DISSERTATION

STRUCTURAL ENGINEERING MASTERS LEVEL EDUCATION
FRAMEWORK OF KNOWLEDGE
FOR THE NEEDS OF INITIAL PROFESSIONAL PRACTICE

Submitted by

Zsuzsa Eniko Balogh

Department of Civil and Environmental Engineering

In partial fulfillment of the requirements

For the Degree of Doctor of Philosophy

Colorado State University

Fort Collins, Colorado

Fall 2012

Doctoral Committee:

Advisor: Marvin E. Criswell

Neil S. Grigg
John W. Van de Lindt
Thomas J. Siller
Michael Anthony De Miranda

ABSTRACT

STRUCTURAL ENGINEERING MASTERS LEVEL EDUCATION

FRAMEWORK OF KNOWLEDGE

FOR THE NEEDS OF INITIAL PROFESSIONAL PRACTICE

For at least the last decade, engineering, civil engineering, along with structural engineering as a profession within civil engineering, have and continue to face an emerging need for "Raising the Bar" of preparedness of young engineers seeking to become practicing professional engineers. The present consensus of the civil engineering profession is that the increasing need for broad and in-depth knowledge should require the young structural engineers to have at least a Masters-Level education. This study focuses on the Masters-Level preparedness in the structural engineering area within the civil engineering field. It follows much of the methodology used in the American Society of Civil Engineers (ASCE) Body of Knowledge determination for civil engineering and extends this type of study to better define the portion of the young engineers preparation beyond the undergraduate program for one specialty area of civil engineering. The objective of this research was to create a Framework of Knowledge for the young engineer which identifies and recognizes the needs of the profession, along with the profession's expectations of how those needs can be achieved in the graduate-level academic setting, in the practice environment, and through lifelong learning opportunities with an emphasis on the initial five years experience past completion of a Masters program in structural engineering. This study applied a modified Delphi method to obtain the critical information from members of the structural engineering profession. The results provide a Framework of Knowledge which will be

useful to several groups seeking to better ensure the preparedness of the future young structural engineers at the Masters-Level.

ACKNOWLEDGEMENTS

The author would like to gratefully thank her supervisor, Dr. Marvin E. Criswell, for providing the needed guidance, assistance, patience, and advice while giving the author the freedom to pursue her own research interests.

The researcher would also like to thank her PhD Committee members for their direction, dedication, and time commitment along and beyond this research project.

This research would not have been possible without the professionalism and enthusiasm of the structural engineers who responded to the questionnaires.

The author gratefully acknowledges Dr. Richard Gutkowski for his continuous support throughout her research from the very beginning.

Finally, and most importantly, she would like to thank her entire family, especially her husband and daughter, for their loving support, encouragement, patience and tolerance throughout these years, and for their faith in her pursuit of her aspirations.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 INTRODUCTION

1.1 Statement of the Research Problem

The International Association for Bridge and Structural Engineering has defined structural engineering as “the science and art of planning, design, construction, operation, monitoring and inspection, maintenance, rehabilitation and preservation, demolishing and dismantling of structures, taking into consideration technical, economic, environmental, aesthetic and social aspects” (International Association for Bridge and Structural Engineers, 2011). This definition describes a profession with many aspects and responsibilities, and it suggests that the proper preparation of the young engineer entering this profession is a multi-component challenging task for the combined educational and professional communities.

The expectations for a structural engineer are changing in our global and increasing high technology environment, both in the United States and elsewhere, although the overall objective of the profession remains the same: namely, to serve the “advancement and betterment of human welfare” (National Society of Professional Engineers, 1954). Many forums have or are researching the questions raised by professionals on how adequately engineering program graduates are prepared for entry-level positions in the profession after completion of their undergraduate studies and/or the academic and professional preparation they should have both right after graduation from a Masters-Level program and after a few (3-5) years of experience working in the professional structural engineering field, at which time they can qualify to apply for professional registration. This preparation for registration and professional practice is especially challenging in engineering specialties where the typical environment in practice includes significant professional practice components which are considerably different from those emphasized in the academic environment. For the structural engineering, design is heavily controlled by building codes, specifications, and construction industry practices, and less so by the results of current research. The use of large and specialized software is pervasive. Project design and management includes working with other construction-team professionals such as architects, and contractors. Local practices, client relations, and business practices are critical.

In the absence of a formal internship or professional school approach, an important challenge is to define the optimum division of the various aspects of the young structural engineer's preparation among formal graduate education, early professional practice, and professional development phase leading up to professional licensure.

1.2 Hypotheses

The hypothesis of this dissertation is that a recommended framework of a Masters-Level graduate structural engineering program that will effectively and efficiently prepare its graduates for a professional career in structural engineering could and should be developed.
Although this framework addresses course topics judged appropriate to provide the overall body of knowledge for the structural engineering professional, it does not involve creating a prescribed curriculum for graduate level structural engineering. The framework is planned to provide critical input to the structural engineering community, the civil engineering profession, and the associated educational institutions through a documented study on graduate level structural engineering programs with similarities to the types of information given in the ASCE Body of Knowledge (BOK2) document which emphasizes undergraduate civil engineering education (American Society of Civil Engineers (ASCE) Body of Knowledge Committee of the CAP3, 2008).

This study focuses on the structural engineering Masters-Level education programs and their roles and effectiveness in preparing their graduates for the productive participation in the global 21st century structural engineering profession. Structural engineering is a specialization of civil engineering. Although it is built on a common base with civil engineering, structural engineering has its own specific characteristics and needs. Thus, the emphasis of the study is primarily to provide information for the outcomes and levels of achievement assigned in the BOK2 to be achieved after the undergraduate degree, especially those assigned to the graduate level, specifically for the structural engineering.

This research study starts with a description of higher education and engineering education in general and the environment within which the structural engineering graduate programs reside. The educational environment in the United States is emphasized, along with some observations of trends outside the United States. The focal point of the study is then narrowed to civil engineering and the challenges that both civil engineering education and the profession face now and likely will face in the next few decades. Using Bloom's Taxonomy of educational objectives (Bloom, Engehart, Furst, & Kratwohl, 1956), the questions surveyed are related to the level of achievement a typical graduate of a Masters program in structural engineering should have for relevant technical and professional subjects upon completion of the Masters degree, and also the achievement levels which should be attained after his/her first three to five years in structural engineering practice. The sources available to the young engineer beyond the structural engineering Masters degree in order to reach the "prepared for licensure" level from a "no experience" level are also addressed in this study. Although continued professional development extends beyond the first five years of experience, the time period addressed in this research study is the first five years.

1.3 Delimitations and Limitations

Delimitations of the study are:

- This study is confined to structural engineering and particularly to the Masters-Level graduate education in the area of structural engineering. Questions related specifically to the doctoral level of structural engineering education are not addressed in this study in part because of the individualized nature typical of structural engineering degree programs at the Ph.D. level and because the Masters degree still generally considered to be the usual entrance level degree for practice in the structural engineering profession.
- This study is concentrated on the Masters-Level structural engineering preparedness in the United States. Coverage of the international aspects is beyond the scope of this study, except for a few key references to the topic which allow a general comparison of U.S. and some typical international programs.
- This study focuses on traditional academic environment in an on-campus setting. While on-line, hybrid, distance, and video-based graduate degree programs and courses in the structural engineering area are emerging in academia and industry, such programs are still relatively few in number and their characteristics vary. Although such programs are mentioned in this study, a detailed examination of these alternative delivery programs is considered to be beyond the scope of this research and could be the topic of a separate extensive study.
- The target panel group of survey participants did not include graduate students, who are not yet in the position to judge the needed level of structural engineering preparedness and to have a deep understanding of what structural engineering practice entails.

Limitations of the study are:

- The methodology to be used includes a modified Delphi study with 30 to 50 participants. This study size is considered to be adequate to provide a broad representation of the profession and yet limit to a practical magnitude the resources needed to compile and analyze the data in a realistic and timely manner for the purpose of this research. The modified Delphi study is described in Section 3.
- The sampling criteria for the identification of potential volunteers who are practicing structural engineers, educators, and professional organization members in the structural/civil engineering area is a limitation of the study. The participants in the Delphi study were volunteers from an invitation list of representative individuals determined to be knowledgeable and interested in the educational preparation of the structural engineer rather than being from a random selection of all the structural engineering population.
- Another methodology-related limitation comes from the number of rounds planned for the modified Delphi method, a method which inherently has no set upper limit on the number of rounds. As this study used a modified Delphi method to share the group's initial assessments, allow reconsideration and revision of individual responses, and reach a firm distribution of group inputs rather than to determine a specific group action and single response. The number of rounds can be limited to the number needed give well considered and useful individual and group information. Rounds beyond the initial two or three would be expected to provide little improvement in the types of information being sought.

1.4 Study Deliverables

The overall objective of this study is to determine the needed content of the Masters-Level graduate programs in structural engineering as perceived by the profession and to thereby provide critical input and a basis for defining an improved framework for the Masters-Level graduate programs in structural engineering which will better prepare its graduates for professional practice.

The future implementation of this framework recognizing the needs of the profession will depend upon resource limitations and current practices of both the academic and the practice environments, along with availability and use of additional academic electives, and initial professional employment, continuing education, and other lifelong learning resources. This study will provide the key information and recommendations in support of the development of what will be called a Framework of Knowledge on structural engineering Masters-Level education, which is consistent with the more-generally stated ASCE Body of Knowledge but is more directed to focus on structural engineering Masters-Level education and the graduate's initial period in practice.

1.5 Significance of the Study

By better harmonizing the Masters-Level structural engineering education with the needs of the structural engineering profession in the United States, this study will have a positive and significant impact, both short term and long term, on the preparedness of the new Masters graduates in structural engineering.

2 BACKGROUND / LITERATURE REVIEW

2.1 Introduction

A critical step in this study is to examine and learn from past studies which have addressed the preparation of the young structural engineer. Several well-known studies have reported on undergraduate engineering and undergraduate civil engineering. However, studies specifically on structural engineering graduate programs are fewer. Major studies on either general engineering or structural engineering that this research study builds upon are described in Section 2.3 of this Chapter.

Structural engineering as a profession has been critiqued and evaluated at various levels of detail in especially the past decade by groups from academia and by the engineering profession, the final "users" of the graduates with a structural engineering degree. These studies have been less formal and much smaller in number than those for engineering in general. Structural engineering in practice includes more knowledge/skill requirements than just applied science, engineering theory and principles, and design provisions. Structural engineering is considered a specialty of civil engineering; however students can pursue it as a stand-alone degree, especially at the graduate level.

Some of the major questions regarding the graduate programs raised by professionals in structural engineering are:

- What aspects of the recent studies on the educational environment and the needs of future engineers are most relevant to the graduate programs in structural engineering?
- What is the current assessment of the graduate programs by the profession?
- What are the resource limitations for both the academic programs and the profession?

- How best to define a framework for graduate programs which addresses both the needs of the profession and resource limits of the graduate programs?
- What areas of desired content could be packaged or repackaged in combined, revised, or a few additional academic courses?

The overall goal of this research is to formulate an organization and description for a graduate level (M.S.) structural engineering education framework, a framework similar to the more undergraduate-oriented Civil Engineering Body of Knowledge for the 21st Century (American Society of Civil Engineers (ASCE) Body of Knowledge Committee of the CAP3, 2008). The framework developed in this study focuses on the preparedness expected for the structural engineering specialty area of civil engineering through graduate studies and early professional experience, and this framework content must be more specific than are the intentionally quite general outcomes contained in the ASCE BOK.

To fully understand and create the best pathway for achieving the goals of this research, the work already reported in the overall field of higher education was explored, and then the reported work in the increasingly specific areas of engineering, civil engineering, and then structural engineering was examined. The limited information published on the relationship between the professional field and academia in the field of graduate (Masters-Level) structural education is most relevant to this study.

2.2 Description of the Structural Engineering Profession

A profession involves responsibility and practice in a specialization, a scope and jurisdiction for this practice which is often defined by licensure or other credentials, formal training associated with higher education and with input from the profession, and a set of professional standards expressing a commitment to doing good work in support of societal needs. As described by several authors (Abbott, 1988) (Freidson, 2001) (Ressler, 2011), a specialized body of knowledge (BOK) is critical to professionalism. It is important that this BOK involves a level of abstraction and openness for change so that robustness to still be applicable when technical advancement, modified professional practices, and other conditions change the details of the work of the profession as a key attribute of engineers/civil engineers/structural engineers.

2.2.1 Definition of Structural Engineering

There are several definitions in the literature of this exciting, vital, and rewarding profession. An informal definition which describes the tasks and challenges of the structural engineer (Schmidt, 2008) is: " Structural engineering is the art of moldings materials we do not wholly understand into shapes we cannot precisely analyze, so as to withstand forces we cannot really assess, in such a way that the community at large has no reason to suspect the extent of our ignorance." One of the main keywords of structural engineering, the word "design", is missing from most definitions found in the literature. Theodore von Kármán's definition of engineering; "Scientists study the world as it is; engineers create the world that has never been." fits perfectly the broad definition of structural engineers. Erik Nelson's definition, "Structural engineering is the design of BIG things", is short and simple, however it describes structural engineering quite well (Nelson, 2012). To fully understand what the structural engineering professional is beyond what can be given by a one sentence definition of this profession, it is necessary to describe in more detail the attributes related to structural engineering.

2.2.2 Attributes of the Successful, Productive Structural Engineer

From the professional literature, the researcher has concluded that the desired attributes of a structural engineer can be organized as follow. The successful, productive structural engineer has abilities in at least the following often interacting knowledge areas and skills:

A. Knowledge Areas

1. Technical – The basic sciences and mathematics, engineering basics, design requirements, design procedures, knowledge of materials, etc. i.e. expertise in the technical fundamentals.

2. Professional practices – knowledge on codes and standards, project and team management, building and construction team organization, ethics and professional standards, business practices, etc.

B. Personal Skills, Interests, and Attitudes

1. General Skills, Interests, and Attitudes
    a. Communications – written, verbal, graphical skills as appropriate for many types of audiences
    b. Teamwork and leadership
    c. Time management and organizational skills
    d. Interpersonal skills
    e. Personal and professional ethics and standards
    f. Adaptable to change, lifelong learning
    g. Skills related to societal needs, sustainability, globalization, etc.
2. Specific Skills, Interests, and Attitudes – those with particular applicability to the structural engineer
    a. Structural sense – ability to “think like the structure” and to be able to accurately envision how the structure, subassembly, member, or component will respond to a force or excitation, i.e. have the type of understanding of how things work exhibited by a master carpenter or master builder.

b. Ability to simplify, to see the big picture – the overall behavior, economy, and utility of the entire structural system and its primary components along with an ability to conduct conceptual and preliminary design and to explore alternatives. An ability to think visually to envision structures as the three-dimensional objects they are.
c. Creativity, restrained by reality.
d. Ability to define and solve problems in uncertain situations.
e. Innovation, consistent with adequate investigation and caution.
f. Aesthetics and a sense of structural engineering history and culture – as structural engineers often work with objects that are effectively very large scale public art.
g. Proficient at reflective evaluation – the ability to critique work separated from the "pride of creation". As often noted by Professor Mel Baron (UC Berkeley) in his classes in the 1970's: The most important task of the structure engineer is to define all the ways a structure, member or component can fail, and then take all the necessary steps to assure that failure does not occur.
h. Entrepreneurship – perhaps best illustrated when a design engineer also leads the approval, financing and construction of the same project: e.g. Eiffel (Eiffel Tower), Roebling (several bridges), Straus (Golden Gate Bridge)
i. Appreciation of the roles of the members of the overall building team – owner, architect, other engineers, contractors, users and occupants, etc., and an ability to work with these team members.

The technical and professional practice knowledge can be directly addressed by the academic and professional communities. The personal skills can be strengthened within these communities, but also depend heavily on the basic abilities, interests, and priorities of the individual.

2.2.3 Size/Number/Demographics

Based on the data from the ASCE (American Society of Civil Engineers, 2012) on active membership numbers, the distribution of ASCE membership is summarized in Table 2-1.

Table 2-1: American Society of Civil Engineers General Membership

Membership Grade	Number
Honorary/Distinguished Members	198
Fellows	6,120
Members	76,717
Associate Members	22,445
Affiliate Members	5,457
Student Members	28,506
Institute Only Members	1,989
Total	141,432

Institute based membership is distributed within eight different Institutes, presented in Table 2-2 with membership numbers as of September 30, 2011.

Table 2-2: American Society of Civil Engineers Institute Membership

Institute Name	Institute Abbreviation	Member Numbers
Architectural Engineering Institute	AEI	6,878
Construction Institute	CI	16,858
Coasts, Oceans, ports and Rivers Institute	COPRI	3,478
Engineering Mechanics Institute	EMI	2,078
Environmental & Water Resources	EWRI	21,965
Geo-Institute	GI	10,447
Structural Engineering Institute	SEI	20,074
Transportation & Development Institute	TDI	15,067

The second largest group in the Civil Engineering profession is Structural Engineering, which is consistent with recent research findings on the structural engineering Masters Degree specialization (Russell, Lenox, Rogers, & Coward, 2010). According to this research, out of the 232 individual programs offering Masters-Level civil engineering degrees (with several specialties), structural engineering was noted as an available area of specialization in 154 programs, second only to the environmental specialization with 167 responses.

2.3 Previous Research / Studies

Previous research has been done on many levels regarding higher education, engineering education, civil engineering education, and/ or structural engineering education. As the education funnel moves from higher education on general to structural engineering education, the available research resources and the number of reported studies in the areas mentioned show a very significant decrease.

2.3.1 Higher Education

The overall educational environment within which the structural engineering graduate programs reside is undergoing change, both in the United States and across the globe, and numerous studies have called for various degrees of systematic change and reform of higher education in response to many pressures - some being resource/financial, information technology, rapid developments in technology, globalization, and natural resource limitations.

A very important overall educational system approach at the international scale has been described in the European University Association publications TRENDS 2010 report (Sursock & Smidt, 2010). The report is focused on the implementation of the Bologna Process for harmonizing university-level academic programs among the member nations of the European Union during the 2000-2010 decade, along with the future of the Bologna Process and the European Higher Education Area (EHEA). The EHEA began during the Bologna Process' decade anniversary, at the Budapest-Vienna Ministerial Conference in March, 2010. The main objective of the Bologna Process is to ensure more comparable, compatible, and coherent systems of higher education in Europe. What we can learn from the process was highlighted in a publication of the Institute for Higher Education Policy (IHEP) (Adelman, Learning Accountability from Bologna: A Higher Education Policy Primer, 2008), and (Adelman, The Bologna Process for U.S. Eyes: Re-learning Higher Education in the Age of Convergence , 2009), produced with the primary support of the Lumina Foundation for Education to the Global Performance Initiative of the Institute for Higher Education Policy. As a result of the Bologna Process, the organization of higher education programs in most of Europe is becoming more consistent across national boundaries, and the trend is toward a division of academic programs between undergraduate and graduate programs that is quite similar to that of the U.S. The overall format of higher education in China, India, Korea, Canada, and many other countries is very similar to that in the United States.

A recent document *The Degree Qualification Profile* (Lumina Foundation, 2011) provides a recommended framework for higher education degrees in the United States and a goal of increasing the degrees earned in higher education in the United States by 60% by the year 2025. Its main focus is on Associate, Bachelors and Masters Degrees. The Lumina Foundation report provides a starting point in creating a degree qualifications profile for higher education in the United States. This profile sets reference points for requirements to earn Associate, Bachelors and Masters Degrees regardless of specialization.

The global-level trends and plans for higher education, including those resulting from the initiatives listed above and reports on the higher education in the United States, serve as important resources for this research by allowing it to be placed in a global framework and to help define the links to the similar initiatives in U.S. higher education.

Several National Academies publications have a “big picture” approach for assessing the abilities of the higher education graduates and the nature of their preparation in the science, engineering, medicine areas within the United States. One of these publications is the *Rising Above the Gathering Storm* (National Academies, 2005) and its follow-up, *Rising Above the Gathering Storm, Revisited: Rapidly Approaching Category 5* (National Academies, 2010). In the first publication, a warning of a "gathering storm" was released indicating that conditions, especially in K-12 STEM education, had deteriorated over the years. The first report identifies needed areas of emphasis or revision, and the second report addresses what has happened in the five years since the 2005 report in the sciences, engineering, and medicine areas. This report was prepared in response to a request by a bipartisan group of senators and members of the Congress to respond to the following questions:

"What are the top 10 actions, in priority order, that federal policymakers could take to enhance the science and technology enterprise so that the United States can successfully compete, prosper, and be secure in the global community of the 21st century? What strategy, with several concrete steps, could be used to implement each of those actions?" The results of the first report were organized around two key challenges: creating high-quality jobs for Americans and responding to the nation's need for clean, affordable, and reliable energy.

Four basic recommendations were defined, focusing on:

- Actions in K–12 education (10,000 Teachers, 10 Million Minds),
- Research (Sowing the Seeds),
- Higher Education (Best and Brightest), and
- Economic Policy (Incentives for Innovation).

Also provided are a total of 20 implementation steps for reaching the goals set in the recommendations.

2.3.2 Engineering Education

There will always be demand for superbly educated engineers, capable of performing in an innovative, creative, and entrepreneurial way (Augustine, 2009).

The National Academy of Engineering (NAE) has published two books related to the education of the future engineer: *The Engineer of 2020: Visions of Engineering in the New Century* (National Academy of Engineering, 2004), and *Educating the Engineer of 2020: Adapting Engineering Education to the New Century* (National Academy of Engineering, 2005). The later document has among its many recommendations a call for the B.S. degree to be considered as pre-engineering and the M.S. degree to be the engineering "professional" degree. This recommendation of the M.S. degree as the entry professional degree had earlier been specifically made for the civil engineering field by the American Society of Civil Engineers (ASCE), as will be later noted in Section 2.3.3.

Following the two National Academies publications discussed above, and as a result of two National Science Board workshops held in 2005 (MIT) and 2006 (GIT) the *Moving Forward to Improve Engineering Education* report (National Science Board, 2007) was published in coordination with NAE.

In the United States, licensure of engineers is done at the state level, with individual states now typically modifying and adopting model law provisions as prepared by a professional non-profit group, the National Council of Examiners for Engineering and Surveying (NCEES).
In 2006, NCEES modified its Model Law (National Council of Examiners for Engineering and Surveying, 2011) for professional registration by increasing the engineering licensing requirements, setting an earlier effective date for implementation as 2020. The 2020 version of the Model Law now includes an educational requirement of an undergraduate degree in

engineering plus 30 additional credits equivalent in intellectual rigor and learning assessments to upper-level undergraduate and/or graduate courses offered at institutions that have a program accredited by EAC/ABET. A definition of acceptable content, the characteristics and source of this additional content, and other critical details are still under study within NCEES.

A recent American Society of Engineering Education (ASEE) initiative (Jamieson, Creating a Culture for Scholarly and Systematic Innovation in Engineering Education - Phase I, 2009) had a goal to ensure that the engineering profession in the United States has well-prepared engineers for the global society. The three key elements of “who, what, and how” are emphasized along with the relationship between them. The Phase 2 report (Jamieson, Creating a Culture for Scholarly and Systematic Innovation in Engineering Education - Phase II, 2011) was presented as a Distinguished Lecture at the 2011 ASEE Conference in Vancouver, June 2011. Engineering faculty and administrators are to determine the content of the program and make decisions on delivery methods. The importance of faculty professional development was highlighted, starting with their graduate education and continuing onto faculty openness to new learning/teaching environments incorporating multidisciplinary projects and experiential curricula in their teaching.

In the December 2011 National ASCE President’s message, (Herrmann, 2011) highlighted the need of more recognition and respect for civil engineers. The self-explanatory graph used in ASCE President-Elect Greg DiLoreto presentation (recreated in Figure 2-1) contains information about the formal education requirements for engineers. Since 1900, the requirement of four years of formal education for engineers has not change, in contrast with many other professions such as Medicine, Law, Architecture, and Accounting. This is one of the rationales for a Body of Knowledge (BOK) and the consideration of more formal education being required for entry into the professional practice of engineering.

From Figure 2-1, the researcher defined several possible observations/conclusions:

1. Unlike other professions, little change has happened in engineering during the last 120 years or so.
2. Possibly, engineering education has increased enough its efficiency to cover all the material (including new materials) in engineering that this increased coverage can be done in the same amount of time, even given the general decline in the number of credit hours seen in the last 40-years for engineering programs, or
3. The present 4-year engineering degree does not present the depth of information and the amount of preparation for practice that is now provided by other professions, such as medical field, law, and more recently, also architecture, and accounting.

One can speculate which one or more of these three statements are the most accurate. The first is known to be false. Although methods and efficiencies in higher education have changed, they have not matched the explosion of new knowledge and they are not isolated to within only the engineering programs. Thus, the third statement must be accepted. However, the good news is that engineers (being creative problem solvers) can see this crisis as a positive one. As noted by Bell, 2012, civil engineers including structural engineers, prefer to see this as a crisis of opportunity (Bell, 2012).

