples of how knowledge and skills can be applied at associated ability levels (ability levels are defined in Table 1, Section 6.2.4).

5.2.1 Written Communications

Writing skills are critical for a person to communicate his/her opinions, findings and compilation of facts to others using clear, concise language. Regardless of the significance of accomplishment, it is of little value if those accomplishments cannot be clearly documented and understood by others. All engineers should have a good grasp of writing skills exiting college (practicing). Upon graduation, they should be familiar with technical report writing and have the skill to formulate business letters, reports, proposals and papers with guidance of an experienced person. At later stages, a person can write a technical communication, requiring only minimal help from colleagues (adapting). The expert operating in a technical writer role is experienced at writing technical documents and coworkers seek his advice in writing them.

5.2.2 Oral Communications

Public speaking within and outside the organization is a critical skill required to both inform others of opinions and findings and to ask for support of new ideas.   A good command of language is expected (observing). A person at Stage 1 should have basic skills to make an oral presentation, but may require help in organization and presentation style from others (Imitating). Often rehearsals are needed. At a practicing level, the engineer can create, organize and give a presentation with little help from coworkers. An adapting person is an accomplished speaker whose advice is sought after by coworkers.

5.2.3 Cultural Savvy

The business world is rapidly becoming more culturally blended and this dynamic is accelerating rapidly in the engineering world. Whether working in a technical or managerial role, individuals working across cultural lines must develop cultural savvy. Co-workers may speak different primary languages. Miscommunication opportunities are common when working in secondary or tertiary languages. Accents, pronunciation, syntax and body language influence communication and working relationships. Skills and knowledge across the Affective and Psychometric Domain are utilized. Regardless of stage, an engineer with little cross culture exposure will operate at a responding and imitating level, whereas an engineer responsible for international sales would operate at an internalizing and adaptive level.

5.2.4 Mathematics

Mathematics is a basic cognitive knowledge. It quantifies theories, as well as physical processes and objects so that they can be replicated. A knowledge of mathematics includes algebra, trigonometry, differential and integral calculus and ordinary differential equations. When a person is familiar with the knowledge and can discuss complex mathematics with others, they are operating at the Remembering level. A person who can do complex mathematical problems but with the assistance of others (e.g. setting up required equations) is demonstrating understanding. A person at Stage 1 can readily apply mathematics through ordinary differential equations (ODE); however, as a person moves into a Stage 3 management role, the required math skills may decline. A person at Stage 4 may be an expert in applied mathematics, and operates at an evaluating or creating level, with others seeking their advice.

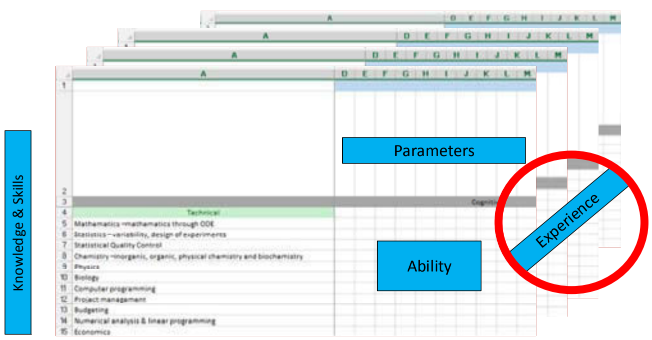
5.2.5 Chemical Engineering Technical Skill –Stoichiometry with and without reactions

Making a material balance on nonreactive and reactive systems is a critical component of chemical engineering. At Stage 1, a person understands the importance of stoichiometry and the basic concepts (understanding). A Stage 1 person must be able to perform simple material balances around separations and reactor systems (applying). Complex systems involving bypass and recycle can be done, but may require assistance and results being verified by an experienced person. Depending on role, a Stage 2 and 3 engineer can perform complex material balances with little or no assistance from an experienced coworker. A stage 2 or 3 person working in sales or management may remain at the Applying competence level or drop to an Understanding level due to lack of practice. Note that this knowledge reflects the ability of a person to perform a material balance and is not indicative of the person’s understanding of mechanisms involved in the process. However, it is likely that a person at Stage 4 in another technical knowledge will be a Stage 4 in stoichiometry too.

5.3 Career Stage Definitions

Knowledge, Skills and Ability requirements are a strong function of the career stage of the chemical engineer. A student winding their way through undergraduate school or heading to graduate school, and a recently hired employee struggling to learn company specific information and how to work in an industrial environment, generally share Stage 1 level KSAs. An experienced engineer striving to maintain expertise, an employee transitioning from engineering into management, a professional transitioning into chemical engineering, and a graduate or professional entering a non-chemical engineering field all share one concern: to develop skills appropriate to their future role.

Requirements for a chemical engineering degree is well documented through curriculum. KSA requirements for post-graduate career stages is less defined. One general conclusion is that some chemical engineers do not start their careers in chemical engineering, and many others move from chemical engineering technical fields to non-chemical engineering and non-technical fields. This variability in career path challenged the BOK team to define some very specific stages in a typical ChE's career.



The BOK matrix classifies knowledge and skills at four career stages. Each stage denotes proficiency in terms of ability. Proficiency is measured by the responsibility involved in completing a task, not in terms of years of experience. Knowledge, skills and abilities will increase or decrease over a person's career. The Stages are expressed numerically 1, 2, 3 and 4, but it is not expected that an individual's career will progress in that sequence, or even experience all four stages. Most ChEs skills will reflect abilities of more than one stage, and will not perfectly align with every KSA for a single stage. For example, a person at Stage 4 in one technical knowledge or skill should not be expected to be at that level for all knowledge and skills. Stage definitions for BOK framework are described as follows:

5.3.1 Stage 1 (Chemical engineer with Minimal Experience)

The engineer with minimal experience should be proficient at Remembering, Understanding and Applying knowledge. A person at this level would be making simple, straightforward calculations under the direction of an experienced engineer. People at this level are generally recent engineering graduates or making a major career change. They require help in applying the knowledge to new areas. They also may need help in defining the required calculations and in making valid assumptions. They are capable of performing relatively complex calculations when procedures are clearly defined.

5.3.2 Stage 2 (Chemical Engineer with Some Experience)

The engineer with some experience should be developing proficiency in Application, Analysis, Synthesis and Evaluation. People at this level make simple and complex calculations. They have the experience to properly analyze major and minor components, to make the valid assumptions and proper decisions with little or no assistance from others on simple systems, but may require more help on complex problems. They provide guidance and training to Stage 1 personnel.

5.3.3 Stage 3 (Chemical Engineer with Significant Experience)

A person at this level is proficient in Analyzing Evaluating and Creating. They perform complex calculations and solve complex problems. They supervise and check the work of less experienced engineers. These people include seasoned faculty, lead engineers and engineering supervisors.

5.3.4 Stage 4 (Expert Chemical Engineer)

These people are the experts that others come to for help with complex problems. People at this level have such in-depth knowledge and experience that they require no assistance and frequently assist others. They are Policy Setters, Technical Stewards and Creators. People at Stage 4 in technical knowledge are senior scientists and highly regarded faculty. Often these people are recognized outside of their organization. They usually have the most vividly clear understanding of basic concepts underlying the knowledge.

5.4 Career Path Potential

Given the broad application of chemical engineering, there are numerous career path potentials for the practicing chemical engineer. The BOK is crafted to analyze typical stages of the chemical engineer's career, but an individual's career path can take many different directions so that timelines at stages will vary. Some engineers may progress along the stages with increasing experience, enhancing ability, but often with a narrow and specialized focus. Other engineers may take different paths, such as in management, broadening skillset and possibly reducing technical focus. This decision is often times established at about Stages 2 or 3, based upon personal preference, strengths, weaknesses and opportunities. The BOK should be used by Chemical Engineers as they move through their career as a tool to identify opportunity and need for KSA growth as they chart their individual path.

6 BOK Observations

The BOK matrix attempts to show the knowledge and skills that are required at each stage of the career of a chemical engineer, from undergraduate through professional life. This chapter establishes the presentation framework, provides a detailed description of the matrix elements and presents findings.

6.1 BOK Structure

The committee approach was to incorporate a revised Bloom's taxonomy into a Knowledge, Skills and Abilities (KSA) matrix evaluated at four competency stages. Requirements may vary by two grouping categories, role and industry, so a group of charts were prepared for both viewpoints. KSA as used in the BOK are summarized as follows:

- Knowledge encompasses an organized body of information. It can be factual and/or procedural.
- Skill is the manipulation of concepts, knowledge and materials.
- Ability is the competence to perform the skill or knowledge.

The approach here involves a matrix with knowledge and skills listed in the rows. Column headings list situation parameters representing where chemical engineers work (industry) and what they do (job role). Rankings in the intersection grid denote a person's ability to use the knowledge or skill within their industry or professional role. Figure 1 demonstrates relationships of the detailed data charts.

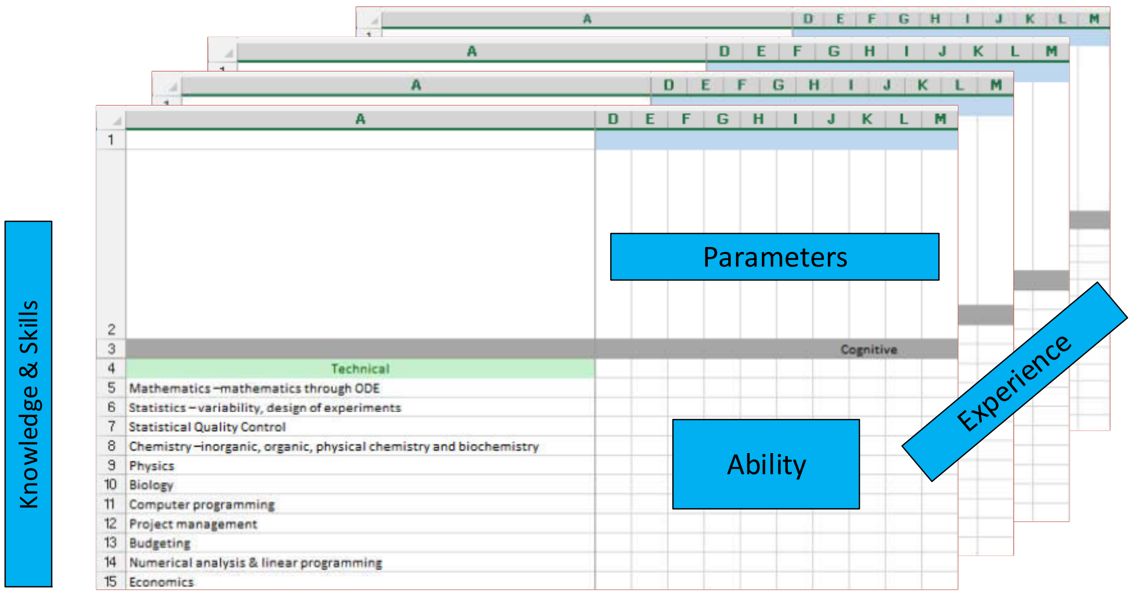
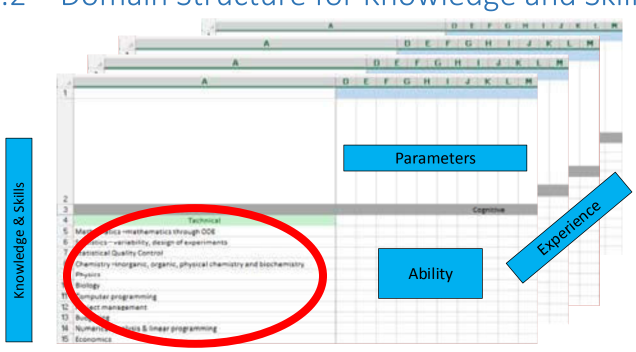


Figure 1. KSA Matrix Structure

The group of four charts for each parameter set provide KSA analysis at four experience point, or stages, in the chemical engineer's career. Ability may grow as an engineer's experience moves from one stage to another, or it may decrease through lack of application. New skills may develop or additional knowledge gained that were not present at earlier stages. The stages represent a general career progression, but not necessarily a linear path. Career stage definitions are provided in Chapter 5 of this document.

Charts were populated by team members based on their expectation of ability level at the career stage. Individual rankings were compiled, discussed, and adjusted to reflect a group consensus. Data were then analyzed and smoothed to reflect aptitude changes over a career. Definitions for knowledge, skill, ability level, Industry and role are given in Appendix 2. Appendix 5 provides the detailed charts prepared by the team. Industry and role parameters were grouped where similar, and analyzed for generalities. Overall observations and summary analysis is presented here.

6.2 Domain Structure for Knowledge and Skills



There are various ways to "measure" the ability one has in using a given knowledge or skill. One method is to use Bloom's taxonomy. The taxonomy groups knowledge and skills into three domains; affective (emotional), cognitive (mental) and psychomotor (physical). Within each domain, knowledge and skills may be grouped into subdomains with similar characteristics. All KSA charts include the same outline for knowledge and skills with domain and subdomain groups indicated by colored headers. The Chemical Engineering BOK was developed using a Revised Bloom's Taxonomy given in Table 1. Skills and knowledge are grouped into three domains:

6.2.1 Affective Domain

The affective domain includes the manner in which we deal with things emotionally, such as feelings, values, appreciation, enthusiasms, motivations, and attitudes. This domain includes five ability levels.

6.2.2 Cognitive Domain

The cognitive domain involves knowledge and the development of intellectual skills. This includes the recall or recognition of specific facts, procedural patterns, and concepts that serve in the development of intellectual abilities and skills. There are three subgroupings for this domain:

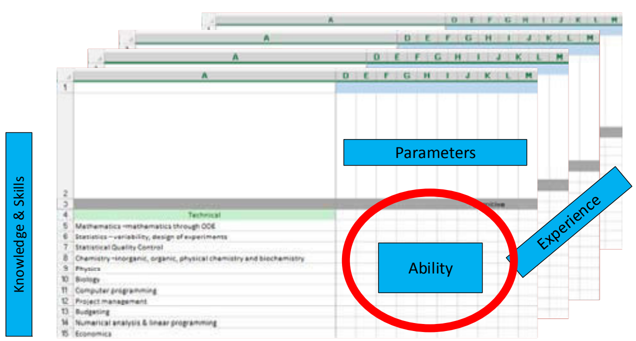
- Chemical Engineering Technical Skills (24 categories);
- Cross Functional Skills (6 categories);
- Basic Technical Knowledge (11 categories).

6.2.3 Psychomotor Domain

The psychomotor domain includes physical movement, coordination, use of the motor-skill areas, and psychology behind application of these skills. Development of these skills requires practice and is measured in terms of speed, precision, distance, procedures, or techniques in execution. There are three subgroupings for this domain:

- Human Skills (8 categories);
- Professional Skills (6 categories);
- Psychomotor Skills (4 categories).

6.2.4 Domain Definition



Within the Revised Bloom's Taxonomy, different metrics are used to measure level of advancement (ability) of a skill or knowledge with the three domains. Table 1 provides levels for each domain along with a brief description, examples, and Keywords of each level. Using appropriate active verbs such as *describe*, *apply*, and *evaluate*, each level in Bloom's taxonomy can be tested for various knowledge, skills and abilities.

Table 1. Levels of Revised Bloom's Taxonomy

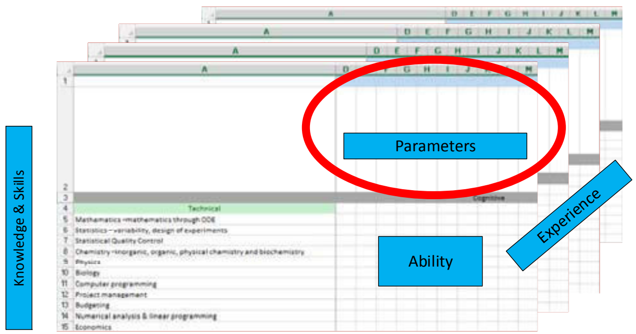
Source: http://www.nwlink.com/~donclark/hrd/bloom.html

Category	Example	Keywords (verbs)
Affective Domain		
Receiving Phenomena: Awareness, willingness to hear, selected attention.	**Examples**: Listen to others with respect. Listen for and remember the name of newly introduced people.	**Keywords**: asks, chooses, describes, follows, gives, holds, identifies, locates, names, points to, selects, sits, erects, replies, uses.
Responding to Phenomena: Active participation on the part of the learners. Attends and reacts to a particular phenomenon. Learning outcomes may emphasize compliance in responding, willingness to respond, or satisfaction in responding (motivation).	**Examples**: Participates in class discussions. Gives a presentation. Questions new ideas, concepts, models, etc. in order to fully understand them. Knows the safety rules and practices them.	**Keywords**: answers, assists, aids, complies, conforms, discusses, greets, helps, labels, performs, practices, presents, reads, recites, reports, selects, tells, writes.
Valuing: The worth or value a person attaches to a particular object, phenomenon, or behavior. This ranges from simple acceptance to the more complex state of commitment. Valuing is based on the internalization of a set of specified values, while clues to these values are expressed in the learner's overt behavior and are often identifiable.	**Examples**: Demonstrates belief in the democratic process. Is sensitive towards individual and cultural differences (value diversity). Shows the ability to solve problems. Proposes a plan to social improvement and follows through with commitment. Informs management on matters that one feels strongly about.	**Keywords**: completes, demonstrates, differentiates, explains, follows, forms, initiates, invites, joins, justifies, proposes, reads, reports, selects, shares, studies, works.
Organization: Organizes values into priorities by contrasting different values, resolving conflicts between them, and creating a unique value system. The emphasis is on comparing, relating, and synthesizing values.	**Examples**: Recognizes the need for balance between freedom and responsible behavior. Accepts responsibility for one's behavior. Explains the role of systematic planning in solving problems. Accepts professional ethical standards. Creates a life plan in harmony with abilities, interests, and beliefs. Prioritizes time effectively to meet the needs of the organization, family, and self.	**Keywords**: adheres, alters, arranges, combines, compares, completes, defends, explains, formulates, generalizes, identifies, integrates, modifies, orders, organizes, prepares, relates, synthesizes.
Internalizing values: Has a value system that controls their behavior. The behavior is	**Examples**: Shows self-reliance when working independently. Cooperates in group activities	**Keywords**: acts, discriminates, displays, influences, listens, modifies, performs, practices,

pervasive, consistent, predictable, and most importantly, characteristic of the learner. Instructional objectives are concerned with the student's general patterns of adjustment (personal, social, emotional).	(displays teamwork). Uses an objective approach in problem solving. Displays a professional commitment to ethical practice on a daily basis. Revises judgments and changes behavior in light of new evidence. Values people for what they are, not how they look.	proposes, qualifies, questions, revises, serves, solves, verifies.
Cognitive Domain		
Remembering: Recall previous learned information.	**Examples**: Recite a policy. Quote prices from memory to a customer. Knows the safety rules.	**Keywords**: defines, describes, identifies, knows, labels, lists, matches, names, outlines, recalls, recognizes, reproduces, selects, states.
Understanding: Comprehending the meaning, translation, interpolation, and interpretation of instructions and problems. State a problem in one's own words.	**Examples**: Rewrites the principles of test writing. Explain in one's own words the steps for performing a complex task. Translates an equation into a computer spreadsheet.	**Keywords**: comprehends, converts, defends, distinguishes, estimates, explains, extends, generalizes, gives an example, infers, interprets, paraphrases, predicts, rewrites, summarizes, translates.
Applying: Use a concept in a new situation or unprompted use of an abstraction. Applies what was learned in the classroom into novel situations in the work place.	**Examples**: Use a manual to calculate an employee's vacation time. Apply laws of statistics to evaluate the reliability of a written test.	**Keywords**: applies, changes, computes, constructs, demonstrates, discovers, manipulates, modifies, operates, predicts, prepares, produces, relates, shows, solves, uses.
Analyzing: Separates material or concepts into component parts so that its organizational structure may be understood. Distinguishes between facts and inferences.	**Examples**: Troubleshoot a piece of equipment by using logical deduction. Recognize logical fallacies in reasoning. Gathers information from a department and selects the required tasks for training.	**Keywords**: analyzes, breaks down, compares, contrasts, diagrams, deconstructs, differentiates, discriminates, distinguishes, identifies, illustrates, infers, outlines, relates, selects, separates.
Evaluating: Make judgments about the value of ideas or materials.	**Examples**: Select the most effective solution. Hire the most qualified candidate. Explain and justify a new budget.	**Keywords**: appraises, compares, concludes, contrasts, criticizes, critiques, defends, describes, discriminates, evaluates, explains, interprets, justifies, relates, summarizes, supports.
Creating: Builds a structure or pattern from diverse elements.	**Examples**: Write a company operations or process manual.	**Keywords**: categorizes, combines, compiles, composes,

Put parts together to form a whole, with emphasis on creating a new meaning or structure.	Design a machine to perform a specific task. Integrates training from several sources to solve a problem. Revises and process to improve the outcome.	creates, devises, designs, explains, generates, modifies, organizes, plans, rearranges, reconstructs, relates, reorganizes, revises, rewrites, summarizes, tells, writes.
Psychomotor Domain		
Observing: The ability to use sensory cues to guide motor activity. This ranges from sensory stimulation, through cue selection, to translation.	**Examples**: Detects non-verbal communication cues. Estimate where a ball will land after it is thrown and then moving to the correct location to catch the ball. Adjusts heat of stove to correct temperature by smell and taste of food. Adjusts the height of the forks on a forklift by comparing where the forks are in relation to the pallet.	**Keywords**: chooses, describes, detects, differentiates, distinguishes, identifies, isolates, relates, selects.
Imitation: Observing and patterning behavior after someone else. Performance may be of low quality.	**Examples:** Copying a work of art. Performing a skill while observing a demonstrator.	**Keywords:** copy, follow, mimic, repeat, replicate, reproduce, trace.
Practicing: This is the intermediate stage in learning a complex skill. Learned responses have become habitual and the movements can be performed with some confidence and proficiency.	**Examples**: Use a personal computer. Repair a leaking faucet. Drive a car.	**Keywords**: assembles, calibrates, constructs, dismantles, displays, fastens, fixes, grinds, heats, manipulates, measures, mends, mixes, organizes, sketches.
Adaptation: Skills are well developed and the individual can modify movement patterns to fit special requirements.	**Examples**: Responds effectively to unexpected experiences. Modifies instruction to meet the needs of the learners. Perform a task with a machine that it was not originally intended to do (machine is not damaged and there is no danger in performing the new task).	**Keywords**: adapts, alters, changes, rearranges, reorganizes, revises, varies.

6.3 Summary BOK Findings



The BOK team's initial opinion was that chemical engineers would possess drastically different skills and knowledge depending on the industry where they work, or the role they perform. As the team worked, they determined that the role a ChE performs is more a function of the role objectives than of industry where they work. For example, a Project Manager must possess organizational, planning and management skills regardless of the industry where they work. However, a high tech industry may require very different skillset from chemical engineers as does a chemical processing industry. As the taxonomy charts given in Appendix 5 were developed, the team decided to develop two sets of charts grouping findings into industry groups or role types. A separate parameter list was developed for industry and role charts. This section provides summary tables by industry and role group, presentation of the industry and role chart sets, and an analysis of how ability changes over time.

6.3.1 Industry View

The Industry outcome table contains seven groupings of industry in columns across the top. The knowledge and skills are grouped as rows in three domains (cognitive, affective and psychometric). The industry groups are as follows:

- Chemical Process Industries consisting of mostly mature processes including:
    - Petrochemicals
    - Oil and gas production and processing
    - Liquefied natural gas (LNG)
    - Industrial gases
    - Polymers
    - Resins
    - Synthetics
    - Pulp and paper
    - Specialty chemicals and products
    - Synthetic fuels and alternative energy
- Food, Drugs and Consumer Products consists of industries with both mature processes and some high tech or ultra-pure technologies. The group includes:
    - Food
    - Consumer products
    - Pharmaceuticals
    - Biotechnology
- High Tech and Emerging Markets includes industries that use chemical engineering technology and highly specialized technology geared to specific industry requirements.

- Materials Science includes industries that use a lot of traditional unit operations and highly mechanical processes with high temperatures and pressures. Typical industries in this group include:
    - Catalysts
    - Ceramics and glass
    - Metals
    - Nanotechnology
- Regulatory includes those organizations/agencies that establish and implement standards, and regulations and monitor and manage compliance.
- Education is exclusively academia.
- Nuclear Energy includes both commercial power generation as well as test facilities and other specialized uses. Generally these industries are highly regulated.

Rankings for the Industry groupings are given in the following tables.

6.3.1.1 Stage 1 Industry	Chemical Process Industries	Academia	Food, Drugs & Consumer Products	High Tech, Emerging Markets	Materials Science	Nuclear Energy	Regulatory
Affective 1. Receiving 2. Responding 3. Valuing 4. Organizing 5. Internalizing							
Beliefs and Values							
Commitment to lifelong learning	**1**	**1**	**1**	**1**	**1**	**1**	**1**
Concern for public welfare	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Ethics	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Respect for others	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Cognitive 1. Remembering 2. Understanding 3. Applying 4. Analyzing 5. Evaluating 6. Creating							
ChE Technical							
Energy balances involving 1st and 2nd law	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Equilibria, chemical and phase	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Fluid flow, pump & compressor sizing & selection, packed beds	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Fluid flow, single-phase flow, two-phase flow (pipes, valves, orifices)	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Heat balances with and without reactions	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Heat transfer equipment design and analysis	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Heat transfer, multiple modes, phase change	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Kinetics, conversion in various reactor types, chemical equilibria	**3**	**3**	**3**	**3**	**3**	**3**	**3**

6.3.1.1 Stage 1 Industry	Chemical Process Industries	Academia	Food, Drugs & Consumer Products	High Tech, Emerging Markets	Materials Science	Nuclear Energy	Regulatory
Kinetics, reactor analysis	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Kinetics, reactor design, heterogeneous catalysis	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Mass transfer, equipment design and analysis	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Mass transfer, single- and two-phase processes	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Materials science	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Plant design, economics	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Plant design, flow configuration, optimization	**2**	**2**	**2**	**2**	**2**	**2**	**2**
Plant design, instrumentation	**1**	**1**	**1**	**1**	**1**	**1**	**1**
Plant design, process control	**2**	**2**	**2**	**2**	**2**	**2**	**2**
Plant operations, optimization	**1**	**1**	**1**	**1**	**1**	**1**	**1**
Plant operations, startup, shutdown	**1**	**1**	**1**	**1**	**1**	**1**	**1**
Plant scale-up	**1**	**1**	**1**	**1**	**1**	**1**	**1**
Separations equipment selection & analysis	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Separations process design	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Stoichiometry with and without reactions	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Stoichiometry, complex systems with recycle, bypass	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Cross Functional							
Energy – systems analysis, efficiency	**1**	**1**	**1**	**1**	**1**	**1**	**1**
Environmental assessment, regulations	**1**	**1**	**1**	**1**	**1**	**1**	**1**
Process simulators, operation, steady state simulation, dynamic simulation	**1**	**1**	**1**	**1**	**1**	**1**	**1**
Process simulators, strengths and weaknesses	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**
Safety, analyses, modeling, procedural policies, regulations	**1**	**1**	**1**	**1**	**1**	**1**	**1**
Sustainability analyses	**1**	**1**	**1**	**1**	**1**	**1**	**1**

6.3.1.1 Stage 1 Industry	Chemical Process Industries	Academia	Food, Drugs & Consumer Products	High Tech, Emerging Markets	Materials Science	Nuclear Energy	Regulatory
Technical							
Biology	**2**	**3**	**2**	**2**	**2**	**2**	**2**
Budgeting	**1**	**1**	**1**	**1**	**1**	**1**	**1**
Chemistry –inorganic, organic, physical chemistry and biochemistry	**2**	**3**	**2**	**2**	**2**	**2**	**2**
Computer programming	**2**	**2**	**2**	**2**	**2**	**2**	**2**
Economics	**1**	**1**	**1**	**1**	**1**	**1**	**1**
Mathematics –mathematics through ODE	**2**	**3**	**2**	**2**	**2**	**2**	**2**
Numerical analysis & linear programming	**1**	**1**	**1**	**1**	**1**	**1**	**1**
Physics	**2**	**3**	**2**	**2**	**2**	**2**	**2**
Project management	**1**	**1**	**1**	**1**	**1**	**1**	**1**
Statistical Quality Control	**2**	**2**	**2**	**2**	**2**	**2**	**2**
Statistics – variability, design of experiments	**2**	**2**	**2**	**2**	**2**	**2**	**2**
Psychomotor 1. Observing 2. Imitating 3. Practicing 4. Adapting							
Human							
Adjusting communication style	**2**	**2**	**2**	**2**	**2**	**2**	**2**
Electronic Communications	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Identifying optimum delivery media	**2**	**2**	**2**	**2**	**2**	**2**	**2**
Listening and interpreting	**2**	**2**	**2**	**2**	**2**	**2**	**2**
Negotiation and conflict management	**2**	**2**	**2**	**2**	**2**	**2**	**2**
Public Relations	**1**	**2**	**1**	**1**	**1**	**1**	**1**
Speaking and presenting	**2**	**2**	**2**	**2**	**2**	**2**	**2**
Telephone Communication	**2**	**2**	**2**	**2**	**2**	**2**	**2**
Professional							
Critical reflection/learning	**2**	**4**	**2**	**2**	**2**	**2**	**2**
Experimental procedures	**3**	**4**	**3**	**3**	**3**	**3**	**3**
Leadership	**2**	**2**	**2**	**2**	**2**	**2**	**2**
Presentation	**3**	**4**	**3**	**3**	**3**	**3**	**3**

6.3.1.1 Stage 1 Industry	Chemical Process Industries	Academia	Food, Drugs & Consumer Products	High Tech, Emerging Markets	Materials Science	Nuclear Energy	Regulatory
Problem solving	**3**	**4**	**3**	**3**	**3**	**3**	**3**
Teamwork	**2**	**2**	**2**	**2**	**2**	**2**	**2**
Technical Psychomotor							
Computer Applications	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Spreadsheets	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Time management	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Typing (keyboarding)	**3**	**3**	**3**	**3**	**3**	**3**	**3**

6.3.1.2 Stage 2 Industry	Chemical Process Industries	Academia	Food, Drugs & Consumer Products	High Tech, Emerging Markets	Materials Science	Nuclear Energy	Regulatory
Affective 1. Receiving 2. Responding 3. Valuing 4. Organizing 5. Internalizing							
Beliefs and Values							
Commitment to lifelong learning	**2**	**2**	**2**	**2**	**2**	**2**	**2**
Concern for public welfare	**4**	**4**	**4**	**4**	**4**	**4**	**4**
Ethics	**4**	**4**	**4**	**4**	**4**	**4**	**4**
Respect for others	**4**	**4**	**4**	**4**	**4**	**4**	**4**
Cognitive 1. Remembering 2. Understanding 3. Applying 4. Analyzing 5. Evaluating 6. Creating							
ChE Technical							
Energy balances involving 1st and 2nd law	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Equilibria, chemical and phase	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Fluid flow, pump & compressor sizing & selection, packed beds	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Fluid flow, single-phase flow, two-phase flow (pipes, valves, orifices)	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Heat balances with and without reactions	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Heat transfer equipment design and analysis	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Heat transfer, multiple modes, phase change	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Kinetics, conversion in various reactor types, chemical equilibria	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Kinetics, reactor analysis	**3**	**3**	**3**	**3**	**3**	**3**	**3**

6.3.1.2 Stage 2 Industry	Chemical Process Industries	Academia	Food, Drugs & Consumer Products	High Tech, Emerging Markets	Materials Science	Nuclear Energy	Regulatory
Kinetics, reactor design, heterogeneous catalysis	3	3	3	3	3	3	3
Mass transfer, equipment design and analysis	3	3	3	3	3	3	3
Mass transfer, single- and two-phase processes	3	3	3	3	3	3	3
Materials science	3	3	3	3	3	3	3
Plant design, economics	3	3	3	3	3	3	3
Plant design, flow configuration, optimization	3	2	3	3	3	3	3
Plant design, instrumentation	3	2	3	3	3	3	3
Plant design, process control	3	2	3	3	3	3	3
Plant operations, optimization	3	2	3	3	3	3	3
Plant operations, startup, shutdown	3	2	3	3	3	3	3
Plant scale-up	3	2	3	3	3	3	3
Separations equipment selection & analysis	3	3	3	3	3	3	3
Separations process design	3	3	3	3	3	3	3
Stoichiometry with and without reactions	3	3	3	3	3	3	3
Stoichiometry, complex systems with recycle, bypass	3	3	3	3	3	3	3
Cross Functional							
Energy – systems analysis, efficiency	3	2	3	3	3	3	3
Environmental assessment, regulations	3	2	3	3	3	3	3
Process simulators, operation, steady state simulation, dynamic simulation	3	2	3	3	3	3	3
Process simulators, strengths and weaknesses	3	2	3	3	3	3	2
Safety, analyses, modeling, procedural policies, regulations	3	2	3	3	3	3	3
Sustainability analyses	3	2	3	3	3	3	3

6.3.1.2 Stage 2 Industry	Chemical Process Industries	Academia	Food, Drugs & Consumer Products	High Tech, Emerging Markets	Materials Science	Nuclear Energy	Regulatory
Technical							
Biology	**2**	**5**	**3**	**2**	**2**	**2**	**2**
Budgeting	**2**	**3**	**2**	**2**	**2**	**2**	**2**
Chemistry –inorganic, organic, physical chemistry and biochemistry	**3**	**5**	**3**	**3**	**3**	**3**	**3**
Computer programming	**2**	**2**	**2**	**2**	**2**	**2**	**2**
Economics	**2**	**2**	**2**	**2**	**2**	**2**	**2**
Mathematics –mathematics through ODE	**3**	**4**	**3**	**3**	**3**	**3**	**3**
Numerical analysis & linear programming	**2**	**3**	**2**	**2**	**2**	**2**	**2**
Physics	**3**	**5**	**3**	**3**	**3**	**3**	**3**
Project management	**2**	**2**	**2**	**2**	**2**	**2**	**2**
Statistical Quality Control	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Statistics – variability, design of experiments	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Psychomotor 1. Observing 2. Imitating 3. Practicing 4. Adapting							
Human							
Adjusting communication style	**2**	**2**	**2**	**2**	**2**	**2**	**2**
Electronic Communications	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Identifying optimum delivery media	**2**	**2**	**2**	**2**	**2**	**2**	**2**
Listening and interpreting	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Negotiation and conflict management	**2**	**2**	**2**	**2**	**2**	**2**	**2**
Public Relations	**2**	**2**	**2**	**2**	**2**	**2**	**2**
Speaking and presenting	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Telephone Communication	**2**	**2**	**2**	**2**	**2**	**2**	**2**
Professional							
Critical reflection/learning	**3**	**4**	**3**	**3**	**3**	**3**	**3**
Experimental procedures	**3**	**4**	**3**	**3**	**3**	**3**	**3**
Leadership	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Presentation	**3**	**4**	**3**	**3**	**3**	**3**	**3**

6.3.1.2 Stage 2 Industry	Chemical Process Industries	Academia	Food, Drugs & Consumer Products	High Tech, Emerging Markets	Materials Science	Nuclear Energy	Regulatory
Problem solving	**3**	**4**	**3**	**3**	**3**	**3**	**3**
Teamwork	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Technical Psychomotor							
Computer Applications	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Spreadsheets	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Time management	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Typing (keyboarding)	**3**	**3**	**3**	**3**	**3**	**3**	**3**

6.3.1.3 Stage 3 Industry	Chemical Process Industries	Academia	Food, Drugs & Consumer Products	High Tech, Emerging Markets	Materials Science	Nuclear Energy	Regulatory
Affective 1. Receiving 2. Responding 3. Valuing 4. Organizing 5. Internalizing							
Beliefs and Values							
Commitment to lifelong learning	**4**	**4**	**4**	**4**	**4**	**4**	**4**
Concern for public welfare	**5**	**5**	**5**	**5**	**5**	**5**	**5**
Ethics	**5**	**5**	**5**	**5**	**5**	**5**	**5**
Respect for others	**4**	**4**	**4**	**4**	**4**	**4**	**4**
Cognitive 1. Remembering 2. Understanding 3. Applying 4. Analyzing 5. Evaluating 6. Creating							
ChE Technical							
Energy balances involving 1st and 2nd law	**5**	**5**	**5**	**5**	**5**	**5**	**4**
Equilibria, chemical and phase	**5**	**5**	**4**	**3**	**5**	**3**	**4**
Fluid flow, pump & compressor sizing & selection, packed beds	**5**	**4**	**4**	**4**	**4**	**4**	**4**
Fluid flow, single-phase flow, two-phase flow (pipes, valves, orifices)	**5**	**4**	**4**	**4**	**4**	**5**	**4**
Heat balances with and without reactions	**5**	**5**	**5**	**5**	**5**	**5**	**4**
Heat transfer equipment design and analysis	**5**	**4**	**4**	**4**	**5**	**4**	**4**
Heat transfer, multiple modes, phase change	**5**	**5**	**4**	**4**	**4**	**4**	**5**
Kinetics, conversion in various reactor types, chemical equilibria	**5**	**5**	**4**	**3**	**4**	**3**	**4**

6.3.1.3 Stage 3 Industry	Chemical Process Industries	Academia	Food, Drugs & Consumer Products	High Tech, Emerging Markets	Materials Science	Nuclear Energy	Regulatory
Kinetics, reactor analysis	5	5	4	3	4	3	4
Kinetics, reactor design, heterogeneous catalysis	5	5	4	3	4	3	4
Mass transfer, equipment design and analysis	5	4	4	3	4	3	4
Mass transfer, single- and two-phase processes	5	5	4	4	5	3	4
Materials science	5	5	4	5	5	5	4
Plant design, economics	4	3	4	4	4	4	3
Plant design, flow configuration, optimization	4	2	4	4	4	4	3
Plant design, instrumentation	5	4	4	4	4	5	3
Plant design, process control	4	4	4	4	4	5	3
Plant operations, optimization	5	4	4	4	4	4	3
Plant operations, startup, shutdown	5	2	4	3	4	5	3
Plant scale-up	5	4	4	3	4	5	3
Separations equipment selection & analysis	5	4	4	3	4	3	4
Separations process design	5	4	4	3	4	3	4
Stoichiometry with and without reactions	5	5	4	4	4	4	4
Stoichiometry, complex systems with recycle, bypass	5	5	4	4	4	4	4
Cross Functional							
Energy – systems analysis, efficiency	4	2	4	4	4	4	3
Environmental assessment, regulations	4	2	4	4	4	4	4
Process simulators, operation, steady state simulation, dynamic simulation	4	2	4	4	4	4	3
Process simulators, strengths and weaknesses	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Safety, analyses, modeling, procedural policies, regulations	4	2	4	4	4	4	4
Sustainability analyses	4	2	4	4	4	4	4

6.3.1.3 Stage 3 Industry	Chemical Process Industries	Academia	Food, Drugs & Consumer Products	High Tech, Emerging Markets	Materials Science	Nuclear Energy	Regulatory
Technical							
Biology	**2**	**5**	**3**	**2**	**2**	**2**	**2**
Budgeting	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Chemistry –inorganic, organic, physical chemistry and biochemistry	**3**	**5**	**3**	**3**	**3**	**3**	**3**
Computer programming	**2**	**2**	**2**	**2**	**2**	**2**	**2**
Economics	**3**	**2**	**3**	**3**	**3**	**3**	**3**
Mathematics –mathematics through ODE	**3**	**4**	**3**	**3**	**3**	**3**	**3**
Numerical analysis & linear programming	**4**	**3**	**4**	**4**	**4**	**4**	**4**
Physics	**3**	**5**	**3**	**3**	**3**	**3**	**3**
Project management	**3**	**1**	**3**	**3**	**3**	**3**	**3**
Statistical Quality Control	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Statistics – variability, design of experiments	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Psychomotor 1. Observing 2. Imitating 3. Practicing 4. Adapting							
Human							
Adjusting communication style	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Electronic Communications	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Identifying optimum delivery media	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Listening and interpreting	**4**	**4**	**4**	**4**	**4**	**4**	**4**
Negotiation and conflict management	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Public Relations	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Speaking and presenting	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Telephone Communication	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Professional							
Critical reflection/learning	**3**	**4**	**3**	**3**	**3**	**3**	**3**
Experimental procedures	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Leadership	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Presentation	**3**	**4**	**3**	**3**	**3**	**3**	**3**

6.3.1.3 Stage 3 Industry	Chemical Process Industries	Academia	Food, Drugs & Consumer Products	High Tech, Emerging Markets	Materials Science	Nuclear Energy	Regulatory
Problem solving	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Teamwork	**4**	**3**	**4**	**4**	**4**	**4**	**4**
Technical Psychomotor							
Computer Applications	**4**	**3**	**4**	**4**	**4**	**4**	**4**
Spreadsheets	**4**	**3**	**4**	**4**	**4**	**4**	**4**
Time management	**4**	**3**	**4**	**4**	**4**	**4**	**4**
Typing (keyboarding)	**3**	**3**	**3**	**3**	**3**	**3**	**3**

6.3.1.4 Stage 4 Industry	Chemical Process Industries	Academia	Food, Drugs & Consumer Products	High Tech, Emerging Markets	Materials Science	Nuclear Energy	Regulatory
Affective 1. Receiving 2. Responding 3. Valuing 4. Organizing 5. Internalizing							
Beliefs and Values							
Commitment to lifelong learning	**5**	**5**	**5**	**5**	**5**	**5**	**5**
Concern for public welfare	**5**	**5**	**5**	**5**	**5**	**5**	**5**
Ethics	**5**	**5**	**5**	**5**	**5**	**5**	**5**
Respect for others	**5**	**5**	**5**	**5**	**5**	**5**	**5**
Cognitive 1. Remembering 2. Understanding 3. Applying 4. Analyzing 5. Evaluating 6. Creating							
ChE Technical							
Energy balances involving 1st and 2nd law	**6**	**6**	**6**	**6**	**6**	**6**	**4**
Equilibria, chemical and phase	**6**	**6**	**6**	**4**	**6**	**6**	**4**
Fluid flow, pump & compressor sizing & selection, packed beds	**6**	**6**	**6**	**5**	**6**	**5**	**4**
Fluid flow, single-phase flow, two-phase flow (pipes, valves, orifices)	**6**	**6**	**6**	**5**	**6**	**5**	**4**
Heat balances with and without reactions	**6**	**6**	**6**	**6**	**6**	**6**	**6**
Heat transfer equipment design and analysis	**6**	**6**	**6**	**4**	**6**	**6**	**4**
Heat transfer, multiple modes, phase change	**6**	**6**	**6**	**4**	**6**	**6**	**4**
Kinetics, conversion in various reactor types, chemical equilibria	**6**	**6**	**5**	**4**	**4**	**6**	**4**

6.3.1.4 Stage 4 Industry	Chemical Process Industries	Academia	Food, Drugs & Consumer Products	High Tech, Emerging Markets	Materials Science	Nuclear Energy	Regulatory
Kinetics, reactor analysis	**6**	**6**	**5**	**4**	**4**	**6**	**4**
Kinetics, reactor design, heterogeneous catalysis	**6**	**6**	**4**	**4**	**4**	**6**	**4**
Mass transfer, equipment design and analysis	**6**	**6**	**6**	**4**	**5**	**6**	**4**
Mass transfer, single- and two-phase processes	**6**	**6**	**6**	**4**	**5**	**6**	**4**
Materials science	**6**	**6**	**6**	**6**	**6**	**6**	**6**
Plant design, economics	**4**	**6**	**5**	**4**	**6**	**6**	**4**
Plant design, flow configuration, optimization	**6**	**6**	**6**	**6**	**5**	**6**	**4**
Plant design, instrumentation	**6**	**2**	**6**	**4**	**4**	**6**	**3**
Plant design, process control	**6**	**2**	**6**	**4**	**4**	**6**	**4**
Plant operations, optimization	**6**	**2**	**6**	**6**	**6**	**6**	**3**
Plant operations, startup, shutdown	**6**	**2**	**6**	**4**	**6**	**6**	**3**
Plant scale-up	**6**	**2**	**6**	**4**	**4**	**6**	**3**
Separations equipment selection & analysis	**6**	**6**	**6**	**4**	**5**	**6**	**4**
Separations process design	**6**	**6**	**6**	**4**	**5**	**6**	**4**
Stoichiometry with and without reactions	**6**	**6**	**6**	**5**	**6**	**5**	**4**
Stoichiometry, complex systems with recycle, bypass	**6**	**6**	**6**	**5**	**6**	**5**	**4**
Cross Functional							
Energy – systems analysis, efficiency	**6**	**2**	**6**	**5**	**6**	**6**	**4**
Environmental assessment, regulations	**6**	**2**	**6**	**5**	**6**	**6**	**5**
Process simulators, operation, steady state simulation, dynamic simulation	**6**	**2**	**6**	**5**	**6**	**6**	**4**
Process simulators, strengths and weaknesses	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**
Safety, analyses, modeling, procedural policies, regulations	**6**	**2**	**6**	**5**	**6**	**6**	**5**
Sustainability analyses	**6**	**6**	**6**	**5**	**6**	**6**	**5**

6.3.1.4 Stage 4 Industry	Chemical Process Industries	Academia	Food, Drugs & Consumer Products	High Tech, Emerging Markets	Materials Science	Nuclear Energy	Regulatory
Technical							
Biology	**2**	**5**	**3**	**2**	**2**	**2**	**2**
Budgeting	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Chemistry –inorganic, organic, physical chemistry and biochemistry	**5**	**5**	**5**	**5**	**5**	**5**	**5**
Computer programming	**2**	**2**	**2**	**2**	**2**	**2**	**2**
Economics	**3**	**2**	**3**	**3**	**3**	**3**	**3**
Mathematics –mathematics through ODE	**3**	**4**	**3**	**3**	**3**	**3**	**3**
Numerical analysis & linear programming	**4**	**3**	**4**	**4**	**4**	**4**	**4**
Physics	**3**	**3**	**3**	**3**	**3**	**5**	**3**
Project management	**3**	**1**	**3**	**3**	**3**	**3**	**3**
Statistical Quality Control	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Statistics – variability, design of experiments	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Psychomotor 1. Observing 2. Imitating 3. Practicing 4. Adapting							
Human							
Adjusting communication style	**4**	**4**	**4**	**4**	**4**	**4**	**4**
Electronic Communications	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Identifying optimum delivery media	**4**	**4**	**4**	**4**	**4**	**4**	**4**
Listening and interpreting	**4**	**4**	**4**	**4**	**4**	**4**	**4**
Negotiation and conflict management	**4**	**4**	**4**	**4**	**4**	**4**	**4**
Public Relations	**4**	**4**	**4**	**4**	**4**	**4**	**4**
Speaking and presenting	**4**	**4**	**4**	**4**	**4**	**4**	**4**
Telephone Communication	**4**	**4**	**4**	**4**	**4**	**4**	**4**
Professional							
Critical reflection/learning	**4**	**4**	**4**	**4**	**4**	**4**	**4**
Experimental procedures	**4**	**4**	**4**	**4**	**4**	**4**	**4**
Leadership	**4**	**4**	**4**	**4**	**4**	**4**	**4**
Presentation	**4**	**4**	**4**	**4**	**4**	**4**	**4**

6.3.1.4 Stage 4 Industry	Chemical Process Industries	Academia	Food, Drugs & Consumer Products	High Tech, Emerging Markets	Materials Science	Nuclear Energy	Regulatory
Problem solving	**4**	**4**	**4**	**4**	**4**	**4**	**4**
Teamwork	**4**	**4**	**4**	**4**	**4**	**4**	**4**
Technical Psychomotor	**4**	**4**	**4**	**4**	**4**	**4**	**4**
Computer Applications	**4**	**4**	**4**	**4**	**4**	**4**	**4**
Spreadsheets	**4**	**4**	**4**	**4**	**4**	**4**	**4**
Time management	**4**	**4**	**4**	**4**	**4**	**4**	**4**
Typing (keyboarding)	**3**	**3**	**3**	**3**	**3**	**3**	**3**

6.3.2 Industry View Observations

Looking at the resulting charts for each of the four career stages the following observations were reached:

- Ability levels generally progress upward as one moves along a career path.
- The regulatory and academia industries (or categories) do not follow the above noted trends and indeed, regulatory and education are distinctly different from the other industry classifications.
- The psychomotor skills are uniform across all industries with the exception of regulatory and education.
- There is very little variation across industry categories for either the affective or psychometric domains with the exception of the regulatory and academia categories.
- There is little variation across industries for Stages 1 and 4 with the exception of the regulatory and academia groups.
- Most engineers do not progress past Stage 3 in the career progression. Very few engineers progress to Stage 4 which represents the highest level of professional technical expertise and experience, and they will only possess the stage 4 ability in a few KSAs, not all.
- The skill and knowledge scores shown for Stage 4 are all 5s and 6s. The differences are due to the fact that some industries have greater need for highly specialized engineers.

6.3.3 Role View

Chemical engineers work in a wide range of positions. This Body of Knowledge evaluates roles for the type of positions that are held by the majority of chemical engineers working in industry, government, and academia.

This analysis is predicated on a base model that assumes that with practice the ability level would typically increase or remain unchanged for a knowledge or skill when progressing from one career stage to the next career stage.

As areas of expertise are developed, the individual becomes more focused and the ability levels may show large increases for the knowledge or skills related to the areas of expertise while the taxonomy levels for other competencies may decline.

Some roles are not applicable to all career stages. For example, a Technical Staff Manager is unlikely to exist in career Stage 1, may exist in career Stage 2, and is most likely to exist in career Stages 3 and 4. As another example, a production process engineer is most likely to exist in career Stages 1 and 2, it may be a supervisory position in career Stage 3, and it is not likely to exist in career Stage 4. Ability level will be designated N/A where they either do not apply to the role. The entire column will be marked N/A where the role is not applicable to the career stage.

Rankings for the role groupings are given in the following tables.

6.3.3.1 Stage 1 Role	Consultant	Economist	Educator	Process Engineer	Production Engineer	Project Manager	Regulatory	Research	Scheduling/Planning	Technical Staff Manager	Technical Task Manager	Technician
Affective 1. Receiving 2. Responding 3. Valuing 4. Organizing 5. Internalizing												
Beliefs and Values												
Commitment to lifelong learning	**N/A**	**N/A**	**3**	**2**	**3**	**N/A**	**3**	**3**	**2**	**N/A**	**N/A**	**3**
Concern for public welfare	**N/A**	**N/A**	**4**	**3**	**4**	**N/A**	**4**	**4**	**3**	**N/A**	**N/A**	**4**
Ethics	**N/A**	**N/A**	**4**	**3**	**4**	**N/A**	**4**	**4**	**3**	**N/A**	**N/A**	**4**
Respect for others	**N/A**	**N/A**	**3**	**2**	**3**	**N/A**	**3**	**3**	**2**	**N/A**	**N/A**	**3**
Cognitive 1. Remembering 2. Understanding 3. Applying 4. Analyzing 5. Evaluating 6. Creating												
ChE Technical												
Energy balances involving 1st and 2nd law	**N/A**	**N/A**	**2**	**1**	**2**	**N/A**	**2**	**2**	**1**	**N/A**	**N/A**	**2**
Equilibria, chemical and phase	**N/A**	**N/A**	**2**	**1**	**2**	**N/A**	**2**	**2**	**1**	**N/A**	**N/A**	**2**
Fluid flow, pump & compressor sizing & selection, packed beds	**N/A**	**N/A**	**2**	**1**	**2**	**N/A**	**2**	**2**	**1**	**N/A**	**N/A**	**2**
Fluid flow, single-phase flow, two-phase flow (pipes, valves, orifices)	**N/A**	**N/A**	**2**	**2**	**2**	**N/A**	**2**	**2**	**1**	**N/A**	**N/A**	**2**
Heat balances with and without reactions	**N/A**	**N/A**	**2**	**1**	**2**	**N/A**	**2**	**2**	**1**	**N/A**	**N/A**	**2**
Heat transfer equipment design and analysis	**N/A**	**N/A**	**2**	**1**	**2**	**N/A**	**2**	**2**	**1**	**N/A**	**N/A**	**2**

6.3.3.1 Stage 1 Role	Consultant	Economist	Educator	Process Engineer	Production Engineer	Project Manager	Regulatory	Research	Scheduling/Planning	Technical Staff Manager	Technical Task Manager	Technician
Heat transfer, multiple modes, phase change	N/A	N/A	2	1	2	N/A	2	2	1	N/A	N/A	2
Kinetics, conversion in various reactor types, chemical equilibria	N/A	N/A	2	1	2	N/A	2	2	1	N/A	N/A	2
Kinetics, reactor analysis	N/A	N/A	2	1	2	N/A	2	2	1	N/A	N/A	2
Kinetics, reactor design, heterogeneous catalysis	N/A	N/A	2	1	2	N/A	2	2	1	N/A	N/A	2
Mass transfer, equipment design and analysis	N/A	N/A	2	1	2	N/A	2	2	1	N/A	N/A	2
Mass transfer, single- and two-phase processes	N/A	N/A	2	1	2	N/A	2	2	1	N/A	N/A	2
Materials science	N/A	N/A	2	1	1	N/A	2	1	1	N/A	N/A	2
Plant design, economics	N/A	N/A	2	1	2	N/A	2	2	1	N/A	N/A	2
Plant design, flow configuration, optimization	N/A	N/A	2	1	2	N/A	2	2	1	N/A	N/A	1
Plant design, instrumentation	N/A	N/A	1	1	2	N/A	1	2	1	N/A	N/A	1
Plant design, process control	N/A	N/A	2	2	2	N/A	2	2	1	N/A	N/A	1
Plant operations, optimization	N/A	N/A	1	1	1	N/A	1	1	1	N/A	N/A	1
Plant operations, startup, shutdown	N/A	N/A	1	1	1	N/A	1	1	1	N/A	N/A	1
Plant scale-up	N/A	N/A	1	1	1	N/A	1	2	1	N/A	N/A	1
Separations equipment selection & analysis	N/A	N/A	2	1	2	N/A	2	2	1	N/A	N/A	2

6.3.3.1 Stage 1 Role	Consultant	Economist	Educator	Process Engineer	Production Engineer	Project Manager	Regulatory	Research	Scheduling/Planning	Technical Staff Manager	Technical Task Manager	Technician
Separations process design	N/A	N/A	2	1	2	N/A	2	2	1	N/A	N/A	2
Stoichiometry with and without reactions	N/A	N/A	2	1	2	N/A	2	2	1	N/A	N/A	2
Stoichiometry, complex systems with recycle, bypass	N/A	N/A	2	1	2	N/A	2	2	1	N/A	N/A	2
Cross Functional												
Energy – systems analysis, efficiency	N/A	N/A	1	1	1	N/A	1	1	1	N/A	N/A	1
Environmental assessment, regulations	N/A	N/A	1	1	1	N/A	2	1	1	N/A	N/A	1
Process simulators, operation, steady state simulation, dynamic simulation	N/A	N/A	1	1	1	N/A	1	1	1	N/A	N/A	1
Process simulators, strengths and weaknesses	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Safety, analyses, modeling, procedural policies, regulations	N/A	N/A	1	1	1	N/A	2	1	1	N/A	N/A	1
Sustainability analyses	N/A	N/A	1	1	1	N/A	1	1	1	N/A	N/A	1
Technical	N/A	N/A										
Biology	N/A	N/A	1	1	1	N/A	1	1	N/A	N/A	N/A	1
Budgeting	N/A	N/A	1	1	1	N/A	1	1	N/A	N/A	N/A	1
Chemistry – inorganic, organic, physical chemistry and biochemistry	N/A	N/A	2	1	2	N/A	2	3	1	N/A	N/A	1
Computer programming	N/A	N/A	1	1	2	N/A	2	2	1	N/A	N/A	1
Economics	N/A	N/A	1	1	1	N/A	1	1	1	N/A	N/A	1

6.3.3.1 Stage 1 Role	Consultant	Economist	Educator	Process Engineer	Production Engineer	Project Manager	Regulatory	Research	Scheduling/Planning	Technical Staff Manager	Technical Task Manager	Technician
Mathematics – mathematics through ODE	N/A	N/A	2	1	2	N/A	2	3	1	N/A	N/A	2
Numerical analysis & linear programming	N/A	N/A	1	1	2	N/A	1	1	1	N/A	N/A	1
Physics	N/A	N/A	2	1	2	N/A	2	2	N/A	N/A	N/A	1
Project management	N/A	N/A	1	1	1	N/A	1	1	1	N/A	N/A	1
Statistical Quality Control	N/A	N/A	2	1	2	N/A	2	2	1	N/A	N/A	1
Statistics – variability, design of experiments	N/A	N/A	2	1	2	N/A	2	2	1	N/A	N/A	1
Psychomotor 1. Observing 2. Imitating 3. Practicing 4. Adapting												
Human												
Adjusting communication style	N/A	N/A	2	1	2	N/A	2	2	1	N/A	N/A	2
Electronic Communications	N/A	N/A	1	1	1	N/A	1	1	1	N/A	N/A	1
Identifying optimum delivery media	N/A	N/A	2	1	2	N/A	2	2	1	N/A	N/A	2
Listening and interpreting	N/A	N/A	2	1	2	N/A	2	2	1	N/A	N/A	2
Negotiation and conflict management	N/A	N/A	2	1	2	N/A	2	2	1	N/A	N/A	2
Public Relations	N/A	N/A	3	1	2	N/A	3	3	2	N/A	N/A	3
Speaking and presenting	N/A	N/A	3	1	2	N/A	3	3	2	N/A	N/A	3
Telephone Communication	N/A	N/A	2	1	2	N/A	2	2	1	N/A	N/A	2