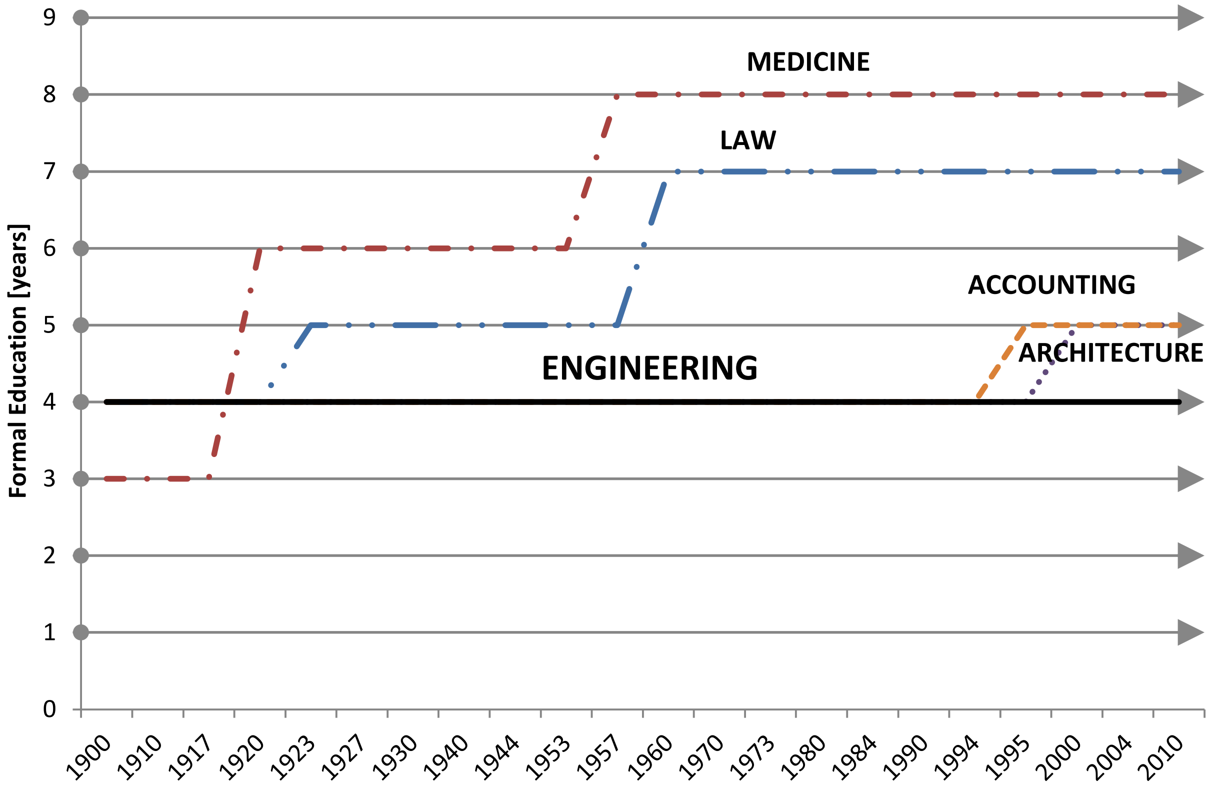


Figure 2-1: Comparison of Five Professions' Formal Educational Needs (Herrmann, 2011)

2.3.3 Civil Engineering

After several national level conferences on civil engineering education and many discussions, the Board of Direction of ASCE adopted the Policy Statement PS 465, Academic Prerequisites for Licensure and Professional Practice (American Society of Civil Engineers, 1998), which recognizes the need for a reform in the preparation of the future civil engineers in the areas of education and experience needed to enter in professional practice. The adoption of Policy Statement 465 resulted in ASCE forming their (ASCE) Body of Knowledge Committee as the administrative-level group for carrying out further study and implementation of PS 465. This BOK Committee formed the ASCE Committee on Academic Prerequisites for Professional Practice (CAP3) which produced the *Body of Knowledge for the 21st Century* (BOK2) publication (American Society of Civil Engineers (ASCE) Body of Knowledge Committee of the CAP3, 2008). This document serves as a valuable guideline for the civil engineering undergraduate curriculum development in the United States. It addresses the allocation of educational responsibilities between the academic programs and the professional community. By breaking the desired outcomes into three major outcome groups (Foundational, Technical, and Professional), the BOK2 assists users to understand the current needs of civil engineering education in preparing graduates for graduate school and/or professional field. The BOK2 focus is limited to undergraduate education in civil engineering. A summary of BOK 2 is presented below in Table 2-3.

The role of the Masters education in civil engineering has been described as having an increased importance in the last couple of years (Siller, Criswell, Fontane, & Grigg, 2004). ASCE released the Vision for Civil Engineering in 2025 report to summarize the discussions of civil engineering leaders at the Summit on the Future of Civil Engineering (American Society of Civil Engineering, 2007). In August 2009, a follow-up work containing recommended action steps is presented in the Achieving the Vision for Civil Engineering in 2025: A Roadmap for the Profession (American Society of Civil Engineers, 2009), a report prepared by the ASCE Task Committee to Achieve the Vision for Civil Engineering in 2025.

Russell et al. created a comprehensive database of available Masters programs and specializations (Russell, Lenox, Rogers, & Coward, 2010). Based on this study, the second highest number of degrees/specializations within civil engineering in the U.S. is structures, with the undifferentiated general civil engineering specialty in the sixth place.

Although relevant, the studies presented in the above cited publications are not focused on structural engineering education and are largely limited to undergraduate education. In contrast, this research addresses specifically the structural engineering professional preparedness to be achieved during the Masters-Level education.

Table 2-3: The Body of Knowledge Rubric

(American Society of Civil Engineers (ASCE) Body of Knowledge Committee of the CAP3, 2008)

Outcome	Level of Achievement					
	1- Knowledge	2- Compre-hension	3- Application	4- Analysis	5- Synthesis	6- Evaluation
Foundational						
1. Mathematics	B	B	B			
2. Natural Sciences	B	B	B			
3. Humanities	B	B	B			
4. Social Sciences	B	B	B			
Technical						
5. Materials Science	B	B	B			
6. Mechanics	B	B	B	B		
7. Experiments	B	B	B	B	M/30	
8. Problem Recognition and Solving	B	B	B	M/30	B	E
9. Design	B	B	B	B		
10. Sustainability	B	B	B	E		
11. Contemporary Issues and Historical Perspectives	B	B	B	E		
12. Risk and Uncertainty	B	B	B	E		
13. Project Management	B	B	B	E		
14. Breadth in Civil Engineering Areas	B	B	B	B		
15. Technical Specialization	B	M/30	M/30	M/30	M/30	E
Professional						
16. Communication	B	B	B	B	E	
17. Public Policy	B	B	E			
18. Business and Public Administration	B	B	E			
19. Globalization	B	B	B	E		
20. Leadership	B	B	B	E		
21. Teamwork	B	B	B	E		
22. Attitudes	B	B	E			
23. Lifelong Learning	B	B	B	E	E	
24. Professional and Ethical Responsibility	B	B	B	B	E	E

Key:	B	Portion of the BOK fulfilled through the bachelor's degree
	M/30	Portion of the BOK fulfilled through the Masters degree or equivalent
	E	Portion of the BOK fulfilled through the pre-licensure experience

2.3.4 Structural Engineering

The main focus of this dissertation is directed toward the structural engineering profession and the formal education preparing entry-level structural engineers upon their completion of a M.S. degree to best perform in the present and future professional environment. Several studies on undergraduate civil engineering were highlighted earlier in this document. Available studies specifically on structural engineering graduate programs are fewer and are more usually in the form of articles or papers rather than as committee or organizational reports. Some of these references that this research builds upon are discussed below.

Jirsa, in a paper entitled *Structural Engineering-Education and Global Issues* (Jirsa, 2004), discusses structural engineering practice in a global economy, highlighting the role of academia, professional societies, and accreditation in the process of structural engineering education. In this paper, in the message is that new approaches are needed for educating engineers to prepare them to be able to adapt and adjust for changing career demands.

Several possible components of the curriculum in structural engineering, such as timber/wood engineering and masonry engineering, cannot be found as a requirement or even as an elective in many structural engineering programs. This perceived deficiency for structural systems other than steel and structural concrete was noted in *Wood Engineering Education—Trends and Challenges* (Gupta & Gopu, 2005), a paper in which they highlighted some of the issues affecting the education on wood engineering in the United States. More recently, Cramer and Wheat noted that wood engineering still received limited or no coverage in many civil/structural engineering programs (Cramer & Wheat, 2011). This lack of content for timber and masonry structures has persisted in spite of the strong industry support through teaching resources and sometimes financial assistance to help facilitate such courses.

One of the first comprehensive publications regarding specifically the structural engineering curriculum and its content was reported in an article entitled *Education for the Structural Engineer-Basic Course Curriculum and Content* (Barnes, 2004). This report serves as a first step of a framework for highlighting the topics included in individual courses along with the overall recommended curriculum for structural engineering. The study reported by Barnes was followed by reports of studies organized by the National Council of Structural Engineering Associations (NCSEA), the first published in 2007 and including the 2006 survey results of courses and topics included in the individual academic institutions (National Council of Structural Engineering Associations, 2007). In updated articles (National Council of Structural Engineering Associations, 2010), a list of educational institutions responses is presented, with each response including how many of each of the recommended courses in the structural engineering curriculum are offered at the identified institutions and at what level: Bachelors, Masters, or as an elective. The papers reported that 53 programs out of the 129 higher education institutions responding and included in the survey offered all the recommended courses. Of the remaining institutions, the courses most often reported missing are wood/timber design, masonry design, and dynamic behavior (including Seismic). Seven programs include timber design courses in the required Bachelors level with one of the programs having timber design combined with the masonry design course, 5 include timber in the required Masters-Level course, and 41 as electives, with one program offering the same combined timber/masonry course option. The Basic Structural Education as described in the proposed educational program (National Council of Structural Engineering Associations, 2010) is shown in Table 2-4.

Table 2-4: Recommended Basic Structural Engineering Curriculum

Curriculum	Analysis	Matrix Methods	Steel Design	Concrete Design	Timber Design	Masonry Design	Dynamic Behavior	Foundation Design/Soil Mechanics	Tech. Writing
Recommended Number of Course	2	1	2	2	1	1	1	1	1

The model curriculum described by these NCSEA reports is heavily influenced by the practicing structural engineering component. It is both evidence of the high level of interest in the academic programs displayed by those in practice and a valuable summary of the recommendation of this practice community.

This research deals with this professional component by addressing directly the young structural engineer's preparedness through graduate education and initial experience within a global and constantly changing social and economic environment.

2.3.5 Preparation Phases

An important organizational task in the design of this study directed toward the Masters-Level structural engineering programs is an examination of the position and role of these graduate programs in the overall task of preparing the aspiring young structural engineer to enter the career as a professional level engineer.

Major phases in the process of the young student becoming prepared to be a successful structural engineer at the professional level can be identified within the context of ASCE BOK2 (American Society of Civil Engineers (ASCE) Body of Knowledge Committee of the CAP3, 2008) for civil engineering. These phases include the following:

1. Bachelors of Science degree in Civil Engineering - preferably with a structural engineering emphasis.

2. Masters degree in Civil/Structural Engineering or equivalent 30 semester credits of acceptable graduate level or upper level undergraduate courses in the structural engineering area identified as M/30 in the ASCE BOK2.
3. Pre-licensure experience identified as E in the ASCE BOK2.
4. PE and/or SE/SECB – Professional Engineering (PE) and/or Structural Engineering (SE)/Structural Engineering Certification Board (SECB) licensing, which follows the first three phases.

Although this present study most directly addresses the Masters-Level programs, it builds on the content of the bachelor's level degree. The fit of this Masters-Level educational phase within the overall preparation of the young professional will be also addressed.

2.4 Gaps and Links

To be determined and described through this research study are the known and possible gaps between the academia and structural engineering professional field. Communication among all stakeholders (professors, structural engineer practitioners and supervisors, policy makers, professional society leaders/members and the young professionals involved) is a key element in the process for studying gaps between the structural engineering professional field and the graduate structural engineering education. How the research identifies and addresses these gaps and links are discussed in the next chapters of this dissertation.

3 METHODOLOGY

3.1 Background - The Delphi Method

The methodology chosen to obtain information from the profession through the survey was the Delphi method. This method has been modified and used to obtain input from members of the structural engineering professional field and a limited number of academics, professional society leaders, and policy makers on the needs, practical limits and objectives required to best describe the appropriate and feasible preparation of the young structural engineer. As the Delphi method has its own characteristics and procedures, a summary of this method and its background is in order.

The Delphi method is a group decision-making technique developed as part of an Air Force sponsored RAND Corporation study in the early 1950's (Dalkey & Helmer, 1963). The Delphi consensus-decision making method entails an iterative process to collect opinions and form consensus group decisions from several to many experts in the field. In the basic Delphi study, participants each submit their input, often subjective input such as opinions, judgment or recommendations, of each of a number of topics. The group responses are summarized without identification of individual responses. In a second round, participants are given the group responses and their own first round responses and are next asked to reconsider their input considering the group input, and then to respond by either restating their original response or a modified response. Additional rounds are used as required for the group's responses to converge toward a group agreement. The great strengths of the method are that no face to-face meetings are required for the group interaction, thus allowing participants from wide geographical boundaries to participate, and the avoidance of direct confrontation of participants with differing and/or conflicting views through the anonymity of the individual's input. This anonymity allows a more open and "blue sky" input.

Linestone and Turoff described the history of the Delphi method, including its philosophical and methodological foundations, in their book *The Delphi Method Techniques and Applications* (Linstone & Turoff, 1975), which also illustrate a wide range of applications, models and variations of the method, along with extensive reference information on the topic.

The paper *The Delphi Method for Graduate Research* (Skumolski, Hartman, & Krahn, 2007) is a detailed discussion of the application of the Delphi Method in graduate research. This paper contains an extensive reference list and describes the Delphi method's history, its purpose, and typical research procedures using the method. The benefits of the methodology are highlighted through several dissertation examples in an organized and structured format which illustrates the diverse applications of the method. This paper serves as an excellent example for this study related to the development of a framework for the structural engineering curriculum in graduate education. Another excellent reference on Delphi applications is *Using Experts' Opinion Through Delphi Technique* (Yousuf, 2007).

As highlighted by Skulmoski et al. the Delphi method's flexibility in its applications is evident in the literature (Skumolski, Hartman, & Krahn, 2007). It is a method for structuring a group communication process to facilitate group problem solving and to structure models (Linstone & Turoff, 1975). The method can also be used as a judgment, decision-aiding or forecasting tool (Rowe, Wright, & Bolger, 1991), and it can also be applied to program planning and administration (Delbeq, Van de Ven, & Gustavson, 1975). In cases when there is partial knowledge about a problem or phenomena (Adler & Ziglio, 1996), the Delphi method can be applied to problems that do not lend themselves to precise analytical techniques but rather could benefit from the subjective judgments of individuals on a collective and to focus their collective human intelligence on the problem at hand (Linstone & Turoff, 1975). Also, the Delphi method can be used to investigate and predict what does not yet exist (Czinkota & Ronkainen, 1997), (Halal, Kull, & Leffmann, 1998), (Skumolski, Hartman, & Krahn, 2007).

The use of the Delphi method in graduate research has been most extensive in the medical field. However, it has been employed in several engineering-related areas such as industrial engineering (Khosravi & Afshari, 2011). The goal of this research is to create a Masters-Level structural engineering curriculum framework recommendation with the input of experts in the structural engineering professional field in the United States. The characteristics of the Delphi method described in the literature are a good fit to the needs of this study.

3.2 Research Approach and Rationale

This study emphasizes the gathering and interpretation of data on the expected preparation of the young structural engineer for professional practice based on an assessment of needs by those involved in structural engineering. An emphasis is given to the Masters-Level program. In addition to a review of relevant literature and information on present graduate programs and industry practices, input on the effectiveness and recommended modifications of the Masters-Level graduate programs and the early years of professional employment were obtained from individual discussions with members of a group of structural engineers located in the Colorado front range area. Each member of this group of 12 engineers also provided input on a draft questionnaire. The finalized questionnaire was then used in a larger study conducted using a modified Delphi procedure.

The major steps of the research study are given later in the flow chart shown in Figure 4-1 and the individual steps shown are discussed in Chapter 4. Defining the needs of the structural engineering profession to be provided to the Masters-Level preparedness of a structural engineer at graduation and after five years in practice (i.e. at the time of professional registration is very often sought) was the major goal to be addressed in this research project. A central need of this study thus was to have a detailed assessment by knowledgeable/qualified professionals on the present and future needs of the profession. The modified Delphi study provided this assessment through a survey of a selected group of these professionals.

This study focused on both the technical and the non-technical and professional aspects of the structural engineering attributes. This task required an understanding of the key characteristics of structural engineering practice, especially those which are more emphasized in structural engineering than in typical engineering or civil engineering areas or are fairly unique to this engineering area.

Some major Structural Engineer attributes in professional practice are:

- Design is heavily governed technically by Codes and Standards, and often is also heavily influenced by local practices and material/labor considerations.
- The product is specific to the project location, including local soil conditions and local construction practices.
- Product design is customized; no one design fits all needs and there is no mass production of the overall project.
- The owner is involved in the project and its financing starting with the project conception and continuing through and beyond the design process.
- Extensive use is made of special/area specific software prepared specifically for structural design.

- Coordination is needed with many other members of the project team- architects, general contractor, sub-contractors, other engineers, with the lead project professional often being an architect (common for building projects, but not for bridge/transportation projects).
- Current research and demands of practice are often not tied closely together. Research results have impact through improved materials and building code changes. This last attribute has been addressed in the *Structural Design Codes: The Bridge Between Research and Practice* (Galambos, 2006) paper.

The product of this research is a recommended framework containing what the structural engineering profession expects the Masters-Level curriculum to provide, along with additional needs and desired skills of the structural engineering professional field beyond those provided by the academic courses which the engineer is expected to gain as a young employee.

To most efficiently obtain the desired information, the Delphi Method was customized to consist of three rounds, each with a specific task.

Participants were identified based on experiences and recommendations of the researcher (Co-PI), faculty advisor (PI), industry connections, and a nation-wide data base listing structural engineers. Delphi participants were contacted through an Invitation letter sent out using e-mail. Those agreeing to participate were asked to respond to the questionnaire by e-mail in the first round and to the questionnaire plus summarized previous round responses in the next rounds. The procedures followed in conducting the modified Delphi Method study are described and discussed in Chapter 4.

The four main characteristics of the Delphi Method, namely anonymity, iteration, controlled feedback, and statistical aggregation are all present in this research study.

- Anonymity assured that the participants could answer the questionnaire freely without any peer-pressure from individuals of the group.
- Iteration allows for modifying the answers from previous rounds based on the group feedback, and the individual's further deliberation of the questions.
- Controlled feedback is an excellent way of keeping the expert group focused by all sharing the same overall results of the previous round. This way, participants each have the same background information and context and thus are better able to reconsider, clarify, or even change their individual input.

By using the levels of achievement as defined in Bloom's Taxonomy (Bloom, Engehart, Furst, & Kratwohl, 1956) to quantify the level of proficiency expected in each of many technical and professional areas, the input of the survey participants was expressed using increasing integer numbers for the increasing levels of achievement using Bloom's descriptions, which facilitated the graphical presentation and statistical study of the results.

4 PROCEDURE

This Chapter is focused on the overall process of this research study, including a description of the major steps in this process.

4.1 Major Tasks Involved

This research consisted of several key steps presented in Figure 4-1 and described in this Chapter. The major elements of this research procedure were:

1. Establish scope, need for the study, and expected benefits.
2. Prepare the survey questionnaire.
3. Select the expert panel.
4. Conduct the modified Delphi study.
5. Analyze and interpret the results of the study.
6. Formulate conclusions and recommendations of the study.

Item 1 was discussed in Chapter 1, items 2, 3, 4 are discussed in this Chapter, the results are presented in Chapter 5, and the conclusions and recommendations are presented in Chapter 6.

4.2 Preparation of the Survey Questionnaire

As shown on Figure 4-1, the Delphi survey questionnaire was developed in two steps:

- Development of the Draft Delphi Questionnaire and
- Development of the Final Delphi Questionnaire.

The Draft questionnaire was prepared to be consistent with its planned use within the modified Delphi formats with contents based largely on some information in the literature and the general professional knowledge and observations of the researcher and a few other individuals with a structural engineering background.

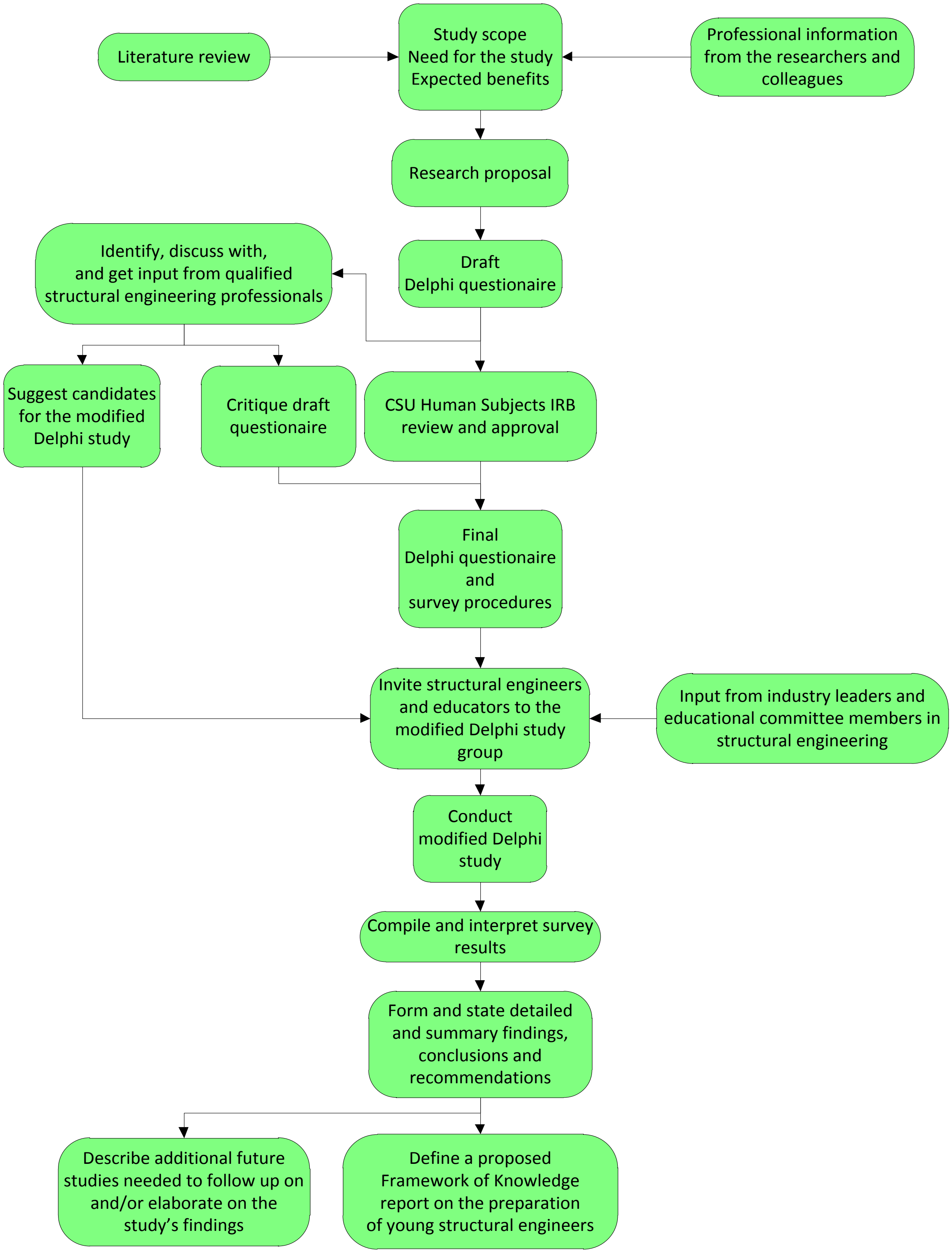


Figure 4-1: Research Study Major Steps

The topics and sub-topics of the questionnaire were selected based on the researcher and other structural engineering professionals' recommendations, and were chosen often the contents of several Masters-Level structural engineering programs. The two rating scales used in the questionnaire were:

1. Bloom's taxonomy for the achievement level rating (6 levels).
2. Importance level of primary information/knowledge sources in addition to the Masters-Level programs, which are available to help reach the desired achievement levels by 5 years after graduation from a Masters- level structural engineering program (4 levels).

Bloom's Taxonomy is a classification system developed by psychologist Benjamin Bloom and his team in 1948 to categorize educational goals for student performance evaluation.
As reported in the ASCE BOK2 report contents on its preparation, the ASCE Levels of Achievement Subcommittee, after an extensive educational psychology literature review, found that Bloom's Taxonomy was a good fit for a relatively simple framework applicable to the BOK (American Society of Civil Engineers, 2005). Applying measurable learning objective based achievement levels also allows the development of a well-organized framework in a defined area, such as structural engineering, the subject of this research.