6.3.3.1 Stage 1 Role

	Consultant	Economist	Educator	Process Engineer	Production Engineer	Project Manager	Regulatory	Research	Scheduling/Planning	Technical Staff Manager	Technical Task Manager	Technician
Professional												
Critical reflection/learning	**N/A**	**N/A**	**2**	**1**	**2**	**N/A**	**2**	**2**	**1**	**N/A**	**N/A**	**2**
Experimental procedures	**N/A**	**N/A**	**3**	**2**	**2**	**N/A**	**3**	**3**	**2**	**N/A**	**N/A**	**3**
Leadership	**N/A**	**N/A**	**2**	**1**	**2**	**N/A**	**2**	**2**	**1**	**N/A**	**N/A**	**2**
Presentation	**N/A**	**N/A**	**3**	**1**	**2**	**N/A**	**3**	**3**	**2**	**N/A**	**N/A**	**3**
Problem solving	**N/A**	**N/A**	**3**	**1**	**3**	**N/A**	**3**	**3**	**2**	**N/A**	**N/A**	**3**
Teamwork	**N/A**	**N/A**	**3**	**1**	**3**	**N/A**	**3**	**3**	**2**	**N/A**	**N/A**	**3**
Technical Psychomotor												
Computer Applications	**N/A**	**N/A**	**3**	**1**	**3**	**N/A**	**3**	**3**	**2**	**N/A**	**N/A**	**3**
Spreadsheets	**N/A**	**N/A**	**3**	**1**	**3**	**N/A**	**3**	**3**	**2**	**N/A**	**N/A**	**3**
Time management	**N/A**	**N/A**	**3**	**1**	**2**	**N/A**	**3**	**3**	**2**	**N/A**	**N/A**	**3**
Typing (keyboarding)	**N/A**	**N/A**	**4**	**2**	**4**	**N/A**	**4**	**4**	**3**	**N/A**	**N/A**	**4**

6.3.3.2 Stage 2 Role	Consultant	Economist	Educator	Process Engineer	Production Engineer	Project Manager	Regulatory	Research	Scheduling/Planning	Technical Staff Manager	Technical Task Manager	Technician
Affective 1. Receiving 2. Responding 3. Valuing 4. Organizing 5. Internalizing												
Beliefs and Values												
Commitment to lifelong learning	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Concern for public welfare	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**
Ethics	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**
Respect for others	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Cognitive 1. Remembering 2. Understanding 3. Applying 4. Analyzing 5. Evaluating 6. Creating												
ChE Technical												
Energy balances involving 1st and 2nd law	**4**	**1**	**4**	**2**	**2**	**2**	**2**	**4**	**2**	**1**	**3**	**1**
Equilibria, chemical and phase	**4**	**1**	**4**	**3**	**3**	**2**	**2**	**4**	**2**	**1**	**3**	**2**
Fluid flow, pump & compressor sizing & selection, packed beds	**4**	**1**	**4**	**3**	**3**	**2**	**2**	**4**	**1**	**1**	**3**	**2**
Fluid flow, single-phase flow, two-phase flow (pipes, valves, orifices)	**4**	**1**	**4**	**3**	**3**	**2**	**2**	**4**	**2**	**1**	**3**	**2**
Heat balances with and without reactions	**4**	**1**	**4**	**2**	**2**	**2**	**2**	**4**	**2**	**1**	**3**	**1**
Heat transfer equipment design and analysis	**4**	**1**	**4**	**3**	**3**	**2**	**2**	**4**	**2**	**1**	**3**	**2**
Heat transfer, multiple modes, phase change	**4**	**1**	**4**	**3**	**3**	**2**	**2**	**4**	**2**	**1**	**3**	**2**
Kinetics, conversion in various reactor types, chemical equilibria	**3**	**1**	**3**	**3**	**2**	**2**	**2**	**3**	**1**	**1**	**3**	**1**
Kinetics, reactor analysis	**3**	**1**	**4**	**3**	**2**	**2**	**2**	**3**	**1**	**1**	**3**	**1**

6.3.3.2 Stage 2 Role	Consultant	Economist	Educator	Process Engineer	Production Engineer	Project Manager	Regulatory	Research	Scheduling/Planning	Technical Staff Manager	Technical Task Manager	Technician
Kinetics, reactor design, heterogeneous catalysis	**3**	**1**	**4**	**3**	**2**	**2**	**2**	**3**	**1**	**1**	**3**	**1**
Mass transfer, equipment design and analysis	**4**	**1**	**4**	**3**	**3**	**2**	**2**	**4**	**2**	**1**	**3**	**2**
Mass transfer, single- and two-phase processes	**4**	**1**	**4**	**3**	**3**	**2**	**2**	**4**	**2**	**1**	**3**	**2**
Materials science	**3**	**1**	**3**	**3**	**2**	**2**	**2**	**3**	**2**	**1**	**2**	**2**
Plant design, economics	**3**	**3**	**4**	**3**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**1**
Plant design, flow configuration, optimization	**3**	**3**	**3**	**3**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**1**
Plant design, instrumentation	**3**	**2**	**3**	**3**	**2**	**2**	**2**	**1**	**2**	**2**	**2**	**1**
Plant design, process control	**3**	**3**	**3**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**1**
Plant operations, optimization	**3**	**2**	**3**	**3**	**2**	**2**	**2**	**1**	**2**	**2**	**2**	**1**
Plant operations, startup, shutdown	**3**	**2**	**3**	**3**	**2**	**2**	**2**	**1**	**2**	**2**	**2**	**1**
Plant scale-up	**3**	**3**	**3**	**3**	**2**	**2**	**2**	**2**	**2**	**1**	**2**	**1**
Separations equipment selection & analysis	**4**	**2**	**3**	**3**	**2**	**2**	**2**	**4**	**2**	**1**	**3**	**2**
Separations process design	**4**	**2**	**3**	**3**	**2**	**2**	**2**	**4**	**2**	**1**	**3**	**2**
Stoichiometry with and without reactions	**4**	**1**	**4**	**3**	**2**	**2**	**2**	**4**	**1**	**1**	**4**	**1**
Stoichiometry, complex systems with recycle, bypass	**3**	**2**	**4**	**3**	**2**	**2**	**2**	**4**	**2**	**1**	**3**	**1**
Cross Functional												
Energy – systems analysis, efficiency	**4**	**2**	**4**	**3**	**2**	**2**	**2**	**3**	**2**	**1**	**3**	**1**
Environmental assessment, regulations	**4**	**3**	**4**	**3**	**2**	**2**	**3**	**3**	**2**	**1**	**3**	**1**
Process simulators, operation, steady state simulation, dynamic simulation	**4**	**1**	**4**	**3**	**3**	**2**	**2**	**3**	**2**	**1**	**3**	**1**
Process simulators, strengths and weaknesses	**4**	**1**	**4**	**3**	**3**	**2**	**2**	**3**	**2**	**1**	**3**	**1**

6.3.3.2 Stage 2 Role	Consultant	Economist	Educator	Process Engineer	Production Engineer	Project Manager	Regulatory	Research	Scheduling/Planning	Technical Staff Manager	Technical Task Manager	Technician
Safety, analyses, modeling, procedural policies, regulations	4	2	4	3	2	2	3	3	2	1	3	1
Sustainability analyses	4	2	4	2	1	2	2	3	2	1	3	1
Technical												
Biology	3	1	5	2	2	2	2	4	1	N/A	2	1
Budgeting	4	2	1	2	2	4	2	4	3	3	4	3
Chemistry –inorganic, organic, physical chemistry and biochemistry	3	1	5	2	2	2	2	3	1	N/A	2	1
Computer programming	2	2	3	2	3	2	2	4	3	1	2	1
Economics	2	5	1	2	2	3	2	3	2	1	3	2
Mathematics –mathematics through ODE	4	4	5	3	4	2	2	4	1	N/A	1	1
Numerical analysis & linear programming	3	3	3	2	3	2	2	4	2	N/A	2	1
Physics	3	1	5	2	2	2	2	3	1	N/A	2	1
Project management	3	2	2	2	2	4	2	3	3	2	4	3
Statistical Quality Control	4	2	4	2	3	3	2	3	2	1	1	1
Statistics – variability, design of experiments	4	2	5	3	3	3	2	4	1	1	1	1
Psychomotor 1. Observing 2. Imitating 3. Practicing 4. Adapting												
Human												
Adjusting communication style	4	3	4	2	2	3	3	3	2	3	4	3
Electronic Communications	3	3	3	3	3	3	3	3	3	3	3	3
Identifying optimum delivery media	4	2	4	3	2	3	3	3	2	3	4	3
Listening and interpreting	4	3	4	3	2	3	3	3	2	3	4	3
Negotiation and conflict management	4	2	2	2	2	3	2	2	2	3	3	3
Public Relations	1	1	1	1	1	1	1	1	1	1	1	1
Speaking and presenting	4	3	4	2	2	3	2	3	2	3	4	3
Telephone Communication	3	3	3	3	3	3	3	3	3	3	3	3

6.3.3.2 Stage 2 Role	Consultant	Economist	Educator	Process Engineer	Production Engineer	Project Manager	Regulatory	Research	Scheduling/Planning	Technical Staff Manager	Technical Task Manager	Technician
Professional												
Critical reflection/learning	3	3	4	3	3	4	2	4	2	3	4	2
Experimental procedures	3	2	4	3	3	4	2	3	2	3	4	2
Leadership	3	2	3	2	3	4	2	3	2	3	4	3
Presentation	3	3	4	2	3	4	2	4	2	3	4	2
Problem solving	3	2	4	3	3	4	2	4	2	3	4	3
Teamwork	2	2	3	2	3	4	3	3	2	3	4	2
Technical Psychomotor												
Computer Applications	3	3	3	3	3	3	3	3	3	3	3	3
Spreadsheets	3	3	2	3	3	3	3	3	3	3	3	3
Time management	3	3	3	3	3	3	3	3	3	3	3	3
Typing (keyboarding)	3	3	3	3	3	3	3	3	3	3	3	3

6.3.3.3 Stage 3 Role	Consultant	Economist	Educator	Process Engineer	Production Engineer	Project Manager	Regulatory	Research	Scheduling/Planning	Technical Staff Manager	Technical Task Manager	Technician
Affective 1. Receiving 2. Responding 3. Valuing 4. Organizing 5. Internalizing												
Beliefs and Values												
Commitment to lifelong learning	**5**	**3**	**5**	**4**	**3**	**3**	**3**	**4**	**3**	**4**	**4**	**3**
Concern for public welfare	**5**	**4**	**5**	**5**	**4**	**5**	**5**	**4**	**4**	**5**	**5**	**4**
Ethics	**5**	**4**	**5**	**4**	**4**	**5**	**4**	**4**	**4**	**5**	**5**	**5**
Respect for others	**5**	**3**	**4**	**3**	**3**	**4**	**3**	**3**	**3**	**5**	**4**	**4**
Cognitive 1. Remembering 2. Understanding 3. Applying 4. Analyzing 5. Evaluating 6. Creating												
ChE Technical												
Energy balances involving 1st and 2nd law	**5**	**4**	**5**	**5**	**4**	**1**	**4**	**5**	**2**	**4**	**5**	**3**
Equilibria, chemical and phase	**5**	**3**	**5**	**4**	**4**	**1**	**4**	**5**	**2**	**4**	**5**	**3**
Fluid flow, pump & compressor sizing & selection, packed beds	**5**	**3**	**5**	**5**	**4**	**2**	**4**	**5**	**2**	**4**	**5**	**2**
Fluid flow, single-phase flow, two-phase flow (pipes, valves, orifices)	**5**	**4**	**5**	**5**	**4**	**1**	**4**	**5**	**2**	**4**	**5**	**3**
Heat balances with and without reactions	**5**	**4**	**5**	**4**	**4**	**1**	**4**	**5**	**2**	**4**	**5**	**3**
Heat transfer equipment design and analysis	**5**	**3**	**4**	**4**	**3**	**2**	**4**	**5**	**2**	**4**	**5**	**3**
Heat transfer, multiple modes, phase change	**5**	**4**	**5**	**5**	**3**	**1**	**4**	**5**	**2**	**4**	**5**	**3**
Kinetics, conversion in various reactor types, chemical equilibria	**5**	**4**	**5**	**4**	**3**	**1**	**4**	**5**	**2**	**4**	**5**	**3**
Kinetics, reactor analysis	**6**	**3**	**4**	**4**	**3**	**1**	**3**	**5**	**2**	**4**	**5**	**3**
Kinetics, reactor design, heterogeneous catalysis	**6**	**3**	**5**	**4**	**3**	**2**	**3**	**5**	**2**	**4**	**5**	**3**

6.3.3.3 Stage 3 Role	Consultant	Economist	Educator	Process Engineer	Production Engineer	Project Manager	Regulatory	Research	Scheduling/Planning	Technical Staff Manager	Technical Task Manager	Technician
Mass transfer, equipment design and analysis	6	3	4	4	3	2	4	5	2	4	5	3
Mass transfer, single- and two-phase processes	5	4	5	4	4	1	4	5	2	4	5	3
Materials science	5	2	4	4	4	2	3	5	3	4	4	3
Plant design, economics	4	6	4	4	3	4	3	5	4	4	5	3
Plant design, flow configuration, optimization	4	5	4	4	3	2	3	5	2	4	5	3
Plant design, instrumentation	4	3	4	5	4	2	3	4	2	4	4	4
Plant design, process control	4	3	4	5	3	2	3	4	2	4	4	4
Plant operations, optimization	4	6	4	4	4	2	3	4	2	4	4	4
Plant operations, startup, shutdown	3	4	3	4	4	2	4	4	3	4	4	4
Plant scale-up	4	3	3	4	3	2	3	5	2	4	4	2
Separations equipment selection & analysis	6	3	4	4	3	2	4	5	2	4	5	3
Separations process design	5	4	5	4	3	1	4	5	2	4	5	2
Stoichiometry with and without reactions	5	4	5	4	5	1	4	5	2	4	5	3
Stoichiometry, complex systems with recycle, bypass	5	3	5	4	4	1	4	5	2	4	5	3
Cross Functional												
Energy – systems analysis, efficiency	6	4	5	4	3	1	3	4	1	4	5	2
Environmental assessment, regulations	5	3	4	4	3	4	6	4	3	5	5	4
Process simulators, operation, steady state simulation, dynamic simulation	6	6	5	5	3	1	3	5	1	4	6	3
Process simulators, strengths and weaknesses	6	4	5	5	2	1	3	5	1	4	5	2
Safety, analyses, modeling, procedural policies, regulations	5	3	4	5	3	4	6	4	3	5	5	4
Sustainability analyses	3	4	4	3	2	1	3	4	1	3	4	2

6.3.3.3 Stage 3 Role

	Consultant	Economist	Educator	Process Engineer	Production Engineer	Project Manager	Regulatory	Research	Scheduling/Planning	Technical Staff Manager	Technical Task Manager	Technician
Technical												
Biology	4	3	4	4	4	1	4	5	1	4	5	2
Budgeting	4	5	2	2	2	6	3	3	5	4	4	3
Chemistry –inorganic, organic, physical chemistry and biochemistry	5	3	5	4	4	2	4	6	1	4	5	2
Computer programming	5	4	3	4	4	2	3	4	3	3	4	2
Economics	5	6	3	3	3	4	2	5	4	3	5	4
Mathematics –mathematics through ODE	5	4	5	4	4	2	4	5	2	4	5	2
Numerical analysis & linear programming	5	6	5	4	4	2	2	5	2	2	4	2
Physics	5	3	5	4	4	2	4	5	1	4	5	2
Project management	5	3	2	3	2	6	2	3	3	3	4	3
Statistical Quality Control	5	3	3	3	5	2	3	5	1	3	4	2
Statistics – variability, design of experiments	5	4	5	3	5	2	3	6	2	3	4	2
Psychomotor 1. Observing 2. Imitating 3. Practicing 4. Adapting												
Human												
Adjusting communication style	4	2	4	2	2	4	3	3	2	4	3	3
Electronic Communications	4	3	4	3	3	4	3	4	3	4	3	4
Identifying optimum delivery media	4	2	4	2	2	3	2	3	1	3	3	3
Listening and interpreting	4	4	4	3	3	4	3	3	3	4	4	4
Negotiation and conflict management	4	4	3	2	2	4	3	3	2	4	4	4
Public Relations	4	3	3	3	3	4	3	3	3	3	4	4
Speaking and presenting	4	3	4	2	2	3	2	3	2	4	3	3
Telephone Communication	4	3	3	3	3	4	3	3	3	3	4	4
Professional												
Critical reflection/learning	4	3	4	3	3	3	3	3	2	3	4	3
Experimental procedures	3	2	3	1	2	1	1	4	1	2	3	2

6.3.3.3 Stage 3 Role	Consultant	Economist	Educator	Process Engineer	Production Engineer	Project Manager	Regulatory	Research	Scheduling/Planning	Technical Staff Manager	Technical Task Manager	Technician
Leadership	4	4	3	2	2	4	2	3	2	4	4	3
Presentation	4	4	4	2	2	3	2	3	2	4	4	3
Problem solving	4	4	3	3	3	4	3	4	3	4	4	3
Teamwork	4	4	3	3	3	4	3	3	3	4	4	4
Technical Psychomotor												
Computer Applications	4	4	3	3	3	2	3	4	3	2	4	3
Spreadsheets	4	4	3	3	3	3	3	3	3	3	3	2
Time management	4	4	3	2	2	4	2	2	3	4	4	2
Typing (keyboarding)	3	3	3	3	3	3	3	3	3	3	3	3

6.3.3.4 Stage 4 Role	Consultant	Economist	Educator	Process Engineer	Production Engineer	Project Manager	Regulatory	Research	Scheduling/Planning	Technical Staff Manager	Technical Task Manager	Technician
Affective 1. Receiving 2. Responding 3. Valuing 4. Organizing 5. Internalizing												
Beliefs and Values												
Commitment to lifelong learning	**5**	**5**	**5**	**5**	**3**	**5**	**5**	**5**	**5**	**5**	**5**	**5**
Concern for public welfare	**5**	**5**	**5**	**5**	**4**	**5**	**5**	**5**	**5**	**5**	**5**	**5**
Ethics	**5**	**5**	**5**	**5**	**4**	**5**	**5**	**5**	**5**	**5**	**5**	**5**
Respect for others	**4**	**4**	**4**	**4**	**3**	**4**	**4**	**4**	**4**	**4**	**4**	**4**
Cognitive 1. Remembering 2. Understanding 3. Applying 4. Analyzing 5. Evaluating 6. Creating												
ChE Technical												
Energy balances involving 1st and 2nd law	**6**	**2**	**6**	**4**	**4**	**1**	**4**	**5**	**1**	**2**	**5**	**3**
Equilibria, chemical and phase	**6**	**2**	**6**	**5**	**3**	**1**	**4**	**5**	**2**	**2**	**5**	**3**
Fluid flow, pump & compressor sizing & selection, packed beds	**6**	**2**	**6**	**5**	**3**	**1**	**4**	**6**	**2**	**2**	**5**	**4**
Fluid flow, single-phase flow, two-phase flow (pipes, valves, orifices)	**6**	**2**	**6**	**5**	**3**	**1**	**4**	**6**	**2**	**2**	**5**	**3**
Heat balances with and without reactions	**6**	**2**	**6**	**4**	**4**	**1**	**4**	**5**	**1**	**2**	**5**	**3**
Heat transfer equipment design and analysis	**6**	**2**	**6**	**5**	**4**	**1**	**4**	**6**	**2**	**2**	**5**	**3**
Heat transfer, multiple modes, phase change	**6**	**2**	**6**	**4**	**3**	**1**	**4**	**5**	**2**	**2**	**5**	**3**
Kinetics, conversion in various reactor types, chemical equilibria	**6**	**2**	**6**	**5**	**2**	**1**	**4**	**5**	**2**	**2**	**5**	**3**

6.3.3.4 Stage 4 Role	Consultant	Economist	Educator	Process Engineer	Production Engineer	Project Manager	Regulatory	Research	Scheduling/Planning	Technical Staff Manager	Technical Task Manager	Technician
Kinetics, reactor analysis	**6**	**2**	**6**	**5**	**1**	**1**	**4**	**5**	**2**	**2**	**5**	**3**
Kinetics, reactor design, heterogeneous catalysis	**6**	**2**	**6**	**4**	**2**	**1**	**4**	**5**	**2**	**2**	**5**	**3**
Mass transfer, equipment design and analysis	**6**	**2**	**6**	**4**	**4**	**1**	**4**	**6**	**2**	**2**	**5**	**4**
Mass transfer, single- and two-phase processes	**6**	**2**	**6**	**4**	**3**	**1**	**4**	**5**	**2**	**2**	**5**	**3**
Materials science	**6**	**2**	**6**	**4**	**3**	**1**	**4**	**5**	**3**	**2**	**5**	**3**
Plant design, economics	**6**	**6**	**4**	**3**	**2**	**5**	**3**	**2**	**2**	**3**	**4**	**3**
Plant design, flow configuration, optimization	**6**	**4**	**4**	**5**	**3**	**1**	**4**	**3**	**2**	**2**	**5**	**3**
Plant design, instrumentation	**5**	**4**	**4**	**5**	**2**	**1**	**4**	**2**	**2**	**2**	**5**	**4**
Plant design, process control	**6**	**4**	**4**	**5**	**3**	**1**	**4**	**2**	**2**	**2**	**5**	**3**
Plant operations, optimization	**6**	**6**	**4**	**5**	**3**	**1**	**4**	**3**	**1**	**2**	**5**	**3**
Plant operations, startup, shutdown	**5**	**6**	**3**	**5**	**3**	**1**	**4**	**2**	**4**	**2**	**4**	**4**
Plant scale-up	**6**	**4**	**4**	**4**	**1**	**1**	**4**	**2**	**2**	**2**	**5**	**3**
Separations equipment selection & analysis	**6**	**2**	**6**	**4**	**4**	**1**	**4**	**6**	**2**	**2**	**5**	**4**
Separations process design	**6**	**2**	**6**	**4**	**3**	**1**	**4**	**6**	**2**	**2**	**5**	**3**
Stoichiometry with and without reactions	**6**	**2**	**6**	**4**	**4**	**1**	**4**	**5**	**1**	**2**	**5**	**3**
Stoichiometry, complex systems with recycle, bypass	**6**	**2**	**6**	**4**	**4**	**1**	**4**	**5**	**1**	**2**	**5**	**3**
Cross Functional												
Energy – systems analysis, efficiency	**6**	**2**	**6**	**5**	**3**	**1**	**4**	**5**	**2**	**3**	**5**	**3**
Environmental assessment, regulations	**6**	**2**	**6**	**5**	**3**	**3**	**6**	**3**	**2**	**3**	**5**	**3**

6.3.3.4 Stage 4 Role	Consultant	Economist	Educator	Process Engineer	Production Engineer	Project Manager	Regulatory	Research	Scheduling/Planning	Technical Staff Manager	Technical Task Manager	Technician
Process simulators, operation, steady state simulation, dynamic simulation	6	2	6	4	3	1	5	5	1	3	5	3
Process simulators, strengths and weaknesses	N/A	N/A	N/A	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Safety, analyses, modeling, procedural policies, regulations	6	2	6	5	3	3	5	3	2	3	5	3
Sustainability analyses	6	2	6	5	2	3	5	3	2	3	5	3
Technical												
Biology	6	1	6	4	2	2	3	6	1	1	3	1
Budgeting	6	6	6	4	2	6	3	4	3	4	6	3
Chemistry –inorganic, organic, physical chemistry and biochemistry	6	1	6	4	2	2	3	6	2	1	3	1
Computer programming	6	1	6	5	2	2	3	4	1	3	3	1
Economics	6	6	6	4	2	6	3	5	2	2	3	3
Mathematics – mathematics through ODE	6	5	6	5	3	2	4	5	2	3	4	3
Numerical analysis & linear programming	6	6	6	5	3	2	3	4	2	1	3	1
Physics	6	1	6	4	2	2	3	6	2	1	3	1
Project management	6	1	6	4	1	6	2	2	3	3	6	1
Statistical Quality Control	6	1	6	4	4	2	4	5	2	3	3	2
Statistics – variability, design of experiments	6	5	6	5	3	2	3	6	2	3	2	4
Psychomotor 1. Observing 2. Imitating 3. Practicing 4. Adapting												
Human												
Adjusting communication style	4	3	4	3	3	4	4	4	4	4	4	4

6.3.3.4 Stage 4 Role	Consultant	Economist	Educator	Process Engineer	Production Engineer	Project Manager	Regulatory	Research	Scheduling/Planning	Technical Staff Manager	Technical Task Manager	Technician
Electronic Communications	4	3	3	3	2	3	3	3	3	3	3	3
Identifying optimum delivery media	4	3	4	3	2	4	3	3	3	3	3	3
Listening and interpreting	4	3	4	4	2	4	4	4	4	4	4	4
Negotiation and conflict management	4	3	3	4	3	4	4	4	4	4	4	4
Public Relations	4	4	4	3	2	3	4	3	2	3	4	3
Speaking and presenting	4	3	4	3	2	3	3	3	3	3	3	3
Telephone Communication	4	3	3	3	2	3	3	3	3	3	3	3
Professional												
Critical reflection/learning	4	2	4	4	3	4	4	4	4	3	4	4
Experimental procedures	3	1	4	3	2	2	3	4	1	2	3	2
Leadership	4	2	3	3	2	4	4	3	3	4	4	3
Presentation	4	2	4	3	2	4	3	3	3	3	4	3
Problem solving	4	4	4	4	3	4	4	4	4	3	4	3
Teamwork	3	1	3	3	2	4	4	4	3	4	4	3
Technical Psychomotor												
Computer Applications	3	4	4	3	2	2	3	3	3	3	3	3
Spreadsheets	3	4	3	3	2	3	3	4	3	3	3	2
Time management	4	3	3	3	2	4	3	4	3	3	3	3
Typing (keyboarding)	3	3	4	3	2	2	3	3	3	3	3	3

6.3.4 Role View Observations

Looking at the resulting charts for each of the four career stages the following observations were reached:

- Values and Beliefs competencies increase in the taxonomy level with each career stage, starting at level 2 (Responding to Phenomena) in Stage 1 and increasing to level 5 (Internalizing Values) in Stage 4. At the beginning of a career, individuals are first being exposed to these attributes of professionalism. Individuals achieving Stage 4 exhibit high levels of professionalism.
- In Stage 1, the taxonomy levels for ChE Technical skills are typically at level 1 (Remembering) or level 2 (Understanding). By Stage 3, the taxonomy levels increase by two or three levels across many of

the competencies. In Stage 4, there is not an increase in taxonomy level across most of the competencies – instead, the competencies most relevant to the specific role increase to the higher taxonomy levels while the competencies less relevant to the specific role may diminish in the taxonomy level.

- In Stage 1, the taxonomy levels in cross functional cognitive competencies are somewhat lower than for ChE Technical competencies, indicating that entry level engineers are learning these competencies at the beginning of their careers. Stage 2 generally shows increases in the taxonomy levels for most competencies. However, both Stage 3 and Stage 4 show a divergence, with those competencies most relevant to the specific role increasing to a higher taxonomy level which the competencies less relevant to the specific role may diminish in taxonomy level.
- The observations for cognitive technical competencies are similar to those of ChE Technical.
- In Stage 1, the taxonomy levels are typically at level 1 (Remembering) or level 2 (Understanding) for human skills. Stages 2 and 3 show increasing taxonomy levels for these competencies. Individuals achieving Stage 4 exhibit the higher taxonomy levels for these competencies, reflective of the high level of professionalism expected for Stage 4.
- Technical Psychomotor skills are expected to be advanced at Taxonomy Level 3 (Practicing) at Stage 1. Stages 2, 3, and 4 show small increases in the taxonomy level, with few advancing to taxonomy level 4 (Adapting).

7 Summation and Path Forward

The content of this BOK provides an analysis of knowledge, skills and abilities for chemical engineering professionals working in a variety of roles for a cross section of industries. Stage 1 charts indicate the competency levels approximating that of a new graduate suggesting minimal requirements for BS degree. Stages 2, 3 and 4 indicate how competencies grow through a career and suggest broad topics suitable for continuing education courses. The need for specific topical content will vary by role and industry.

By developing the BOK taxonomy tables to the detail level found in Appendix 5, then collapsing information to prepare the summaries found in the body of the report, the BOK development team verified the concept that professional requirements are shared within industries groups, but may vary between industry groups. Job roles have similar requirements regardless of industry.

The BOK makes no comparison with ABET requirements or define a framework for continuing education programs. The BOK teams hopes that the information in this report is useful to ABET and AIChE or other continuing education providers as they develop program requirements.

The BOK team attempted to provide solid professional analysis of KSAs required for a chemical engineer. Comparing this BOK to other engineering disciplines shows that education programs and goals differ between disciplines. Chemical engineers graduate with the basic set of knowledge and skills at a relatively low cognitive level. They then hone their abilities by on-the-job training and short courses on topics related to their industry and unavailable through formal education. The KSAs provided in this BOK should be useful in guiding the education efforts of AIChE, and may be of use to other interested users.

A1. Appendix 1 – Abbreviations and Acronyms

Abbreviation	Definition
ABET	Accreditation Board for Engineering and Technology
AIChE	American Institute of Chemical Engineers
AM	Analysis modeling
BOD	AIChE Board of Directors
BOK	Body of Knowledge
BS	Bachelors of Science
CEOC	Career and Education Operating Council; AIChE leadership body responsible for oversight of educational, professional and financial needs of AIChE members and stakeholders
CEP	*Chemical Engineering Progress* an AIChE publication
CFSE	Certified Functional Safety Engineer
ChE	Chemical Engineer
CPI	Chemical process industries
EH&S	Environmental Health & Safety
EPA	Environmental Protection Agency
EPE	Examinations for Professional Engineers; NCEES committee responsible for overseeing FE and PE exam development
F.AIChE	AIChE Fellow
FE	Fundamentals of Engineering
KSA	Knowledge Skills and Abilities
LLC	Limited liability corporation
LNG	Liquefied natural gas
MBA	Masters of Business Administration
MS	Masters of Science
NA	Not asked
N/A	Not Applicable
NCEES	National Council for Examiners for Engineering and Surveying
NSPE	National Society of Professional Engineers
ODE	Ordinary differential equations
OSHA	Occupational Safety and Health Administration
PAKS	Professional Activities and Knowledge Skills. The surveys NCEES conducts to assure that the content of licensure exams is relevant to engineering knowledge required.
PE	Professional Engineer
PhD	Doctor of Philosophy
PSM	Process Safety Management
R&D	Research & Development
RE	Reaction engineering
UO	Unit operations

A2. Appendix 2 – Taxonomy Definitions

The following definitions describe the BOK team interpretation of category labels used in the charts. Definitions are sequenced in the tables in the same order that they appear in the charts. The definitions were developed by the BOK team specifically for use within the context of this BOK.

A2.1 Knowledge & Skills

Affective Domain	
Beliefs and Values	
Commitment to lifelong learning	The is acceptance and adherence to a policy to continually strive to improve one's skills, knowledge and professional practice by all means of education or training both formal and informal.
Concern for public welfare	The sincere concern for public welfare. It should certainly include the users of any products or processes for which one has responsibility, but also include all aspects of the general public safety.
Ethics	The body of beliefs and principles that should govern one's operations within a certain field. It goes beyond just compliance with rules and regulations and should aim at ensuring highest quality of goods and services, as well as public safety.
Respect for others	The need to have knowledge of the customs and beliefs of others and understand how they might be affected by your actions.
Cognitive Domain	
Chemical Engineering Technical	
Energy balances involving 1st and 2nd law	Energy balances represent calculations on the energy flows within a well-specified system including a direction of transport. Examples include heat transfer considerations, thermodynamic process cycles, and state changes such as heat exchangers, Rankine cycle, Joule-Thompson effect, etc. This category does not include fluid flow calculations (Bernoulli Equation).
Equilibria, chemical and phase	Thermodynamic balance between chemical species in reactive systems (chemical equilibrium) and components in two or more phases (phase equilibrium).
Fluid flow, pump & compressor sizing & selection, packed beds	Fluid flow applications that involves calculations related to pumps, packed beds, compressors, cyclones and other complex equipment.
Fluid flow, single-phase flow, two-phase flow (pipes, valves, orifices)	Applications of fluid mechanics to single- and multiple-phase flow that include calculations related to flow rates, Reynolds numbers, head, pressure drop, and hydrostatics.
Heat balances with and without reactions	Heat balances account for heat absorption or release due to transitions such as phase change, reaction (endothermic or exothermic), mixing, etc.

Heat transfer equipment design and analysis	This area of practice requires knowledge needed to design or specify the equipment used for heat exchange including practical troubleshooting.
Heat transfer, multiple modes, phase change	Heat transfer phenomenon includes conduction, convection, and radiation and also accounts for phase changes (evaporation, melting, sublimation, condensation, etc).
Kinetics, conversion in various reactor types, chemical equilibria	Study of chemical reaction rates, and conversion on ideal and real reactors. Also considers effect of temperature and pressure on reaction selectivity.
Kinetics, reactor analysis	Evaluation of existing reactors with regard to reaction rate, order, concentration and type of reactor.
Kinetics, reactor design, heterogeneous catalysis	Study of the influence of catalysts that exist in a distinct phase (different from one or more of the reactants). Also considers flow distributions and catalyst poisoning. Study of ideal and real reactors.
Mass transfer, equipment design and analysis	Practice of using mass and energy balance calculations to design equipment for separations processes and or other complex unit operations
Mass transfer, single- and two-phase processes	Transport of a chemical specie or multiple species among or between distinct phases.
Materials science	Materials science is the field of study focused on materials and their various properties with an emphasis on synthesis and uses in a variety of applications.
Plant design, economics	This is the practice area that requires specific knowledge of the costs of various types of process equipment and the design factors affecting those costs, as well as the practical experience of operation required to include operating costs.
Plant design, flow configuration, optimization	This field of practice deals with the design of overall plants to optimize flows and overall plant performance, typically using process flow diagrams.
Plant design, instrumentation	Design of instrument and sensing systems for required monitoring of plant operations
Plant design, process control	Design of control systems and required sensors to ensure controlled plant operation
Plant operations, optimization	This area requires a fairly comprehensive familiarity with overall plant operations and the ways different units and processes interact so as to be able to optimize the plant performance with regard to chosen variable(s).
Plant operations, startup, shutdown	This is the specialized area of practice that includes detailed knowledge of general plant operations and how to most efficiently and safely start up a process line from a cold start and also how to shut down units. These practitioners require a certain amount of theoretical understanding, as well as extensive field experience.
Plant scale-up	This is the field of expertise that deals with scaling up of the equipment size and flows of reactants and products so as to move a process from a smaller scale to a larger scale while still

	turning out product that meets all specifications in an economical fashion.
Separations equipment selection & analysis	This is the area requiring specific knowledge of both the theory, as well as practical aspects of equipment required for achieving various types of separations. It could broadly include a number of sub-disciplines such as distillation columns, absorption/adsorption units, centrifuges and many other types of specific pieces of equipment.
Separations process design	This is the field of practice involved with the design of processes that result in the separation of components of a mixture based on differences in properties of the individual components.
Stoichiometry with and without reactions	Stoichiometry represents the quantitative aspects of chemistry. It includes balancing chemical reactions, mass and mole fractions, and mixing. It includes the laws of conservation of mass and the law of constant proportions.
Stoichiometry, complex systems with recycle, bypass	This is similar to general stoichiometry, but allows for recycle or bypass of non-reacted or partially reacted mixtures.
Cross Functional	
Energy - systems analysis, efficiency	This discipline requires knowledge of energy generation and energy transfer, as well as thermodynamics and some engineering economics.
Environmental assessment, regulations	This study area requires a general familiarity with environmental standards and regulations as they are applied in practice and how and when to use the various models or impact assessment tools available.
Process simulators, operation, steady state simulation, dynamic simulation	This area involves a familiarity with both computer simulation models and the underlying principles of mass and energy balances, fluid dynamics and separations.
Process simulators, strengths and weaknesses	The strength of a good process simulator is that it lets one explore a wide range of process scenarios quickly and economically to determine which design parameters might have the best potential for a particular project. It will work best when the mechanism underlying a process is well understood and defined and the simulation is performed over a well-defined domain. The weakness inherent in the use of simulators is that the user may apply a simulator to a situation or set of parameters where the logic or basic tenets inherent in the simulator are not applicable and the user may not have the experience required to recognize unrealistic results.
Safety, analyses, modeling, procedural policies, regulations	This cross functional area requires a basic understanding of process safety principles and hazard analysis techniques, as well as a general understanding of the applicable regulations.
Sustainability analyses	This field requires an understanding of the basic principles of sustainability and life cycle assessments and how to use these in practice.

Technical	
Biology	Biology deals with the study of life and living organisms, including their structure, function, growth, evolution, distribution, population interactions, and taxonomy.
Budgeting	Budgeting involves the allocation of available funds within a project, department, company or governmental entity. It requires knowledge or estimates of cash flows, expenses, costs of labor and materials.
Chemistry –inorganic, organic, physical chemistry and biochemistry	Chemistry deals with the properties, composition, interaction, and changes in matter. This can include organic (carbon based) and inorganic chemicals, physical chemistry, thermodynamics or chemistry of living organisms (biochemistry).
Computer programming	Computer programming involves activities such as algorithm development, compilation, testing, application, and analysis in order to perform computer based tasks or operations automatically. These process involves implementation of an algorithm (or coding) in an appropriate variety of programming languages and or software packages.
Economics	Economics analyze the financial flows related to process equipment cost, maintenance, labor, and materials use-production. In chemical engineering, applications of economics usually involves cost engineering and the knowledge and tools that are used to determine the relative economic viability of a project and day-to-day production.
Mathematics	For engineers, this generally involves the application of analytical tools and methods that could include algebra, geometry, trigonometry, calculus, and differential equations.
Numerical analysis & linear programming	Linear programming and numerical analysis are both methods for solving complex mathematical problems. Linear programming is used to obtain best results of a set of variables assuming linear interaction between variables. Numerical analysis refers to the use of quantitative approximations with metrics that include error analysis and boundary evaluation to determine quantitative answer or model a system.
Physics	Physics covers the study of matter and its motion through time and space and its relationship to energy.
Project management	Project management is the act of planning, organizing, and controlling available resources to achieve a specific goal. For chemical engineers, projects are often the design or retrofit of a unit operation or large multi-step process but can also include research and documentation projects.
Statistical Quality Control	The application of statistical methods that makes use of representative sampling to ensure that a product meets specifications (i.e. quality assurance). Knowledge required is related to sample sizes, confidence interval, standard deviation, acceptance criteria, etc.

Statistics – variability, design of experiments	Chemical engineers use statistics when analyzing the variability of a process by looking at distributions, means and outliers. The results from the statistical analysis can be used to validate a new process or check performance of an existing one. Design of experiments is a method to minimize the number of experiments required by determining the effect of the input variables on the product and using this information to identify sets of experimental conditions that deliver the most information.
Psychomotor Domain	
Human	
Adjusting communication style	This is the ability to adjust communication style to more effectively communicate in a different personal, cultural or societal environment.
Electronic communications	This is the ability to use a variety of electronic media (texting, e-mails, social media, etc.) in a facile and appropriate way to communicate with others.
Identifying optimum delivery media	This involves the skill of being able to find the most effective media to fit the intended audience so that a message is most effectively delivered and has the best chance of being well understood.
Listening and interpreting	This is an ability to listen to what others are saying and correctly understand what is said well enough to interpret and use it in a practical way.
Negotiation and conflict management	This is the art of trying to resolve potentially contentious differences between parties in a manner that best allows for the development of viable solutions to a variety of different problems.
Public relations	This is the ability of disseminating information in a manner that is not only accurate but helps to put forth and promote a certain image that may be required or desired.
Speaking and presenting	This is the ability to present information effectively in a way that others can understand and assimilate.
Telephone communications	This reflects the ability to use the telephone most effectively to both understand what the other party means and to convey in a culturally acceptable manner the message you wish to disseminate.
Professional	
Critical reflection/learning	This is the ability to critically reflect on new learnings and continually implement into ongoing projects and practices.
Experimental procedures	Experimental procedures deals with one’s knowledge of experimental practices and procedures to develop data useful in addressing design or operation problems encountered in real life.

Leadership	This is a skill that allows one to motivate and guide a group or organization to achievement of an optimal solution. Proper application of this skill can lead to a better solution more quickly than could be reached by individuals working alone.
Presentation	This is the skill of being able to assimilate, organize and present or communicate information in a fashion that is both understandable and designed to engage the recipients in the process.
Problem solving	Problem solving deals with one's ability to analyze, define and segment various types of problems and develop efficient and cost effective solutions.
Teamwork	Teamwork is the ability of individuals to work effectively in groups that have diverse skills, abilities, personalities and cultures to solve specific problems. It entails the ability to put aside personal or individual concerns to achieve the optimal solutions.
Technical Psychomotor Skills	
Computer Applications	This is the familiarity with required computer applications.
Spreadsheets	This is the ability to use different applications of spreadsheet programs in an effective and efficient manner for a variety of engineering purposes.
Time management	This is the ability to manage one's time effectively and in a manner that allows for the completion of multiple tasks in a way that prioritizes, but also ensures that all required deadlines are met or addressed in an accepted fashion.
Typing (keyboarding)	This is the ability to quickly and accurately use a keyboard for computer applications.

A2.2 Industry

Petrochemicals, Oil & Gas, LNG, Industrial Gases	Fuels such as oil & gas and LNG are generally used for transportation and energy production. Petrochemical are chemical produced from petroleum feedstocks. Industrial gases are products of petrochemical and separation processes, as well as cryogenic products.
Polymers, Resins, Synthetics	Tend to be organic compounds typically consisting of long chain hydrocarbons with other species such as O, N, etc. present. Polymers are long chains of repeating units (monomers).
Pulp and Paper	This industry includes all operations that produce paper, cardboard or other cellulosic products.
Specialty Chemicals/Chemical Products	Relates to chemicals which may be intermediates for other industries. Examples include adhesives, cleaning materials, cosmetic additives, construction chemicals, catalysts.
Synthetic Fuels and Alternative Energy	This field includes anything that relates to the production of fuels (by biochemical or thermochemical processes) through the processing of waste or biomass or by utilization of non-fossil

	fuel energy sources such as solar, wind, tidal, hydrothermal or similar sources.
Academia	This field includes professors and lecturers providing formal technical education in universities. Primary format is through lectures, assignments and exams. E-learning and continuing education programs might be involved. Preparing research proposals, conducting research programs, directing graduate students and publishing technical papers is usually performed.
Biotechnology, Pharmaceuticals	Biotechnology uses microorganisms and genetically modified cells to produce valuable compounds including therapeutics. Pharmaceuticals are human therapeutics typically made utilizing chemical engineering principals and processes.
Consumer Products including Soaps, Detergents, Perfumes, Fats, Oils, and Cosmetics	This industry produces products with very specific properties either directly for consumers or for a producer who is likely to use the intermediate product to manufacture specific consumer products.
Food	This is the industry that involves the development, processing, production, preservation and packaging of food.
Aerospace, Automotive, Electronics,	These industries tend to deal with products that utilize or contain specialized materials and which may involve both chemicals and electronic components. May also involve electronics can involve toxic and hazardous gases, detection systems, scrubber design and life safety systems.
Catalysts	This industry deals with the production of catalysts used in the manufacturing of chemical, petrochemical or refining operations. These products are generally of high value and the production generally uses specialized and proprietary information.
Ceramics, Glass	Inorganic, nonmetallic solids prepared by heating followed by cooling.
Metals	Generally solid material that is hard, shiny, ductile, with good electrical and thermal conductivity (e.g., iron, gold, silver, copper, and aluminum, and alloys such as brass and steel, etc.).
Nanotechnology	These include industries that deal with the manipulation of matter at the molecular and atomic levels to create a wide variety of nanoscopic devices or products that often possess very difference properties than on the macro level. The following industries most prominently include nanotechnology segments: semiconductors, materials including textiles and tires, medicine and medical equipment, sensors and other types of instrumentation, automotive and aviation, food, packaging, cosmetics and other consumer products. The number of different applications and affected industries are rapidly growing.
Nuclear Energy	This is the industry that involves the generation or use of nuclear energy. It includes utilities that generate nuclear energy, as well as suppliers of equipment or services such as nuclear

	reactors and the engineering companies that design and construct the overall facilities. It might also be considered to include those using nuclear energy in a research environment.
Environmental, Health and Safety	This industrial field includes all who specialize in the analysis, impact assessment of facility or product design that might affect EH&S.
Government	Government entails a number of different work areas that can include regulatory oversight, standards and enforcement, legislative support, standard setting, as well as research and/or research management.

A2.3 Role

Consultant	This is an engineer who is working either as external or internal consultant and is expected to have more specialized knowledge of a specific subject area.
Economist	An engineer working in production planning with knowledge of engineering economics, capital planning, production and maintenance costs and return on investment.
Educator	An individual who is teaching some subjects relating to chemical engineering whether as a full-time faculty member, adjunct faculty or instructor in a continuing education program.
Checker	This individual is one with the responsibility for verifying calculations for technical accuracy.
Process Controls Engineer	An engineer who designs or specifies controls required on a specific process and then monitors and trouble shoots problems with controls and required instrumentation.
Process Design Engineer	An engineer working on some aspect of process design who should have knowledge of mass and energy balances, process flow diagrams and process equipment, for large grassroots capital projects or for smaller plant modification.
Safety Systems	This individual is expected to have specialized knowledge of the equipment that specifically affects safety.
Standard Setter	This is a an individual with more in depth technical knowledge that allows them to help in the establishment of general standards, codes and best practices for design or operation.
Flow assurance (upstream engineering)	An engineer responsible for ensuring oil and/or gas flows unimpeded from the wellhead to the processing facility. Includes knowledge of prevention and remediation methods involving blockage by waxes, asphaltenes, scale and hydrates.
Operations Quality Control	An individual with responsibilities for ensuring that products or processes meet the technical specifications both initially and over time.
Production Process Engineer	An engineer who supplies day to day support for a production process.
Project Manager	The individual who has overall responsibility, including financial, for a project.

Auditor	Person with responsibility for checking that procedures are followed and that that proper documentation occurs.
Environmental Engineer	This individual has responsibility for the relationship with the environmental regulators and following the regulatory process and meeting the requirement. The environmental engineer can work either for a producer or consulting firm and may design environmentally related processes.
Regulator	This is a staff member for a governmental agency that has responsibility for administering and ensuring compliance with standards and laws. These are most often environmental or safety regulations, but could include other regulatory.
Safety Engineer	An individual responsible for the safe design and production implementation of a process or product and for compliance with all appropriate standards, practices and regulations, as well as continuing risk assessment and reduction.
Industrial Researcher	This individual works in areas of applied or fundamental research. The research could be related to developing new products or processes or improving the efficiency and cost effectiveness of existing products/processes. The individual could be working for an industrial firm or under contract to a specific company.
Product Applications Engineer	An engineer who specializes in the various applications of a specific product or product line and who can help solve technical problems that might arise from the use of specific products.
Maintenance Engineer	An engineer specializing in appropriate and good maintenance procedures application.
Planner In Production	This individual has responsibility for tracking and reporting on day to day productivity. In project planning and maintenance planning, this individual deals with job details including equipment specifications, procurement, and costs.
Scheduler	This is an individual that is responsible for developing schedules for specific projects or ongoing production lines. The responsibilities include monitoring progress, modifying accordingly and reporting.
Technical Staff Manager	This individual has management responsibility for a technical staff with an emphasis on administrative rather than purely technical job aspects.
Technical Task Manager	An engineering manager responsible for seeing that the technical aspects of a job are done correctly. This includes ensuring that the latest and most appropriate technical information is applied.
Marketing & Sales Engineer	An engineer who conducts marketing and sales. Often this individual will deal with one line of products (specific chemicals or processes). For equipment sales, this may be a technical, specialized design engineer.

Operator/Technician	This is someone who has specific responsibility for ensuring that a specific process line is operating properly. This individual deals with many process excursions both efficiently and safely.

A3. Appendix 3 - Data and Demographics

This appendix provides data which helped the BOK development team to determine the knowledge, skills and abilities (KSA) required for chemical engineers. The appendix includes data from three sources:

- A 2014 survey on occupations and industries that new graduates entered;
- A 2013 salary survey provides work demographic information for currently employed AIChE members;
- Professional Engineer licensure exam specification knowledge as determined by a survey of licensed chemical engineers.

The first two data sets provided an initial foundation for the industry and role lists in the KSA matrix. The third was a starting point for knowledge and skill list.

A3.1 Career Plans for Recent Chemical Engineering Graduates

AIChE periodically collects data on the immediate plans of chemical engineer graduates for all degree levels. The BOK team worked with information from earlier surveys which are consistent with the updated information presented here. The latest was conducted in 2014 (*2014 ChE Graduation Plans Report*, Phillip Downs, Joseph St. Germain and Rachael Powell, October, 2014. Results summarized in "AIChE's Initial Placement Survey: Where is the Class of 2014?" *CEP*, **110** (11) 5, Nov, 2014). Both department chairmen and students were polled. Because AIChE plans to survey only graduates in the future, only graduate survey results are presented here. Table A.3.1 presents an overview of the 1361 BS, 38 MS and 73 PhD respondent's answers. Table A.3.2 shows the breakdown of industries graduates selected and Table A.3.3 shows education plans for those seeking additional degrees. Because AIChE considers the PhD as the final degree level, PhD graduates were not asked if they had additional education plans. Values in A.3.2 and A.3.3 represent the fraction of total responses. The term "NA" denotes "Not Asked".

Table A.3.1. Overview of graduate employment plans for chemical engineers at each degree level in 2014

Employment Plans	B.S.	M.S.	Ph.D.
Unemployed	18.2%	28.6%	39.7%
Unknown	0.0%	0.0%	0.0%
Returning to home country	0.5%	0.0%	4.1%
Government Employment	1.9%	2.9%	0.0%
Academic Employment	NA	0.0%	26.0%
Industrial Employment	50.5%	34.3%	30.1%
Other Employment	4.7%	11.4%	0.0%
Continuing Education	24.1%	22.9%	NA
Total	100.0%	100.0%	100.0%

Table A.3.2. Industrial career plans for chemical engineers at each degree levels. Values based upon total responses.

Industry	B.S.	M.S.	Ph.D.
Chemical	10.10%	2.90%	4.10%
Fuels	10.80%	8.60%	8.20%
Food and Consumer Products	5.10%	5.70%	1.40%
Materials	3.60%	2.90%	1.40%
Engineering services - Design and construction	3.70%	2.90%	0.00%
Business services	0.80%	0.00%	0.00%
Biotechnology, pharmaceuticals, and related industries	4.30%	0.00%	4.10%
Other	4.90%	5.70%	1.40%
Electronics	2.50%	2.90%	5.50%
Engineering services -Environmental engineering	1.20%	0.00%	0.00%
Utilities	0.90%	0.00%	0.00%
Pulp and paper	1.80%	0.00%	0.00%
Engineering services - Research and testing	0.60%	2.90%	4.10%
Aerospace	0.00%	0.00%	0.00%
Industry total	50.5%	34.3%	30.1%

Table A.3.3. Additional education plans for chemical engineers at B.S. and M.S. levels. Values based upon total responses.

Additional Education	B.S.	M.S.
Chemical engineering	13.9%	22.9%
Medical	3.4%	0.0%
Other engineering	1.0%	0.0%
Legal	0.3%	0.0%
Other science	2.0%	0.0%
MBA	0.6%	0.0%
Other	1.3%	0.0%
Continuing Education Total	16.3%	22.9%

A3.2 Career Fields of Working Population.

Every two years, AIChE conducts a salary survey which collects information on where practicing chemical engineers work. The latest survey was in 2013 (*Chemical Engineering Progress* (CEP), June 2013). Table A.3.4 below gives distribution of industries for those responding to the survey. Table A.3.5 shows the distribution of job functions for survey respondents.

Table A.3.4. Distribution of industries employing chemical engineers based upon 2013 Salary Survey.

Industry	Percent	Industry	Percent
Specialty Chemicals	11.9 %	Materials and Composites	1.5 %
Engineering/ Design/ Construction/ Consulting	11.8 %	Agricultural Chemicals	1.5 %
Petroleum Production/ Refining	8.2 %	Equipment Manufacturing	1.5 %
Education	7.7 %	Nuclear Energy and Allied Fields	1.5 %
Commodity Chemicals	4.5 %	Business/ Finance/ Law/ Insurance	1.4 %
Pharmaceuticals	4.0 %	Public Utilities	1.4 %
Biotechnology/ Life Sciences	3.9 %	Industrial Gases	1.3 %
Environmental Engineering	3.5 %	Software	1.3 %
Research & Development (R&D)	3.3 %	Safety and Health	1.1 %
Petrochemicals and Petroleum Products	3.2 %	Forest Products/ Pulp and Paper	1.1 %
Foods and Beverages	2.9 %	Oilfield Services and Exploration*	1.0 %
Government	2.8 %	Electronics/ Computers*	1.0 %
Plastics and Rubber Products	2.4 %	Paints and Coatings*	0.9 %
Catalysts	2.4 %	Aerospace/ Aeronautics/ Astronautics*	0.6 %
Other	2.4 %	Automotive*	0.6 %
Natural Gas	2.3 %	Soaps/ Detergents/ Perfumes/ Cosmetics*	0.6 %
Alternative Energy Sources	2.1 %	Synthetic Fibers/ Textiles/ Films*	0.6 %
Metals/ Metallurgical Products/ Minerals Processing	1.7 %	Total	100.0 %

*Number of responses too small to be statistically accurate.

Table A.3.5. Distribution of job functions for chemical engineers, based upon 2013 Salary Survey.

Job Function	Percent	Job Function	Percent
Research and Development	16.52%	Technical Service	2.49%
Process Engineering	15.58%	Government/Regulatory Affairs	2.13%
Consulting	8.05%	Design	2.00%
Engineering, Procurement and Construction	6.54%	Instrumentation and Control Engineering	1.96%
Education-Non Consulting	6.26%	Finance/Law/Licensing*	1.19%
Process Safety, Health and Loss Prevention	5.15%	Product Engineering*	1.10%
Operations and Maintenance	4.33%	Quality Control*	0.90%
Environmental Engineering /Sustainabiity	3.76%	Other*	0.82%
Management-Corporate/General	3.48%	Planning and Economics*	0.78%
Project Management	3.43%	Information Management*	0.70%
Sales and Marketing	3.15%	Equipment Manufacturing*	0.65%
Education- Consulting	2.94%	Purchasing*	0.25%
Project Engineering	2.82%	Software and Programming*	0.25%
Plant Management	2.53%	Supply Chain and Logistics*	0.25%
		Total	100.00%

*Number of responses too small to be statistically accurate.

A3.3 Exams for Professional Licensure.

While the BOK does not focus specifically on the knowledge required for licensure, the content of the Fundamentals of Engineering Exam (FE Exam) and Professional Engineering Exam (PE Exam) specifications provide insight into what knowledge is important for chemical engineers. NCEES conducts a Professional Activities and Knowledge Skills (PAKS) Survey every six to eight years for both exams. Its purpose is to ensure that the exams are testing currently relevant chemical engineering knowledge. The groups setting exam specifications consist of both academic and industrial members. Academic members are in the majority for the FE Exam while practicing engineers dominate the PE Exam group. Table A.3.6 Presents the FE Exam specifications, effective January 2014.

Table A.3.6. Exam specifications for Chemical FE Exam as of 2014

	Knowledge Category	Approximate % of Exam
1	Mathematics	8%
2	Probability and Statistics	4%
3	Engineering Sciences	4%
4	Computational tools	4%
5	Materials Science	4%
6	Chemistry	8%
7	Fluid Mechanics/Dynamics	8%
8	Thermodynamics	8%
9	Material/Energy Balances	8%
10	Heat transfer	8%
11	Mass transfer and Separation	8%
12	Chemical Reaction Engineering	8%
13	Process Design and Economics	8%
14	Process Control	5%
15	Safety, Health and Environment	5%
16	Ethics and Professional Practice	2%
	Total	100%

The PE Exam is designed to measure minimum competency of a practicing chemical engineer with four to six years of practical experience. Table A.3.7 shows the specifications of the Chemical PE Exam as of 2011. Because this BOK's purpose was to provide guidance for developing AIChE training courses, Table A.3.7 presented a starting point for defining the important technical knowledge domains.

Table A.3.7. Exam specifications for Chemical PE Exam as of 2011.

Knowledge Category	Approximate % of Exam	Description of Category
Mass-energy balances & thermodynamics	23%	10% mass balance; 13% thermodynamics
Heat transfer	16%	Including mechanisms, application, measurement
Kinetics	11%	Includes parameters, reactor design, heterogeneous reactions
Fluids	16%	Including properties, application, measurement,
Mass transfer	14%	Includes phase equilibria, separation processes, equipment,
Plant design and operation	20%	Includes economics, design, safety, environmental, materials, process control

Copies of the full specification can be downloaded at http://ncees.org/exams/.

A4. Appendix 4 – 2013 Study on Preparing Students for Industry.

In November 2013 at the AIChE National meeting a plenary session was held to address the question of how effectively academia prepares chemical engineers for the demands of Industry. The April 2014 issue of *Chemical Engineering Progress* included an article communicating findings of the plenary session. The BOK team felt that the points addressed in the session provided independent validation of the diverse concerns experienced in chemical engineering profession. A copy of the article is reproduced below.

How Well are We Preparing ChE Students for Industry?

www.aiche.org/cep April 2014 **CEP**, p. 4, 5, 13-15

The chemical engineering domain of expertise continues to expand as new fields of research arise based on chemical engineering fundamentals. Chemical engineers continue to be leaders in the traditional chemical process industries (CPI), but can now also be found in horizon areas such as biological engineering and nanotechnology. With this ever-expanding scope, AIChE continues to monitor and explore the chemical engineering curriculum and student preparedness for the industrial sector. This subject was recently addressed at a special plenary organized by the late John Chen*, AIChE Fellow, Past President of AIChE, and Emeritus C. R. Anderson Professor and Dean of Engineering at Lehigh Univ., at the AIChE Annual Meeting in San Francisco, CA, this past November.

Leaders from several major chemical companies, including Dow Chemical, Air Products, and others, have recently voiced their concern about the changing field of chemical engineering, indicating a growing imbalance in faculty interests/expertise and in graduates' capabilities or lack thereof.

What is industry looking for in chemical engineers? Are these needs being met? To answer these questions, leaders from several industries that employ chemical engineers (chemical, petroleum, and pharmaceutical) provided their perspective at the plenary.

From the traditional CPI, Rui Vogt Alves da Cruz, Associate Director of Research and Development at Dow Chemical Co., informally surveyed 93 of his colleagues - leaders and/or recruiters in the three main areas of chemical engineering: engineering and design, manufacturing, and research and development - about what a typical chemical company looks for in its newly hired chemical engineers. He asked them to rate the importance of skills and expertise in six key areas that Chen had identified:

- unit operations (UO), including thermodynamics, transport phenomena, separations, particle technology, and related areas
- reaction engineering (RE), including kinetics, catalysis, and related areas
- analysis and modeling (AM), including simulation, process control, and related areas
- materials, including materials science, surface science, polymers, and related areas
- bio, including biotechnology, medical science, life sciences, and related areas
- nano, including nanotechnology, nano applications, and related areas.