The original Bloom's taxonomy has been revised to better fit the today's outcome-based assessment language (Anderson & Krathwohl, 2001). In the updated version, the revisions include the conversion of the first achievement level "knowledge" to "remember". The revised Bloom's taxonomy uses descriptions indicating action instead of major cognitive process categories. The revised taxonomy identifies the increasing levels as remembering, understanding, applying, analyzing, evaluating, and creating, rather than the original levels of knowledge, comprehension, application, analysis, synthesis, and evaluation terms (Coffey, Heather, 2008).

The original Bloom's Taxonomy was used in the present study for consistency with the ASCE BOK2 (American Society of Civil Engineers (ASCE) Body of Knowledge Committee of the CAP3, 2008). However, the revised Bloom's taxonomy would also have been a good fit.

In the Bloom's Taxonomy knowledge levels, the intervals of effort needed and achievement between the individual six levels are not even and numbers identifying these levels are strictly ordinal variables and they were so considered in the analysis. For these ordered ordinal variables, such convenient and widely used statistics such as means and standard deviations are strictly inapplicable, although when these ordinal numbers identify well-ordered increasing levels, they can provide some usable approximate information.

4.2.1 Colorado Professionals Input for Questionnaire Content Validation

The questionnaire conceived for the modified Delphi study was finalized based on several individual discussions with a pilot group of twelve structural engineering professionals representing civil/structural engineering firms from Colorado (mostly from the Denver metropolitan area). Their comments and recommendations related to the topics of the questionnaire were considered and many were incorporated in the final Round 1 questionnaire. The individual comments and recommendations suggested for addition to the questionnaire were very often specific to the structural engineer's particular area of expertise and/or the focus of the firm they represented. The impact of this group's input was positive in finalizing the questionnaire, as the revised questionnaire included several areas of structural engineering not present in the initial questionnaire, including more topics in specialized structural engineering areas such as bridge design.

4.3 Selection of Expert Participant Panel

As part of a typical Delphi study, the researcher selects an expert panel with expertise in the specific focus area of the research topic. For Delphi studies in general, no specified criteria is available for the expert panel selection, in part because the objective of the Delphi study can vary widely and the objective often has a large impact on this selection. Instead, common sense, practical logistics, and existing documentation from previous Delphi studies are relied upon as guides (Keeney, Hasson, & McKenna, 2006). The number of expert participants to be included also does not follow a prescriptive rule. Delphi study panel sizes have varied from under 15 to thousands. Instead of focusing on the expert panel size, it was suggested (Linstone & Turoff, 1975) that the most important criteria should be how many varieties of experts are needed to ensure all the significant perspectives are included.

In this research, the structural engineering profession is the overall group of interest. Expert structural engineers were selected from three major sub-groups: *Academia*, *Professional Firms* with service profiles including structural engineering, and *Professional Societies* associated with the structural engineering profession, with the largest number from the Professional Firms segment. There was an overlap in subgroup membership for individuals in many cases, such as when representatives from a structural engineering firm were also active members in the organization or administration of a professional society or were also serving as faculty members at a University offering graduate-level structural engineering degrees.

4.3.1 Delphi Study Participant's Profile

The criteria to be met by the expert participants in the study was to represent the structural engineering industry, academic institutions with structural engineering major/concentration, or professional societies related to the structural engineering profession.

Within the industry, the focus was on individuals in structural engineering firms or civil engineering firms with structural engineering services available and who were registered engineers with authority and experience in hiring and training young engineers.

Participants in the academic institution representative group were required to be faculty members and/or administrators of institutions of higher education in the United States that offers graduate degrees in structural engineering.

Participants from the professional societies related to structural engineering were chosen from the officers, engineering staff, and major activity leaders of American Society of Civil Engineers (ASCE), Structural Engineering Institute (SEI), National Council of Structural Engineers Associations (NCSEA), Structural Engineering Certification Board (SECB), Structural Stability Research Council (SSRC), or the individual state's Structural Engineers Associations (SEAs).

The selection of target participants with a professional firm background was based on the following primary resources: American Society of Civil Engineers (*ASCE*), American Council of Engineering Companies (*ACEC*), Structural Engineers Associations (*SEA's*) throughout the United States, discussions with structural engineers residing in Colorado during the November and December 2011 period preceding the start of the Delphi study, recommendations from professional structural engineers, and interactions at professional meetings, including at the American Society of Civil Engineers/Structural Engineering Institute (ASCE/SEI)-sponsored 43rd Structures Congress held in Chicago, Illinois during March 2012.

4.3.2 American Society of Civil Engineers (ASCE)

American Society of Civil Engineers (ASCE), founded in 1852, represents more than 140,000 members of the civil engineering profession worldwide and is America's oldest national engineering society. The ASCE defines nine geographical regions in the United States as shown in Table 4-1.

Table 4-1: US Regions Defined by ASCE

Region 1	Region 2	Region 3	Region 4	Region 5	Region 6	Region 7	Region 8	Region 9
Connecticut Maine Massachusetts New Hampshire New Jersey New York Vermont Rhode Island	Delaware Maryland Pennsylvania Washington	Illinois Michigan Minnesota North Dakota Ohio Wisconsin	Arkansas Indiana Kentucky North Carolina South Carolina Tennessee West Virginia Virginia	Alabama Florida Georgia Louisiana Mississippi	New Mexico Oklahoma Texas	Colorado Iowa Kansas Missouri Nebraska South Dakota Wyoming	Alaska Arizona Hawaii Idaho Montana Nevada Utah Oregon	California

4.3.3 American Council of Engineering Companies (ACEC)

ACEC's roots date back to 1909 when the American Institute of Consulting Engineers (AICE) the forerunner of ACEC was established. Today ACEC is a large federation of 51 state and regional councils of America's engineering industry. Member firms range in size from a single registered professional engineer to corporations employing thousands of professionals. Consulting firms from the wide spectrum of engineering are included, not just firms involved in civil engineering. More than 5,000 members of the ACEC represent more than 500,000 employees throughout the United States. Based on the number of employees, six company categories are defined by ACEC:

- Small (1-30 employees)
- Medium (31-75 employees)
- Medium Large (76-150 employees)
- Large (151-499 employees)
- Extra Large (500-999 employees)
- Extremely Large (1000+ employees)

Four selection criteria, listed below, were adopted in this research for use with the searchable database available in the ACEC web site www.acec.org:

- State

  All fifty states were analyzed separately.

- Discipline

  The “Civil-Structural” discipline was selected.

- Markets served

  The “Structural Design, Special Structures” were used as the served markets.

- Number of employees

The nationwide structural engineering profile provided by ACEC was utilized in fitting the Delphi participants profile to the national trend for geographical distribution and firm size. The selection with the firm-size criteria described above is summarized in the Table 4-2.

Table 4-2: Structural Engineering Firm Distribution by Size

Size of Firm	Small	Medium	Medium Large	Large	Extra Large	Extremely Large	Total
Number of firms	344	113	68	137	70	165	897
% of 897 firms	38	13	8	15	8	18	100

In most cases, the selected firms had a primary contact person listed. The position of the listed contact person at the firm (such as Principal, Chief Executive Officer, Lead Structural Engineer, Structural Engineer, etc.) and this individual’s education credentials were checked to ensure the candidates to be invited to participate in the expert panel had a strong background in structural engineering.

4.3.4 Structural Engineers Associations (SEA)

A network of state-wide structural engineering associations which includes as members many structural engineers, especially those in consulting practice, exists and are coordinated at the national level by the National Council of Structural Engineering Associations (NCSEA). The objective of NCSEA, as given on their website, is to "constantly improve the level of standard of practice of the structural engineering profession throughout the United States, and to provide an identifiable resource for those needing communication with the profession".

The membership information of the Structural Engineers Associations (SEA) organizations was also researched as an additional source of structural engineering firm identity and names of structural engineers within the firm that qualify for this Delphi study. In some instances, additional resources were needed to identify the most qualified representative for the structural engineering firms selected. The Structural Engineers Association's (SEAs) data base was used to determine the participants' qualifications, and in some cases to select different contact person (other than the person listed on the ACEC site) for the appointed structural engineering firm. ACEC data were used to identify the 897 firms initially, candidates were chosen from the listed contact name, in conjunction with the SEA data base.

Of the fifty states in the United States, five (Maryland, North Dakota, South Dakota, West Virginia, and Wyoming) do not have an individual structural engineers association within the overall SEA organization. Ten states (Arkansas, Delaware, Idaho, Nebraska, Nevada, North Dakota, Rhode Island, South Dakota, Vermont, and Wyoming) were eliminated from consideration due to there being less than 10 structural engineering companies listed in the ACEC database. As a result, the project procedure was to select structural engineering firms from 40 states, with additional company selections for states with the highest number of structural engineering firms listed, these being California, Illinois, and New York. A total of 68 target companies with a structural engineering profile were selected. From the list of structural engineers listed for each target company, individual qualifications and titles were searched to identify one (or more) qualified potential survey participant. In the initial panel selection, the assumption that structural firms follow the overall ACEC firm-size distribution was made.

Table 4-3 shows the distribution by size of the firms that were selected for inclusion in the study. The selection was such to reflect closely the national distribution from the ACEC data and shown in Table 4-2.

Table 4-3: Distribution of Represented Structural Engineering Firms by Size

Size of Firm	Small	Medium	Medium Large	Large	Extra Large	Extremely Large	Total
Number of firms	25	8	7	10	4	14	68
% of 68	36.8	11.8	10.3	14.7	5.9	20.6	100
% of 897 firms	38	13	8	15	8	18	100

4.3.5 Initial Expert Panel

The initial Expert Panel for the study consisted of 87 participants with the firm-size distribution shown in Table 4-2. The structural engineers validating the questionnaire were also invited to participate in the Delphi expert panel pool. The distribution by regions of the initial participants nationwide including invited participants from structural firms, professional societies, and academic institutions, is summarized in Table 4-4.

Table 4-4: Initial Expert Panel Distribution by Regions in the United States

ASCE Region (Table 4-1)	1	2	3	4	5	6	7	8	9	Washington D.C.
Number of representatives	10	5	12	9	9	4	26	9	2	1
% of total (87) representation	11.5	5.7	13.8	10.4	10.4	4.6	29.9	10.3	2.3	1.1

It is evident from Table 4-4 that ASCE Region 7 has the highest representation. The initial expert panel with 29.9% representation from Region 7 is largely due to the inclusion of the expert group members (all from Colorado) in the initial expert panel.

4.4 Conduct of the Survey

The Delphi study survey for this research was conducted in three phases, namely Round 1, Round 2, and Round 3. For all three rounds, the survey participants were instructed to assume the default or typical path of the young structural engineer, namely, undergraduate engineering followed by a Masters-Level program emphasizing structural engineering, and then initial employment in structural engineering practice. Five years as the initial professional practice phase was chosen as this is the typical requirement for minimum professional licensure. The invitation letters (sent out via e-mail) for Round 1, Round 2, and Round 3 are presented in the Appendix as Figure A-2, Figure A-3, and Figure A-4.

4.4.1 Round 1

The initial assessment by the Delphi-study participants included 44 sub-topics organized into five major topic groups. The Round 1 questionnaire and the instructions on its use as sent (via e-mail) to the participants is given in Table 4-5 to Table 4-10.

Table 4-5: Round 1 Questionnaire Page 1

ROUND 1

Harmonizing the graduate level (Masters) structural engineering education with the structural engineering professional field.

Using the Key provided below, please complete the following table reflecting your recommendations as an expert in the structural engineering field.
Please use 1-6 notation for the achievement level you recommend.

#1 Key set on Achievement Level:
http://www.asce.org/uploadedFiles/Leadership_Training_-_New/BOK2E_%28ASCE_2008%29_ebook.pdf pages 81-85
For clarification, please find below a typical list of Blooms Taxonomy- with measurable action verbs.
Note: Not all action verbs need to be addressed in a given level. It is understood that some of the Topics might not be of interest in your specific structural engineering area.
(http://apps.asce.org/pdf/Revised_Civil_Draft_Commentary.pdf):

1. **Knowledge**: Knowledge is defined as the remembering of previously learned material.
   Examples of verbs: define; describe; enumerate; identify; label; list; match; name; reproduce; select; state.
2. **Comprehension**: Comprehension is defined as the ability to grasp the meaning of material.
   Examples of verbs: classify; cite; convert; describe; discuss; estimate; explain; generalize; give examples; paraphrase; restate (in own words); summarize.
3. **Application**: Application refers to the ability to use learned material in new and concrete situations.
   Examples of verbs: administer; apply; calculate; chart; compute; determine; demonstrate; implement; prepare; provide; relate; report; solve; use.
4. **Analysis**: Analysis refers to the ability to break down material into its component parts so that its organizational structure may be understood.
   Examples of verbs: analyze; break down; correlate; differentiate; discriminate; distinguish; formulate; illustrate; infer; organize; outline; prioritize; separate; subdivide.
5. **Synthesis**: Synthesis refers to the ability to put together to form a new whole.
   Examples of verbs: adapt; combine; compile; compose; create; design; develop; devise; facilitate; generate; integrate; modify; plan; reconstruct; revise; structure.
6. **Evaluation**: Evaluation concerns the ability to judge the value of material for a given purpose.
   Examples of verbs: appraise; compare & contrast; conclude; criticize; critique; decide; defend; evaluate; judge; justify.

Zsuzsa Balogh 2011-2012
Delphi study questionnaire Page **1**

Table 4-6: Round 1 Questionnaire Page 2

ROUND 1

Outcome/Topic/Level of Achievement	In the following subject areas, what **level of achievement** should a typical graduate of a Masters program in structural engineering have **upon completion of the Masters degree work?** Please use the achievement levels provided in the **#1 Key** on Page 1	In the following subject areas, what **level of achievement** the available **electives** (if any) should be offered at the **top fifty US institutions** offering graduate level structural engineering degree/emphasis? Please use the achievement levels provided in the **#1 Key** on Page 1	In the following subject areas, what **level of achievement** should a typical graduate of a Masters program in structural engineering have **after his or her first five years in structural engineering practice?** Please use the achievement levels provided in the **#1 Key** on Page 1
A. BASIC MECHANICS AND ENGINEERING TOOLS			
Round 1 Scores	**Participant Score Round 1**	**Participant Score Round 1**	**Participant Score Round 1**
A1. Advanced mechanics of materials			
A2. Structural analysis – framed structures			
A3. Finite element analysis/modeling			
A4. Elastic stability			
A5. Structural dynamics			
A6. Analysis of plates and shells			
A7. Properties & behavior of CE materials			
A8. Numerical methods			
Comments/Topic A Round 1			

Zsuzsa Balogh 2011-2012
Delphi study questionnaire Page **2**

Table 4-7: Round 1 Questionnaire Page 3

ROUND 1

Outcome/Topic/Level of Achievement	In the following subject areas, what **level of achievement** should a typical graduate of a Masters program in structural engineering have **upon completion of the Masters degree work?** Please use the achievement levels provided in the **#1 Key** on Page 1	In the following subject areas, what **level of achievement** the available **electives** (if any) should be offered at the **top fifty US institutions** offering graduate level structural engineering degree/emphasis? Please use the achievement levels provided in the **#1 Key** on Page 1	In the following subject areas, what **level of achievement** should a typical graduate of a Masters program in structural engineering have **after his or her first five years in structural engineering practice?** Please use the achievement levels provided in the **#1 Key** on Page 1
A. GENERAL STRUCTURAL ENGINEERING TOOLS			
Round 1 Scores	**Participant Score Round 1**	**Participant Score Round 1**	**Participant Score Round 1**
B1. Behavior of structural systems, Load path			
B2. Building codes & general requirements			
B3. Architectural/aesthetics considerations			
B4. Conceptual & preliminary planning			
B5. Design loads, including evaluation			
B6. Foundations & geotechnical topics			
Comments/Topic B Round 1			

Zsuzsa Balogh 2011-2012
Delphi study questionnaire Page 3

Table 4-8: Round 1 Questionnaire Page 4

ROUND 1

Outcome/Topic/Level of Achievement	In the following subject areas, what **level of achievement** should a typical graduate of a Masters program in structural engineering have **upon completion of the Masters degree work?** Please use the achievement levels provided in the **#1 Key** on Page 1	In the following subject areas, what **level of achievement** the available **electives** (if any) should be offered at the **top fifty US institutions** offering graduate level structural engineering degree/emphasis? Please use the achievement levels provided in the **#1 Key** on Page 1	In the following subject areas, what **level of achievement** should a typical graduate of a Masters program in structural engineering have **after his or her first five years in structural engineering practice?** Please use the achievement levels provided in the **#1 Key** on Page 1
A. TECHNOLOGY AND COMMUNICATION TOOLS			
Round 1 Scores	**Participant Score Round 1**	**Participant Score Round 1**	**Participant Score Round 1**
C1. Project plans & specifications			
C2. Communication software & tools (such as Word, Excel, Mathcad)			
C3. Computer graphics			
C4. Structural engineering design software			
C5. Building information management (BIM) systems, software use.			
C6. Programming skills			
Comments/Topic C Round 1			

Zsuzsa Balogh 2011-2012
Delphi study questionnaire Page 4

Table 4-9: Round 1 Questionnaire Page 5

ROUND 1

Outcome/Topic/Level of Achievement	In the following subject areas, what **level of achievement** should a typical graduate of a Masters program in structural engineering have **upon completion of the Masters degree work?** Please use the achievement levels provided in the **#1 Key** on Page 1	In the following subject areas, what **level of achievement** the available **electives** (if any) should be offered at the **top fifty US institutions** offering graduate level structural engineering degree/emphasis? Please use the achievement levels provided in the **#1 Key** on Page 1	In the following subject areas, what **level of achievement** should a typical graduate of a Masters program in structural engineering have **after his or her first five years in structural engineering practice?** Please use the achievement levels provided in the **#1 Key** on Page 1
A. STRUCTURAL ENGINEERING TOPICS AND TOOLS			
Round 1 Scores	**Participant Score Round 1**	**Participant Score Round 1**	**Participant Score Round 1**
D1. Structural steel design - basics			
D2. Structural steel – more advanced topics			
D3. Reinforced concrete design basics			
D4. Prestressed concrete design			
D5. Reinforced concrete – advanced topics			
D6. Masonry design			
D7. Timber design			
D8. Design with structural aluminum			
D9. Bridge design – short/mid span.			
D10. Bridge design – long span systems			
D11. Earthquake engineering – basic			
D12. EQ – high risk areas			
D13. Design to resist unusual loads/blast			
D14. Special concerns for high rise systems			
D15. Condition of structures/repair, renovation, reuse			
D16. Special requirements - residential			
D17. Special requirement – light commercial			
Comments/Topic D Round 1			

Zsuzsa Balogh 2011-2012
Delphi study questionnaire Page **5**

Table 4-10: Round 1 Questionnaire Page 6

ROUND 1

Outcome/Topic/Level of Achievement	In the following subject areas, what **level of achievement** should a typical graduate of a Masters program in structural engineering have **upon completion of the Masters degree work?** Please use the achievement levels provided in the **#1 Key** on Page 1	In the following subject areas, what **level of achievement** the available **electives** (if any) should be offered at the **top fifty US institutions** offering graduate level structural engineering degree/emphasis? Please use the achievement levels provided in the **#1 Key** on Page 1	In the following subject areas, what **level of achievement** should a typical graduate of a Masters program in structural engineering have **after his or her first five years in structural engineering practice?** Please use the achievement levels provided in the **#1 Key** on Page 1
A. MANAGEMENT AND PROFESSIONAL TOOLS			
Round 1 Scores	**Participant Score Round 1**	**Participant Score Round 1**	**Participant Score Round 1**
E1. Design office organization/management/office ethics			
E2. Business development and practices			
E3. Design/build & other project methods			
E4. Leadership skills/Adaptation to changes			
E5. Working with architects, contractors, etc.			
E6. LEED, Green Buildings, energy use			
E7. International design and construction practices			
Comments/Topic E Round 1			
B. ADDITIONAL TOPICS			
Round 1 Scores	**Participant Score Round 1**	**Participant Score Round 1**	**Participant Score Round 1**

Zsuzsa Balogh 2011-2012
Delphi study questionnaire Page **6**

The requested participant input was to assign the achievement level the participant judges that aspiring structural engineers should have at two times, at the time of graduation from a Masters program in structural engineering and after five years experience in the structural engineering field. An assessment of the achievement levels expected to be obtainable in a typical structural program through the use of electives was requested both to explore what the profession expects to be available in the academic programs and to clearly indicate that the evaluation for the recent Masters-Level graduate is to be the expectations for most or all of the graduate, which may be somewhat lower to significantly lower than that available through electives.

There were 33 participants returning the questionnaire in Round 1, which is 37.9% of those invited (87 total). The Round 1 participants' distribution by firm size, affiliation, and qualification is presented in this Chapter in Table 4-11, Figure 4-2, Table 4-12, Figure 4-3, and Table 4-13, figures and tables which also include data on the responses to Round 2 and 3.

Sixty-eight of the 87 individuals invited were in the Structural Engineering firm group (as reflected in Table 4-11). As seen in Table 4-12, sum of the participants with the listed affiliations is higher than the actual total number of participants, due to multiple affiliations of several participants.

Table 4-11: Distribution of Company Representatives by Firm Size

	Firm Size						
	Small	Medium	Medium Large	Large	Extra Large	Extremely Large	TOTAL
Initial (Target) Panel							
Invited	25	8	7	10	4	14	68
% of 68	37	12	10	15	6	21	100
Panel Returning R1							
Participants	6	3	3	7	2	4	25
% of 25	24	12	12	28	8	16	100
Panel Returning R2							
Participants	6	3	3	6	2	4	24
% of 24	25	13	13	25	8	17	100
Panel Returning R3							
Participants	5	1	2	5	2	3	18
% of 18	28	6	11	28	11	17	100

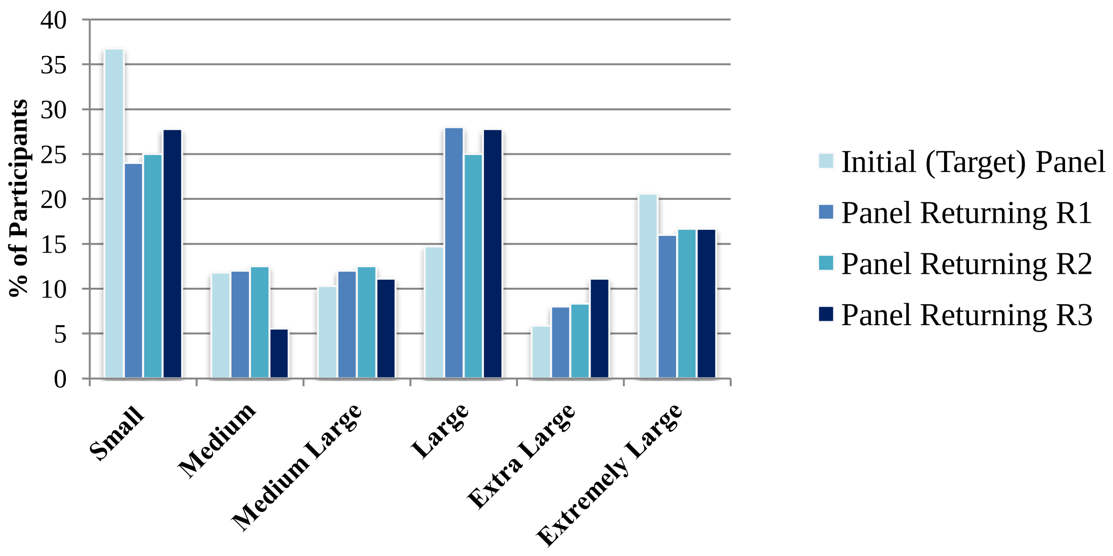


Figure 4-2: Distribution of Panel Participants by Firm Size

Table 4-12: Distribution of Participants by Affiliation

	Affiliation			
	Structural Engineering Firm	Professional Society	Academia	TOTAL
Initial (Target) Panel				
Participants	68	10	20	98
% of 98	69	10	20	100
Panel Returning R1				
Participants	25	5	10	40
% of 40	63	13	25	100
Panel Returning R2				
Participants	24	5	10	39
% of 39	62	13	26	100
Panel Returning R3				
Participants	18	5	9	32
% of 32	56	16	28	100

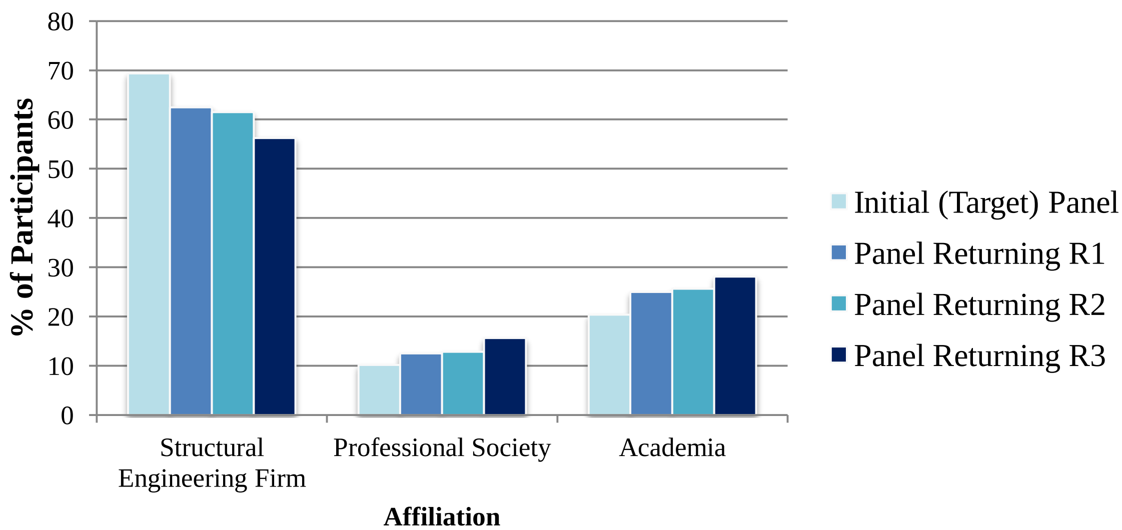


Figure 4-3: Distribution of Panel Participants by Affiliation

Table 4-13: Participant Qualifications

	PE	SE, SECB	Hiring Authority	Hiring Authority-Firms
Round 1 (% of 33)	93.9%	39.4%	72.7%	24 of 25=96%
Round 2 (% of 32)	93.8%	37.5%	71.9%	23 of 24=95.9%
Round 3 (% of 25)	92.0%	40.0%	68.0%	17 of 18= 94.4%

4.4.2 Round 2

The purpose of Round 2 was to provide the respondees of Round 1 with an opportunity to view a summary of the group's evaluations and to give them the option to revise, given this feedback on group response and additional time for reflection, their own individual evaluations. This is consistent with the basic principles of the Delphi Method. It was expected that a potential third round configured to repeat Round 2 would not result in significant changes and could negatively affect the response rate. The results (as described in Chapter 5) after two rounds are thus used to define the summary of the evaluations.