On a scale of 1 to 5, with 5 being most important, the Dow respondents rated the key chemical engineering skills as follows: UO, 4.6; RE, 4.0; AM, 4.0; materials, 3.2; bio, 2.1; and nano, 1.8.
"The results highlight the importance of what we call the chemical engineering core disciplines,"

Cruz said. "So unit operations clearly came in first; reaction engineering second; analysis and modeling third; and materials science, especially in some areas of research and development, fourth," he reported.

Next, Cruz asked these colleagues to assess the proficiency of the chemical engineers they had hired over the last five years in each of the six areas of expertise.

"Even though those were the chemical engineers we interviewed, we brought in for site interviews, we made offers to based on the skills we sought - there were still considerable perceived gaps in unit operations, analysis and modeling, and material sciences," he noted.

In addition to the six areas of expertise that Chen identified, Cruz asked his colleagues to also rate the importance of several other skills and competencies: communication and presentation skills (4.7), project management (4.3), process and lab safety (4.2), equipment design and instrumentation (3.9), design of experiments and statistics (3.8), programming skills (3.4), and analytical methods (3.3).

"When asked the follow-up question about how satisfied they were with the proficiency of the chemical engineers they hired in each one of these areas, major gaps were identified in communication and presentation skills, project management, process and lab safety, and especially in the design of experiments and statistics," Cruz said.

Subsequent discussions among those who participated in Cruz's inquiry provided some anecdotal observations regarding chemical engineering hires. For example, manufacturing and engineering leaders expressed their concern with some graduate chemical engineers' lack of familiarity with equipment and lack of mechanical skills. They cited instances of candidates who had very little exposure to pumps, heat exchangers, and distillation columns during their course work, which, Cruz emphasized, is extremely important for engineers who will be designing and operating chemical processes.

From the petroleum sector, Ashok Krishna, Vice President of Downstream and Chemical Technology at Chevron Coip., conducted a similar poll of about 100 of his colleagues. adding the categories of process engineering/design and process safety, and business skills, which includes technical writing, presentations, and communications.

Krishna's colleagues ranked the importance of the eight categories to the petroleum industry in descending order as follows: process engineering (high), unit operations (high), analysis and modeling (high), business skills (high), materials (medium-high), reaction engineering (medium-high), nano (low), and bio (low).

"Not surprisingly, the results are almost a match to what Dow found internally," Krishna said. "Clearly from our point of view, as for the chemical industry, we still need lots of folks who understand unit operations, basic distillation, thermodynamics, reaction engineering, modeling, and process control. Process design, process engineering, and process safety are also very important for us."

The Chevron participants also noted a gap between what is needed in industry and what new hires are bringing to the table.

"Again, not a big surprise. We find that they're not quite as skilled as we'd like them to be," Krishna said. He added that this is particularly the case with regard to materials science, process engineering and design, analysis and modeling, and business skills.

Krishna specifically emphasized the importance of process safety and process control to the petroleum industry - and ChE graduates' lack of preparedness in these areas. "We do see a gap in process safety," Krishna noted. "More and more, we're dealing with aging plants ... So the idea of having engineers who understand the concept of process safety and the tools available to eliminate all loss of containment is an emerging area of concern to us."

Steven Poehlein, principal at Elixir Pharma Consulting, LLC, drew on his vast experience (previously, he held a range of technical, managerial, and executive positions at Merck) to shed some light on the needs of the pharmaceutical industry.

The pharmaceutical industry is unique in many ways, he noted, particularly in the complexity and diversity of the unit operations that an engineer will encounter. This, combined with the global nature of the business, the complex supply chains, and the necessity to ensure the safety and efficacy of each and every drug that is manufactured, makes this industry particularly challenging, Poehlein added.

What does the pharmaceutical industry need in today's chemical engineering graduates? Poehlein provided the following list: understanding of the fundamentals; demonstrated ability to apply fundamentals to new unit operations and control strategies; literacy in process economics and cost structures; ability to work cross-functionally; ability to apply process technology to either manual or automated plants; and a deeper understanding of analytics and measurements. Poehlein's ranking of importance of the key chemical engineering areas of expertise was similar to those found by Cruz and Krishna, with the exception of bio, which he ranked more important for pharmaceuticals: UO (5), RE (5), AM (4), bio (4), materials (3), and nano (2).

The academic aspect

Chen spearheaded the effort to review what faculty are emphasizing. He evaluated the current distribution of faculty expertise and strengths by surveying all of the ABET-accredited chemical engineering departments in the U.S. and asking department chairs to assess the expertise of each of their faculty members in six areas. It is important to note that the response rate was low (40%), so the results should be viewed more qualitatively than quantitatively, stated Chen. These data were combined with data obtained from websites of several universities that did not respond to the survey to give a data pool of 40 departments representing 708 faculty members.

Collectively, the responses paint a qualitative picture of today's chemical engineering faculty.
The most prevalent field of specialization is bio, followed by materials, unit operations, analysis and modeling, reaction engineering, and finally nano.

"The most important for the current faculty, the highest concentration, the greatest investment by the academic department, is bio," Chen said.

This is particularly true among the more-junior faculty members, with a higher concentration of bio (and a correspondingly lower concentration of unit operations) among the assistant professors. The reverse is true for the more-senior faculty, with bio being less prevalent and unit operations more prevalent among emeritus professors. This observation raises questions about what this means for the future.

"The greatest strength in almost all departments is bio," Chen said. "The three areas that are often called core areas - unit operations, reaction engineering, and materials science - are at best moderate. I think they're rather weak," he continued. "The question is, is that important to the future of the profession?"

There does appear to be more collective faculty expertise in these newer topics of biotechnology and biological engineering. But it is not clear if the evolution of the new interest areas are at the expense of strength in so-called core chemical engineering disciplines such as stages of operations and process engineering. Could this apparent mismatch of faculty expertise and interest have consequences for industry's needs - both in terms of the graduates hired by companies as well as the research carried out by universities, which eventually trickles into industrial practice?

"Many have noticed that there seems to be a shift in expertise of chemical engineering faculty over the years," said Jim Hill, a professor of chemical engineering at Iowa State Univ. "The question arises, does it matter? As we lose faculty members or experts in traditional core areas of chemical engineering, will this have any effect on the needs of industry?"

Assessing the change
Change is inevitable - moment to moment, day to day, decade to decade, nothing stays the same. However, some changes are more drastic and deserve further scrutiny.

Several participants at the plenary feel this may be the case based on the changes being observed in the field of chemical engineering. While chemical engineers hold expertise applicable to a broad range of jobs, their function has historically been based on core chemical engineering skills related to unit operations, transport phenomena, thermodynamics, etc. Thus, questions arise:

- Has there been a statistically significant change in faculty interests and expertise among U.S. chemical engineering departments over the past decade?
- If so, is this change impacting the capabilities of chemical engineering graduates?

Moving forward
This first informal look suggests that the expertise of today's chemical engineering faculty, and the skillsets that the chemical, petroleum, and pharmaceutical industries need their new hires to have, may not completely align.

In addition to quantifying what has been found qualitatively, other questions remain. Assuming that faculty expertise has shifted, does this impact what is being taught to chemical engineers? Is this shift in faculty expertise a short-term phase, or is it indicative of more drastic future changes? Where are the growing opportunities for chemical engineering graduates? Will future opportunities be concentrated in these new areas of bio and nano?

AIChE has formed a task force to monitor the continually evolving chemical engineering discipline (i.e., faculty, research, and curriculum).

*Chen passed away shortly after the meeting.

A5. Appendix 5 – Taxonomy Charts

The BOK team developed detailed taxonomy charts to map how skills and knowledge change over four career stages. The

A5.1 Stage 1 Industry

A5.1 Stage 1 Industry	Petrochemicals, Oil & Gas, LNG, Industrial Gases	Polymers, Resins, Synthetics	Pulp and Paper	Specialty Chemicals, Chemical Products	Synthetic Fuels and Alternative Energy
Affective 1. Receiving 2. Responding 3. Valuing 4. Organizing 5. Internalizing					
Beliefs and Values					
Commitment to lifelong learning	1	1	1	1	1
Concern for public welfare	3	3	3	3	3
Ethics	3	3	3	3	3
Respect for others	3	3	3	3	3
Cognitive 1. Remembering 2. Understanding 3. Applying 4. Analyzing 5. Evaluating 6. Creating					
ChE Technical					
Energy balances involving 1st and 2nd law	3	3	3	3	3
Equilibria, chemical and phase	3	3	3	3	3
Fluid flow, pump & compressor sizing & selection, packed beds	3	3	3	3	3
Fluid flow, single-phase flow, two-phase flow (pipes, valves, orifices)	3	3	3	3	3
Heat balances with and without reactions	3	3	3	3	3
Heat transfer equipment design and analysis	3	3	3	3	3
Heat transfer, multiple modes, phase change	3	3	3	3	3
Kinetics, conversion in various reactor types, chemical equilibria	3	3	3	3	3
Kinetics, reactor analysis	3	3	3	3	3
Kinetics, reactor design, heterogeneous catalysis	3	3	3	3	3
Mass transfer, equipment design and analysis	3	3	3	3	3
Mass transfer, single- and two-phase processes	3	3	3	3	3
Materials science	3	3	3	3	3

ere are two sets of charts, one considering the industry in which ChEs work, and the other considering the job role.

Academia	**Biotechnology, Pharmaceuticals**	**Consumer Products including Soaps, Detergents, Perfumes, Fats, Oils, and Cosmetics**	**Food**	**Aerospace, Auto-motive, Electronics**	**Catalysts**	**Ceramics, Glass**	**Metals**	**Nanotech**	**Nuclear Energy**	**Environmental, Health & Safety**	**Government**
1	1	1	1	1	1	1	1	1	1	1	1
3	3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3	3

A5.1 Stage 1 Industry	Petrochemicals, Oil & Gas, LNG, Industrial Gases	Polymers, Resins, Synthetics	Pulp and Paper	Specialty Chemicals, Chemical Products	Synthetic Fuels and Alternative Energy
Plant design, economics	3	3	3	3	3
Plant design, flow configuration, optimization	2	2	2	2	2
Plant design, instrumentation	1	1	1	1	1
Plant design, process control	2	2	2	2	2
Plant operations, optimization	1	1	1	1	1
Plant operations, startup, shutdown	1	1	1	1	1
Plant scale-up	1	1	1	1	1
Separations equipment selection & analysis	3	3	3	3	3
Separations process design	3	3	3	3	3
Stoichiometry with and without reactions	3	3	3	3	3
Stoichiometry, complex systems with recycle, bypass	3	3	3	3	3
Cross Functional					
Energy - systems analysis, efficiency	1	1	1	1	1
Environmental assessment, regulations	1	1	1	1	1
Process simulators, operation, steady state simulation, dynamic simulation	1	1	1	1	1
Process simulators, strengths and weaknesses	N/A	N/A	N/A	N/A	N/A
Safety, analyses, modeling, procedural policies, regulations	1	1	1	1	1
Sustainability analyses	1	1	1	1	1
Technical					
Biology	2	2	2	2	2
Budgeting	1	1	1	1	1
Chemistry –inorganic, organic, physical chemistry and biochemistry	2	2	2	2	2
Computer programming	2	2	2	2	2
Economics	1	1	1	1	1
Mathematics –mathematics through ODE	2	2	2	2	2
Numerical analysis & linear programming	1	1	1	1	1
Physics	2	2	2	2	2
Project management	1	1	1	1	1
Statistical Quality Control	2	2	2	2	2
Statistics – variability, design of experiments	2	2	2	2	2

Academia	Biotechnology, Pharmaceuticals	Consumer Products including Soaps, Detergents, Perfumes, Fats, Oils, and Cosmetics	Food	Aerospace, Auto-motive, Electronics	Catalysts	Ceramics, Glass	Metals	Nanotech	Nuclear Energy	Environmental, Health & Safety	Government
3	3	3	3	3	3	3	3	3	3	3	3
2	2	2	2	2	2	2	2	2	2	2	2
1	1	1	1	1	1	1	1	1	1	1	1
2	2	2	2	2	2	2	2	2	2	2	2
1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1
3	3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3	3
1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1
3	2	2	2	2	2	2	2	2	2	2	2
1	1	1	1	1	1	1	1	1	1	1	1
3	2	2	2	2	2	2	2	2	2	2	2
2	2	2	2	2	2	2	2	2	2	2	2
1	1	1	1	1	1	1	1	1	1	1	1
3	2	2	2	2	2	2	2	2	2	2	2
1	1	1	1	1	1	1	1	1	1	1	1
3	2	2	2	2	2	2	2	2	2	2	2
1	1	1	1	1	1	1	1	1	1	1	1
2	2	2	2	2	2	2	2	2	2	2	2
2	2	2	2	2	2	2	2	2	2	2	2

A5.1 Stage 1 Industry	Petrochemicals, Oil & Gas, LNG, Industrial Gases	Polymers, Resins, Synthetics	Pulp and Paper	Specialty Chemicals, Chemical Products	Synthetic Fuels and Alternative Energy
Psychomotor 1. Observing 2. Imitating 3. Practicing 4. Adapting					
Human					
Adjusting communication style	2	2	2	2	2
Electronic Communications	3	3	3	3	3
Identifying optimum delivery media	2	2	2	2	2
Listening and interpreting	2	2	2	2	2
Negotiation and conflict management	2	2	2	2	2
Public Relations	1	1	1	1	1
Speaking and presenting	2	2	2	2	2
Telephone Communications	2	2	2	2	2
Professional					
Critical reflection/learning	2	2	2	2	2
Experimental procedures	3	3	3	3	3
Leadership	2	2	2	2	2
Presentation	3	3	3	3	3
Problem solving	3	3	3	3	3
Teamwork	2	2	2	2	2
Technical Psychomotor					
Computer Applications	3	3	3	3	3
Spreadsheets	3	3	3	3	3
Time management	3	3	3	3	3
Typing (keyboarding)	3	3	3	3	3

Academia	Biotechnology, Pharmaceuticals	Consumer Products including Soaps, Detergents, Perfumes, Fats, Oils, and Cosmetics	Food	Aerospace, Auto-motive, Electronics	Catalysts	Ceramics, Glass	Metals	Nanotech	Nuclear Energy	Environmental, Health & Safety	Government
2	2	2	2	2	2	2	2	2	2	2	2
3	3	3	3	3	3	3	3	3	3	3	3
2	2	2	2	2	2	2	2	2	2	2	2
2	2	2	2	2	2	2	2	2	2	2	2
2	2	2	2	2	2	2	2	2	2	2	2
2	1	1	1	1	1	1	1	1	1	1	1
2	2	2	2	2	2	2	2	2	2	2	2
2	2	2	2	2	2	2	2	2	2	2	2
4	2	2	2	2	2	2	2	2	2	2	2
4	3	3	3	3	3	3	3	3	3	3	3
2	2	2	2	2	2	2	2	2	2	2	2
4	3	3	3	3	3	3	3	3	3	3	3
4	3	3	3	3	3	3	3	3	3	3	3
2	2	2	2	2	2	2	2	2	2	2	2
3	3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3	3

A5.2 Stage 2 Industry

	Petrochemicals, Oil & Gas, LNG, Industrial Gases	Polymers, Resins, Synthetics	Pulp and Paper	Specialty Chemicals, Chemical Products	Synthetic Fuels and Alternative Energy
Affective 1. Receiving 2. Responding 3. Valuing 4. Organizing 5. Internalizing					
Beliefs and Values					
Commitment to lifelong learning	2	2	2	2	2
Concern for public welfare	4	4	4	4	4
Ethics	4	4	4	4	4
Respect for others	4	4	4	4	4
Cognitive 1. Remembering 2. Understanding 3. Applying 4. Analyzing 5. Evaluating 6. Creating					
ChE Technical					
Energy balances involving 1st and 2nd law	3	3	3	3	3
Equilibria, chemical and phase	3	3	3	3	3
Fluid flow, pump & compressor sizing & selection, packed beds	3	3	3	3	3
Fluid flow, single-phase flow, two-phase flow (pipes, valves, orifices)	3	3	3	3	3
Heat balances with and without reactions	3	3	3	3	3
Heat transfer equipment design and analysis	3	3	3	3	3
Heat transfer, multiple modes, phase change	3	3	3	3	3
Kinetics, conversion in various reactor types, chemical equilibria	3	3	3	3	3
Kinetics, reactor analysis	3	3	3	3	3
Kinetics, reactor design, heterogeneous catalysis	3	3	3	3	3
Mass transfer, equipment design and analysis	3	3	3	3	3
Mass transfer, single- and two-phase processes	3	3	3	3	3
Materials science	3	3	3	3	3
Plant design, economics	3	3	3	3	3
Plant design, flow configuration, optimization	3	3	3	3	3
Plant design, instrumentation	3	3	3	3	3
Plant design, process control	3	3	3	3	3
Plant operations, optimization	3	3	3	3	3
Plant operations, startup, shutdown	3	3	3	3	3

Academia	Biotechnology, Pharmaceuticals	Consumer Products including Soaps, Detergents, Perfumes, Fats, Oils, and Cosmetics	Food	Aerospace, Auto-motive, Electronics	Catalysts	Ceramics, Glass	Metals	Nanotech	Nuclear Energy	Environmental, Health & Safety	Government
2	2	2	2	2	2	2	2	2	2	2	2
4	4	4	4	4	4	4	4	4	4	4	4
4	4	4	4	4	4	4	4	4	4	4	4
4	4	4	4	4	4	4	4	4	4	4	4
3	3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3	3
2	3	3	3	3	3	3	3	3	3	3	2
2	3	3	3	3	3	3	3	3	3	3	2
2	3	3	3	3	3	3	3	3	3	3	2
2	3	3	3	3	3	3	3	3	3	3	2
2	3	3	3	3	3	3	3	3	3	3	2

A5.2 Stage 2 Industry	Petrochemicals, Oil & Gas, LNG, Industrial Gases	Polymers, Resins, Synthetics	Pulp and Paper	Specialty Chemicals, Chemical Products	Synthetic Fuels and Alternative Energy
Plant scale-up	3	3	3	3	3
Separations equipment selection & analysis	3	3	3	3	3
Separations process design	3	3	3	3	3
Stoichiometry with and without reactions	3	3	3	3	3
Stoichiometry, complex systems with recycle, bypass	3	3	3	3	3
Cross Functional					
Energy - systems analysis, efficiency	3	3	3	3	3
Environmental assessment, regulations	3	3	3	3	3
Process simulators, operation, steady state simulation, dynamic simulation	3	3	3	3	3
Process simulators, strengths and weaknesses	3	3	3	3	3
Safety, analyses, modeling, procedural policies, regulations	3	3	3	3	3
Sustainability analyses	3	3	3	3	3
Technical					
Biology	2	2	2	2	2
Budgeting	2	2	2	2	2
Chemistry –inorganic, organic, physical chemistry and biochemistry	3	3	3	3	3
Computer programming	2	2	2	2	2
Economics	2	2	2	2	2
Mathematics –mathematics through ODE	3	3	3	3	3
Numerical analysis & linear programming	2	2	2	2	2
Physics	3	3	3	3	3
Project management	2	2	2	2	2
Statistical Quality Control	3	3	3	3	3
Statistics – variability, design of experiments	3	3	3	3	3
Psychomotor 1. Observing 2. Imitating 3. Practicing 4. Adapting					
Human					
Adjusting communication style	2	2	2	2	2
Electronic Communications	3	3	3	3	3
Identifying optimum delivery media	2	2	2	2	2

Academia	Biotechnology, Pharmaceuticals	Consumer Products including Soaps, Detergents, Perfumes, Fats, Oils, and Cosmetics	Food	Aerospace, Auto-motive, Electronics	Catalysts	Ceramics, Glass	Metals	Nanotech	Nuclear Energy	Environmental, Health & Safety	Government
2	3	3	3	3	3	3	3	3	3	3	2
3	3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3	3
2	3	3	3	3	3	3	3	3	3	3	2
2	3	3	3	3	3	3	3	3	3	3	3
2	3	3	3	3	3	3	3	3	3	3	2
2	3	3	3	3	3	3	3	3	3	3	1
2	3	3	3	3	3	3	3	3	3	3	3
2	3	3	3	3	3	3	3	3	3	3	3
5	4	2	2	2	2	2	2	2	2	2	2
3	2	2	2	2	2	2	2	2	2	2	2
5	3	3	3	3	3	3	3	3	3	3	3
2	2	2	2	2	2	2	2	2	2	2	2
2	2	2	2	2	2	2	2	2	2	2	2
4	3	3	3	3	3	3	3	3	3	3	2
3	2	2	2	2	2	2	2	2	2	2	2
5	3	3	3	3	3	3	3	3	3	3	3
2	2	2	2	2	2	2	2	2	2	2	2
3	3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3	3
2	2	2	2	2	2	2	2	2	2	2	2
3	3	3	3	3	3	3	3	3	3	3	3
2	2	2	2	2	2	2	2	2	2	2	2

A5.2 Stage 2 Industry	Petrochemicals, Oil & Gas, LNG, Industrial Gases	Polymers, Resins, Synthetics	Pulp and Paper	Specialty Chemicals, Chemical Products	Synthetic Fuels and Alternative Energy
Listening and interpreting	3	3	3	3	3
Negotiation and conflict management	2	2	2	2	2
Public Relations	2	2	2	2	2
Speaking and presenting	3	3	3	3	3
Telephone Communications	2	2	2	2	2
Professional					
Critical reflection/learning	3	3	3	3	3
Experimental procedures	3	3	3	3	3
Leadership	3	3	3	3	3
Presentation	3	3	3	3	3
Problem solving	3	3	3	3	3
Teamwork	3	3	3	3	3
Technical Psychomotor					
Computer Applications	3	3	3	3	3
Spreadsheets	3	3	3	3	3
Time management	3	3	3	3	3
Typing (keyboarding)	3	3	3	3	3

Academia	Biotechnology, Pharmaceuticals	Consumer Products including Soaps, Detergents, Perfumes, Fats, Oils, and Cosmetics	Food	Aerospace, Auto-motive, Electronics	Catalysts	Ceramics, Glass	Metals	Nanotech	Nuclear Energy	Environmental, Health & Safety	Government
3	3	3	3	3	3	3	3	3	3	3	3
2	2	2	2	2	2	2	2	2	2	2	2
2	2	2	2	2	2	2	2	2	2	2	2
3	3	3	3	3	3	3	3	3	3	3	3
2	2	2	2	2	2	2	2	2	2	2	2
4	3	3	3	3	3	3	3	3	3	3	3
4	3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3	3
4	3	3	3	3	3	3	3	3	3	3	3
4	3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3	3

A5.3 Stage 3 Industry	Petrochemicals, Oil & Gas, LNG, Industrial Gases	Polymers, Resins, Synthetics	Pulp and Paper	Specialty Chemicals, Chemical Products	Synthetic Fuels and Alternative Energy
Affective 1. Receiving 2. Responding 3. Valuing 4. Organizing 5. Internalizing					
Beliefs and Values					
Commitment to lifelong learning	4	4	4	4	4
Concern for public welfare	5	5	5	5	5
Ethics	5	5	5	5	5
Respect for others	4	4	4	4	4
Cognitive 1. Remembering 2. Understanding 3. Applying 4. Analyzing 5. Evaluating 6. Creating					
ChE Technical					
Energy balances involving 1st and 2nd law	5	5	5	5	5
Equilibria, chemical and phase	5	5	5	5	5
Fluid flow, pump & compressor sizing & selection, packed beds	5	5	4	5	5
Fluid flow, single-phase flow, two-phase flow (pipes, valves, orifices)	5	5	5	5	5
Heat balances with and without reactions	5	5	5	5	5
Heat transfer equipment design and analysis	5	5	5	5	5
Heat transfer, multiple modes, phase change	5	5	4	5	5
Kinetics, conversion in various reactor types, chemical equilibria	5	5	5	5	5
Kinetics, reactor analysis	5	5	5	5	5
Kinetics, reactor design, heterogeneous catalysis	5	5	5	5	5
Mass transfer, equipment design and analysis	5	5	4	5	5
Mass transfer, single- and two-phase processes	5	5	5	5	5
Materials science	5	5	5	5	5
Plant design, economics	4	4	4	4	4
Plant design, flow configuration, optimization	4	4	4	4	4
Plant design, instrumentation	5	5	4	5	5
Plant design, process control	4	4	4	4	4
Plant operations, optimization	5	5	5	5	5
Plant operations, startup, shutdown	5	5	4	5	5

Academia	Biotechnology, Pharmaceuticals	Consumer Products including Soaps, Detergents, Perfumes, Fats, Oils, and Cosmetics	Food	Aerospace, Auto-motive, Electronics	Catalysts	Ceramics, Glass	Metals	Nanotech	Nuclear Energy	Environmental, Health & Safety	Government
4	4	4	4	4	4	4	4	4	4	4	4
5	5	5	5	5	5	5	5	5	5	5	5
5	5	5	5	5	5	5	5	5	5	5	5
4	4	4	4	4	4	4	4	4	4	4	4
5	5	5	5	5	5	5	5	5	5	4	4
5	5	4	4	3	5	5	5	3	3	4	4
4	4	4	4	4	4	4	4	4	4	4	4
4	4	4	4	4	5	4	4	4	5	4	4
5	5	5	5	5	5	5	5	5	5	4	4
4	5	4	4	4	5	5	4	4	4	3	4
5	4	4	5	4	4	4	5	4	4	4	5
5	5	4	3	3	5	4	3	3	3	4	4
5	5	4	3	3	5	4	3	3	3	4	4
5	5	4	3	3	5	4	3	3	3	4	4
4	4	4	4	3	4	4	3	3	3	3	4
5	4	4	4	4	5	5	5	4	3	4	4
5	4	4	5	5	5	5	5	5	5	3	4
3	4	4	4	4	4	4	4	4	4	3	3
2	4	4	4	4	4	4	4	4	4	3	2
4	4	4	4	4	4	4	4	4	5	4	2
4	4	4	4	4	4	4	4	4	5	3	2
4	4	4	4	4	4	4	4	4	4	3	2
2	5	4	4	3	4	4	4	3	5	3	2

A5.3 Stage 3 Industry	Petrochemicals, Oil & Gas, LNG, Industrial Gases	Polymers, Resins, Synthetics	Pulp and Paper	Specialty Chemicals, Chemical Products	Synthetic Fuels and Alternative Energy
Plant scale-up	5	5	5	5	5
Separations equipment selection & analysis	5	5	4	5	5
Separations process design	5	5	4	5	5
Stoichiometry with and without reactions	5	5	5	5	5
Stoichiometry, complex systems with recycle, bypass	5	5	5	5	5
Cross Functional					
Energy - systems analysis, efficiency	4	4	4	4	4
Environmental assessment, regulations	4	4	4	4	4
Process simulators, operation, steady state simulation, dynamic simulation	4	4	4	4	4
Process simulators, strengths and weaknesses	4	4	4	4	4
Safety, analyses, modeling, procedural policies, regulations	4	4	4	4	4
Sustainability analyses	4	4	4	4	4
Technical					
Biology	2	2	2	2	2
Budgeting	3	3	3	3	3
Chemistry –inorganic, organic, physical chemistry and biochemistry	3	3	3	3	3
Computer programming	2	2	2	2	2
Economics	3	3	3	3	3
Mathematics –mathematics through ODE	3	3	3	3	3
Numerical analysis & linear programming	4	4	4	4	4
Physics	3	3	3	3	3
Project management	3	3	3	3	3
Statistical Quality Control	3	3	3	3	3
Statistics – variability, design of experiments	3	3	3	3	3
Psychomotor 1. Observing 2. Imitating 3. Practicing 4. Adapting					
Human					
Adjusting communication style	3	3	3	3	3
Electronic Communications	3	3	3	3	3
Identifying optimum delivery media	3	3	3	3	3

Academia	Biotechnology, Pharmaceuticals	Consumer Products including Soaps, Detergents, Perfumes, Fats, Oils, and Cosmetics	Food	Aerospace, Auto-motive, Electronics	Catalysts	Ceramics, Glass	Metals	Nanotech	Nuclear Energy	Environmental, Health & Safety	Government
4	5	4	4	3	4	4	4	3	5	3	2
4	5	4	4	3	3	3	5	3	3	3	4
4	5	4	4	3	3	3	5	3	3	3	4
5	4	4	4	4	5	4	4	4	4	4	3
5	5	4	4	4	5	4	4	4	4	4	4
2	4	4	4	4	4	4	4	4	4	4	2
2	4	4	4	4	4	4	4	4	4	4	3
2	4	4	4	4	4	4	4	4	4	4	2
4	4	4	4	4	4	4	4	N/A	4	4	4
2	4	4	4	4	4	4	4	4	4	4	3
2	4	4	4	4	4	4	4	4	4	4	3
5	4	2	2	2	2	2	2	2	2	2	2
3	3	3	3	3	3	3	3	3	3	3	3
5	3	3	3	3	3	3	3	3	3	3	3
2	2	2	2	2	2	2	2	2	2	2	2
2	3	3	3	3	3	3	3	3	3	3	2
4	3	3	3	3	3	3	3	3	3	3	2
3	4	4	4	4	4	4	4	4	4	4	4
5	3	3	3	3	3	3	3	3	3	3	3
1	3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3	3