The Round 2 questionnaire included the same topics as did Round 1, with the addition of a group of six questions recommended for inclusion in the participant's Round 1 responses. These additions are shown in Table 4-14 along with the general form of the Round 2 questionnaire.

Table 4-14: Round 2 Questionnaire Page 7

ROUND 2

Outcome/Topic/Level of Achievement	In the following subject areas, what **level of achievement** should a typical graduate of a Masters program in structural engineering have **upon completion of the Masters degree work?** Please use the achievement levels provided in the **#1 Key**		In the following subject areas, what **level of achievement** the available **electives** (if any) should be offered at **the top fifty US institutions** offering graduate level structural engineering degree/emphasis? Please use the achievement levels provided in the **#1 Key**		In the following subject areas, what **level of achievement** should a typical graduate of a Masters program in structural engineering have **after his or her first five years in structural engineering practice?** Please use the achievement levels provided in the **#1 Key**	
A. ADDITIONAL TOPICS (recommended by participants in Round 1)						
Round 1 Results and Round 2 Scores	**Panel Score Round 1**	**Participant Score Round 2**	**Panel Score Round 1**	**Participant Score Round 2**	**Panel Score Round 1**	**Participant Score Round 2**
F1. Communication skills (oral, writing, graphical)	#.###		#.###		#.###	
F2. Effective speaking	#.###		#.###		#.###	
F3. Financial assessment	#.###		#.###		#.###	
F4. Working as a team	#.###		#.###		#.###	
F5. Total building design project (including architectural, mechanical systems, preparing drawings, specifications).	#.###		#.###		#.###	
F6. Bridge design codes (as an addition to B2)						
Comments/Topic F Round 2						

Zsuzsa Balogh 2011-2012
Delphi study questionnaire Page 7

In Round 2, a total of 32 of the 33 respondees of the Round 1 expert panel participants returned the questionnaire of the modified Delphi study, which represents 96.97% of those responding in Round 1. The Round 2 participants' distribution by firm size, affiliation, and qualification is presented in this Chapter in Table 4-11, Figure 4-2, Table 4-12, Figure 4-3, and Table 4-13.

Before the planned Round 3 was conducted, a statistical study was carried out to determine how similar the responses to the questionnaire in Round 1 and 2 were. If the differences between these two sets of results are sufficiently small, then the conclusion may be reached that an additional similar round, one which essentially repeats Round 2, would give minor change and that the Round 2 results may be used as the expert group's overall evaluation. The Kendall's tau-b method was used as the strength of relationship test to quantify the similarity of the Round 1 and Round 2 results. These results are expressed using ordinal variables, and the Kendall's tau-b method is considered the appropriate statistical tool when variables of this type are involved.

Kendall's rank order coefficient (Kendall's tau-b) for each subtask were determined from the Round 1 and Round 2 results at each of the three conditions considered; at graduation from the Masters-Level program, after 5 years of professional experience, and available in the elective offerings. The Kendall's tau-b method and its use are further described in Section 5.3, where the results of the comparison of Round 1 and Round 2 values are reported.

4.4.3 Round 3

The emphasis of Round 3 was designed to describe the expectations on how the young structural engineer would supplement their capabilities achieved at the completion of the Masters-Level program to reach the levels expected by the profession after their initial five years in practice, the time at which the young engineer has reached the experience level typically required to apply for professional registration. In Round 3, the expert panel participants were asked to give input on the perceived importance and usefulness of five sources for this additional preparation.

In Table 4-15 and Table 4-16, the first two pages of the Round 3 questionnaire are presented including the response Key #2 as presented in Table 5-2, to illustrate organization of this third (last) round questionnaire.

A total of 25 expert panel participants returned the Round 3 questionnaire, which represents 75.76% of those responding in Round 1.

4.4.1 Distribution of Participants Comparison for Round 1, 2, and 3

The participants' distribution by firm size of the initial (target) and Round 1, 2, and 3 expert panel participants are shown in Table 4-11. Figure 4-2 indicates that the distributions in Round 1, 2, and 3 were fairly close to the initial (target) panel distribution for medium, medium-large, and extremely-large companies.

Almost the same number of large firm representatives returned Round 1 questionnaire (7) as were invited (10), which is a response rate of 70%, almost twice the response percentage of 37% for the overall group of invitees from structural engineering firms. For the small firms, this response percentage is (6/25) 24%, just less than two–thirds of the overall response rate. This indicates that representatives of small firms were more reluctant to respond, while representatives of the large, but not extremely large firms (response rate of 4/14=29%) companies were more willing to respond relative to the overall response rate.

Table 4-15: Round 3 Questionnaire Page 1

ROUND 3

Harmonizing the graduate level (Masters) structural engineering education with the structural engineering professional field.

Please complete the following table (using Key #2) on the **importance** of the identified primary modes (such as experience in practice, in-house training, additional university courses, short courses, and self-learning) for the young structural engineer to reach the previously (Round 1 and Round 2) identified levels of achievement after his or her first five years in structural engineering practice.

#2 Key set on Source Importance Level:
1. not an important source
2. somewhat important source
3. important source
4. extremely important source

Zsuzsa Balogh 2011-2012
Delphi study questionnaire Page 1

Table 4-16: Round 3 Questionnaire Page 2

ROUND 3

Outcome/Topic/Level of Achievement	In the following subject areas, what **level of achievement** should a typical graduate of a Masters program in structural engineering have **upon completion of the Masters degree work?**		In the following subject areas, what **level of achievement** should a typical graduate of a Masters program in structural engineering have **after his or her first five years in structural engineering practice?**		**Please complete** the following table (using Key #2) on the **importance** of the identified primary modes (such as experience in practice, in-house training, additional university courses, short courses, and self-learning) for the young structural engineer to reach the previously **(Panel Mean Scores)** identified levels of achievement after his or her first five years in structural engineering practice. #2 Key				
A. BASIC MECHANICS AND ENGINEERING TOOLS					**Added Courses**	**Short Courses**	**In-house Training**	**Experience in Practice**	**Self learning**
Round 1 and 2 Results	**Participant Score**	**Panel Mean Score**	**Participant Score**	**Panel Mean Score**					
A1. Advanced mechanics of materials	#	3.188	#	4.125					
A2. Structural analysis – framed structures	#	3.969	#	5.406					
A3. Finite element analysis	#	3.094	#	4.625					
A4. Elastic stability	#	3.000	#	4.344					
A5. Structural dynamics	#	3.000	#	4.344					
A6. Analysis of plates and shells	#	2.156	#	3.375					
A7. Properties & behavior of CE materials	#	3.063	#	4.438					
A8. Numerical Methods	#	2.375	#	2.875					
Comments/Topic A									

#2 Key set on Source Importance Level:
1. not an important source
2. somewhat important source
3. important source
4. extremely important source

Zsuzsa Balogh 2011-2012
Delphi study questionnaire Page 2

- Affiliation

The affiliation distribution of the initial (target) and Round 1, 2, and 3 expert panel participants is shown in Table 4-12. Some participants had multiple affiliations. Figure 4-3 shows that Professional Society and Academia respondents answered in a higher percentage than did those from the structural engineering firms and the overall group.

- Qualification

One of the selection criteria of the Initial (Target) Panel in the Modified Delphi study on Masters-Level structural engineering preparedness was for the invitee to be an active participant of the structural engineering profession in industry, professional society, and/or academics. Professional Engineer (PE), Structural Engineer (SE), Structural Engineer Certification Board (SECB), and hiring authority qualifications of the participants in Round 1, 2, 3 are summarized in Table 4-13.

The lower number of respondees holding an SE or SECB relative to the 92% holding a P.E. reflects the current use of the S.E. licensure in only some states. The proportion of respondees with the authority to hire new engineers is much higher for those in a structural engineering firm than when the professional society and academic segments are added. This follows from the use of the individual authority to hire structural engineers at their firm being one of the criteria for inclusion in the expert panel as a firm representative, while those only in academics or in a civil/structural engineering organization not often having this authority.

4.5 Delphi Study Timeframe

The timeframe for administering the three rounds is summarized in Table 4-17. Round 1 had the longest duration, due primarily to few additional participants being added to the expert panel after the American Society of Civil Engineers/Structural Engineering Institute (ASCE/SEI)-sponsored 43rd Structures Congress held in Chicago, Illinois during March 29-31, 2012.

Table 4-17: Delphi-Study Rounds Time Frame

Rounds	Invitation Sent	Deadline: Completed Questionnaire Received
R1	March 14, 2012	April 30, 2012
R2	May 1, 2012	May 16, 2012
R3	May 17, 2012	May 31, 2012

The dates in Table 4-17 include the date of the first invitation (via e-mail) to the expert panel members and the last date for which an e-mail response needed to be received to be included in the response data for the specific round. In the timeframes listed, reminders (via e-mail) were also sent to the panel participants, kindly reminding them about the approaching deadlines.

5 RESULTS

In this chapter, the responses from the 33 expert participants in Round 1, 32 expert participants in Round 2, and 25 expert participants in Round 3 of this Delphi research are presented and analyzed.

The data analysis consisted of two categories:

- Qualitative Analysis

  The qualitative analysis includes the comments and recommendations of the expert panel participants.

- Quantitative Analysis

  The quantitative analysis comprises an integrated presentation on the participant's evaluations for the individual tasks and the accompanying statistical data evaluation.

5.1 Qualitative Analysis

Although the primary results of the survey are the numerical evaluations of the questionnaire topics and subtopics using the applicable Key Set, some relevant information resulted from individual participant comments.

In all three rounds, the questionnaire contained a Comments section which allowed for expert participant feedback on any of the structural engineering topics listed A through F. In Round 1 and Round 2, a total of 12 respondees provided observations/comments. In most cases, there were not enough comments about any individual topic to establish a general trend of respondent concern or recommendation, although several comments noted that some or most of the professional practice topics should be addressed in the initial experience phase and after completion of the Masters-Level program. Many of the comments seemed to reflect participant’s experience and responsibilities at a particular structural engineering firm. The summary of these comments by topics are listed below:

General Comments:

- Most participants who added recommendations mentioned that many of the areas, especially the ones related to a specialization area (such as design with structural aluminum or design for special loading conditions/blast), might be of high importance for those working in that specific field, perhaps for a specialized firm, but are not subtopics necessarily of high importance for the majority of engineers associated with a typical structural engineering firm.
- A recommendation from one expert panel participant was the creation of a combined structural /mechanical design field specialization emphasizing the load paths and structural design requirements for mechanical components. Employment areas noted as among those which would benefit from such a specialty would be the auto industry, space industry, and manufacturing, nuclear, and industrial markets, where structural engineers could be key participating professionals. Although only the structural/mechanical combination was mentioned in participant comments, many combinations of structural engineering and other areas can and do occur as some structural engineers specialize in foundations, environmental structures and other areas.

Comments received for the individual topic areas include:

A. Basic Mechanics and Engineering Tools:

- Upon completion of a Masters degree in structural engineering, graduates should be able to apply (Bloom’s Taxonomy achievement Level 3) all eight topics listed.

- Structural analysis and the area of plates and shells are a must in a Masters-Level structural engineering program.
- The area of numerical methods has practical use only if the structural engineer is involved in programming software.
- Properties and behavior of civil engineering materials (A7) should include "smart" materials, nanotechnology; a good MS program should at least introduce these topics, perhaps using a series of guest lecturers or media-based delivery by experts in the classrooms.

B. General Structural Engineering Tools:

- Building codes and general requirements (B2), Architectural/aesthetical considerations (B3), and Conceptual and preliminary planning (B4) should be learned on the job.
- Bridge design codes should be addressed more in the questionnaire. This comment supported the additional bridge code-related topic in the added F topic area.

C. Technology and Communication Tools:

- Programming should not focus on specific software. Graduates at the Masters–Level should be fluent in both Excel and in MathCAD (or similar software package).
- It is important for the student to be exposed to structural engineering software and to learn how to evaluate what the design software is telling, not to learn in detail a particular structural engineering software.
- Although exposure on how to read plans and specifications is important while the student is in school, this topic should be learned primarily on the job due to the wide variation in practices amongst industries (buildings, bridges, mining, and other areas) and even amongst companies.

- Integrating contract documents with construction contracts and other legal documents are topics better learned on the job.
- Communication software and tools (C2) and computer graphics (C3) are essential for graduate research and thesis preparation; other C items are better learned on the job.

D. Structural Engineering Topics and Tools:

- Bridge design is a specialty area and should be offered only as an elective option in a Masters program in structural engineering.
- As a weakness, it was noted that the bridge design-long span systems (D10) subtopic is not addressed in most structural engineering programs.
- The importance of earthquake engineering, especially design for structures in the high risk areas, depends on the seismic zone of practice.
- A recommendation received was to consider the addition of special structures such as sports stadiums and arenas, large civic buildings, towers, parking facilities as an additional topic.
- Unusual loads/blast should be included as a topic within a structural integrity area.

E. Management and Professional Tools:

- Ethics should be emphasized in all levels of structural engineering education (including the Masters-Level).
- Section E, Management and Professional Tools, is a much overlooked area in the graduate programs, and a semester long course should be dedicated to addressing these issues.

- Design office organization/management/office ethics (E1) and business development and practices (E2) are better taught in the office environment after an introduction to these topics in the engineering academic program.

The comments received in Round 1 lead to the additional Topic Group F for Round 2. In Round 2, one comment was received on the new (F) topic group.

F. Additional Topics:

- One participant noted that a total building design project (F5) is usually not pursued at a research-driven institution offering the Masters-Level structural engineering degree. This usual lack of a design project was also stated as a major concern of the respondee.

5.2 Round Parameters for the Quantitative Analysis

The contents of the questionnaire for each round have been described in Section 4.4.1, Section 0, and Section 4.4.3. For each round, the participant was given instructions on how to rate the expected competency level or an importance using a numerical scale.

Round 1 and Round 2 focused on the expected achievement levels for each subtopic of the five (A through E) topic areas in Round 1 and six (A through F) topic areas in Round 2 identified in structural engineering for the young professional at three levels of preparation:

- At graduation from a Masters-Level structural engineering program in the United States
- After the young engineer’s first five years of practice in the structural engineering profession
- Achievement level possible through an elective course or courses expected to be available at the larger institutions offering coursework in support of a sizeable graduate-level structural engineering program.

The sequential three-step model/schedule of the young engineer’s preparation consisting of an undergraduate program in civil engineering, a graduate program in structural engineering, and then the initial 5 years of work experience has been assumed in the study because it is the most usual, the most basic, and the best defined path to the structural engineering profession in the United States, although individual aspiring young structural engineers follow a wide variety of schedules and often either have some work experience before graduate school or are employed part or full time while doing graduate work.

Round 1 consisted of five topic areas (see Table 4-5 through Table 4-10):

A. Basic Mechanics and Engineering Tools

B. General Structural Engineering Tools

C. Technology and Communication Tools

D. Structural Engineering Topics and Tools

E. Management and Professional Tools

Round 2 included an additional topic area F which contained six subjects recommended by participants in their Round 1 comments.

Topic areas A through F include a total of 50 individual topics with the following breakdown of number of topics for each topic area: A/8 topics, B/6, C/6, D/17, E/7, F/6.

Bloom's Taxonomy (Bloom, Engehart, Furst, & Kratwohl, 1956) was chosen to describe the achievement level assessments. Key Set #1, shown in Table 5-1, was used to indicate the increasing Bloom's achievement levels by increasing integer numbers. Although the numerical scale in Key Set#1 are ordered, the scale strictly is comprised of ordinal values.

Table 5-1: Key Set # 1

Key	Level
1	Knowledge
2	Comprehension
3	Application
4	Analysis
5	Synthesis
6	Evaluation

Using participant ratings based on the numerical values of Key Set #1, the mean values of the Round 1 responses were computed and only used as an approximate and simple way to convey information on the expert panel's Round 1 evaluations for the participant's information while they were completing Round 2. Round 2 responses were similarly summarized and conveyed to the participants for their information when they were completing Round 3. Round 1 and Round 2 responses on the participant's expectations for the typical young engineer were determined for each item at the time of graduation from a Masters-Level structural engineering program and after five years in practice, along with the level that should be achievable during graduate work through the use of available electives. Each of the 44 (Round 1) or 50 (Round 2 and 3) content items was separately rated by the participants.

Round 3 assessed the paths for reaching the additional achievement level expected to be reached in the young engineer's first five-year period in practice following the time of the Masters-Level graduation. These Round 3 scores represent the perceived importance level of the identified five primary learning modes (listed below) anticipated to be available for the young structural engineer to reach the previously identified additional levels of achievement expected to be developed after the Masters program and before completion of the first five years in structural engineering practice.

The five primary modes identified for use in Round 3 are:

- Added Academic Courses
- Short Courses
- In-house Training
- Experience in Practice
- Self Learning

A different key set was adopted for use in Round 3. Key Set # 2, shown in Table 5-2, rates the source importance level of the five primary learning modes identified above on a four point scale. This key set is considered to use cardinal variables in contrast with the Key Set #1's ordinal variables.

Table 5-2: Key Set #2

Key	Source
1	Not an important
2	Somewhat important
3	Important
4	Extremely Important

5.3 Quantitative Analysis

The data obtained from the three rounds were first summarized in both tabular and then graphical forms. Next, observations and conclusions were made to interpret the information from the survey. The organization of the results from this Delphi study was based on the structural engineering Topics A through E in Round 1, and Topics A through F in Rounds 2 and 3. The expected preparation level for the individual subtopics within these five topics in the structural engineering professional field was each assessed by the 33 expert participants returning the questionnaire in Round 1. Input on the six topics in Round 2 was received from 32 expert participants, and 25 expert participants returned their input in Round 3. More information on the respondees demographics is given in Section 4.3

The data from the Round 1 and Round 2 of the Delphi questionnaire were analyzed using the Statistical Package for Social Sciences (SPSS) version 20.0 for Windows (Morgan, Leech, Gloeckner, & Barett, 2011).

The numbers ranging from 1 to 6 that were assigned to the rank-ordered categories for the achievement levels using Bloom's taxonomy, as described in Table 5-1, were considered to be ordinal variables. Although Key Set #1 assigns higher numbers to the higher achievement levels, the achievement intervals between these achievement levels are not uniform and thus such usual statistical tools as the mean and standard deviation are approximate and their use can be considered inappropriate. Thus, a non-parametric statistical analysis was performed.

A key step in the data analysis was how consistent the responses of Round 2 were with those of Round 1, as a high level of agreement would indicate that an additional Round 3 using the same format likely would result in little change and thus minimally improved data. The test used to determine the strength of the statistical similarity between the results of the two rounds was the Kendall's tau-b test. This method is the professionally accepted statistical methodology when analyzing ordinal data such as the achievement levels of Bloom's taxonomy (Bloom, Engehart, Furst, & Kratwohl, 1956). The Kendall's tau-b value can be interpreted similar to the "r"-Pearson correlation coefficient for cardinal data (Morgan, Leech, Gloeckner, & Barett, 2011) as a higher tau-b value signifies more similarity between the two data sets being examined. A tau-b value of unity results when the two data sets are identical. The tau-b value is used along with a significance level (p), which considers the effect of sample size in determining its value which indicates the probability that the determined Kendall's tau-b value could occur by chance.

If the correlation between the data sets is statistically significant, the p value is small ($p<0.05$). A practice often used, as is described by(Morgan, Leech, Gloeckner, & Barett, 2011) is to report computed p values smaller than 0.05 as $p<0.001$ as this value of 0.05 is the typical level the researchers use to assess whether the null hypothesis (no significant association exists between the data sets) should be rejected or not. In the analysis of the Round 1 and Round 2 data, all significance levels, p, computed using SPSS were found to be ≤ 0.001.

This comparison of Round 1 and Round 2 results, described in more detail in Sec. 5.4, was used to help determine if the responses were stable enough that a Round 3 with a format similar to the first two rounds would be needed. "Comparison plots" (such as Figure 5-4, Figure 5-5, and Figure 5-6) have been used, along with the p and Kendall's tau-b statistics summarized in Table 5-3 and Table 5-4, to more visually show the changes between Round 1 and the Round 2 responses.

Because neither the significance level, p, nor the Kendall's tau-b statistic give a measure of the typical value for a single set of data similar to that given by the mean value used for cardinal data, additional measures needed to be employed to present and interpret the data. Two methodologies used in this chapter are:

a) Stacked bar charts (Figure 5-7 through Figure 5-24) visually presenting the distribution of achievement levels assigned to each subtask, and

b) Percentages of responses above a designated level of ordered ordinal values assigned to each subtopic using the Bloom's taxonomy levels of Key Set #1 (Table 5-5).

In Round 3, the analysis was based on the Key Set #2 values for importance levels (shown in Table 5-2), numbers which were defined as cardinal variables. Mean values were used in the data analysis of the Round 3 responses.

5.4 Results of Round 1 and Round 2

Complete data on the Round 1 and Round 2 responses for each of the 44 questions in Categories A through E and the Round 2 responses for the six questions in Category F are given in Appen Table A-1 through Table A-50. An analysis of how well the results of these two rounds compare based on the methods described in Sec. 5.3 has been made to examine the correlation of the results and thus the merit of conducting additional rounds of the Delphi study with the same format of Rounds 1 and 2 in order to reach a better correlation. If the participant assessments in Round 2 are little changed from those of Round 1 after the participants' review of their Round 1 results along with some information on the overall panel response, it can be assumed that additional rounds with the same format would show minor or no change.

A typical frequency diagram of responses is shown in Figure 5-1. The frequency bars show the percentage of participant responses for each achievement level. The vertical axis is representing the 32 participants' responses (in %) in Round 2 on subtopic A1 (Advanced Mechanics of Materials). The increased heights of the orange bars to the right relative to the darker blue bars illustrate the movement in expected achievement level during the initial five years of experience.

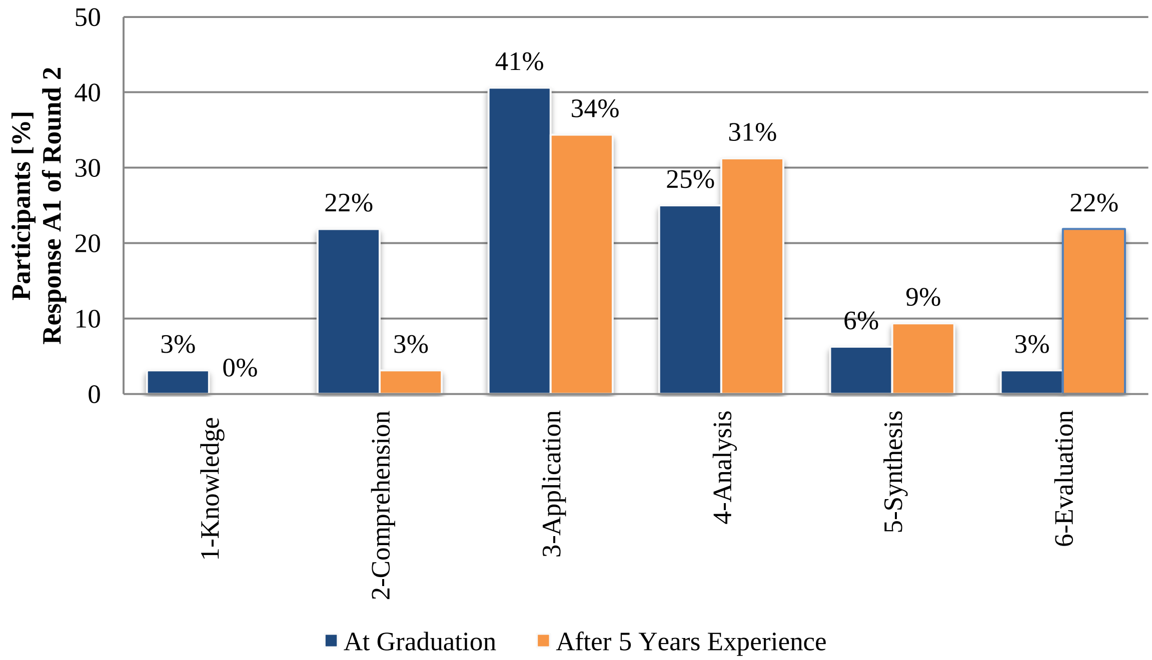


Figure 5-1: Typical Response Frequency, Shown for A1-Advanced Mechanics of Materials

Data on the correlation, between Rounds 1 and 2, as measured by its strength (tau-b) and significance (p), are summarized in Table 5-3 for the times at graduation, after 5 years experience, and elective offerings. These data and their significance are discussed next.

Table 5-3: Correlation and Correlation Significance between the Round 1 and Round 2

Question	At Graduation		After 5 Years of Experience		Elective Offerings	
	p	Kendall's tau-b	p	Kendall's tau-b	p	Kendall's tau-b
A. Basic Mechanics and Engineering Tools						
A1. Advanced Mechanics of Materials	<0.001	0.882	<0.001	0.950	<0.001	0.907
A2. Structural Analysis – Framed Structures	<0.001	0.920	<0.001	0.889	<0.001	0.956
A3. Finite Element Analysis/Modeling	<0.001	0.971	<0.001	0.940	<0.001	0.965
A4. Elastic Stability	<0.001	0.920	<0.001	0.926	<0.001	0.941
A5. Structural Dynamics	<0.001	0.860	<0.001	0.993	<0.001	0.963
A6. Analysis of Plates and Shells	<0.001	0.922	<0.001	0.992	<0.001	0.967
A7. Properties & Behavior of CE Materials	<0.001	0.962	<0.001	0.961	<0.001	0.953
A8. Numerical Methods	<0.001	0.980	<0.001	0.989	<0.001	0.922
B. General Structural Engineering Tools						
B1. Behavior of Structural Systems. Load Path.	<0.001	0.994	<0.001	1.000	<0.001	0.988
B2. Building Codes & General Requirements	<0.001	0.924	<0.001	0.990	<0.001	0.975
B3. Architectural/Aesthetics Considerations	<0.001	0.944	<0.001	0.973	<0.001	1.000
B4. Conceptual & Preliminary Planning	<0.001	0.960	<0.001	0.969	<0.001	0.990
B5. Design Loads, Including Evaluation	<0.001	0.959	<0.001	1.000	<0.001	0.944
B6. Foundations & Geotechnical Topics	<0.001	0.939	<0.001	0.976	<0.001	0.922
C. Technology and Communication Tools						
C1. Project Plans & Specifications	<0.001	1.000	<0.001	1.000	<0.001	0.988
C2. Communication Software & Tools	<0.001	0.913	<0.001	0.952	<0.001	0.975
C3. Computer Graphics	<0.001	0.981	<0.001	0.939	<0.001	1.000
C4. Structural Engineering Design Software	<0.001	0.937	<0.001	0.987	<0.001	0.990
C5. Building Information Management (BIM) Systems	<0.001	0.961	<0.001	0.953	<0.001	0.944
C6. Programming Skills	<0.001	0.941	<0.001	0.967	<0.001	0.922
D. Structural Engineering Topics and Tools						
D1. Structural Steel Design – Basics	<0.001	0.935	<0.001	0.980	<0.001	0.974
D2. Structural Steel – More Advanced Topics	<0.001	0.956	<0.001	0.982	<0.001	0.942
D3. Reinforced Concrete Design Basics	<0.001	0.958	<0.001	0.980	<0.001	0.986
D4. Prestressed Concrete Design	<0.001	0.958	<0.001	0.968	<0.001	0.965
D5. Reinforced Concrete – Advanced Topics	<0.001	0.964	<0.001	0.984	<0.001	0.944
D6. Masonry Design	<0.001	0.985	<0.001	0.962	<0.001	0.965
D7. Timber Design	<0.001	0.985	<0.001	0.977	<0.001	0.962
D8. Design with Structural Aluminum	<0.001	0.953	<0.001	0.968	<0.001	0.986
D9. Bridge Design – Short/Mid Span	<0.001	0.964	<0.001	0.993	<0.001	0.958
D10. Bridge Design – Long Span Systems	<0.001	0.966	<0.001	0.975	<0.001	0.981
D11. Earthquake Engineering – Basics	<0.001	0.918	<0.001	0.975	<0.001	0.922
D12. Earthquake – High Risk Areas	<0.001	0.972	<0.001	0.997	<0.001	0.965
D13. Design to Resist Unusual Loads/Blast	<0.001	1.000	<0.001	0.932	<0.001	1.000
D14. Special Concerns for High Rise Systems	<0.001	1.000	<0.001	1.000	<0.001	1.000
D15. Condition of Structures/Repair, Renovation, Reuse	<0.001	1.000	<0.001	1.000	<0.001	0.961
D16. Special Requirements – Residential	<0.001	0.966	<0.001	0.983	<0.001	1.000
D17. Special Requirement – Light Commercial	<0.001	0.966	<0.001	0.977	<0.001	0.979
E. Management and Professional Tools						
E1. Design Office Organization/Management/Ethics	<0.001	1.000	<0.001	0.942	<0.001	1.000
E2. Business Development and Practices	<0.001	1.000	<0.001	0.979	<0.001	0.937
E3. Design/Build & Other Project Methods	<0.001	1.000	<0.001	0.996	<0.001	1.000
E4. Leadership Skills/Adaptation to Changes	<0.001	1.000	<0.001	0.978	<0.001	0.984
E5. Working with Architects, Contractors, etc.	<0.001	1.000	<0.001	0.948	<0.001	1.000
E6. LEED, Green Buildings, Energy Use	<0.001	1.000	<0.001	0.961	<0.001	0.968
E7. International Design and Construction Practices	<0.001	1.000	<0.001	0.978	<0.001	0.954
F. Additional Topics						
F1. Communication Skills (Oral, Written, Graphical)	N/A	N/A	N/A	N/A	N/A	N/A
F2. Effective Speaking	N/A	N/A	N/A	N/A	N/A	N/A
F3. Financial Assessment	N/A	N/A	N/A	N/A	N/A	N/A
F4. Working as a Team	N/A	N/A	N/A	N/A	N/A	N/A
F5. Total Building Design Project	N/A	N/A	N/A	N/A	N/A	N/A
F6. Bridge Design Codes (as an addition to B2)	N/A	N/A	N/A	N/A	N/A	N/A
Maximum	<0.001	1.000	<0.001	1.000	<0.001	1.000
Minimum	<0.001	0.860	<0.001	0.889	<0.001	0.910

5.4.1 Study of the Correlation of the Round 1 and Round 2 Questionnaire Results

The Delphi method as used in this study provides data which contains information on the dispersion of participant input, and a comparison of the results from two or more rounds facilitates an examination of much the group response has changed between or among rounds. This information is useful to indicate how stable the results from the latest round are and to project the likely magnitudes of change another round would provide. An examination of the differences and similarity of the panel's evaluations and the differences in the Round 1 and Round 2 results are next given.

5.4.1.1 Measures of Correlation

As noted earlier in Section 5.3, the Kendall rank correlation coefficient (tau-b) may be used to evaluate the degree of similarity between two sets of ordinal data, and the significance level, p, associated with the tau-b value indicated the strength of this significance, with a lower p value indicating that the degree of similarity is less likely to have happened by chance. Because the Kendall tau-b and p statistics are not as widely used in engineering topics as are statistical tools for ordinal data, a short introduction is next given on the background and calculation of these values for a simple case, adapted from (Abdi, 2007).

For the basic problem of comparing two rankings of the same set of objects, the Kendall rank correlation coefficient is a ratio of the number of different pairs between the two ordered sets and the total number of ordered pairs. Consider three objects that are first ranked in the order (1, 2, 3). 1 becomes before 2 and before 3, and 2 becomes before 3. The ordered pairs of two rankings are thus (1, 2), (1, 3) and (2, 3). If the second ranking of these three objects is (1, 3, 2), the corresponding ordered pairs are (1, 2), (1, 3), and (3, 2). Of the six ordered pairs, three from each ranking, there are two sets of identical ordered pairs: (1, 2) and (1, 3), and the last two are reversed: (2, 3) and (3, 2). The Kendall rank correlation coefficient, tau-b, is computed as one minus the ratio of twice the number of different pairs divided by the number of ordered pairs in the two rankings, which in this case is 1 – (twice the two different pairs= 2 times 2 = 4/six ordered pairs in the two rankings), giving a value of tau-b = 1 – 4/6 = 1/3. A second ranking of (2, 1, 3) would similarly result in only two different ordered pairs, these now being (1, 2) and (2, 1), and thus also a tau-b = 1/3. A second ranking of either (2,3,1) or (1,3,2) results in tau-b = -1/3, and a second ranking of (3,2,1), the reverse of the first, results in the smallest possible tau-b of negative one. If, instead of 3 objects, the problem involved the ranking of N objects, the two rankings would have N (N-1) ordered pairs and more possible tau-b values. Instead of the four possible values for the N = 3 example above, there are 7 for N=4, 11 for N=5, etc. Just as there are two possible second rankings giving each of tau-b = 1/3 and -1/3, but only one giving tau-b = 1 and -1, the number of possible rankings giving a specified tau-b value increase as the tau-b value is closer to zero.

The significance level, p, is the probability that the given tau-b value could be as large or larger than the computed tau-b value by chance. For the N=3 example, the p value associated with tau-b = 1/3 would be 0.500, as a possible value of either tau-b = 1/3 or 1 happens for 3 of the possible 6 rank orders (these being (1,2,3), (1,3,2), (2,1,3), (2,3,1), (3,1,2) and (3,2,1)) for the second ranking. The number of possible rank orders is N factorial. Instead of (3)(2)(1) = for N=3, (4)(3)(2)(1) = 24 are possible for N = 4, 120 for N = 5, 720 for N = 6, etc. As N gets larger, it can be shown that the distribution of the tau-b values from all the possible second rankings approaches a normal distribution. Because of this convergence to the normal for large values of n, the value of p can be computed with the assistance of the standard normal curve values.

The Kendall's tau-b rankings are of objects, the Kendall's tau-b ranking is sometimes interpreted as being similar to r, the Pearson correlation coefficient (which follows from the normal distribution of possible Kendall rankings at the data set size becomes large), the value of p, the probability of a tau-b value greater than or equal to a given value becomes smaller and thus closer to the minimum possible value of zero as the tau-b value is closer to one and as N, the number of objects, i.e. the sample size, becomes larger. A fairly large tau-b value has a much larger probability of occurring by chance for a small sample size than does the same tau-b value for a much larger size effect and the tau-b value is thus more significant and the correlation is stronger for the second case. For an examination of the correlation/similarity of the two sets of evaluations resulting from Rounds 1 and 2 of our Delphi study, the calculations as carried out by the SPSS software are similar in concept but more involved in detail.

The results shown in Table 5-3 indicate, by the tau-b values being close to or equal to the maximum value of 1, that the Round 1 and Round 2 results are very similar, and the very low values of p show that this similarity is very significant and very unlikely to have occurred by chance. When the tau-b value is 1.000, the Round 1 and Round 2 outcomes for the subtask of interest were identical.

The tau-b and p values for the individual subtasks are next displayed and discussed.

5.4.1.2 Correlation Strength of Round 1 and Round 2 Evaluations

For the general use case of comparing two sets of rankings, the Kendall tau-b values are commonly interpreted using the descriptions given in Table 5-4. This usual table is expected to be of little use for our case because of the comparison of Round 1 and Round 2 results being a comparison of two sets of data from very similar sources.

Table 5-4: Kendall tau-b Effect on Correlation

Effect Size, tau-b	Strength of Correlation
tau-b ≥ |0.70|	Much larger than typical
tau-b = |0.50|	Larger than typical
tau-b = |0.30|	Medium or typical
tau-b = |0.10|	Small or smaller than typical

The significance level, p, will be smaller in the second case, the one with the larger sample size. Because of this, the significance level measure, the p, is significantly affected by the sample size, enough so that it is sometimes presented as a measure of sample size effect. High strength of correlation (Kendall's tau-b statistical values) were expected to result in this study from the comparison of the two data sets (Round 1 and Round 2 participant assessments) as these two data sets are highly related and large changes between the two data sets were not expected. In this sense, they are not typical of what would be typical in the sense of data from two more distinctly different samples are not being compared.

The expected trend of high Kendall's tau-b values is shown in the data. In all cases, the Kendall's tau-b values showed strength of correlation much larger than is generally considered typical (Table 5-4) between the Round 1 and Round 2 results. This was the case both at graduation and after 5 Years of Experience for all questions, as is apparent from the results shown in Figure 5-2, Figure 5-3, and Table 5-3.

As seen on Figure 5-2, Figure 5-3, the majority of the subject topics had a tau-b value >0.90, some at 1.00 and with only three below 0.90. The high values (>0.90) show a very strong correlation. For eleven cases for "Masters-Level Graduation", 6 cases for "After 5 Years of Experience, and 8 cases for "Elective Offerings", the results for Round 1 and Round 2 were identical, giving the tau-b values of unity in Table 5-3.

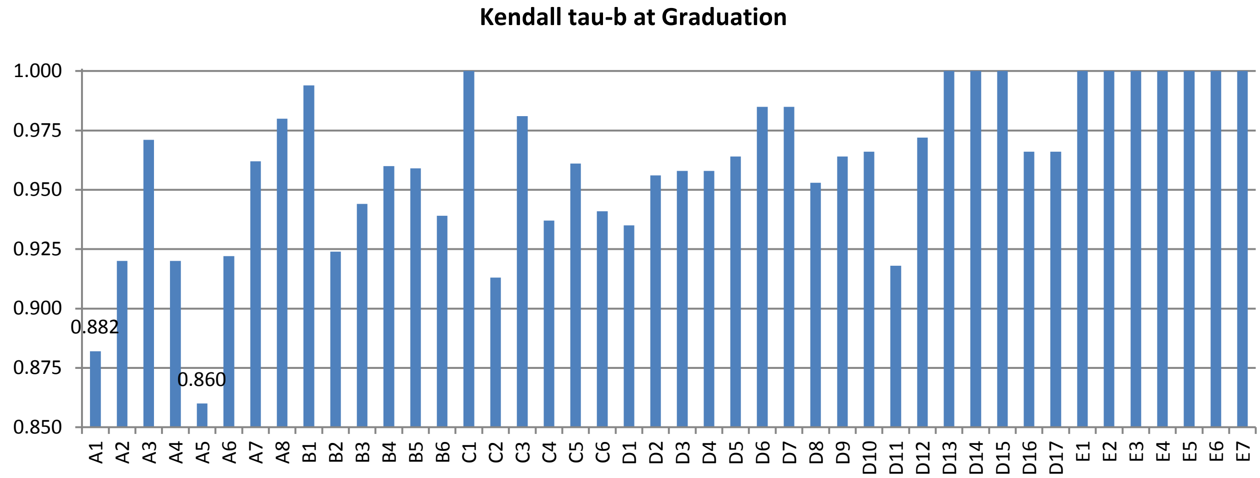


Figure 5-2: Strength of Opinion Movement for the Time of Masters-Level Graduation

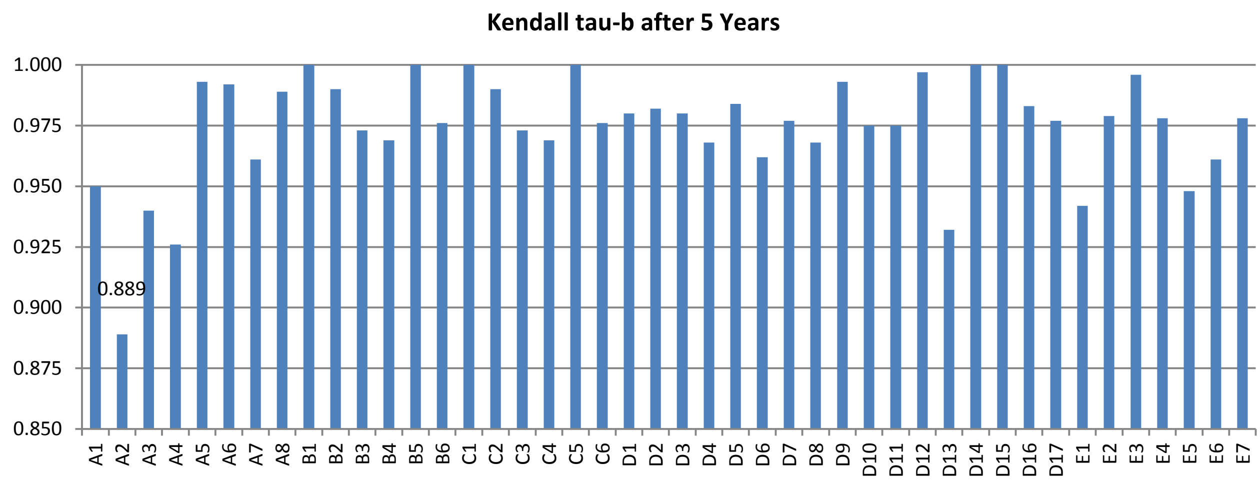


Figure 5-3: Strength of Opinion Movement for after 5 Years Experience

To illustrate the pattern of change from Round 1 to Round 2 that resulted in the lower tau-b values, details of the two response sets for the three cases with the lowest tau-b values (0.860, 0.882, and 0.889) are next presented. This detailed comparison for Subtopic A1, Advanced Mechanics of Materials (tau-b (32) = 0.882 at graduation) is presented in Figure 5-4. The comparison for A2, Structural Analysis-Framed Structures (tau-b (32) = 0.889 after 5 Years of Experience) is shown in Figure 5-5, and Figure 5-6 presents the comparison for A5, Structural Dynamics (tau-b (32) = 0.860 at graduation from a Masters-Level structural engineering program). The value 32 represents the expert panel size. The vertical scale for each of the horizontal segments for which responses were received is the percent of each of the individual responses options, and the number given for each bar is the number of the 32 cases for each condition. For example, Figure 5-4 shows that of the 13 responses at the Application (Key value=3) level in Round 2, 9 were also at that level in Round 1, 3 were at the next lower "Comprehension" level in Round 1, and 1 was assigned to the "Knowledge" (Key value=1) in the first round. For all other conditions, the Round 1 and Round 2 responses for Questions A1 were the same. Thus, these four changes in the 32 responses are responsible for the Question A1 tau-b value of 0.882 being less than 1. Similarly, one quite significant change (of 3 levels) at the Round 2 "Evaluation" level resulted in the 0.889 value for Question A2 at the 5-years of experience level, and five changes of one level higher or lower gave the lowest value of 0.860 for Question A5 at graduation.

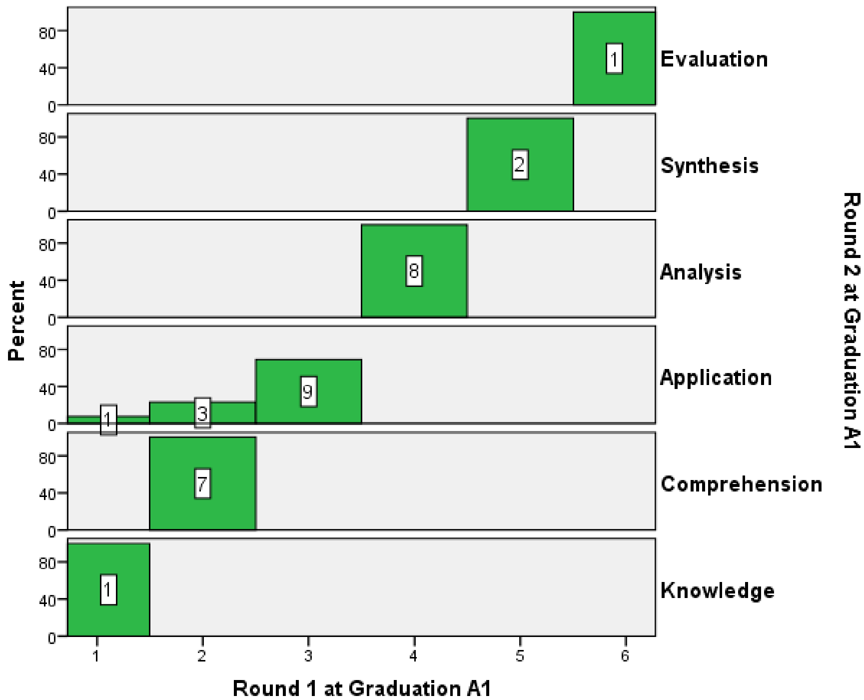


Figure 5-4: Opinion Movement for Question A1-Advanced Mechanics of Materials

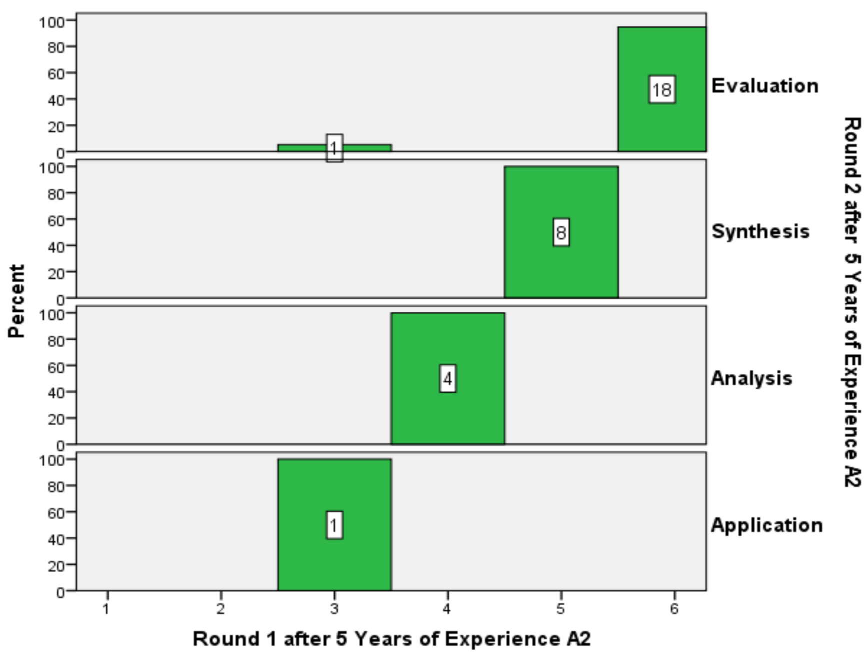


Figure 5-5: Opinion Movement for Question A2-Structural Analysis-Framed Structures

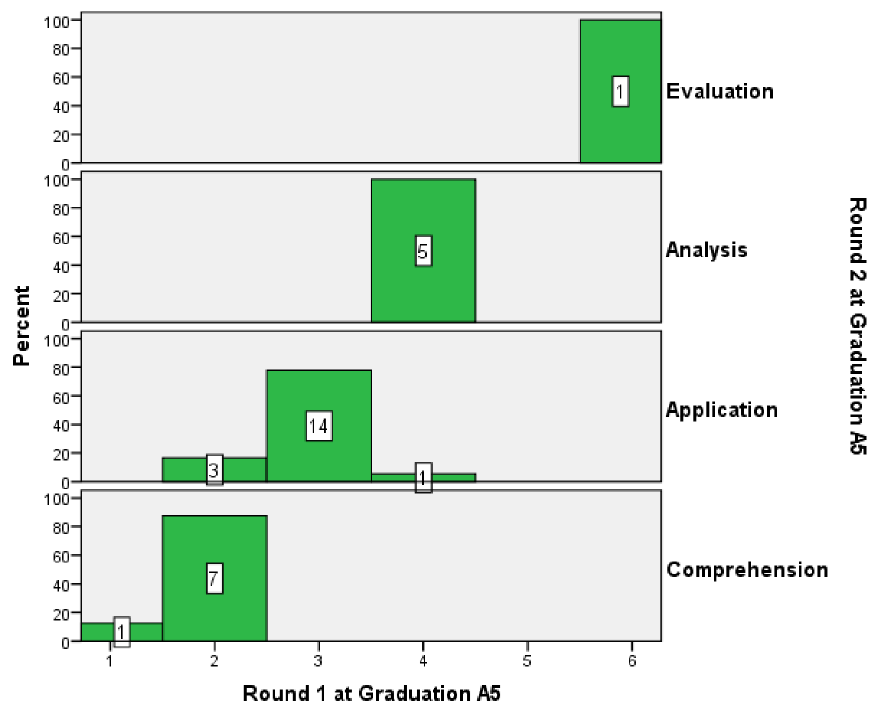


Figure 5-6: Opinion Movement for Question A5-Structural Dynamics

The strong correlation that resulted between Round 1 and Round 2 suggests that the use of a Round 3 with the same general format of Round 2 would produce only minor or no changes and thus correlation would be only nominally better. Therefore, Round 3 did not continue with the format of Rounds 1 and 2; rather it was restructured to address the importance level of the five primary educational modes identified to be relevant in obtaining higher achievement levels after completion of the Masters-Level degree.