A5.3 Stage 3 Industry	Petrochemicals, Oil & Gas, LNG, Industrial Gases	Polymers, Resins, Synthetics	Pulp and Paper	Specialty Chemicals, Chemical Products	Synthetic Fuels and Alternative Energy
Listening and interpreting	4	4	4	4	4
Negotiation and conflict management	3	3	3	3	3
Public Relations	3	3	3	3	3
Speaking and presenting	3	3	3	3	3
Telephone Communications	3	3	3	3	3
Professional					
Critical reflection/learning	3	3	3	3	3
Experimental procedures	3	3	3	3	3
Leadership	3	3	3	3	3
Presentation	3	3	3	3	3
Problem solving	3	3	3	3	3
Teamwork	4	4	4	4	4
Technical Psychomotor					
Computer Applications	4	4	4	4	4
Spreadsheets	4	4	4	4	4
Time management	4	4	4	4	4
Typing (keyboarding)	3	3	3	3	3

Academia	Biotechnology, Pharmaceuticals	Consumer Products including Soaps, Detergents, Perfumes, Fats, Oils, and Cosmetics	Food	Aerospace, Auto-motive, Electronics	Catalysts	Ceramics, Glass	Metals	Nanotech	Nuclear Energy	Environmental, Health & Safety	Government
4	4	4	4	4	4	4	4	4	4	4	3
3	3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3	3
4	3	3	3	3	3	3	3	3	3	3	3
4	3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3	3
4	3	3	3	3	3	3	3	3	3	3	3
4	3	3	3	3	3	3	3	3	3	3	3
3	4	4	4	4	4	4	4	4	4	4	3
3	4	4	4	4	4	4	4	4	4	4	4
3	4	4	4	4	4	4	4	4	4	4	4
3	4	4	4	4	4	4	4	4	4	4	4
3	3	3	3	3	3	3	3	3	3	3	3

A5.4 Stage 4 Industry	Petrochemicals, Oil & Gas, LNG, Industrial Gases	Polymers, Resins, Synthetics	Pulp and Paper	Specialty Chemicals, Chemical Products	Synthetic Fuels and Alternative Energy
Affective 1. Receiving 2. Responding 3. Valuing 4. Organizing 5. Internalizing					
Beliefs and Values					
Commitment to lifelong learning	5	5	5	5	5
Concern for public welfare	5	5	5	5	5
Ethics	5	5	5	5	5
Respect for others	5	5	5	5	5
Cognitive 1. Remembering 2. Understanding 3. Applying 4. Analyzing 5. Evaluating 6. Creating					
ChE Technical					
Energy balances involving 1st and 2nd law	6	6	6	6	6
Equilibria, chemical and phase	6	6	6	6	6
Fluid flow, pump & compressor sizing & selection, packed beds	6	6	6	6	6
Fluid flow, single-phase flow, two-phase flow (pipes, valves, orifices)	6	6	6	6	6
Heat balances with and without reactions	6	6	6	6	6
Heat transfer equipment design and analysis	6	6	6	6	6
Heat transfer, multiple modes, phase change	6	6	6	6	6
Kinetics, conversion in various reactor types, chemical equilibria	6	6	6	6	6
Kinetics, reactor analysis	6	6	6	6	6
Kinetics, reactor design, heterogeneous catalysis	6	6	6	6	6
Mass transfer, equipment design and analysis	6	6	6	6	6
Mass transfer, single- and two-phase processes	6	6	6	6	6
Materials science	6	6	6	6	6
Plant design, economics	4	4	4	4	4
Plant design, flow configuration, optimization	6	6	6	6	6
Plant design, instrumentation	6	6	6	6	6
Plant design, process control	6	6	6	6	6
Plant operations, optimization	6	6	6	6	6
Plant operations, startup, shutdown	6	6	6	6	6

Academia	Biotechnology, Pharmaceuticals	Consumer Products including Soaps, Detergents, Perfumes, Fats, Oils, and Cosmetics	Food	Aerospace, Auto-motive, Electronics	Catalysts	Ceramics, Glass	Metals	Nanotech	Nuclear Energy	Environmental, Health & Safety	Government
5	5	5	5	5	5	5	5	5	5	5	5
5	5	5	5	5	5	5	5	5	5	5	5
5	5	5	5	5	5	5	5	5	5	5	5
5	5	5	5	5	5	5	5	5	5	5	5
6	6	6	6	6	6	6	6	6	6	5	3
6	6	6	6	4	6	6	6	4	6	5	4
6	6	6	6	5	6	6	5	5	5	5	4
6	6	6	6	5	6	6	5	5	5	5	4
6	6	6	6	6	6	6	6	6	6	5	6
6	6	6	6	4	6	6	6	4	6	5	4
6	6	6	6	4	6	6	6	4	6	5	5
6	6	4	4	4	6	4	4	4	6	5	4
6	6	4	4	4	6	4	4	4	6	5	4
6	6	4	4	4	6	4	4	4	6	5	4
6	6	6	6	4	5	5	5	4	6	5	4
6	6	6	6	4	5	5	5	4	6	5	4
6	5	6	6	6	6	6	6	6	6	5	6
6	6	4	6	4	6	6	6	4	6	5	3
6	6	6	6	6	4	4	4	6	6	4	3
4	6	6	6	4	4	4	4	4	6	4	2
4	6	6	6	4	4	4	4	4	6	4	3
4	6	6	6	6	6	6	6	6	6	4	2
2	6	6	6	4	6	6	6	4	6	4	2

A5.4 Stage 4 Industry	Petrochemicals, Oil & Gas, LNG, Industrial Gases	Polymers, Resins, Synthetics	Pulp and Paper	Specialty Chemicals, Chemical Products	Synthetic Fuels and Alternative Energy
Plant scale-up	6	6	6	6	6
Separations equipment selection & analysis	6	6	6	6	6
Separations process design	6	6	6	6	6
Stoichiometry with and without reactions	6	6	6	6	6
Stoichiometry, complex systems with recycle, bypass	6	6	6	6	6
Cross Functional					
Energy - systems analysis, efficiency	6	6	6	6	6
Environmental assessment, regulations	6	6	6	6	6
Process simulators, operation, steady state simulation, dynamic simulation	6	6	6	6	6
Process simulators, strengths and weaknesses	6	6	6	6	6
Safety, analyses, modeling, procedural policies, regulations	6	6	6	6	6
Sustainability analyses	6	6	6	6	6
Technical					
Biology	2	2	2	2	2
Budgeting	3	3	3	3	3
Chemistry –inorganic, organic, physical chemistry and biochemistry	5	5	5	5	5
Computer programming	2	2	2	2	2
Economics	3	3	3	3	3
Mathematics –mathematics through ODE	3	3	3	3	3
Numerical analysis & linear programming	4	4	4	4	4
Physics	3	3	3	3	3
Project management	3	3	3	3	3
Statistical Quality Control	3	3	3	3	3
Statistics – variability, design of experiments	3	3	3	3	3
Psychomotor 1. Observing 2. Imitating 3. Practicing 4. Adapting					
Human					
Adjusting communication style	4	4	4	4	4
Electronic Communications	3	3	3	3	3
Identifying optimum delivery media	4	4	4	4	4

Academia	Biotechnology, Pharmaceuticals	Consumer Products including Soaps, Detergents, Perfumes, Fats, Oils, and Cosmetics	Food	Aerospace, Auto-motive, Electronics	Catalysts	Ceramics, Glass	Metals	Nanotech	Nuclear Energy	Environmental, Health & Safety	Government
4	6	6	6	4	4	4	4	4	6	4	2
6	6	6	6	4	5	5	5	4	6	5	4
6	6	6	6	4	5	5	5	4	6	5	4
6	6	6	6	5	6	6	6	5	5	5	3
6	6	6	6	5	6	6	6	5	5	5	5
2	6	6	6	5	6	6	6	5	6	6	2
2	6	6	6	5	6	6	6	5	6	6	3
2	6	6	6	5	6	6	6	5	6	6	2
6	6	6	6	6	6	6	6	N/A	6	6	6
2	6	6	6	5	6	6	6	5	6	6	3
8	6	6	6	5	6	6	6	5	6	6	3
5	5	2	2	2	2	2	2	2	2	2	2
3	3	3	3	3	3	3	3	3	3	3	3
5	5	5	5	5	5	5	5	5	5	5	5
2	2	2	2	2	2	2	2	2	2	2	2
2	3	3	3	3	3	3	3	3	3	3	2
4	3	3	3	3	3	3	3	3	3	3	2
3	4	4	4	4	4	4	4	4	4	4	4
5	3	3	3	3	3	3	3	3	5	3	3
1	3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3	3
4	4	4	4	4	4	4	4	4	4	4	4
3	3	3	3	3	3	3	3	3	3	3	3
4	4	4	4	4	4	4	4	4	4	4	4

A5.4 Stage 4 Industry	Petrochemicals, Oil & Gas, LNG, Industrial Gases	Polymers, Resins, Synthetics	Pulp and Paper	Specialty Chemicals, Chemical Products	Synthetic Fuels and Alternative Energy
Listening and interpreting	4	4	4	4	4
Negotiation and conflict management	4	4	4	4	4
Public Relations	4	4	4	4	4
Speaking and presenting	4	4	4	4	4
Telephone Communications	4	4	4	4	4
Professional					
Critical reflection/learning	4	4	4	4	4
Experimental procedures	4	4	4	4	4
Leadership	4	4	4	4	4
Presentation	4	4	4	4	4
Problem solving	4	4	4	4	4
Teamwork	4	4	4	4	4
Technical Psychomotor					
Computer Applications	4	4	4	4	4
Spreadsheets	4	4	4	4	4
Time management	4	4	4	4	4
Typing (keyboarding)	3	3	3	3	3

Academia	Biotechnology, Pharmaceuticals	Consumer Products including Soaps, Detergents, Perfumes, Fats, Oils, and Cosmetics	Food	Aerospace, Auto-motive, Electronics	Catalysts	Ceramics, Glass	Metals	Nanotech	Nuclear Energy	Environmental, Health & Safety	Government
4	4	4	4	4	4	4	4	4	4	4	4
4	4	4	4	4	4	4	4	4	4	4	4
4	4	4	4	4	4	4	4	4	4	4	4
4	4	4	4	4	4	4	4	4	4	4	4
4	4	4	4	4	4	4	4	4	4	4	4
4	4	4	4	4	4	4	4	4	4	4	4
4	4	4	4	4	4	4	4	4	4	4	4
4	4	4	4	4	4	4	4	4	4	4	4
4	4	4	4	4	4	4	4	4	4	4	4
4	4	4	4	4	4	4	4	4	4	4	4
4	4	4	4	4	4	4	4	4	4	4	4
4	4	4	4	4	4	4	4	4	4	4	4
4	4	4	4	4	4	4	4	4	4	4	4
4	4	4	4	4	4	4	4	4	4	4	4
3	3	3	3	3	3	3	3	3	3	3	3

A5.5 Stage 1 Role	Consultant - expert, provides solutions	Economist - Strategic & optimization Capital unit - production planning	Educator (teacher, trainer)	Checker - Technical Accuracy	Process controls & instrument engineer - designs, develops process	Process Design Engineer on capital project develops detailed eng; size & spec equip	Safety systems (SIS, PSV, fire protection)	Standard setter (Define codes, practices, procedures, tools)	Flow assurance (upstream engineering) - Get out of ground & to processing	Operations Quality control - operational testing to assure product quality, product release, trending
Affective 1. Receiving 2. Responding 3. Valuing 4. Organizing 5. Internalizing										
Beliefs and Values										
Commitment to lifelong learning	N/A	N/A	3	N/A	3	3	3	N/A	3	3
Concern for public welfare	N/A	N/A	4	N/A	4	4	4	N/A	4	4
Ethics	N/A	N/A	4	N/A	4	4	4	N/A	4	4
Respect for others	N/A	N/A	3	N/A	3	3	3	N/A	3	3
Cognitive 1. Remembering 2. Understanding 3. Applying 4. Analyzing 5. Evaluating 6. Creating										
ChE Technical										
Energy balances involving 1st and 2nd law	N/A	N/A	2	N/A	2	2	2	N/A	2	2
Equilibria, chemical and phase	N/A	N/A	2	N/A	2	2	1	N/A	2	2
Fluid flow, pump & compressor sizing & selection, packed beds	N/A	N/A	2	N/A	2	3	2	N/A	2	2
Fluid flow, single-phase flow, two-phase flow (pipes, valves, orifices)	N/A	N/A	2	N/A	2	3	3	N/A	2	2
Heat balances with and without reactions	N/A	N/A	2	N/A	2	2	3	N/A	2	2
Heat transfer equipment design and analysis	N/A	N/A	2	N/A	2	3	2	N/A	2	2
Heat transfer, multiple modes, phase change	N/A	N/A	2	N/A	2	2	3	N/A	2	2

Production Process engineer - providing engineering support for day to day operations	Project manager -capital project leader; scope, schedule, budget contract hiring	Auditor - Verifying Procedures/Plant Walkthrough	Environmental engineer permitting, wastewater, emission dispersion, LDA rate	Regulator - perform inspections, approve permits	Safety engineer -slips, trips & falls, risk assessment, etc.	Industrial Research - develops new process	Product applications engineer (research) develops products & provides tech support to end-user	Maintenance engineer - manages planning, tech staff, preventive planned & non-planned	Planner (daily operations) order raw materials, plan shipment	Scheduler (project) project activity planning	Technical Staff Manager HR mgt responsibilities	Technical Task Manager - Technical task lead - no HR	Marketing & sales engineer	Operator/technician - operating a process daily
3	N/A	3	3	3	3	3	3	N/A	3	3	N/A	N/A	3	3
4	N/A	4	4	4	4	4	4	N/A	4	4	N/A	N/A	4	4
4	N/A	4	4	4	4	4	4	N/A	4	4	N/A	N/A	4	4
3	N/A	3	3	3	3	3	3	N/A	3	3	N/A	N/A	3	3
2	N/A	2	2	2	2	2	2	N/A	2	1	N/A	N/A	2	1
2	N/A	2	2	2	2	2	2	N/A	2	1	N/A	N/A	2	1
2	N/A	2	2	2	2	2	2	N/A	2	1	N/A	N/A	2	1
2	N/A	2	2	2	2	2	2	N/A	2	1	N/A	N/A	2	1
2	N/A	2	2	2	2	2	2	N/A	2	1	N/A	N/A	2	1
2	N/A	2	2	2	2	2	2	N/A	2	1	N/A	N/A	2	1
2	N/A	2	2	2	2	2	2	N/A	2	1	N/A	N/A	2	1

A5.5 Stage 1 Role	Consultant - expert, provides solutions	Economist - Strategic & optimization Capital unit - production planning	Educator (teacher, trainer)	Checker - Technical Accuracy	Process controls & instrument engineer - designs, develops process	Process Design Engineer on capital project develops detailed eng; size & spec equip	Safety systems (SIS, PSV, fire protection)	Standard setter (Define codes, practices, procedures, tools)	Flow assurance (upstream engineering) - Get out of ground & to processing	Operations Quality control - operational testing to assure product quality, product release, trending
Kinetics, conversion in various reactor types, chemical equilibria	N/A	N/A	2	N/A	2	3	1	N/A	2	2
Kinetics, reactor analysis	N/A	N/A	2	N/A	2	2	2	N/A	2	2
Kinetics, reactor design, heterogeneous catalysis	N/A	N/A	2	N/A	2	2	1	N/A	2	2
Mass transfer, equipment design and analysis	N/A	N/A	2	N/A	2	3	1	N/A	2	2
Mass transfer, single- and two-phase processes	N/A	N/A	2	N/A	2	2	1	N/A	2	2
Materials science	N/A	N/A	2	N/A	1	2	1	N/A	2	1
Plant design, economics	N/A	N/A	2	N/A	2	2	1	N/A	2	2
Plant design, flow configuration, optimization	N/A	N/A	2	N/A	2	2	2	N/A	2	2
Plant design, instrumentation	N/A	N/A	1	N/A	3	1	2	N/A	1	2
Plant design, process control	N/A	N/A	2	N/A	3	2	3	N/A	2	2
Plant operations, optimization	N/A	N/A	1	N/A	1	1	1	N/A	1	1
Plant operations, startup, shutdown	N/A	N/A	1	N/A	1	1	1	N/A	1	1
Plant scale-up	N/A	N/A	1	N/A	1	1	1	N/A	1	1
Separations equipment selection & analysis	N/A	N/A	2	N/A	2	2	1	N/A	2	2
Separations process design	N/A	N/A	2	N/A	2	3	1	N/A	2	2
Stoichiometry with and without reactions	N/A	N/A	2	N/A	2	2	2	N/A	2	2
Stoichiometry, complex systems with recycle, bypass	N/A	N/A	2	N/A	1	2	2	N/A	2	2

Production Process engineer - providing engineering support for day to day operations	Project manager -capital project leader; scope, schedule, budget contract hiring	Auditor - Verifying Procedures/Plant Walkthrough	Environmental engineer permitting, wastewater, emission dispersion, LDA rate	Regulator - perform inspections, approve permits	Safety engineer -slips, trips & falls, risk assessment, etc.	Industrial Research - develops new process	Product applications engineer (research) develops products & provides tech support to end-user	Maintenance engineer - manages planning, tech staff, preventive planned & non-planned	Planner (daily operations) order raw materials, plan shipment	Scheduler (project) project activity planning	Technical Staff Manager HR mgt responsibilities	Technical Task Manager - Technical task lead - no HR	Marketing & sales engineer	Operator/technician - operating a process daily
2	N/A	2	2	1	2	2	2	N/A	2	1	N/A	N/A	2	1
2	N/A	2	2	2	2	2	2	N/A	2	1	N/A	N/A	2	1
2	N/A	2	2	2	2	2	2	N/A	2	1	N/A	N/A	2	1
2	N/A	2	2	2	2	2	2	N/A	2	1	N/A	N/A	2	1
2	N/A	2	2	2	2	2	2	N/A	2	1	N/A	N/A	2	1
1	N/A	2	2	1	1	1	1	N/A	1	1	N/A	N/A	2	1
2	N/A	2	2	1	2	2	2	N/A	2	2	N/A	N/A	2	1
2	N/A	2	2	1	2	2	2	N/A	1	2	N/A	N/A	1	1
2	N/A	1	1	1	2	2	1	N/A	1	1	N/A	N/A	1	1
2	N/A	2	2	2	2	2	2	N/A	1	2	N/A	N/A	1	1
1	N/A	1	1	1	1	1	1	N/A	1	1	N/A	N/A	1	1
1	N/A	1	1	1	1	1	1	N/A	1	1	N/A	N/A	1	1
1	N/A	1	1	1	2	2	1	N/A	1	2	N/A	N/A	1	1
2	N/A	2	2	2	2	2	2	N/A	1	1	N/A	N/A	2	1
2	N/A	2	2	2	2	2	2	N/A	1	1	N/A	N/A	2	1
2	N/A	2	2	2	2	2	2	N/A	1	1	N/A	N/A	1	1
2	N/A	2	2	2	2	2	2	N/A	1	1	N/A	N/A	1	1

A5.5 Stage 1 Role

	Consultant - expert, provides solutions	Economist - Strategic & optimization Capital unit - production planning	Educator (teacher, trainer)	Checker - Technical Accuracy	Process controls & instrument engineer - designs, develops process	Process Design Engineer on capital project develops detailed eng; size & spec equip	Safety systems (SIS, PSV, fire protection)	Standard setter (Define codes, practices, procedures, tools)	Flow assurance (upstream engineering) - Get out of ground & to processing	Operations Quality control - operational testing to assure product quality, product release, trending
Cross Functional										
Energy - systems analysis, efficiency	N/A	N/A	1	N/A	1	1	1	N/A	1	1
Environmental assessment, regulations	N/A	N/A	1	N/A	1	1	1	N/A	1	1
Process simulators, operation, steady state simulation, dynamic simulation	N/A	N/A	1	N/A	1	1	1	N/A	1	1
Process simulators, strengths and weaknesses	N/A	N/A	N/A	N/A	N/A	1	N/A	N/A	N/A	N/A
Safety, analyses, modeling, procedural policies, regulations	N/A	N/A	1	N/A	1	1	2	N/A	1	1
Sustainability analyses	N/A	N/A	1	N/A	1	1	1	N/A	1	1
Technical										
Biology	N/A	N/A	1	N/A	1	1	1	N/A	1	1
Budgeting	N/A	N/A	1	N/A	1	2	1	N/A	2	1
Chemistry –inorganic, organic, physical chemistry and biochemistry	N/A	N/A	2	N/A	2	2	2	N/A	2	2
Computer programming	N/A	N/A	1	N/A	2	3	2	N/A	1	2
Economics	N/A	N/A	1	N/A	1	1	1	N/A	2	1
Mathematics –mathematics through ODE	N/A	N/A	2	N/A	2	2	2	N/A	2	2
Numerical analysis & linear programming	N/A	N/A	1	N/A	2	2	1	N/A	2	1
Physics	N/A	N/A	2	N/A	2	2	1	N/A	2	2

Production Process engineer - providing engineering support for day to day operations	Project manager -capital project leader; scope, schedule, budget contract hiring	Auditor - Verifying Procedures/Plant Walkthrough	Environmental engineer permitting, wastewater, emission dispersion, LDA rate	Regulator - perform inspections, approve permits	Safety engineer -slips, trips & falls, risk assessment, etc.	Industrial Research - develops new process	Product applications engineer (research) develops products & provides tech support to end-user	Maintenance engineer - manages planning, tech staff, preventive planned & non-planned	Planner (daily operations) order raw materials, plan shipment	Scheduler (project) project activity planning	Technical Staff Manager HR mgt responsibilities	Technical Task Manager - Technical task lead - no HR	Marketing & sales engineer	Operator/technician - operating a process daily
1	N/A	1	1	1	1	1	1	N/A	1	1	N/A	N/A	1	1
1	N/A	1	2	2	1	1	1	N/A	1	1	N/A	N/A	1	1
1	N/A	1	1	1	1	1	1	N/A	1	1	N/A	N/A	1	1
1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1	N/A	1	1	2	2	1	1	N/A	1	1	N/A	N/A	1	1
1	N/A	1	1	1	1	1	1	N/A	1	1	N/A	N/A	1	1
1	N/A	N/A	2	1	1	1	1	N/A	N/A	N/A	N/A	N/A	1	N/A
1	N/A	1	2	1	1	1	1	N/A	1	N/A	N/A	N/A	2	N/A
2	N/A	1	2	2	2	3	2	N/A	1	1	N/A	N/A	2	N/A
2	N/A	1	2	1	1	2	2	N/A	1	1	N/A	N/A	2	N/A
1	N/A	N/A	2	1	1	1	1	N/A	1	1	N/A	N/A	2	N/A
2	N/A	2	2	2	2	3	2	N/A	1	1	N/A	N/A	1	2
2	N/A	N/A	2	1	1	1	1	N/A	1	1	N/A	N/A	1	N/A
2	N/A	1	2	1	1	2	2	N/A	N/A	N/A	N/A	N/A	1	N/A

A5.5 Stage 1 Role	Consultant - expert, provides solutions	Economist - Strategic & optimization Capital unit - production planning	Educator (teacher, trainer)	Checker - Technical Accuracy	Process controls & instrument engineer - designs, develops process	Process Design Engineer on capital project develops detailed eng; size & spec equip	Safety systems (SIS, PSV, fire protection)	Standard setter (Define codes, practices, procedures, tools)	Flow assurance (upstream engineering) - Get out of ground & to processing	Operations Quality control - operational testing to assure product quality, product release, trending
Project management	N/A	N/A	1	N/A	1	1	1	N/A	1	1
Statistical Quality Control	N/A	N/A	2	N/A	2	2	2	N/A	2	3
Statistics – variability, design of experiments	N/A	N/A	2	N/A	2	2	2	N/A	2	3
Psychomotor 1. Observing 2. Imitating 3. Practicing 4. Adapting										
Human										
Adjusting communication style	N/A	N/A	2	N/A	2	1	2	N/A	2	2
Electronic Communications	N/A	N/A	1	N/A	1	1	1	N/A	1	1
Identifying optimum delivery media	N/A	N/A	2	N/A	2	2	2	N/A	2	2
Listening and interpreting	N/A	N/A	2	N/A	2	2	2	N/A	2	2
Negotiation and conflict management	N/A	N/A	2	N/A	2	2	2	N/A	2	2
Public Relations	N/A	N/A	3	N/A	3	1	3	N/A	3	3
Speaking and presenting	N/A	N/A	3	N/A	2	1	2	N/A	2	3
Telephone Communications	N/A	N/A	2	N/A	2	1	2	N/A	2	2
Professional										
Critical reflection/learning	N/A	N/A	2	N/A	2	2	2	N/A	2	2
Experimental procedures	N/A	N/A	3	N/A	2	3	3	N/A	3	3
Leadership	N/A	N/A	2	N/A	2	1	2	N/A	2	2
Presentation	N/A	N/A	3	N/A	2	1	2	N/A	3	3
Problem solving	N/A	N/A	3	N/A	3	1	3	N/A	3	3
Teamwork	N/A	N/A	3	N/A	3	1	3	N/A	3	3

Production Process engineer - providing engineering support for day to day operations	Project manager -capital project leader; scope, schedule, budget contract hiring	Auditor - Verifying Procedures/Plant Walkthrough	Environmental engineer permitting, wastewater, emission dispersion, LDA rate	Regulator - perform inspections, approve permits	Safety engineer -slips, trips & falls, risk assessment, etc.	Industrial Research - develops new process	Product applications engineer (research) develops products & provides tech support to end-user	Maintenance engineer - manages planning, tech staff, preventive planned & non-planned	Planner (daily operations) order raw materials, plan shipment	Scheduler (project) project activity planning	Technical Staff Manager HR mgt responsibilities	Technical Task Manager - Technical task lead - no HR	Marketing & sales engineer	Operator/technician - operating a process daily
1	N/A	1	1	1	1	1	1	N/A	2	1	N/A	N/A	1	N/A
2	N/A	1	1	1	2	2	2	N/A	1	1	N/A	N/A	1	1
2	N/A	1	1	1	2	2	2	N/A	1	1	N/A	N/A	1	1
1	N/A	2	2	2	2	2	2	N/A	2	2	N/A	N/A	2	2
1	N/A	1	1	1	1	1	1	N/A	1	1	N/A	N/A	1	1
1	N/A	2	2	2	2	2	2	N/A	2	2	N/A	N/A	2	2
2	N/A	2	2	2	2	2	2	N/A	2	2	N/A	N/A	2	2
1	N/A	2	2	2	2	2	2	N/A	2	2	N/A	N/A	2	2
1	N/A	1	3	3	3	3	3	N/A	3	3	N/A	N/A	3	3
2	N/A	3	3	3	3	3	3	N/A	2	2	N/A	N/A	3	2
2	N/A	2	2	2	2	2	2	N/A	2	2	N/A	N/A	2	2
2	N/A	2	2	2	2	2	2	N/A	2	2	N/A	N/A	2	2
2	N/A	1	3	1	3	3	3	N/A	1	2	N/A	N/A	2	3
1	N/A	1	2	2	2	2	2	N/A	2	2	N/A	N/A	2	2
1	N/A	1	3	3	3	3	3	N/A	1	2	N/A	N/A	3	1
2	N/A	1	3	2	3	3	3	N/A	3	3	N/A	N/A	3	3
2	N/A	3	3	3	3	3	3	N/A	3	3	N/A	N/A	3	3

A5.5 Stage 1 Role	Consultant - expert, provides solutions	Economist - Strategic & optimization Capital unit - production planning	Educator (teacher, trainer)	Checker - Technical Accuracy	Process controls & instrument engineer - designs, develops process	Process Design Engineer on capital project develops detailed eng; size & spec equip	Safety systems (SIS, PSV, fire protection)	Standard setter (Define codes, practices, procedures, tools)	Flow assurance (upstream engineering) - Get out of ground & to processing	Operations Quality control - operational testing to assure product quality, product release, trending
Technical Psychomotor										
Computer Applications	N/A	N/A	3	N/A	3	1	3	N/A	3	3
Spreadsheets	N/A	N/A	3	N/A	3	1	3	N/A	3	3
Time management	N/A	N/A	3	N/A	3	1	3	N/A	3	3
Typing (keyboarding)	N/A	N/A	3	N/A	3	3	3	N/A	3	3

Production Process engineer - providing engineering support for day to day operations	Project manager -capital project leader; scope, schedule, budget contract hiring	Auditor - Verifying Procedures/Plant Walkthrough	Environmental engineer permitting, wastewater, emission dispersion, LDA rate	Regulator - perform inspections, approve permits	Safety engineer -slips, trips & falls, risk assessment, etc.	Industrial Research - develops new process	Product applications engineer (research) develops products & provides tech support to end-user	Maintenance engineer - manages planning, tech staff, preventive planned & non-planned	Planner (daily operations) order raw materials, plan shipment	Scheduler (project) project activity planning	Technical Staff Manager HR mgt responsibilities	Technical Task Manager - Technical task lead - no HR	Marketing & sales engineer	Operator/technician - operating a process daily
2	N/A	3	3	3	3	3	3	N/A	3	3	N/A	N/A	3	3
2	N/A	3	3	3	3	3	3	N/A	3	3	N/A	N/A	3	2
1	N/A	3	3	3	3	3	3	N/A	3	3	N/A	N/A	3	3
3	N/A	3	3	3	3	3	3	N/A	3	3	N/A	N/A	3	3