5.4.2 Frequencies of Participants' Answers in Round 2

The preceding examination of the correlations between Round 1 and Round 2 responses show that Round 1 served its two intended purposes of producing the first set of results for the communication to the survey participants and as the initial data used in a comparison with the Round 2 data by which the very strong level of correlation could be demonstrated. Since the values obtained in the second round are the improved and more informed values, but are little different than the first round values, only the Round 2 values are addressed in the rest of this Chapter. The expected competency summary was calculated for each of the fifty questions of the questionnaires at graduation, after 5 Years of Experience, and with elective offerings in Round 2, with the results shown in Table 5-5. For each at the three educational levels (graduation, with 5 Years of Experience, available through electives), the percentage of responses for each task assigned to the top two of the six Bloom's achievement levels (≥ 5) and to the top four levels (≥ 3) are listed. These two measures were chosen as they were found to provide more useful information on typical expected achievement levels and increases with experience than did other possible "at or above" levels. Only 7 of the 44 subtasks in Group A through F were assigned a Bloom's level of 5 or 6 by more than 10% of the experts at the time of graduation, while the percentage of level 5 or 6 responses for the time after 5 Years of Experience are somewhat uniformly distributed between about 10% and 85%. The "≥ 3" measure for the 44 evaluations (Group A through F) at the time of Masters-Level graduation was between 7% and 25% for 8 subtasks, between 26% and 50% for 15 subtasks, between 51% and 75% for 14 subtasks, and between 76% and 97% for 7 subtasks, a wide distribution which was found very useful in identifying individual subtasks usually assigned the higher and lower expected achievement levels.

The graphical representation of the expected frequencies by achievement level in Round 2 for all six structural engineering topics (A to F) are shown on Figure 5-7 to Figure 5-24 for the three levels of preparation. These stacked bar charts contain a great deal of information and may take some study to reveal the most useful information. The largest bar segment identifies the achievement level most often assigned.

Table 5-5: Expected Competency Summary for Round 2

Question	At Graduation		After 5 Years		Elective Offerings	
	≥ 5 Level	≥ 3 Level	≥ 5 Level	≥ 3 Level	≥ 5 Level	≥ 3 Level
A. Basic Mechanics and Engineering Tools						
A1. Advanced Mechanics of Materials	9	75	31	97	16	84
A2. Structural Analysis – Framed Structures	28	97	84	100	45	97
A3. Finite Element Analysis/Modeling	6	75	50	100	22	88
A4. Elastic Stability	3	66	38	100	16	84
A5. Structural Dynamics	3	75	41	97	23	84
A6. Analysis of Plates and Shells	3	31	16	78	13	66
A7. Properties & Behavior of CE Materials	6	66	47	97	23	81
A8. Numerical Methods	3	44	13	56	9	66
B. General Structural Engineering Tools						
B1. Behavior of Structural Systems. Load Path.	28	81	84	100	31	97
B2. Building Codes & General Requirements	3	53	75	100	9	70
B3. Architectural/Aesthetics Considerations	0	31	19	84	3	41
B4. Conceptual & Preliminary Planning	3	41	38	94	6	47
B5. Design Loads, Including Evaluation	19	81	75	100	16	88
B6. Foundations & Geotechnical Topics	0	63	44	100	13	75
C. Technology and Communication Tools						
C1. Project Plans & Specifications	0	28	75	100	6	41
C2. Communication Software & Tools	16	94	72	100	25	88
C3. Computer Graphics	0	44	26	90	6	61
C4. Structural Engineering Design Software	0	56	69	100	9	72
C5. Building Information Management (BIM) Systems	0	34	25	91	0	34
C6. Programming Skills	0	34	6	53	9	56
D. Structural Engineering Topics and Tools						
D1. Structural Steel Design – Basics	25	97	84	100	38	94
D2. Structural Steel – More Advanced Topics	0	66	56	100	9	88
D3. Reinforced Concrete Design Basics	28	97	88	100	38	91
D4. Prestressed Concrete Design	9	75	47	94	25	78
D5. Reinforced Concrete – Advanced Topics	9	69	59	97	13	84
D6. Masonry Design	0	63	50	94	6	72
D7. Timber Design	0	63	53	88	6	69
D8. Design with Structural Aluminum	0	23	13	68	3	39
D9. Bridge Design – Short/Mid Span	3	55	42	90	10	77
D10. Bridge Design – Long Span Systems	0	26	3	74	3	52
D11. Earthquake Engineering – Basics	13	78	53	97	23	84
D12. Earthquake – High Risk Areas	3	38	28	91	9	63
D13. Design to Resist Unusual Loads/Blast	0	23	3	74	6	48
D14. Special Concerns for High Rise Systems	0	23	10	68	3	45
D15. Condition of Structures/Repair, Renovation, Reuse	0	34	25	84	3	45
D16. Special Requirements – Residential	0	28	19	81	0	33
D17. Special Requirement – Light Commercial	0	28	19	84	0	40
E. Management and Professional Tools						
E1. Design Office Organization/Management/Office Ethics	0	19	34	94	0	48
E2. Business Development and Practices	0	10	22	81	0	25
E3. Design/Build & Other Project Methods	0	13	23	87	3	23
E4. Leadership Skills/Adaptation to Changes	0	32	25	91	3	40
E5. Working with Architects, Contractors, etc.	0	27	34	100	3	33
E6. LEED, Green Buildings, Energy Use	0	23	19	84	3	40
E7. International Design and Construction Practices	0	7	3	48	3	14
F. Additional Topics						
F1. Communication Skills (Oral, Written, Graphical)	4	96	85	100	33	100
F2. Effective Speaking	0	58	76	100	20	100
F3. Financial Assessment	0	8	4	92	0	20
F4. Working as a Team	0	58	96	100	8	92
F5. Total Building Design Project	0	70	85	100	4	85
F6. Bridge Design Codes (as an addition to B2)	0	38	32	91	4	65

A suggested approach to help interpret these stacked bar charts is to view where the turquoise (dark) “4 = Analysis” bars are located, with the proportion of responses at Levels 5 or 6 and at Levels 1, 2 and 3 being quite visible as the bar height above or below the “4 = Analysis” bar. The additional preparation expected during the initial 5 years in practice can be discerned with the assistance of viewing how the “4 = Analysis” bars move from the “at graduation” to the “after 5 years” plots.

The achievement level movements between at graduation and after 5 Years of Experience times are summarized in Table 5-6. In the majority of cases, the change for “at graduation” to “five years of experience” was an increase. Only once was the expected achievement level decreased two levels from “at graduation” to “after 5 Years of Experience”, and a decrease of one level occurred 12 times out of the total 1379 responses possible in Group A through F (29 to 32 individuals assessing each of 44 subtasks). In 83 cases (6.02% of 1379), expected achievement level assigned by a survey member for a subtask did not change.

In the rest of this section, general trends and some of the largest and smallest expected achievement levels are noted for each topic area group, along with the response distribution for one or more subtopic within the topic group chosen to illustrate some of the results discussed. As noted earlier, details of the response data for each topic question are contained in the Appen. In the observations and discussions on the results for the individual Topic Groups which follows, the data for the “≥ Level 3” are given most emphasis at the time of graduation, and the data for “≥ Level 5” is given primary emphasis for the expectations after the initial five years of experience. The results shown in Table 5-5 are used extensively in the following discussions on the frequencies of participants’ Round 2 answers.

Table 5-6: Achievement Level Movement between Graduation and after 5 Yrs of Experience

Question Achievement Level Difference Round 2	-2	-1	0	+1	+2	+3	+4	+5	∑
A. Basic Mechanics and Engineering Tools									
A1. Advanced Mechanics of Materials	0	1	11	11	8	0	1	0	32
A2. Structural Analysis – Framed Structures	0	0	2	16	12	2	0	0	32
A3. Finite Element Analysis/Modeling	0	0	3	13	12	4	0	0	32
A4. Elastic Stability	0	0	4	14	13	1	0	0	32
A5. Structural Dynamics	0	0	6	10	15	1	0	0	32
A6. Analysis of Plates and Shells	0	1	6	12	11	2	0	0	32
A7. Properties & Behavior of CE Materials	0	0	4	14	12	2	0	0	32
A8. Numerical Methods	1	1	15	11	4	0	0	0	32
B. General Structural Engineering Tools									
B1. Behavior of Structural Systems. Load Path.	0	0	5	11	11	4	1	0	32
B2. Building Codes & General Requirements	0	0	0	4	12	13	3	0	32
B3. Architectural/Aesthetics Considerations	0	0	4	12	13	1	2	0	32
B4. Conceptual & Preliminary Planning	0	0	1	9	16	5	1	0	32
B5. Design Loads, Including Evaluation	0	1	5	11	7	5	3	0	32
B6. Foundations & Geotechnical Topics	0	0	2	14	13	2	1	0	32
C. Technology and Communication Tools									
C1. Project Plans & Specifications	0	0	0	4	6	12	8	2	32
C2. Communication Software & Tools	0	0	9	10	11	2	0	0	32
C3. Computer Graphics	0	0	7	11	9	4	0	0	31
C4. Structural Engineering Design Software	0	0	1	6	12	9	2	2	32
C5. Building Information Management (BIM) Systems	0	0	3	8	14	5	2	0	32
C6. Programming Skills	0	2	14	8	7	1	0	0	32
D. Structural Engineering Topics and Tools									
D1. Structural Steel Design – Basics	0	0	6	10	11	5	0	0	32
D2. Structural Steel – More Advanced Topics	0	0	2	12	13	4	1	0	32
D3. Reinforced Concrete Design Basics	0	0	5	12	10	5	0	0	32
D4. Prestressed Concrete Design	0	1	5	12	12	2	0	0	32
D5. Reinforced Concrete – Advanced Topics	0	1	4	9	13	4	1	0	32
D6. Masonry Design	0	0	3	11	12	4	2	0	32
D7. Timber Design	0	1	3	12	11	3	2	0	32
D8. Design with Structural Aluminum	0	0	7	12	9	2	1	0	31
D9. Bridge Design – Short/Mid Span	0	0	4	13	9	3	2	0	31
D10. Bridge Design – Long Span Systems	0	0	9	13	9	0	0	0	31
D11. Earthquake Engineering – Basics	0	1	3	13	13	2	0	0	32
D12. Earthquake – High Risk Areas	0	1	4	7	16	3	1	0	32
D13. Design to Resist Unusual Loads/Blast	0	0	9	10	11	1	0	0	31
D14. Special Concerns for High Rise Systems	0	1	5	10	14	0	0	0	30
D15. Condition of Structures/Repair, Renovation, Reuse	0	0	1	10	12	6	0	0	29
D16. Special Requirements – Residential	0	0	1	12	11	4	1	0	29
D17. Special Requirement – Light Commercial	0	0	1	11	11	5	1	0	29
E. Management and Professional Tools									
E1. Design Office Organization/Management/Office Ethics	0	0	1	6	11	11	2	0	31
E2. Business Development and Practices	0	0	0	10	10	8	1	0	29
E3. Design/Build & Other Project Methods	0	0	1	8	9	12	0	0	30
E4. Leadership Skills/Adaptation to Changes	0	0	2	10	11	8	0	0	31
E5. Working with Architects, Contractors, etc.	0	0	1	5	13	8	2	1	30
E6. LEED, Green Buildings, Energy Use	0	0	1	12	12	5	0	0	30
E7. International Design and Construction Practices	0	0	5	15	9	1	0	0	30
F. Additional Topics									
F1. Communication Skills (Oral, Written, Graphical)	0	0	0	7	16	4	0	0	27
F2. Effective Speaking	0	0	1	4	13	7	1	0	26
F3. Financial Assessment	0	0	0	9	14	2	1	0	26
F4. Working as a Team	0	0	1	0	6	10	8	1	26
F5. Total Building Design Project	0	0	1	3	16	5	2	0	27
F6. Bridge Design Codes (as an addition to B2)	0	0	5	4	9	4	0	0	22

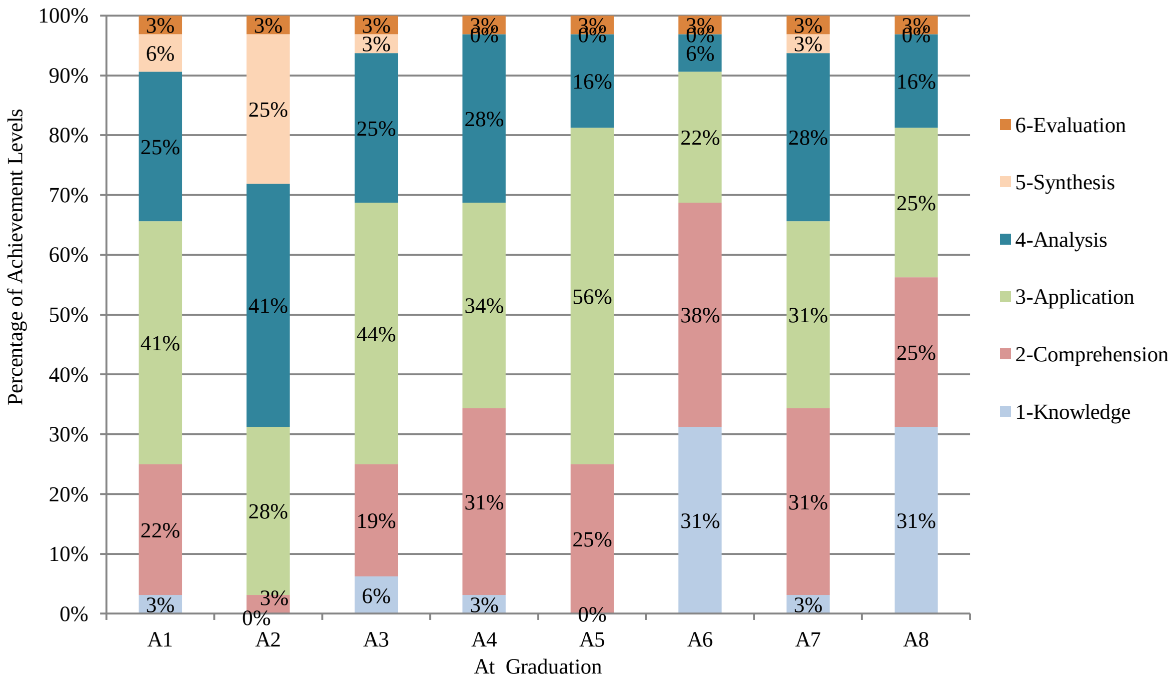


Figure 5-7: Frequencies of Achievement Levels for Topic Group A at Graduation

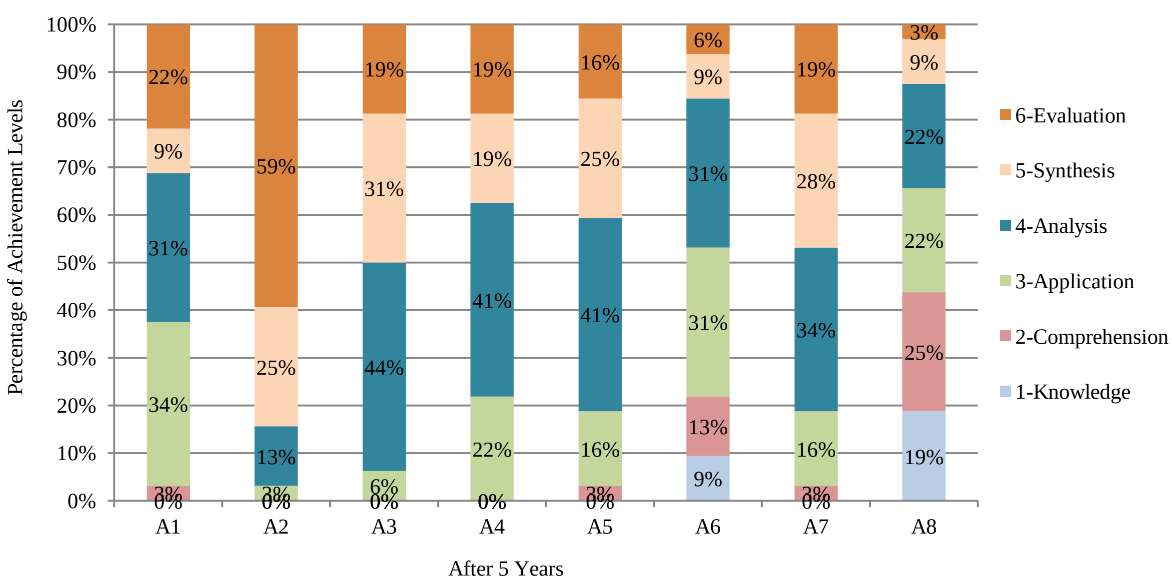


Figure 5-8: Frequencies of Achievement Levels for Topic Group A after 5 Yrs of Experience

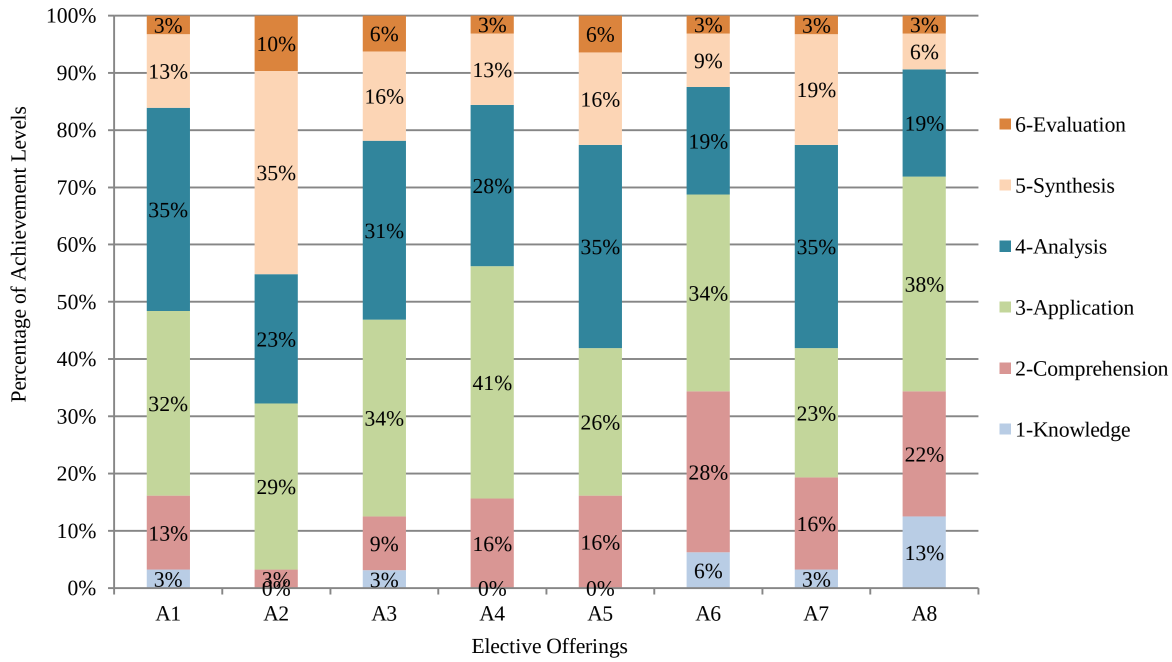


Figure 5-9: Frequencies of Achievement Levels for Topic Group A at Elective Offerings

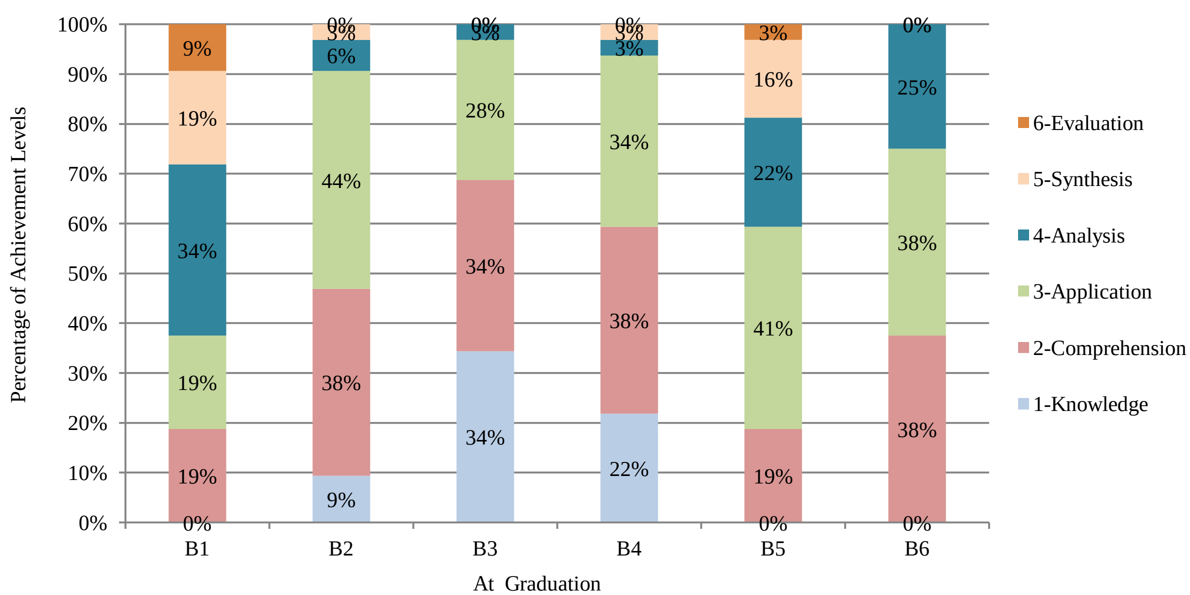


Figure 5-10: Frequencies of Achievement Levels for Topic Group B at Graduation

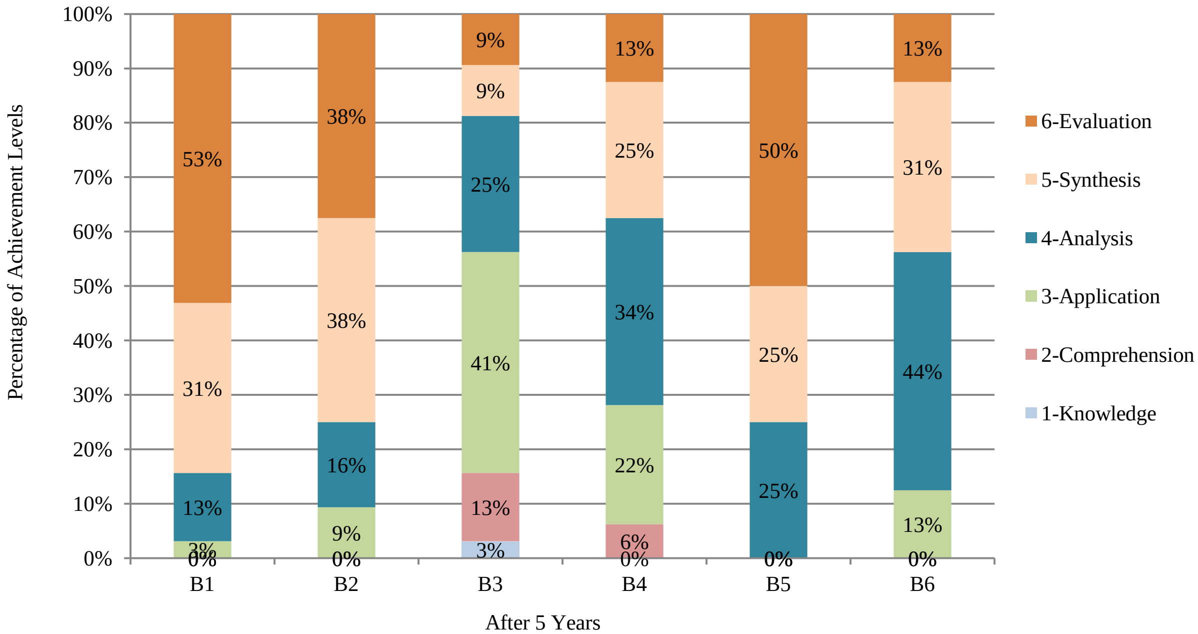


Figure 5-11: Frequencies of Achievement Levels for Topic Group B after 5 Yrs of Experience