A5.6 Stage 2 Role

A5.6 Stage 2 Role	Consultant - expert, provides solutions	Economist - Strategic & optimization Capital unit - production planning	Educator (teacher, trainer)	Checker - Technical Accuracy	Process controls & instrument engineer - designs, develops process	Process Design Engineer on capital project develops detailed eng; size & spec equip	Safety systems (SIS, PSV, fire protection)	Standard setter (Define codes, practices, procedures, tools)	Flow assurance (upstream engineering) - Get out of ground & to processing	Operations Quality control - operational testing to assure product quality, product release, trending
Affective 1. Receiving 2. Responding 3. Valuing 4. Organizing 5. Internalizing										
Beliefs and Values										
Commitment to lifelong learning	3	3	3	3	3	3	3	3	3	3
Concern for public welfare	4	4	4	4	4	4	4	4	4	4
Ethics	4	4	4	4	4	4	4	4	4	4
Respect for others	3	3	3	3	3	3	3	3	3	3
Cognitive 1. Remembering 2. Understanding 3. Applying 4. Analyzing 5. Evaluating 6. Creating										
ChE Technical										
Energy balances involving 1st and 2nd law	4	1	4	2	3	3	2	4	3	3
Equilibria, chemical and phase	4	1	4	2	3	3	3	4	3	3
Fluid flow, pump & compressor sizing & selection, packed beds	4	1	4	2	2	4	3	4	3	3
Fluid flow, single-phase flow, two-phase flow (pipes, valves, orifices)	4	1	4	2	3	4	4	4	3	3
Heat balances with and without reactions	4	1	4	2	3	3	4	4	3	3
Heat transfer equipment design and analysis	4	1	4	2	2	4	3	4	3	2

Production Process engineer - providing engineering support for day to day operations	Project manager -capital project leader; scope, schedule, budget contract hiring	Auditor - Verifying Procedures/Plant Walkthrough	Environmental engineer permitting, wastewater , emission dispersion, LDA rate	Regulator - perform inspections, approve permits	Safety engineer -slips, trips & falls, risk assessment, etc.	Industrial Research - develops new process	Product applications engineer (research) develops products & provides tech support to end-user	Maintenance engineer - manages planning, tech staff, preventive planned & non-planned	Planner (daily operations) order raw materials, plan shipment	Scheduler (project) project activity planning	Technical Staff Manager HR mgt responsibilities	Technical Task Manager - Technical task lead - no HR	Marketing & sales engineer	Operator/technician - operating a process daily
3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
3	1	3	3	3	3	4	3	2	3	2	1	3	3	2
3	1	3	3	2	3	4	3	2	2	2	1	3	3	2
3	2	1	3	2	3	4	3	2	2	1	2	3	3	2
4	1	3	3	2	3	4	3	3	3	1	1	3	3	2
3	1	3	3	2	3	4	3	2	1	2	1	3	3	2
3	2	3	3	2	3	4	3	3	3	2	1	3	2	2

A5.6 Stage 2 Role	Consultant - expert, provides solutions	Economist - Strategic & optimization Capital unit - production planning	Educator (teacher, trainer)	Checker - Technical Accuracy	Process controls & instrument engineer - designs, develops process	Process Design Engineer on capital project develops detailed eng; size & spec equip	Safety systems (SIS, PSV, fire protection)	Standard setter (Define codes, practices, procedures, tools)	Flow assurance (upstream engineering) - Get out of ground & to processing	Operations Quality control - operational testing to assure product quality, product release, trending
Heat transfer, multiple modes, phase change	4	1	4	2	3	3	4	4	3	3
Kinetics, conversion in various reactor types, chemical equilibria	3	1	3	2	3	4	3	3	2	2
Kinetics, reactor analysis	3	1	4	2	2	3	3	3	2	2
Kinetics, reactor design, heterogeneous catalysis	3	1	4	2	2	3	3	3	2	2
Mass transfer, equipment design and analysis	4	1	4	2	2	3	3	4	3	3
Mass transfer, single- and two-phase processes	4	1	4	2	2	3	3	4	3	3
Materials science	3	1	3	2	2	3	3	4	3	2
Plant design, economics	3	3	4	2	3	3	2	4	3	2
Plant design, flow configuration, optimization	3	3	3	2	3	3	3	4	3	2
Plant design, instrumentation	3	2	3	2	4	3	3	3	3	3
Plant design, process control	3	3	3	2	4	4	4	4	3	2
Plant operations, optimization	3	2	3	2	3	3	3	3	4	2
Plant operations, startup, shutdown	3	2	3	2	3	3	3	3	2	2
Plant scale-up	3	3	3	2	2	3	3	4	3	2
Separations equipment selection & analysis	4	2	3	2	2	3	3	4	3	2
Separations process design	4	2	3	2	2	3	3	4	3	2

Production Process engineer - providing engineering support for day to day operations	Project manager -capital project leader; scope, schedule, budget contract hiring	Auditor - Verifying Procedures/Plant Walkthrough	Environmental engineer permitting, wastewater , emission dispersion, LDA rate	Regulator - perform inspections, approve permits	Safety engineer -slips, trips & falls, risk assessment, etc.	Industrial Research - develops new process	Product applications engineer (research) develops products & provides tech support to end-user	Maintenance engineer - manages planning, tech staff, preventive planned & non-planned	Planner (daily operations) order raw materials, plan shipment	Scheduler (project) project activity planning	Technical Staff Manager HR mgt responsibilities	Technical Task Manager - Technical task lead - no HR	Marketing & sales engineer	Operator/technician - operating a process daily
3	1	3	3	2	3	4	3	2	3	2	1	3	3	2
4	1	3	3	1	3	3	3	1	3	1	1	3	3	2
4	1	3	3	2	3	3	3	1	1	1	1	3	1	2
4	2	3	3	2	3	3	3	1	1	1	1	3	2	2
3	2	3	3	2	3	4	3	2	3	2	1	3	3	2
3	2	3	3	2	3	4	3	2	1	2	1	3	2	2
3	2	3	3	2	2	3	3	3	1	1	1	2	2	2
3	2	3	3	2	3	2	2	2	3	2	2	2	2	2
3	2	2	3	2	3	3	2	2	1	2	2	2	2	2
3	2	2	3	2	3	3	2	2	2	2	2	2	2	2
3	2	3	3	2	2	3	3	2	2	2	2	2	2	2
4	2	2	2	2	3	3	2	2	3	2	2	2	2	2
3	2	2	2	2	3	2	2	2	2	2	2	2	2	3
3	2	2	3	1	3	3	2	2	2	2	1	2	2	1
3	2	3	3	2	3	4	3	3	1	2	1	3	3	2
3	1	3	4	2	3	4	3	3	1	2	1	3	3	2

A5.6 Stage 2 Role	Consultant - expert, provides solutions	Economist - Strategic & optimization Capital unit - production planning	Educator (teacher, trainer)	Checker - Technical Accuracy	Process controls & instrument engineer - designs, develops process	Process Design Engineer on capital project develops detailed eng; size & spec equip	Safety systems (SIS, PSV, fire protection)	Standard setter (Define codes, practices, procedures, tools)	Flow assurance (upstream engineering) - Get out of ground & to processing	Operations Quality control - operational testing to assure product quality, product release, trending
Stoichiometry with and without reactions	4	1	4	2	3	3	3	4	3	3
Stoichiometry, complex systems with recycle, bypass	3	2	4	2	1	3	3	4	3	3
Cross Functional										
Energy - systems analysis, efficiency	4	2	4	2	2	3	3	4	2	2
Environmental assessment, regulations	4	3	4	2	2	2	3	4	3	2
Process simulators, operation, steady state simulation, dynamic simulation	4	3	4	2	3	3	3	4	3	2
Process simulators, strengths and weaknesses	4	1	4	2	3	3	3	4	3	2
Safety, analyses, modeling, procedural policies, regulations	4	2	4	2	3	2	3	4	3	1
Sustainability analyses	3	2	4	2	1	2	2	4	1	1
Technical										
Biology	3	1	5	1	2	2	2	3	2	2
Budgeting	4	2	2	1	2	2	2	3	2	2
Chemistry –inorganic, organic, physical chemistry and biochemistry	3	1	5	1	3	3	3	3	3	3
Computer programming	2	2	3	1	3	3	2	2	3	3
Economics	2	5	2	1	2	3	2	2	3	2

Production Process engineer - providing engineering support for day to day operations	Project manager -capital project leader; scope, schedule, budget contract hiring	Auditor - Verifying Procedures/Plant Walkthrough	Environmental engineer permitting, wastewater , emission dispersion, LDA rate	Regulator - perform inspections, approve permits	Safety engineer -slips, trips & falls, risk assessment, etc.	Industrial Research - develops new process	Product applications engineer (research) develops products & provides tech support to end-user	Maintenance engineer - manages planning, tech staff, preventive planned & non-planned	Planner (daily operations) order raw materials, plan shipment	Scheduler (project) project activity planning	Technical Staff Manager HR mgt responsibilities	Technical Task Manager - Technical task lead - no HR	Marketing & sales engineer	Operator/technician - operating a process daily
3	2	3	3	2	3	4	3	2	1	1	1	4	1	2
3	1	3	3	2	3	4	3	2	1	2	1	3	1	2
3	1	2	2	2	3	3	3	2	2	2	1	3	2	2
2	2	3	4	4	4	3	3	2	2	2	1	3	2	2
3	1	2	2	2	3	3	3	2	1	2	1	3	2	2
3	2	1	2	2	3	3	3	2	1	2	1	3	1	1
2	2	3	3	4	4	3	3	2	2	2	1	3	2	2
2	2	1	3	3	2	3	2	2	1	2	1	3	1	1
3	2	1	3	2	2	4	3	1	1	1	N/A	2	2	1
2	4	1	2	2	2	3	4	4	4	2	3	4	3	2
3	2	2	3	3	3	4	3	1	2	1	N/A	2	2	1
3	2	1	3	1	3	4	3	2	3	2	1	2	2	1
2	3	2	2	2	3	2	3	4	2	2	1	3	3	2

A5.6 Stage 2 Role	Consultant - expert, provides solutions	Economist - Strategic & optimization Capital unit - production planning	Educator (teacher, trainer)	Checker - Technical Accuracy	Process controls & instrument engineer - designs, develops process	Process Design Engineer on capital project develops detailed eng; size & spec equip	Safety systems (SIS, PSV, fire protection)	Standard setter (Define codes, practices, procedures, tools)	Flow assurance (upstream engineering) - Get out of ground & to processing	Operations Quality control - operational testing to assure product quality, product release, trending
Mathematics –mathematics through ODE	4	4	5	2	4	3	3	2	4	4
Numerical analysis & linear programming	3	3	3	1	3	3	2	2	3	2
Physics	3	1	5	1	3	3	2	3	3	2
Project management	3	2	2	1	2	2	2	2	2	2
Statistical Quality Control	4	2	4	2	4	2	2	2	3	4
Statistics – variability, design of experiments	4	2	5	2	4	3	2	2	4	4
Psychomotor 1. Observing 2. Imitating 3. Practicing 4. Adapting										
Human										
Adjusting communication style	4	3	4	2	2	1	3	3	2	2
Electronic Communications	3	3	3	3	3	3	3	3	3	3
Identifying optimum delivery media	4	2	4	2	2	2	3	3	2	2
Listening and interpreting	4	3	4	2	2	3	3	4	2	2
Negotiation and conflict management	4	2	2	2	2	2	2	4	2	2
Public Relations	1	1	3	1	3	3	3	1	2	3
Speaking and presenting	4	3	4	1	2	2	2	4	2	3
Telephone Communications	3	3	3	3	3	2	3	3	3	3

Production Process engineer - providing engineering support for day to day operations	Project manager -capital project leader; scope, schedule, budget contract hiring	Auditor - Verifying Procedures/Plant Walkthrough	Environmental engineer permitting, wastewater , emission dispersion, LDA rate	Regulator - perform inspections, approve permits	Safety engineer -slips, trips & falls, risk assessment, etc.	Industrial Research - develops new process	Product applications engineer (research) develops products & provides tech support to end-user	Maintenance engineer - manages planning, tech staff, preventive planned & non-planned	Planner (daily operations) order raw materials, plan shipment	Scheduler (project) project activity planning	Technical Staff Manager HR mgt responsibilities	Technical Task Manager - Technical task lead - no HR	Marketing & sales engineer	Operator/technician - operating a process daily
3	2	3	4	2	2	5	3	2	2	2	N/A	1	2	2
3	2	1	3	2	2	4	3	3	1	1	N/A	2	2	1
3	2	1	3	2	2	3	3	1	1	1	N/A	2	1	1
2	4	2	2	2	2	3	3	4	3	3	2	4	2	2
3	2	2	2	2	2	3	3	3	2	1	1	1	1	3
3	2	1	3	1	2	4	3	2	1	1	1	1	2	1
2	3	2	3	2	3	3	3	2	2	2	3	3	3	2
3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
2	3	2	3	3	3	3	3	2	2	2	3	3	3	2
2	3	2	3	3	3	3	3	3	2	2	3	4	4	2
2	3	2	2	2	2	2	2	3	2	2	3	3	3	2
3	1	1	3	3	3	3	3	1	3	3	1	1	3	3
2	3	3	3	3	3	3	3	2	2	2	3	3	4	2
3	3	3	3	3	3	3	3	3	3	3	3	3	3	3

A5.6 Stage 2 Role	Consultant - expert, provides solutions	Economist - Strategic & optimization Capital unit - production planning	Educator (teacher, trainer)	Checker - Technical Accuracy	Process controls & instrument engineer - designs, develops process	Process Design Engineer on capital project develops detailed eng; size & spec equip	Safety systems (SIS, PSV, fire protection)	Standard setter (Define codes, practices, procedures, tools)	Flow assurance (upstream engineering) - Get out of ground & to processing	Operations Quality control - operational testing to assure product quality, product release, trending
Professional										
Critical reflection/learning	3	3	4	2	3	3	2	4	3	3
Experimental procedures	3	2	4	1	2	3	3	4	3	3
Leadership	3	2	3	1	2	2	3	4	3	3
Presentation	3	3	4	1	2	2	2	3	3	3
Problem solving	3	2	4	2	3	3	3	4	3	3
Teamwork	2	2	3	1	3	2	3	4	3	3
Technical Psychomotor										
Computer Applications	3	3	3	3	3	2	3	3	3	3
Spreadsheets	3	3	3	3	3	3	3	3	3	3
Time management	3	3	3	3	3	2	3	3	3	3
Typing (keyboarding)	3	3	3	3	3	3	3	3	3	3

Production Process engineer - providing engineering support for day to day operations	Project manager -capital project leader; scope, schedule, budget contract hiring	Auditor - Verifying Procedures/Plant Walkthrough	Environmental engineer permitting, wastewater , emission dispersion, LDA rate	Regulator - perform inspections, approve permits	Safety engineer -slips, trips & falls, risk assessment, etc.	Industrial Research - develops new process	Product applications engineer (research) develops products & provides tech support to end-user	Maintenance engineer - manages planning, tech staff, preventive planned & non-planned	Planner (daily operations) order raw materials, plan shipment	Scheduler (project) project activity planning	Technical Staff Manager HR mgt responsibilities	Technical Task Manager - Technical task lead - no HR	Marketing & sales engineer	Operator/technician - operating a process daily
3	4	2	3	2	3	4	3	2	2	2	3	4	2	2
2	1	1	3	1	3	4	3	2	1	2	2	3	2	3
2	4	1	3	2	3	3	3	2	2	2	3	4	3	2
2	4	1	3	3	3	3	3	2	1	2	3	4	3	1
3	4	1	3	2	3	4	3	3	3	3	3	4	2	3
3	4	3	3	3	3	3	3	2	3	3	3	4	3	3
2	2	3	3	3	3	3	3	2	3	3	3	3	3	3
2	3	3	3	3	3	3	3	3	4	3	3	3	3	2
2	3	3	3	3	3	3	3	3	4	3	3	3	3	3
3	3	3	3	3	3	3	3	2	3	3	3	3	3	2

A5.7 Stage 3 Role	Consultant - expert, provides solutions	Economist - Strategic & optimization Capital unit - production planning	Educator (teacher, trainer)	Checker - Technical Accuracy	Process controls & instrument engineer - designs, develops process	Process Design Engineer on capital project develops detailed eng; size & spec equip	Safety systems (SIS, PSV, fire protection)	Standard setter (Define codes, practices, procedures, tools)	Flow assurance (upstream engineering) - Get out of ground & to processing	Operations Quality control - operational testing to assure product quality, product release, trending
Affective 1. Receiving 2. Responding 3. Valuing 4. Organizing 5. Internalizing										
Beliefs and Values										
Commitment to lifelong learning	5	3	5	3	3	3	4	5	3	3
Concern for public welfare	5	4	5	4	4	4	5	5	4	5
Ethics	5	4	5	4	4	4	4	5	4	5
Respect for others	5	3	4	3	3	3	3	3	3	3
Cognitive 1. Remembering 2. Understanding 3. Applying 4. Analyzing 5. Evaluating 6. Creating										
ChE Technical										
Energy balances involving 1st and 2nd law	5	4	5	4	4	5	5	5	4	3
Equilibria, chemical and phase	5	3	5	4	3	5	5	4	5	3
Fluid flow, pump & compressor sizing & selection, packed beds	5	3	5	4	2	5	5	5	5	4
Fluid flow, single-phase flow, two-phase flow (pipes, valves, orifices)	5	4	5	4	5	5	5	5	6	3
Heat balances with and without reactions	5	4	5	4	4	5	4	5	4	3
Heat transfer equipment design and analysis	5	3	4	4	2	5	4	5	4	2
Heat transfer, multiple modes, phase change	5	2	5	4	5	5	5	5	4	3

Production Process engineer - providing engineering support for day to day operations	Project manager -capital project leader; scope, schedule, budget contract hiring	Auditor - Verifying Procedures/Plant Walkthrough	Environmental engineer permitting, wastewater, emission dispersion, LDA rate	Regulator - perform inspections, approve permits	Safety engineer -slips, trips & falls, risk assessment, etc.	Industrial Research - develops new process	Product applications engineer (research) develops products & provides tech support to end-user	Maintenance engineer - manages planning, tech staff, preventive planned & non-planned	Planner (daily operations) order raw materials, plan shipment	Scheduler (project) project activity planning	Technical Staff Manager HR mgt responsibilities	Technical Task Manager - Technical task lead - no HR	Marketing & sales engineer	Operator/technician - operating a process daily
3	3	3	3	3	4	4	3	3	3	4	4	4	3	3
4	5	5	5	5	5	4	4	4	4	4	5	5	4	4
4	5	4	4	4	4	4	4	4	4	4	5	5	5	4
3	4	3	3	3	3	3	3	3	3	3	5	4	4	3
4	1	3	5	2	3	5	4	3	3	2	4	5	3	2
4	1	3	5	2	3	5	4	3	2	2	4	5	3	2
4	2	3	4	2	3	5	4	5	2	1	4	5	3	3
4	1	3	4	2	5	5	4	3	1	1	2	5	3	3
4	1	3	5	2	3	5	4	3	3	2	4	5	3	2
4	2	3	5	2	4	5	4	4	3	1	4	5	3	2
4	1	3	5	2	3	5	4	3	3	1	2	5	3	2

A5.7 Stage 3 Role

	Consultant - expert, provides solutions	Economist - Strategic & optimization Capital unit - production planning	Educator (teacher, trainer)	Checker - Technical Accuracy	Process controls & instrument engineer - designs, develops process	Process Design Engineer on capital project develops detailed eng; size & spec equip	Safety systems (SIS, PSV, fire protection)	Standard setter (Define codes, practices, procedures, tools)	Flow assurance (upstream engineering) - Get out of ground & to processing	Operations Quality control - operational testing to assure product quality, product release, trending
Kinetics, conversion in various reactor types, chemical equilibria	5	4	5	4	3	5	5	4	3	2
Kinetics, reactor analysis	6	2	4	4	2	4	3	5	2	2
Kinetics, reactor design, heterogeneous catalysis	6	3	5	4	2	5	3	5	2	2
Mass transfer, equipment design and analysis	6	3	4	4	2	5	3	5	4	3
Mass transfer, single- and two-phase processes	5	3	5	4	2	5	3	5	5	3
Materials science	5	2	4	4	4	4	5	5	4	4
Plant design, economics	4	6	4	3	4	5	3	5	4	2
Plant design, flow configuration, optimization	4	5	4	3	5	5	3	5	4	2
Plant design, instrumentation	4	3	4	4	6	4	6	5	4	4
Plant design, process control	4	3	4	4	6	4	6	5	4	2
Plant operations, optimization	4	6	4	4	5	5	3	4	5	3
Plant operations, startup, shutdown	3	4	3	3	5	4	5	4	5	3
Plant scale-up	4	3	3	3	5	5	3	4	3	2
Separations equipment selection & analysis	6	3	4	4	2	5	3	5	4	2
Separations process design	5	2	5	4	2	5	3	5	4	2
Stoichiometry with and without reactions	5	2	5	4	3	5	4	5	5	5

Production Process engineer - providing engineering support for day to day operations	Project manager -capital project leader; scope, schedule, budget contract hiring	Auditor - Verifying Procedures/Plant Walkthrough	Environmental engineer permitting, wastewater, emission dispersion, LDA rate	Regulator - perform inspections, approve permits	Safety engineer -slips, trips & falls, risk assessment, etc.	Industrial Research - develops new process	Product applications engineer (research) develops products & provides tech support to end-user	Maintenance engineer - manages planning, tech staff, preventive planned & non-planned	Planner (daily operations) order raw materials, plan shipment	Scheduler (project) project activity planning	Technical Staff Manager HR mgt responsibilities	Technical Task Manager - Technical task lead - no HR	Marketing & sales engineer	Operator/technician - operating a process daily
4	1	3	4	2	3	5	4	3	3	1	2	5	3	2
4	1	3	3	2	4	5	4	3	1	1	2	5	2	2
4	2	3	3	2	3	5	4	3	1	1	2	5	3	2
4	2	3	5	2	3	5	4	4	1	1	3	5	3	2
4	1	3	5	2	3	5	4	3	1	1	2	5	2	2
3	2	3	4	2	3	5	4	5	1	1	2	4	2	2
3	4	3	4	2	3	2	2	5	3	2	3	5	2	2
4	2	3	5	1	4	5	2	3	1	2	3	5	2	2
3	2	3	4	2	5	4	3	4	3	1	2	4	3	3
3	2	3	4	1	5	4	3	3	3	1	2	4	3	3
5	2	3	4	2	3	4	3	3	4	1	2	4	2	4
4	2	3	4	2	5	4	4	4	4	2	4	4	2	4
4	2	3	4	1	3	6	4	3	3	1	4	4	2	1
4	2	3	5	2	4	5	4	4	1	1	3	5	3	2
4	1	3	5	2	3	5	4	3	2	2	4	5	3	3
4	1	3	5	2	3	5	3	3	1	1	2	5	1	2

A5.7 Stage 3 Role	Consultant - expert, provides solutions	Economist - Strategic & optimization Capital unit - production planning	Educator (teacher, trainer)	Checker - Technical Accuracy	Process controls & instrument engineer - designs, develops process	Process Design Engineer on capital project develops detailed eng; size & spec equip	Safety systems (SIS, PSV, fire protection)	Standard setter (Define codes, practices, procedures, tools)	Flow assurance (upstream engineering) - Get out of ground & to processing	Operations Quality control - operational testing to assure product quality, product release, trending
Stoichiometry, complex systems with recycle, bypass	5	2	5	4	1	5	4	5	4	3
Cross Functional										
Energy - systems analysis, efficiency	6	4	5	4	4	6	3	5	4	1
Environmental assessment, regulations	5	3	4	4	4	4	4	5	4	1
Process simulators, operation, steady state simulation, dynamic simulation	6	6	5	4	6	6	5	5	4	2
Process simulators, strengths and weaknesses	6	4	5	4	6	5	4	5	3	1
Safety, analyses, modeling, procedural policies, regulations	5	3	4	4	4	5	5	5	4	1
Sustainability analyses	3	4	4	3	2	3	2	5	3	1
Technical										
Biology	4	3	5	4	3	4	3	4	3	4
Budgeting	4	5	2	2	2	3	2	3	2	2
Chemistry –inorganic, organic, physical chemistry and biochemistry	5	3	5	4	3	4	4	5	5	5
Computer programming	5	4	3	3	5	4	2	2	4	3
Economics	5	6	3	3	3	3	2	4	4	2
Mathematics –mathematics through ODE	5	4	5	3	4	4	5	4	5	4

Production Process engineer - providing engineering support for day to day operations	Project manager -capital project leader; scope, schedule, budget contract hiring	Auditor - Verifying Procedures/Plant Walkthrough	Environmental engineer permitting, wastewater, emission dispersion, LDA rate	Regulator - perform inspections, approve permits	Safety engineer -slips, trips & falls, risk assessment, etc.	Industrial Research - develops new process	Product applications engineer (research) develops products & provides tech support to end-user	Maintenance engineer - manages planning, tech staff, preventive planned & non-planned	Planner (daily operations) order raw materials, plan shipment	Scheduler (project) project activity planning	Technical Staff Manager HR mgt responsibilities	Technical Task Manager - Technical task lead - no HR	Marketing & sales engineer	Operator/technician - operating a process daily
4	1	3	4	2	3	5	4	2	1	1	2	5	1	2
5	1	3	4	3	3	5	3	2	1	1	4	3	3	2
5	4	5	6	6	6	4	4	4	3	3	5	5	3	4
5	1	3	4	3	5	6	3	2	1	1	4	6	3	2
3	1	2	3	1	5	6	3	1	1	1	4	5	3	1
5	4	5	5	6	6	4	4	4	2	3	5	5	2	3
3	3	2	5	4	2	3	3	2	1	1	3	4	2	1
4	2	3	5	2	4	5	5	2	1	1	2	5	3	2
2	6	2	3	2	3	3	5	6	4	4	4	4	4	2
3	2	3	5	2	5	5	6	2	1	1	1	5	2	2
4	2	2	3	2	3	4	4	2	3	3	3	4	2	2
4	4	2	2	2	3	5	4	5	3	3	3	5	5	2
3	2	3	4	2	3	5	3	2	2	2	2	5	2	2

A5.7 Stage 3 Role	Consultant - expert, provides solutions	Economist - Strategic & optimization Capital unit - production planning	Educator (teacher, trainer)	Checker - Technical Accuracy	Process controls & instrument engineer - designs, develops process	Process Design Engineer on capital project develops detailed eng; size & spec equip	Safety systems (SIS, PSV, fire protection)	Standard setter (Define codes, practices, procedures, tools)	Flow assurance (upstream engineering) - Get out of ground & to processing	Operations Quality control - operational testing to assure product quality, product release, trending
Numerical analysis & linear programming	5	6	5	3	5	4	4	2	5	2
Physics	5	1	5	4	3	3	5	5	5	2
Project management	5	2	1	3	3	3	2	2	3	2
Statistical Quality Control	5	3	4	2	4	2	3	3	4	6
Statistics – variability, design of experiments	5	4	5	2	4	4	3	3	4	5
Psychomotor 1. Observing 2. Imitating 3. Practicing 4. Adapting										
Human										
Adjusting communication style	4	3	4	2	2	3	3	3	2	2
Electronic Communications	4	3	4	3	3	3	3	4	3	3
Identifying optimum delivery media	4	2	4	2	2	2	3	3	2	2
Listening and interpreting	4	4	4	2	3	3	3	4	3	3
Negotiation and conflict management	4	4	3	2	2	2	2	4	2	2
Public Relations	4	3	3	3	3	2	3	4	3	3
Speaking and presenting	4	3	4	2	2	3	2	4	2	3
Telephone Communications	4	3	3	3	3	2	3	3	3	3
Professional										
Critical reflection/learning	4	3	4	2	3	3	3	4	3	3

Production Process engineer - providing engineering support for day to day operations	Project manager -capital project leader; scope, schedule, budget contract hiring	Auditor - Verifying Procedures/Plant Walkthrough	Environmental engineer permitting, wastewater, emission dispersion, LDA rate	Regulator - perform inspections, approve permits	Safety engineer -slips, trips & falls, risk assessment, etc.	Industrial Research - develops new process	Product applications engineer (research) develops products & provides tech support to end-user	Maintenance engineer - manages planning, tech staff, preventive planned & non-planned	Planner (daily operations) order raw materials, plan shipment	Scheduler (project) project activity planning	Technical Staff Manager HR mgt responsibilities	Technical Task Manager - Technical task lead - no HR	Marketing & sales engineer	Operator/technician - operating a process daily
4	2	1	3	2	2	4	3	2	1	1	2	4	1	1
3	2	1	4	2	3	5	5	2	1	1	3	5	2	2
2	6	2	2	2	2	3	3	4	4	4	3	4	4	2
5	2	2	4	2	2	4	5	3	1	1	3	4	1	4
5	2	2	3	2	4	6	6	2	1	1	3	2	2	1
3	4	2	3	2	4	3	3	3	3	2	4	3	4	2
3	4	3	3	3	3	3	4	3	3	3	4	3	4	3
3	3	2	3	3	3	3	3	2	3	3	3	3	4	2
3	4	3	3	3	4	3	3	3	3	3	4	4	4	3
3	4	2	2	3	3	3	2	3	2	3	4	4	4	3
2	4	3	4	3	3	3	3	3	3	3	3	4	4	3
2	3	2	3	3	3	3	3	2	2	2	4	3	4	2
3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
3	4	2	3	2	3	4	3	3	2	2	3	4	3	2

A5.7 Stage 3 Role	Consultant - expert, provides solutions	Economist - Strategic & optimization Capital unit - production planning	Educator (teacher, trainer)	Checker - Technical Accuracy	Process controls & instrument engineer - designs, develops process	Process Design Engineer on capital project develops detailed eng; size & spec equip	Safety systems (SIS, PSV, fire protection)	Standard setter (Define codes, practices, procedures, tools)	Flow assurance (upstream engineering) - Get out of ground & to processing	Operations Quality control - operational testing to assure product quality, product release, trending
Experimental procedures	3	2	4	1	2	3	3	4	3	3
Leadership	4	4	3	1	2	3	3	4	3	3
Presentation	4	4	4	1	2	2	2	3	3	3
Problem solving	4	4	4	2	4	4	3	4	3	4
Teamwork	4	4	3	2	3	3	3	4	3	3
Technical Psychomotor										
Computer Applications	4	4	3	3	4	3	4	3	4	3
Spreadsheets	4	4	3	3	4	3	4	3	4	3
Time management	4	3	3	3	3	3	3	3	3	3
Typing (keyboarding)	3	3	3	3	3	3	3	3	3	3

Production Process engineer - providing engineering support for day to day operations	Project manager -capital project leader; scope, schedule, budget contract hiring	Auditor - Verifying Procedures/Plant Walkthrough	Environmental engineer permitting, wastewater, emission dispersion, LDA rate	Regulator - perform inspections, approve permits	Safety engineer -slips, trips & falls, risk assessment, etc.	Industrial Research - develops new process	Product applications engineer (research) develops products & provides tech support to end-user	Maintenance engineer - manages planning, tech staff, preventive planned & non-planned	Planner (daily operations) order raw materials, plan shipment	Scheduler (project) project activity planning	Technical Staff Manager HR mgt responsibilities	Technical Task Manager - Technical task lead - no HR	Marketing & sales engineer	Operator/technician - operating a process daily
2	1	1	3	1	3	4	3	2	1	1	2	3	2	3
3	4	1	3	2	2	3	3	2	2	2	4	4	3	2
2	4	2	3	3	3	3	3	2	2	2	4	4	4	1
4	4	2	3	2	3	4	4	3	3	3	4	4	2	4
4	4	3	3	4	3	3	3	3	3	2	4	4	4	3
3	2	3	3	3	4	4	3	3	3	3	3	4	3	3
3	3	3	3	3	3	3	3	3	4	3	3	3	3	2
3	4	2	3	3	3	2	3	3	4	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3	3	3	3	2

A5.8 Stage 4 Role	Consultant - expert, provides solutions	Economist - Strategic & optimization Capital unit - production planning	Educator (teacher, trainer)	Checker - Technical Accuracy	Process controls & instrument engineer - designs, develops process	Process Design Engineer on capital project develops detailed eng; size & spec equip	Safety systems (SIS, PSV, fire protection)	Standard setter (Define codes, practices, procedures, tools)	Flow assurance (upstream engineering) - Get out of ground & to processing	Operations Quality control - operational testing to assure product quality, product release, trending
Affective 1. Receiving 2. Responding 3. Valuing 4. Organizing 5. Internalizing										
Beliefs and Values										
Commitment to lifelong learning	5	5	5	5	5	5	5	5	5	5
Concern for public welfare	5	5	5	5	5	5	5	5	5	5
Ethics	5	5	5	5	5	5	5	5	5	5
Respect for others	5	4	4	4	4	4	4	4	4	4
Cognitive 1. Remembering 2. Understanding 3. Applying 4. Analyzing 5. Evaluating 6. Creating										
ChE Technical										
Energy balances involving 1st and 2nd law	6	4	6	5	3	6	6	5	6	5
Equilibria, chemical and phase	6	3	6	5	3	6	6	4	6	3
Fluid flow, pump & compressor sizing & selection, packed beds	6	3	6	5	2	6	6	6	5	5
Fluid flow, single-phase flow, two-phase flow (pipes, valves, orifices)	6	4	6	5	6	6	6	6	6	3
Heat balances with and without reactions	6	4	6	5	4	6	6	5	6	5
Heat transfer equipment design and analysis	6	3	6	5	2	6	6	6	6	5
Heat transfer, multiple modes, phase change	6	2	6	5	5	6	6	5	6	3

Production Process engineer - providing engineering support for day to day operations	5	5	5	4	5	5	5	5	5	5	5
Project manager -capital project leader; scope, schedule, budget contract hiring	5	5	5	4	1	1	2	1	1	2	1
Auditor - Verifying Procedures/Plant Walkthrough	5	5	5	4	3	3	3	3	3	3	3
Environmental engineer permitting, wastewater, emission dispersion, LDA rate	5	5	5	4	6	6	6	5	6	6	6
Regulator - perform inspections, approve permits	5	5	5	4	5	3	5	3	5	5	3
Safety engineer -slips, trips & falls, risk assessment, etc.	5	5	5	4	3	3	3	5	3	4	3
Industrial Research - develops new process	5	5	5	4	6	6	6	6	6	6	6
Product applications engineer (research) develops products & provides tech support to end-user	5	5	5	4	4	4	6	6	4	6	4
Maintenance engineer - manages planning, tech staff, preventive planned & non-planned	5	5	5	4	3	4	5	4	3	4	4
Planner (daily operations) order raw materials, plan shipment	5	5	5	4	3	2	2	1	3	3	3
Scheduler (project) project activity planning	5	5	5	4	1	1	1	1	2	1	1
Technical Staff Manager HR mgt responsibilities	5	5	5	5	4	2	2	2	4	4	2
Technical Task Manager - Technical task lead - no HR	5	5	5	4	5	5	5	5	5	5	5
Marketing & sales engineer	5	5	5	4	3	4	3	3	3	3	3
Operator/technician - operating a process daily	5	5	5	4	3	3	4	3	3	3	3

A5.8 Stage 4 Role

	Consultant - expert, provides solutions	Economist - Strategic & optimization Capital unit - production planning	Educator (teacher, trainer)	Checker - Technical Accuracy	Process controls & instrument engineer - designs, develops process	Process Design Engineer on capital project develops detailed eng; size & spec equip	Safety systems (SIS, PSV, fire protection)	Standard setter (Define codes, practices, procedures, tools)	Flow assurance (upstream engineering) - Get out of ground & to processing	Operations Quality control - operational testing to assure product quality, product release, trending
Kinetics, conversion in various reactor types, chemical equilibria	6	4	6	5	3	6	6	4	4	3
Kinetics, reactor analysis	6	2	6	5	2	5	6	6	2	2
Kinetics, reactor design, heterogeneous catalysis	6	3	6	5	2	6	3	5	2	2
Mass transfer, equipment design and analysis	6	3	6	5	2	6	3	6	6	5
Mass transfer, single- and two-phase processes	6	3	6	5	2	6	6	6	6	3
Materials science	6	2	6	5	4	6	3	6	6	4
Plant design, economics	6	6	4	5	4	5	3	5	5	2
Plant design, flow configuration, optimization	6	6	4	5	6	6	5	5	6	2
Plant design, instrumentation	5	4	4	5	6	5	6	6	5	4
Plant design, process control	6	4	4	5	6	6	5	5	6	2
Plant operations, optimization	6	6	4	5	6	6	6	4	6	3
Plant operations, startup, shutdown	5	6	3	5	6	5	6	4	6	3
Plant scale-up	6	4	4	5	5	6	3	4	3	2
Separations equipment selection & analysis	6	2	6	5	2	5	3	6	6	5
Separations process design	6	2	6	5	2	6	6	5	6	3
Stoichiometry with and without reactions	6	2	6	5	3	6	6	5	6	5

Production Process engineer - providing engineering support for day to day operations	Project manager -capital project leader; scope, schedule, budget contract hiring	Auditor - Verifying Procedures/Plant Walkthrough	Environmental engineer permitting, wastewater, emission dispersion, LDA rate	Regulator - perform inspections, approve permits	Safety engineer -slips, trips & falls, risk assessment, etc.	Industrial Research - develops new process	Product applications engineer (research) develops products & provides tech support to end-user	Maintenance engineer - manages planning, tech staff, preventive planned & non-planned	Planner (daily operations) order raw materials, plan shipment	Scheduler (project) project activity planning	Technical Staff Manager HR mgt responsibilities	Technical Task Manager - Technical task lead - no HR	Marketing & sales engineer	Operator/technician - operating a process daily
5	1	3	5	3	3	6	4	4	1	1	2	5	2	3
5	1	3	5	5	3	6	5	4	1	1	2	5	2	4
5	1	3	5	5	3	6	5	4	1	1	2	5	3	3
5	1	3	6	5	3	6	6	4	1	1	2	5	3	4
5	1	3	6	3	3	6	4	4	1	1	2	5	2	3
5	2	3	6	3	3	6	4	6	1	1	2	5	2	3
3	5	3	5	3	3	2	2	5	3	2	3	5	2	3
5	1	3	6	2	5	6	2	4	1	1	3	5	2	3
5	2	3	5	2	5	4	3	5	3	1	2	5	3	5
5	2	3	6	2	5	4	2	4	3	1	2	5	3	3
6	2	3	6	2	5	4	3	3	4	1	2	5	2	4
6	2	3	5	2	5	4	4	5	4	5	4	4	2	6
6	2	3	5	2	5	6	4	3	3	1	4	5	2	3
5	3	3	6	5	4	6	6	4	1	1	3	5	3	4
5	1	3	6	3	3	6	6	4	1	2	4	5	3	3
5	1	3	6	5	3	6	3	3	1	1	2	5	2	3

A5.8 Stage 4 Role	Consultant - expert, provides solutions	Economist - Strategic & optimization Capital unit - production planning	Educator (teacher, trainer)	Checker - Technical Accuracy	Process controls & instrument engineer - designs, develops process	Process Design Engineer on capital project develops detailed eng; size & spec equip	Safety systems (SIS, PSV, fire protection)	Standard setter (Define codes, practices, procedures, tools)	Flow assurance (upstream engineering) - Get out of ground & to processing	Operations Quality control - operational testing to assure product quality, product release, trending
Stoichiometry, complex systems with recycle, bypass	6	2	6	5	2	6	6	5	6	5
Cross Functional										
Energy - systems analysis, efficiency	6	6	6	5	4	6	3	6	6	3
Environmental assessment, regulations	6	3	6	5	4	6	4	6	6	3
Process simulators, operation, steady state simulation, dynamic simulation	6	6	6	5	6	6	6	6	6	3
Process simulators, strengths and weaknesses	6	6	6	4	6	6	5	5	6	3
Safety, analyses, modeling, procedural policies, regulations	6	3	6	5	4	6	6	6	6	3
Sustainability analyses	6	2	6	5	3	6	3	6	3	3
Technical										
Biology	6	3	6	5	3	4	3	6	3	4
Budgeting	6	6	6	5	4	5	3	6	3	2
Chemistry –inorganic, organic, physical chemistry and biochemistry	6	3	6	5	3	4	3	6	6	6
Computer programming	6	4	6	5	6	3	3	6	4	3
Economics	6	6	6	5	4	5	3	6	4	2
Mathematics –mathematics through ODE	6	5	6	5	5	4	5	6	4	4

Production Process engineer - providing engineering support for day to day operations	Project manager -capital project leader; scope, schedule, budget contract hiring	Auditor - Verifying Procedures/Plant Walkthrough	Environmental engineer permitting, wastewater, emission dispersion, LDA rate	Regulator - perform inspections, approve permits	Safety engineer -slips, trips & falls, risk assessment, etc.	Industrial Research - develops new process	Product applications engineer (research) develops products & provides tech support to end-user	Maintenance engineer - manages planning, tech staff, preventive planned & non-planned	Planner (daily operations) order raw materials, plan shipment	Scheduler (project) project activity planning	Technical Staff Manager HR mgt responsibilities	Technical Task Manager - Technical task lead - no HR	Marketing & sales engineer	Operator/technician - operating a process daily
5	1	3	6	5	3	6	4	2	1	1	2	5	2	3
5	1	3	6	5	3	6	3	3	1	1	3	5	5	3
5	4	5	6	6	6	4	4	4	3	3	5	5	3	4
5	1	3	6	5	6	6	3	2	1	1	4	6	3	3
5	1	3	6	2	5	6	3	1	1	1	4	5	3	1
5	4	5	6	6	6	4	4	4	2	3	5	5	2	3
3	3	3	6	5	6	3	3	3	1	1	3	5	2	3
4	2	4	5	3	4	6	6	2	1	1	2	6	3	4
3	6	3	3	4	3	5	5	6	5	4	4	6	4	2
5	2	3	5	3	3	6	6	3	1	1	1	6	2	4
4	2	2	3	3	3	6	4	2	3	3	3	4	2	2
5	6	2	3	4	4	5	5	5	3	3	3	5	5	2
5	2	4	4	3	4	6	3	3	2	2	2	5	3	3

A5.8 Stage 4 Role	Consultant - expert, provides solutions	Economist - Strategic & optimization Capital unit - production planning	Educator (teacher, trainer)	Checker - Technical Accuracy	Process controls & instrument engineer - designs, develops process	Process Design Engineer on capital project develops detailed eng; size & spec equip	Safety systems (SIS, PSV, fire protection)	Standard setter (Define codes, practices, procedures, tools)	Flow assurance (upstream engineering) - Get out of ground & to processing	Operations Quality control - operational testing to assure product quality, product release, trending
Numerical analysis & linear programming	6	6	6	5	5	5	4	6	5	3
Physics	6	1	6	5	3	3	5	6	5	2
Project management	6	1	6	5	3	4	3	6	3	2
Statistical Quality Control	6	3	6	5	5	3	3	6	5	6
Statistics – variability, design of experiments	6	5	6	4	5	5	6	6	4	5
Psychomotor 1. Observing 2. Imitating 3. Practicing 4. Adapting										
Human										
Adjusting communication style	4	3	4	3	3	3	4	4	4	4
Electronic Communications	4	3	4	3	4	3	3	4	3	3
Identifying optimum delivery media	4	3	4	2	3	3	3	3	3	3
Listening and interpreting	4	4	4	4	4	4	4	4	4	3
Negotiation and conflict management	4	5	3	4	3	3	4	4	4	4
Public Relations	4	4	4	3	3	3	3	4	3	3
Speaking and presenting	4	3	4	2	3	3	3	4	3	3
Telephone Communications	4	3	3	3	3	3	3	3	3	3
Professional										
Critical reflection/learning	4	4	4	4	4	4	4	4	4	4
Experimental procedures	3	2	4	1	4	4	3	4	3	4
Leadership	4	4	3	3	3	3	4	4	3	3

Production Process engineer - providing engineering support for day to day operations	Project manager -capital project leader; scope, schedule, budget contract hiring	Auditor - Verifying Procedures/Plant Walkthrough	Environmental engineer permitting, wastewater, emission dispersion, LDA rate	Regulator - perform inspections, approve permits	Safety engineer -slips, trips & falls, risk assessment, etc.	Industrial Research - develops new process	Product applications engineer (research) develops products & provides tech support to end-user	Maintenance engineer - manages planning, tech staff, preventive planned & non-planned	Planner (daily operations) order raw materials, plan shipment	Scheduler (project) project activity planning	Technical Staff Manager HR mgt responsibilities	Technical Task Manager - Technical task lead - no HR	Marketing & sales engineer	Operator/technician - operating a process daily
4	2	1	5	3	3	5	3	2	1	1	2	5	1	1
5	2	1	4	3	3	6	6	3	1	1	3	5	2	2
2	6	2	3	2	3	3	3	4	4	4	3	6	4	2
5	2	2	5	3	4	4	6	3	1	1	4	3	1	4
5	2	2	3	2	5	6	6	4	1	1	3	2	5	2
4	4	4	4	3	4	3	4	3	4	4	4	4	4	3
3	4	3	3	3	3	3	4	3	3	3	4	3	4	3
3	4	3	3	4	3	3	3	3	3	3	3	3	4	2
4	4	4	4	3	4	4	4	4	4	4	4	4	4	4
4	4	4	4	4	4	3	4	3	4	4	4	4	4	3
3	4	3	4	4	4	3	4	3	3	3	3	4	4	3
3	3	3	4	3	3	3	3	3	4	3	4	3	4	2
3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
4	4	3	4	3	4	4	4	4	4	3	3	4	3	4
4	2	1	3	3	3	4	4	2	1	1	2	3	2	2
3	4	3	4	4	4	3	3	3	3	3	4	4	4	4

A5.8 Stage 4 Role	Consultant - expert, provides solutions	Economist - Strategic & optimization Capital unit - production planning	Educator (teacher, trainer)	Checker - Technical Accuracy	Process controls & instrument engineer - designs, develops process	Process Design Engineer on capital project develops detailed eng; size & spec equip	Safety systems (SIS, PSV, fire protection)	Standard setter (Define codes, practices, procedures, tools)	Flow assurance (upstream engineering) - Get out of ground & to processing	Operations Quality control - operational testing to assure product quality, product release, trending
Presentation	4	4	4	2	3	3	3	4	3	3
Problem solving	4	4	4	3	4	4	4	4	4	4
Teamwork	4	4	3	3	4	3	4	4	4	3
Technical Psychomotor										
Computer Applications	4	4	4	3	4	4	4	3	4	3
Spreadsheets	4	4	3	3	4	3	4	3	4	3
Time management	4	3	3	3	4	3	3	3	3	3
Typing (keyboarding)	3	3	4	3	3	3	3	3	3	3

Production Process engineer - providing engineering support for day to day operations	Project manager -capital project leader; scope, schedule, budget contract hiring	Auditor - Verifying Procedures/Plant Walkthrough	Environmental engineer permitting, wastewater, emission dispersion, LDA rate	Regulator - perform inspections, approve permits	Safety engineer -slips, trips & falls, risk assessment, etc.	Industrial Research - develops new process	Product applications engineer (research) develops products & provides tech support to end-user	Maintenance engineer - manages planning, tech staff, preventive planned & non-planned	Planner (daily operations) order raw materials, plan shipment	Scheduler (project) project activity planning	Technical Staff Manager HR mgt responsibilities	Technical Task Manager - Technical task lead - no HR	Marketing & sales engineer	Operator/technician - operating a process daily
3	4	3	3	4	3	3	3	3	3	3	4	4	4	2
4	4	2	4	4	4	4	4	4	4	4	4	4	2	4
4	4	4	3	4	4	3	4	3	3	3	4	4	4	4
4	2	3	3	3	3	4	3	3	3	3	3	4	3	3
4	3	3	3	3	3	3	4	3	4	3	3	3	3	2
4	4	3	3	3	3	3	4	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	4	3	3	3	3	3

A6. Appendix 6 – Acknowledgments

The following are contributors to the BOK. The purpose in providing these biographical summaries is to demonstrate that BOK development was conducted by a diverse team that represented the concerns and experiences of stakeholders.

Linda H. Bergeron P.E., F.AIChE	Linda has worked as a chemical engineer in industry for 28 years, 21 of the last in chlor-alkali chemical manufacturing. She has held various technical and production roles, currently focusing on process design and optimization, process control, and process safety management. She holds a BS in chemical engineering from Clemson University and a Master of Engineering Management from Pennsylvania State University. She serves on the NCEES PE Chemical Exam development committee.
Anne Bertelsmann, Ph.D., P.E.	Anne has worked for several large companies in the chemicals, pharmaceuticals and refining industry. She has experience with front end design, process safety, cGMP, sterile filling and advanced process control. Her roles included process engineer, technical production support, maintenance manager and PHA coordinator. She serves on the NCEES PE Chemical Exam development committee.
Denise Chastain-Knight, P.E., CFSE, F.AIChE	Denise earned a BS Chemical Engineering in 1986 from Georgia Institute of Technology. She has worked in corporate engineering and consulting. She has experience in the gypsum, resins, polymers, specialty chemicals, oil & gas, bio-fuel, polysilicon, power, foods, and pharmaceutical industries. Her roles include product development, process design, project management, process and functional safety consulting. She was General Arrangements Chair for the AIChE 1994 Spring National Meeting and held multiple local section offices. She has served on the NCEES PE Chemical Exam development committee for 14 years.
James T. Cobb Jr, Ph.D, P.E., F.AIChE	Dr. Cobb was a professor of chemical engineering at the University of Pittsburgh. He graduated with a bachelor of science degree from Massachusetts Institute of Technology in 1960, then received his Master's degree from Purdue University in 1963; he earned his Ph.D. from Purdue University in 1966. He was a member of the American Institute of Chemical Engineers (AIChE) serving as CEOC chair and on the nominations and professional development committees, He became active in National Council of Examiners for Engineering and Surveying (NCEES) in 1976 and served on both the FE and PE exam development committees. He was also an active member of the Pennsylvania Society of Professional Engineers (PSPE).
Joseph J. Cramer, Ph.D., P.E., F.AIChE	Joe is currently Director Emeritus, Program Development, for AIChE. He was Director, Technical Programming from 1994 until his retirement in January 2012 and also Secretary of the Executive Board of the Programming Committee (EBPC). Previously, he was with Stone and Webster Engineering serving as a project manager and process safety program manager and with Brown & Root and Bechtel leading air quality engineering departments. Cramer has extensive experience in the presentation of expert testimony and has presented both short courses and webinars on that subject on behalf of AIChE. He received his BS and PhD from the University of Pennsylvania and a Masters in Chemical

	Engineering Practice from the MIT Practice School and is a Fellow of AIChE, a licensed P.E. in Texas, and currently serves on the AIChE Admissions Committee and the NCEES Ch. E. PE Exam Committee. He consults to AIChE on programming and PE licensing issues and now serves on the Career and Educational Operating Council (CEOC) and as Programming Chair for AIChE's Management Division. Past service to the Institute included a term on AIChE's Board of Directors (1993-1995), many years on AIChE's Chemical Engineering Technology Operating Council (CTOC) and assignments as meeting program chair for an AIChE national meeting (Minneapolis-1992) and as chair of AIChE's Environmental Engineering Division (1991).
Howard C. 'Skip' Harclerode II, P.E., F.AIChE, F.NSPE	Skip has 15 years of industrial experience, 9 years as owner and operator of a large mechanical/general contracting company and 22 years of experience as an engineering consultant. He is also presently serving his 11^{th} year on the Maryland State Board for Professional Engineers and his sixth year as Board Chairman. He has worked with chromium chemicals, fertilizers, resins, polymers, specialty chemicals, oil & gas, bio-fuel, synthetic fibers, catalysts, power, foods, and the consumer products industries. His roles include product development, process design, project management, process safety and design engineering consulting services in all disciplines of engineering.
Cory Jensen PE, EMIT	Cory earned a B.S.-ChE from South Dakota School of Mines & Technology, M.S. ChE/BiolE from Colorado State University, and most recently has attended the Colorado School of Mines in a Mechanical-Systems program while completing requirements for a science technology engineering policy (STEP) certificate. Cory's professional experience includes: specialty chemicals (organo-siloxanes), biofuels process design-R&D, cement manufacturing, power generation, all aspects of industrial water programs (including wastewater), sustainable buildings, higher education ethics, sustainable community development, environmental engineering-science, policy development, molding-integrated parts manufacture, food grade production, and information technology development. As a researcher, Cory has worked with complex chemical (e.g. advanced fuels), biological (e.g. biosensors), and policy (e.g. chemical regulation) systems.
Tom Kenat Ph.D, P.E., F.AIChE	Tom received his Ph.D. chemical engineering from Carnegie Mellon University in 1968. He has over 40 years of engineering experience and has served as an independent consultant since 1992 on polymers, reaction engineering, process control, distillation, corrosion, and pollution control. His experience includes initial design of process equipment for new processes developed in R&D and improving existing processes. Tom also does conceptual engineering and evaluation of new technology for technical feasibility, economic feasibility, patentability, and market potential. He is an active member of AIChE and the Chemical Engineers PE Exam development Committee.
Phil Knieper P.E.	Philip has 51 years of experience in process engineering associated with the manufacture of commodity chemicals. His engineering roles included process maintenance, process improvement, optimization, process and equipment design, plant start-up, etc. His leadership roles included the management of the complex's process engineering department and simultaneously the management of the corporate materials of construction laboratory. In the most

	recent 6 years, Phil has worked as a consultant/mentor process engineer at the same lower Mississippi River complex specializing in emergency relief systems. Phil has a BS in Chemical Engineering from Tulane University and an MS in Chemical Engineering from Kansas State University. He is an active member of the AIChE for 48 years and contributes to NCEES on the PE Chemical Exam Committee for the past 14 years.
William R Parrish, Ph.D., P.E., F.AIChE	Bill worked 25 years in R&D of oil and gas company. He obtained thermophysical properties of fluids, managed the company's statistics group, and provided technical consulting to company's oil, gas and chemical operations. He has served on the NCEES PE Chemical development committee for over 15 years. Since retiring, he gives short courses on natural gas processing. He also represents AIChE at various NCEES functions.
Jeff Perl, Ph.D., P.E., CHMM, F.AIChE	Jeff Perl is president and principal engineer with Chicago Chem Consultants Corp. He is also an Adjunct Professor of Chemical Engineering at the University of Illinois - Chicago where he teaches the two semester senior ChE (capstone) process design course. Jeff is a former US Air Force Bio-Environmental Engineer Officer (Reserve), where he served under both The Civil Engineer and The Surgeon General of the Air Force. Jeff is a graduate of the Illinois Institute of Technology, BS, MS, PhD ChE and is a licensed Professional Engineer (PE), as well as a Certified Hazardous Materials Manager (CHMM). Jeff is a Fellow of AIChE and IHMM and is also a member of ASHRAE and Am Soc Quality. Jeff's work interests include: Process Design and Evaluation, Forensic Engineering, Equipment Evaluation and Sizing, Pilot Studies, Expert Legal Support Services
Robert F. Reardon, Ph.D., P.E.	Robert earned a BS Chemistry in 1977 at University of North Carolina, a MS in chemical engineering in 1981 at North Carolina State University, and a PhD Adult Education in 2004 from University of Georgia. He has industrial experience in chemical and polymer production and has worked extensively in process controls and process safety management. Robert currently teaches quantitative research methods, leadership, organizational change, and educational theory in the Education Ph.D. program at Texas State University in San Marcos, TX. He also works as a process safety consultant in chemicals, food processing and oil and gas. He has been a member of the Chemical PE Exam Development Committee of NCEES since 1993 and is currently the Chair of the Committee.
Freeman Self, P.E., F.AIChE	Freeman is a process engineer with Bechtel, specializing in process safety, and a Bechtel Distinguished Engineer. He is active in industrial groups including DIERs (Design Institute for Emergency Relief Systems) and the American Petroleum Institute-Committee for Pressure Relief. Committed to local sections, he has served South Texas Section in many positions, including Chair. He co-founded STS's Young Professional Group and was an original member of Prairie View A&MU's Advisory Board, served as Chair, and continues on the Board. He has served as Treasurer of Fuels and Petroleum Division (F&PD), Past Chair of CEOC (Career and Education Operating Council), and former member of the Board of Directors. He is currently an Advisory Editor for the Webinar Committee which develops webinars for AIChE Academy, and serves on the 2014 Strategic Plan Committee. He received a BChE from Georgia Tech, MSChE from Rice University and MBA from the University of Houston.

Jeffrey J. Siirola, PhD.	Jeff Siirola retired in 2011 as a Technology Fellow after more than 39 years at Eastman Chemical. He now holds half time positions at Purdue University and at Carnegie Mellon University teaching process synthesis, process design, and chemical technology and industry structure. He has served as Secretary of ABET and trustee and president of CACHE. He is a member of the National Academy of Engineering and was the 2005 President of the American Institute of Chemical Engineers.
David L. Silverstein, Ph.D., P.E.	David is a Professor of Chemical & Materials Engineering at the University of Kentucky and Director of the College of Engineering's Extended Campus Programs in Paducah, KY where he has taught for 15 years. His professional interests include development and assessment of conceptual learning tools and faculty professional development.
Tom Stephan, P.E.	Tom has 37 years of experience in technical roles as an individual contributor and a manager, primarily with operating companies in refining and petrochemicals. His work has involved process technology development, implementation of new technology, design for capital projects, and plant operations. He has spent most of his career with Exxon Research and Engineering, Amoco Chemical Company, BP Chemicals, and Flint Hills Resources.
Ranil Wickramasinghe, Ph.D., P.E.	Prof. Ranil Wickramasinghe obtained his PhD in Chemical Engineering from the University of Minnesota, and a BS and MS from the University of Melbourne, Australia. Professor Wickramasinghe has worked in the biotechnology industry in Boston, MA and has worked for the Department of Chemical and Biological Engineering at Colorado State University and the Department of Chemical Engineering at the University of Arkansas. Ranil's research focuses on membrane based separations for applications in biotechnology, biofuels and environmental engineering.