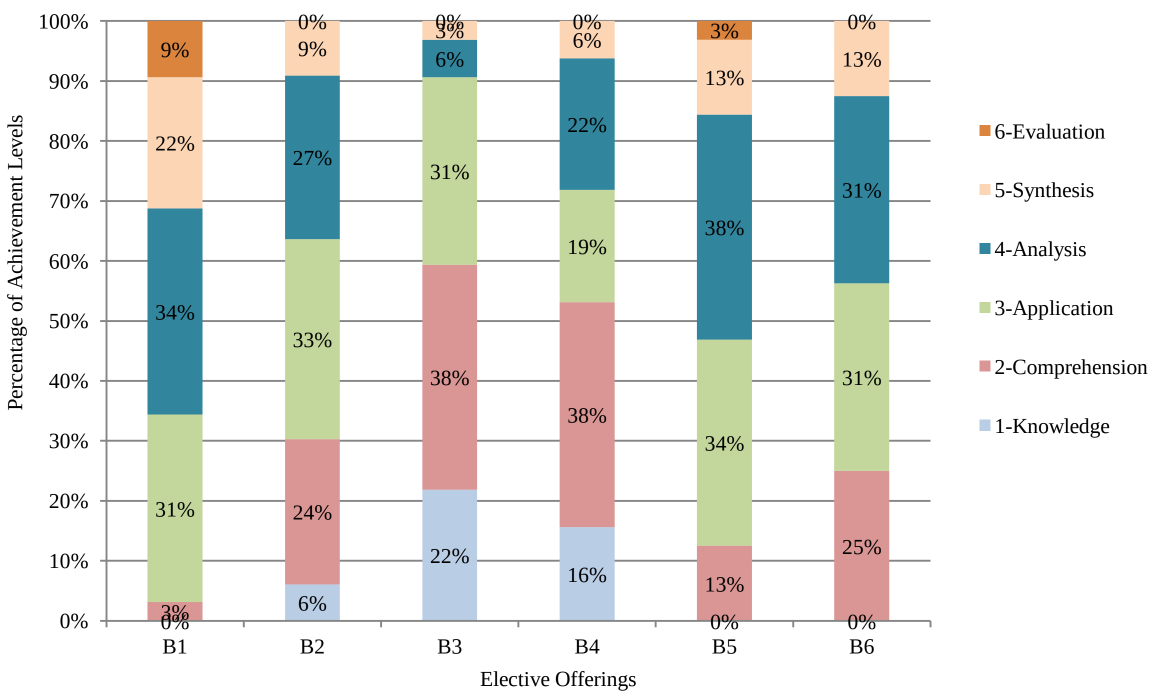


Figure 5-12: Frequencies of Achievement Levels for Topic Group B at Elective Offerings

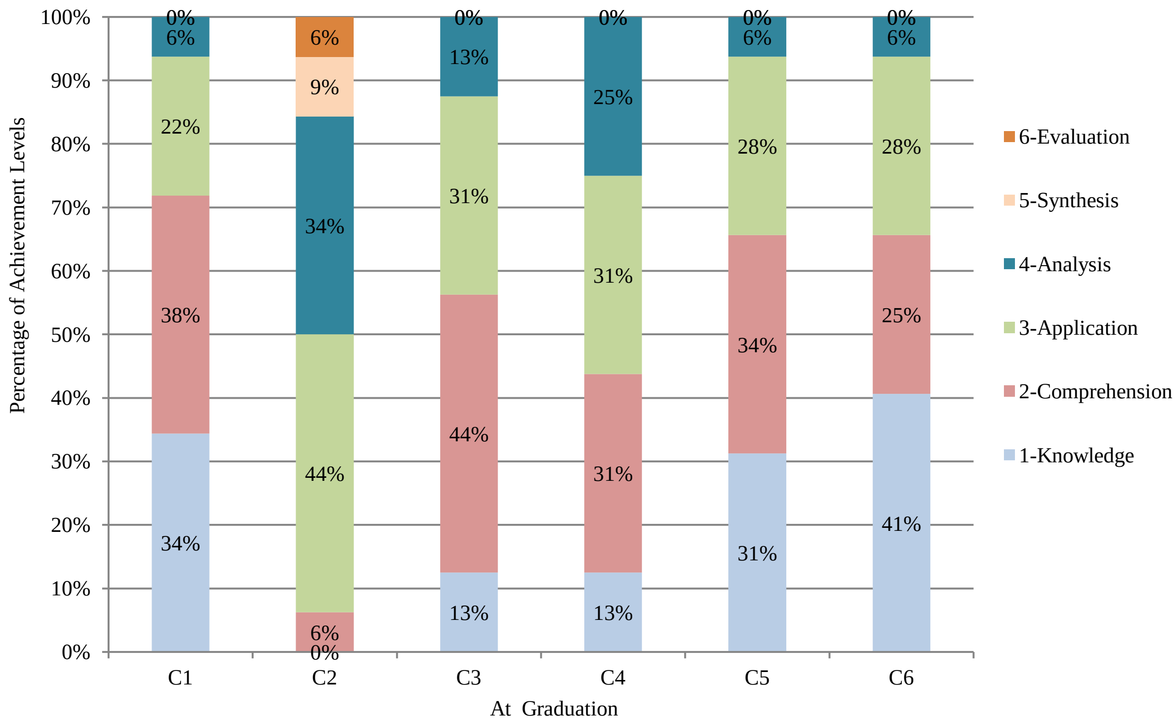


Figure 5-13: Frequencies of Achievement Levels for Topic Group C at Graduation

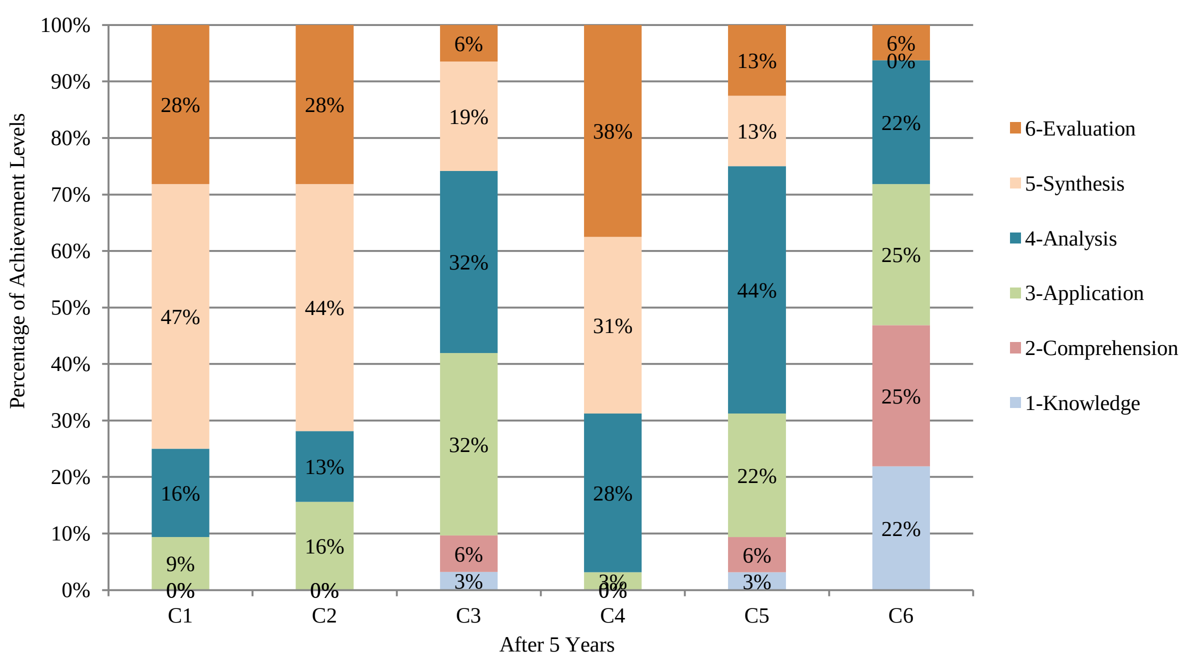


Figure 5-14: Frequencies of Achievement Levels for Topic Group C after 5 Yrs Experience

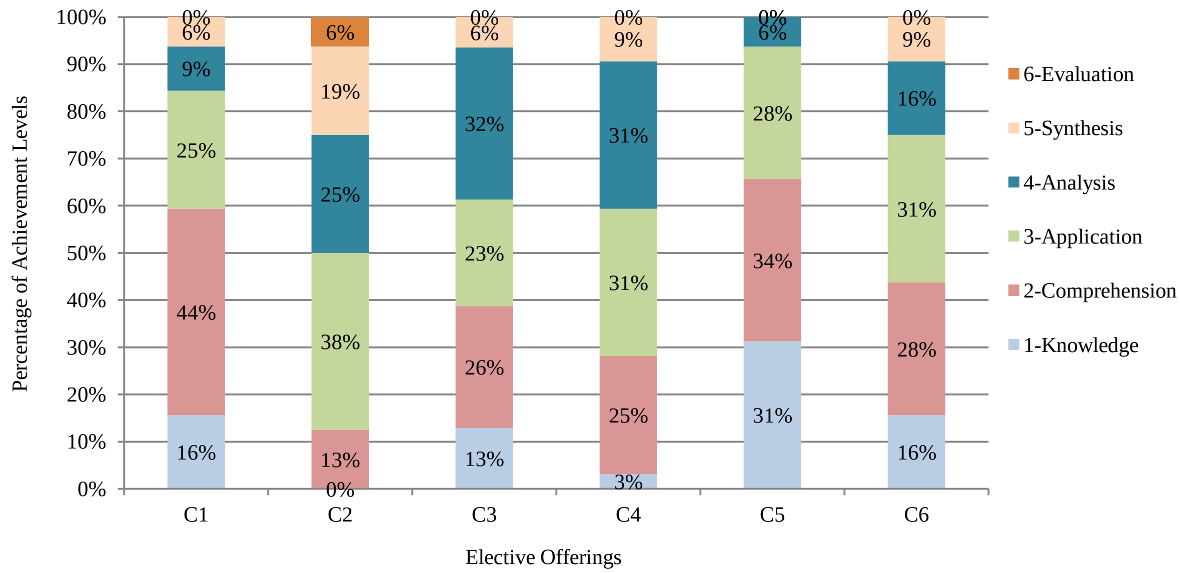


Figure 5-15: Frequencies of Achievement Levels for Topic Group C at Elective Offerings

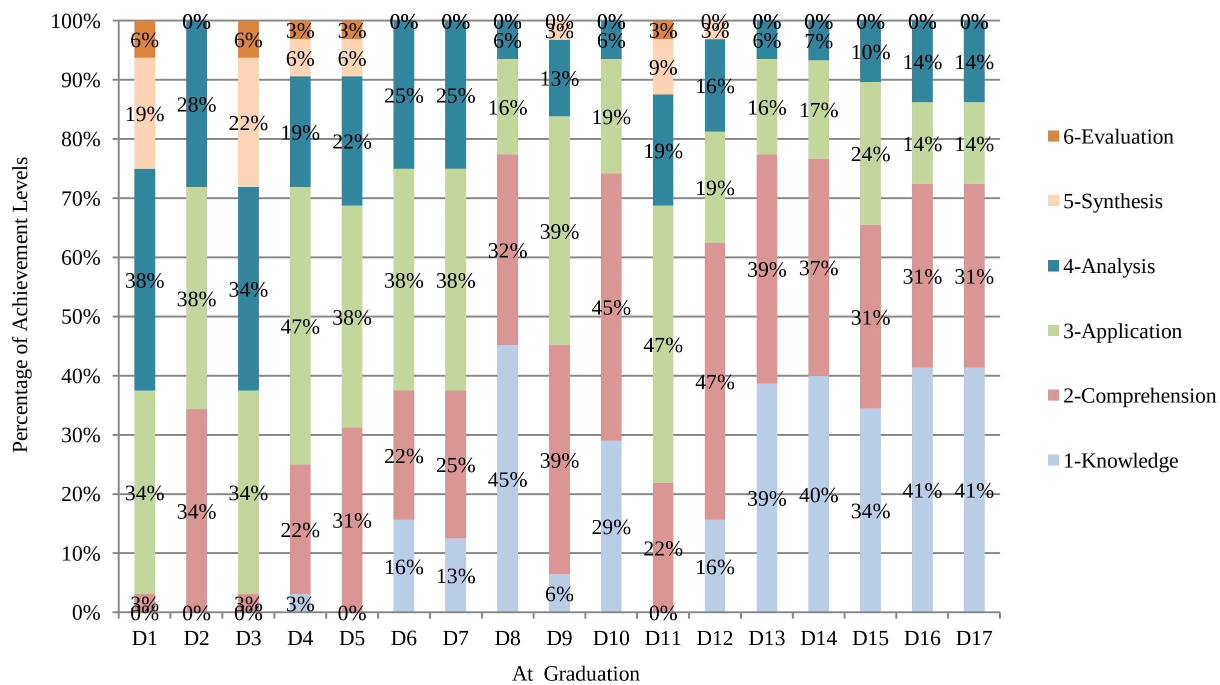


Figure 5-16: Frequencies of Achievement Levels for Topic Group D at Graduation

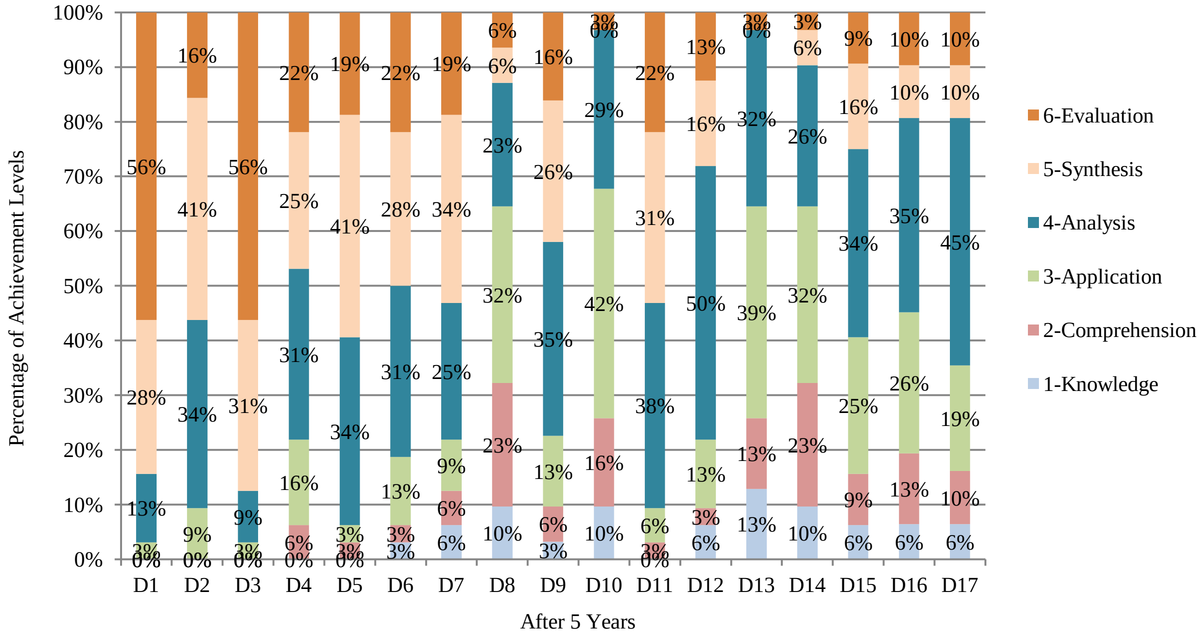


Figure 5-17: Frequencies of Achievement Levels for Topic Group D after 5 Yrs Experience

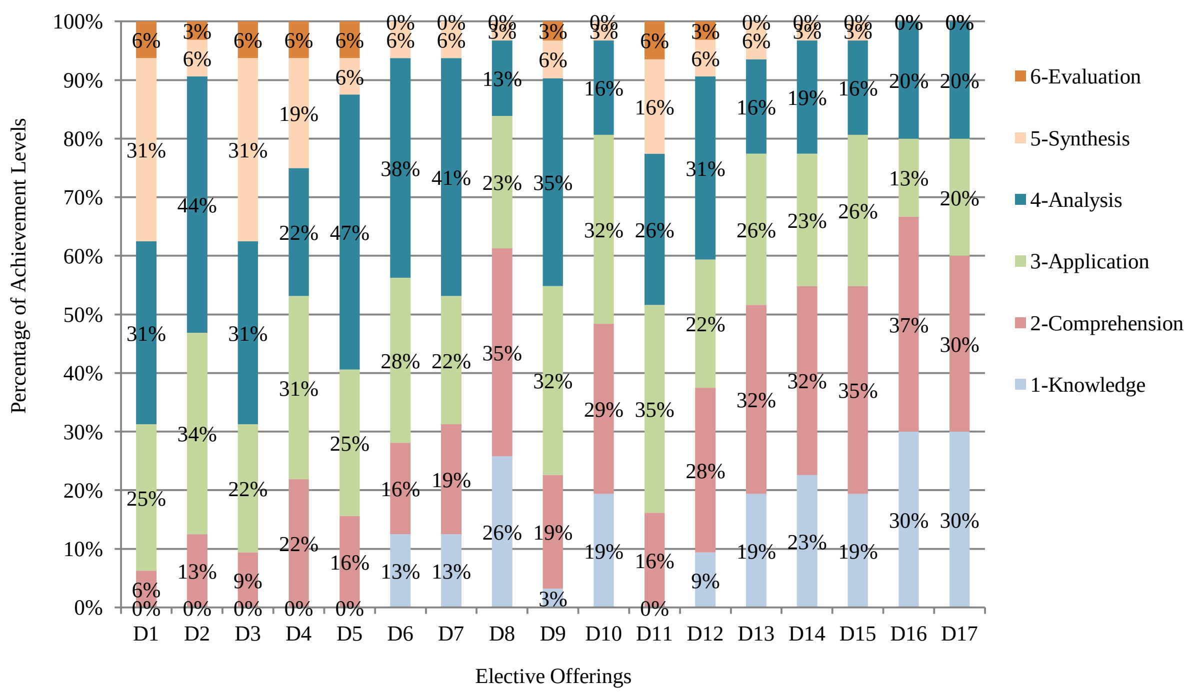


Figure 5-18: Frequencies of Achievement Levels for Topic Group D at Elective Offerings

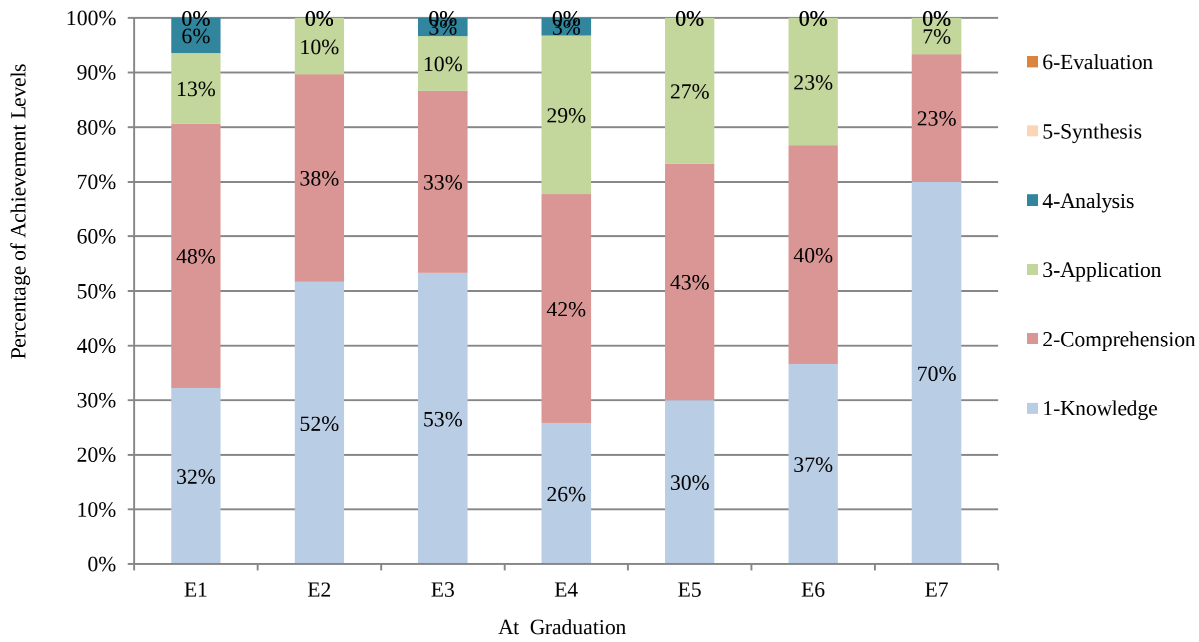


Figure 5-19: Frequencies of Achievement Levels for Topic Group E at Graduation

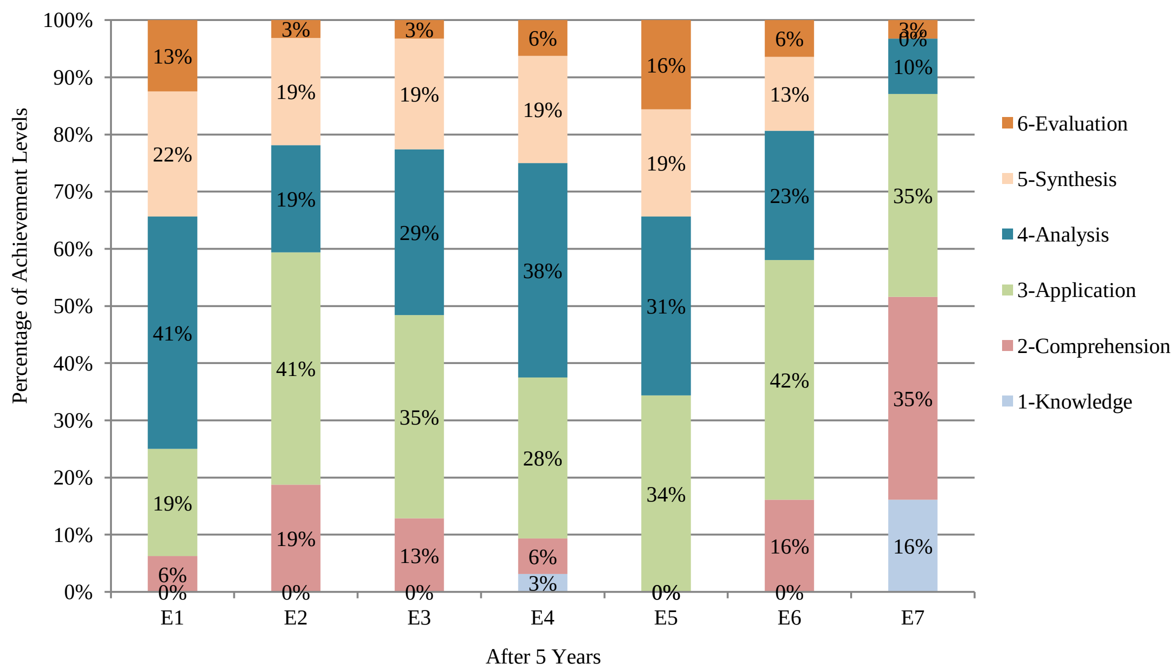


Figure 5-20: Frequencies of Achievement Levels for Topic Group E after 5 Yrs Experience

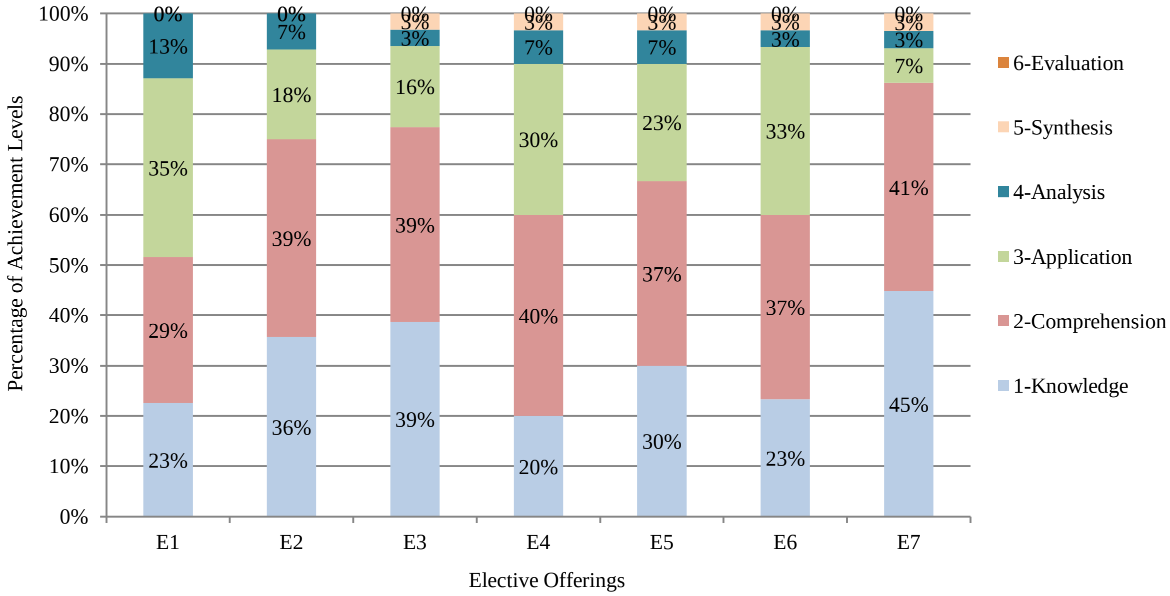


Figure 5-21: Frequencies of Achievement Levels for Topic Group E at Elective Offerings

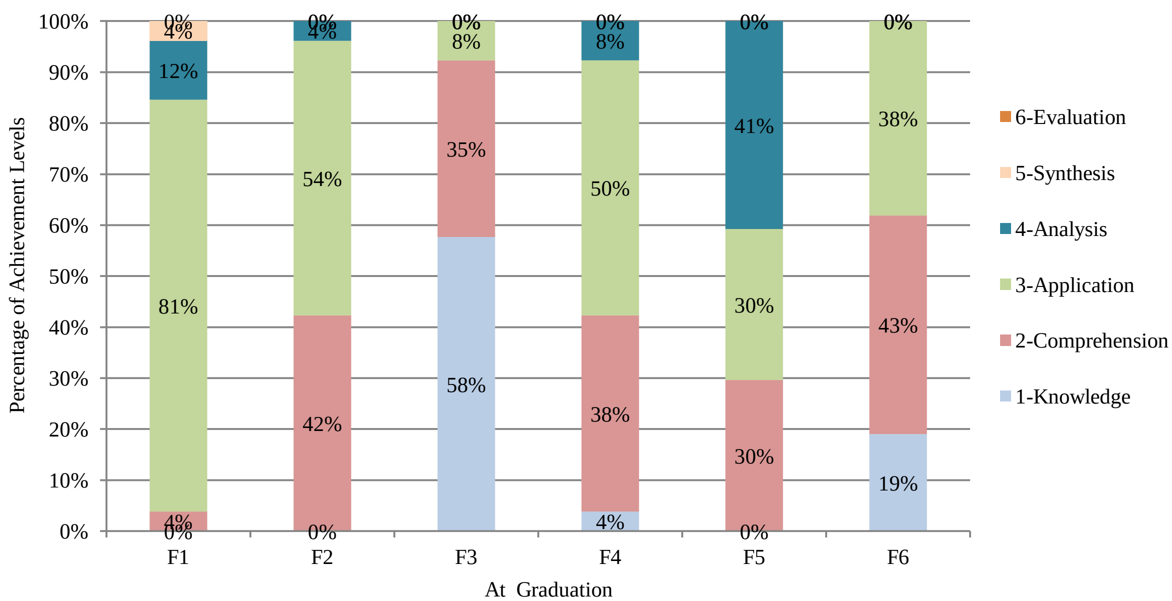


Figure 5-22: Frequencies of Achievement Levels for Topic Group F at Graduation

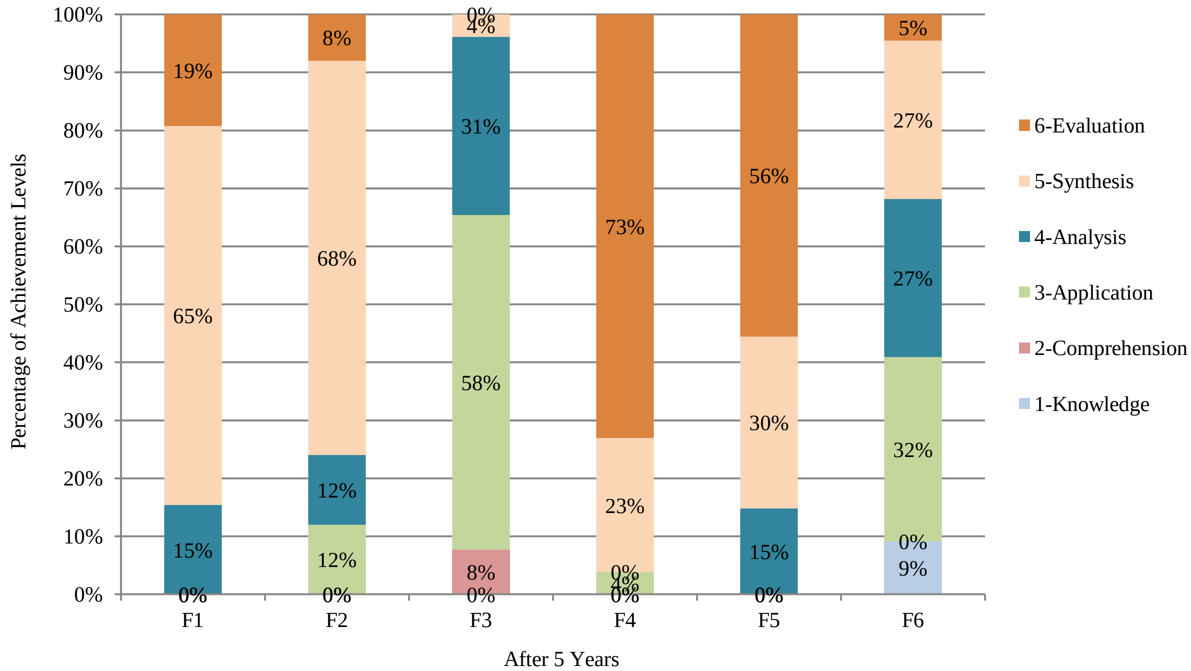


Figure 5-23: Frequencies of Achievement Levels for Topic Group F after 5 Yrs Experience

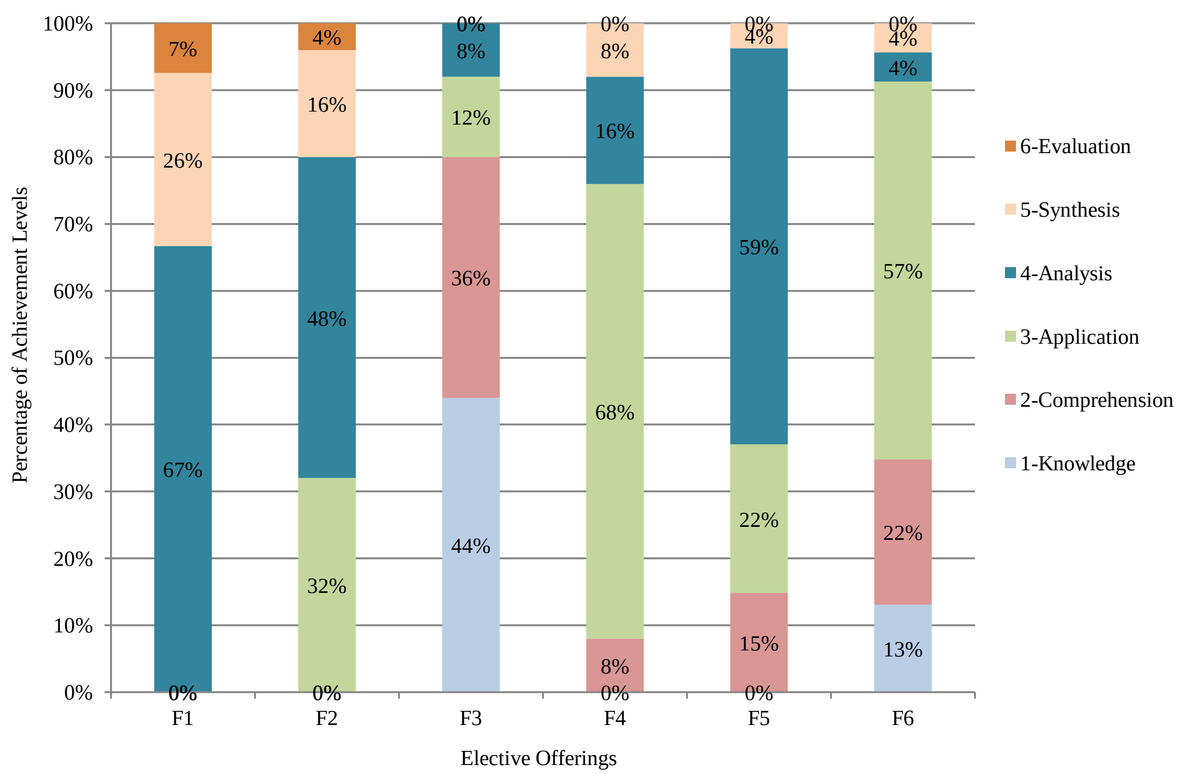


Figure 5-24: Frequencies of Achievement Levels for Topic Group F at Elective Offerings

5.4.2.1 Topic Group A

For the Basic Mechanics and Engineering Tools (A) topic, an achievement Level of ≥ 3. was usually expected at the time of graduation, with the ≥ Level 3 expected by 60% or more of the participants for 6 of the 8 subtasks. The lowest achievement level expectation by the expert participants at graduation was for Analysis of Plates and Shells (A6) with 31% ≥ Level 3, with 44% at that level for A8, Numerical Methods. After 5 Years of Experience, the Numerical Methods (A8) sub-topic was assigned the lowest expected achievement level with 13% ≥ Level 5, not much below the 16% value for A6, Plates and Shells. The highest expectations of achievement level at graduation for a Masters-Level structural engineering graduate was Structural Analysis-Framed Structures (A2) both at graduation (97% ≥ Level 3) and after 5 Years of Experience (84% ≥ Level 5), as shown in Figure 5-25.

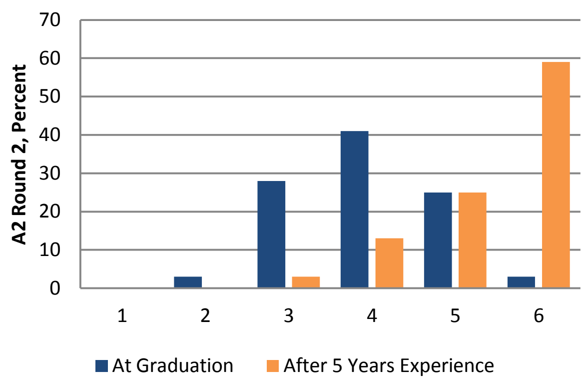


Figure 5-25: Subtopic A2 (Structural Analysis-Framed Structures) Responses of Round 2

In addition to the subtask A2 just mentioned, fairly high expectations at the after 5 year level using the "≥ Level 5" measures also were assigned to subtasks A3, Finite Element Analysis/Modeling (50% at ≥ Level 5), A7, Properties and Behavior of Civil Engineering materials (47% at ≥ Level 5) and A5, Structural Dynamics (41% at ≥ Level 5). For the after 5 Years of Experience state, 97% to 100% of the participants expected a competency level of ≥ Level 3 for all subtasks except for A6, Plates and Shells (78% at ≥ Level 3) and A8, Numerical Methods (56% at ≥ Level 3).

5.4.2.2 Topic Group B

For the General Structural Engineering Tools (B) topic, the highest expectations of achievement level were for the Behavior of Structural Systems, Load Path (B1) at both graduation (81% ≥ Level 3) and after 5 Years of Experience (84% ≥ Level 5), as shown on Figure 5-26. The expectations at graduation is also 81% for B5, Design Loads, and the expectations for both B5, Design Loads, and B2, Building Codes and General Requirements are also quite high after 5 Years of Experience, both at 75% at ≥ Level 5. The Architectural/ Aesthetics Considerations (B3) was assigned the lowest achievement level expectation by the participant panel for both the time of graduation (31% ≥ Level 3, meaning that 69% are expected to be at Levels 1 and 2) and after five years of practice (84% at ≥ Level 3). In four of the six subtasks in Topic Group B (all but B3 and B4), all participants expected at least a Level 3 competency after the initial 5 Years of Experience.

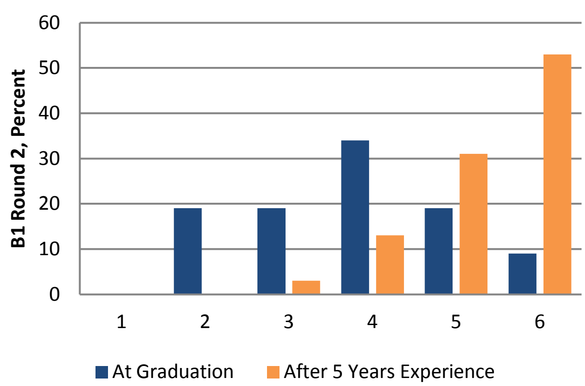


Figure 5-26: Subtopic B1 (Behavior of Structural Systems. Load Path) Responses of Round 2

5.4.2.3 Topic Group C

In the Technology and Communication Tools (C) topic area, the highest level of achievement was assigned to the Communication Software & Tools (C2) subject area at graduation (94% at ≥ Level 3) as is shown on Figure 5-27. This 94% level of expectation is notably higher than the next highest at the "≥ Level 3" at the time of graduation, which is C4, Structural Engineering Design Software, at 56%, followed by C3, Computer Graphics, at 44%. The lowest achievement level expectations at graduation were the Project Plans and Specifications (C1) with 28% at ≥ Level 3, meaning 72% are at Levels 1 and 2, and the Programming Skills (C6) area is lowest (53% ≥ Level 3 meaning 47% at Levels 1 and 2, and 6% at ≥ Level 5) at the five years of experience level. After 5 Years of Experience, the highest area is C1, Project Plans and Specifications (75% ≥ Level 5), see Figure 5-28, with high values also for the subtopic C2, Communication Software and Tools noted above (72% at ≥ Level 5) and subtopic C4, Structural Engineering Design Software (69% at ≥ Level 5). After the initial five years of experience, an achievement level of ≥ Level 5 of over 90% is expected for all but C6, Programming Skills.

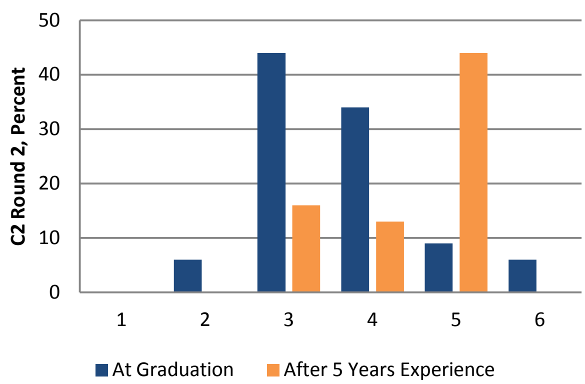


Figure 5-27: Subtopic C2 (Communication Software & Tools) Responses of Round 2

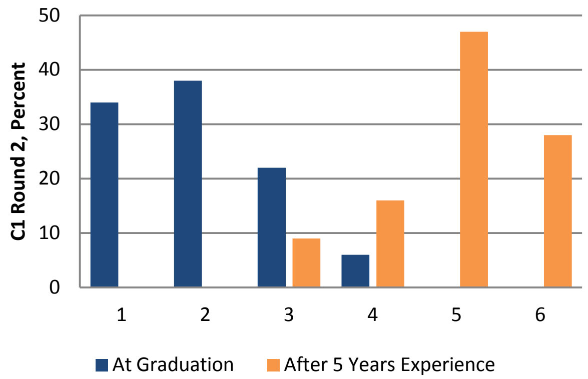


Figure 5-28: Subtopic C1 (Project Plans and Specifications) Responses of Round 2

5.4.2.4 Topic Group D

The Structural Engineering Topics and Tools (D) group included seventeen items addressing many structural material systems and design applications, ranging from some considered very basic to some representing special topics.

Reinforced Concrete Design Basics (D3) was assigned the highest expected achievement levels at both Masters-Level graduation and after 5 Years of Experience having the achievement level distribution for the subtopic is shown on Figure 5-29. The levels assigned for Reinforced Concrete Design Basics (D3) at graduation were at 97% at ≥ Level 3 and 88% at the ≥ Level 5 after 5 years experience. Very similar expectations resulted for Structural Steel Design-Basics (D1), which was also assigned 97% at ≥ Level 3 at graduation and an only slightly smaller 84% ≥ Level 5 after 5 years experience. Thus, the expert panel assigned a high level of importance to studies in both steel and reinforced concrete design. Other subtopics for which the ≥ Level 3 expectations exceed 50% at the time of graduation include D11, Earthquake Engineering-Basics (78%); D5, Reinforced Concrete-Advanced Topics (69%); D2, Structural Steel-More Advanced Topics (66%); D6, Masonry Design (63%); D7, Timber Design (63%) and D9, Bridge Design-Short/Mid Span (55%).

Subtopics D8, Design with Structural Aluminum; D13, Design to Resist Unusual Loads/Blast; and D14, Special Concerns for High Risk Systems are the subtopics assigned the lowest achievement level expectations at graduation (each with 23% ≥Level 3), with several others (D10, Bridge Design-Long Span Systems; D16, Special Requirements-Residential; D17, Special Requirements-Light Commercial ; and D12, Earthquake-High Risk Areas) assigned expectations at of less than 40% at ≥ Level 3. Subtasks assigned the lowest expectations after five years, using the % ≥ Level 5 measure, included D10, Bridge Design-Long Span Systems and D13, Design to Resist Unusual Loads/Blast, both at 3%; D14, Special Concerns for High Risk Systems (10%); and D8, Design with Structural Aluminum (13%). It should be noted that these four subtasks can be considered to represent specialty areas. Using the ≥ Level 5 data for after 5 years experience, other subtasks assign the higher evaluations, although significantly lower than for basic steel (D1) and concrete (D3) design, included D5 (Reinforced Concrete-Advanced Topics) (59%); D2, Structural Steel-More Advanced Topics (56%); D7, Timber Design, and D11, Earthquake Engineering-Basics (both at 57%) and D6, Masonry Design (50%).

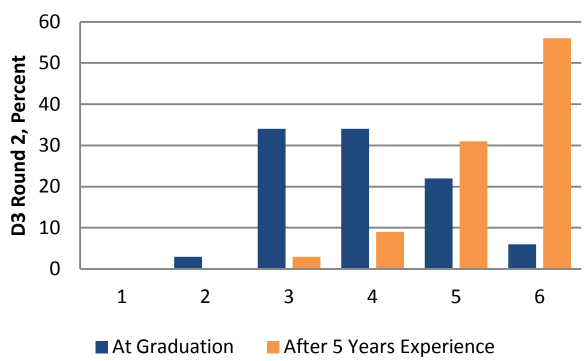


Figure 5-29: Topic D3 (Reinforced Concrete Design Basics) Responses of Round 2

5.4.2.5 Topic Group E and F

Topic Groups E, Management and Professional Tools, and F, Additional Topics, include many topics that are very important and integral to professional practice and which are not often emphasized in the academic programs. The results reflected this trend. Many of the highest increases in expected achievement levels between graduation and after five years experience are for the subtasks of these two areas.

The highest achievement levels expected at graduation were E4, Leadership Skills and Adaptation to Changes (32% at ≥ Level 3) for Group E, and F1, Communication Skills (96% ≥ Level 3) for Group F. Details of the assessments for these two subtasks are shown on Figure 5-30 and Figure 5-32. The highest expected levels after five years experience were E5, Working with Architects, Contractors, Others, (100% ≥Level 3) and F4, Working as a Team (96% at ≥ Level 5); see Figure 5-31 and Figure 5-33.

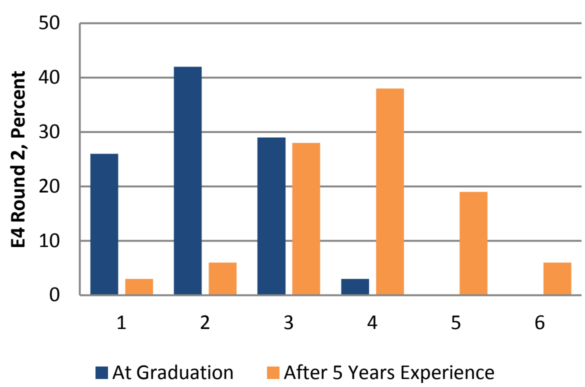


Figure 5-30: Topic E4 (Leadership Skills/Adaptation to Changes) Responses of Round 2

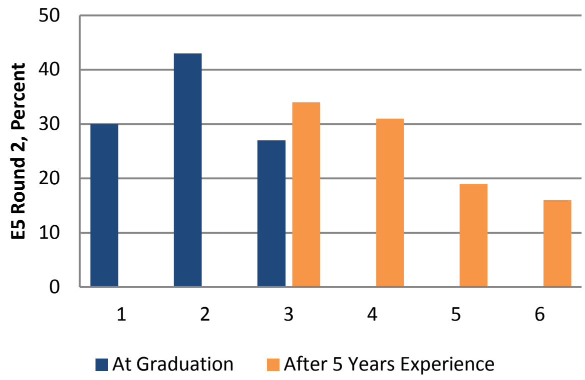


Figure 5-31: Topic E5 (Working with Architects, Contractors, etc.) Responses of Round 2

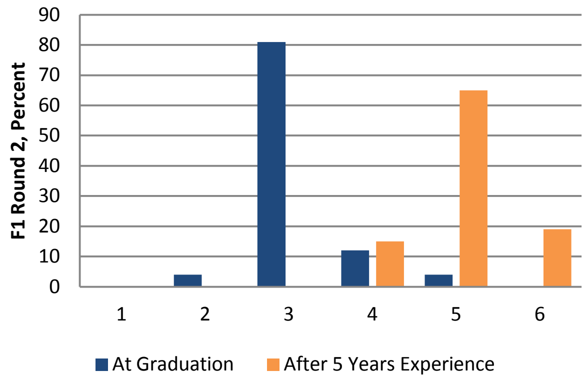


Figure 5-32: Topic F1 (Communication Skills) Responses of Round 2

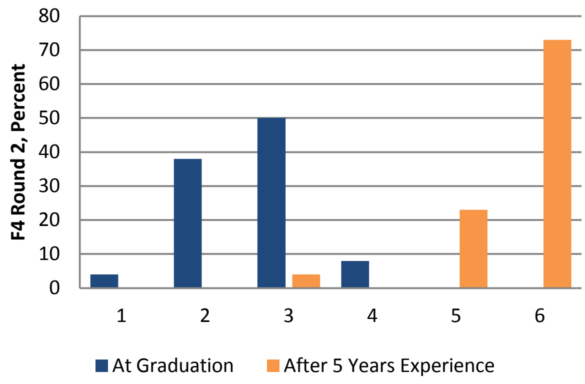


Figure 5-33: Topic F4 (Working as a Team) Responses of Round 2

The lowest expected achievement levels among Group E and F topics at the time of Masters-Level graduation were assigned to E7, International Design and Construction Practices (7% at ≥Level 3 at graduation) and F3, Financial Assessment (8% at ≥ Level 3 at graduation). Subtask F1, Communication Skills, was the only subtask expected by any of the participants to reach the ≥ Level 5 proficiency by any individuals at the time of Masters-Level graduation.

The lowest expected achievement levels after 5 Years of Experience based on the "≥ Level 3" was for E7, International Design and Construction Practices (48% ≥ Level 3), considerably below the next two lowest, these being F3, Financial Assessment (92% ≥ Level 3) along with F6, Bridge Design Codes (91% ≥ Level 3). Using the "≥ Level 5" measure, the lowest value with 5 Years of Experience were also subtasks E7 and F3.

5.4.3 Expected Achievement Change after 5 Years of Experience

The first five years of the young engineer's professional experience has an extremely important influence in his or her preparation for a long and productive professional career. Often this employment period is all with the first employer. The difference between the expected achievement level after 5 years and at graduation represents the portion of the young structural engineer's preparation which is not expected to be provided by the Masters-Level program. As shown in Table 5-6 and noted earlier in Sec. 5.4.2, only in a very few cases (13 out of a possible total of 1379 individual assessments) did the expected achievement level decrease from the time of graduation to after five years of practice, and in 93% of the cases, the expected achievement levels increased. In addition to the summary of Table 5-6, a complete set of histograms showing "At Graduation" and "After 5 Years of Experience" for each of the fifty subtopics questions is shown in the Appen (Figure A-5 through Figure A-54). The extent of the increase of the histogram bar heights toward the right side (higher Bloom's level) for the "After 5 Years of

Experience" data versus the "At Graduation" values on these plots and those repeated in Sec. 5.4.2 gives visual information on the change.

In Group A, Basic Mechanics and Engineering Tools areas, the lowest expected achievement level movement in the first five years in a young structural engineer's career after the Masters degree is in the Numerical Methods subtopic (A8), with the second lowest for A1, Advanced Mechanics of Materials. These two topics can be considered as basic academic tools embedded in but not explicitly further developed in typical structural design work. The highest increase is for the A3, Finite Element Analysis/Modeling, a subtask now often utilized in structural design.

In Group B, General Structural Engineering Tools, most sub-topics increased by one to two achievement levels, with the lowest increases for B3, Architectural/Aesthetics Considerations area and, B1, Behavior of Structural Systems/Load Paths, and the highest in the B2, Building Codes & General Requirements. These changes reflected the fairly high proficiency level (81% at ≥ Level 3) expected for B1 at graduation, the secondary role often assigned B3 in structural design - it being addressed primarily in the architectural design, and the constant presence and importance of building codes, industry practices, and general requirements in practice.

The Group C, Technology and Communication Tools, sub-topics with the extreme smallest and largest changes during the first five years in practice are C6, Programming Skills, at the lowest level after five years and, C1, Project Plans and Specifications, at the highest level.

The participants seems to view C6, Programming Skills, as a component of the academic preparation not usually needing significant additional development in practice, while observing that C1, Project Plans and Specifications, is much more integral to practice than to the academic studies. Other subtasks in Group C assigned a 2 or 3 level increase by a majority of the participants were C4, Structural Engineering Design Software, and C5, Building Information Management (BIM) Systems.

Group D, Structural Engineering Topics and Tools, had the most extensive list of subtopics, with the lowest change in expected achievement level during the first five years of practice being in the D10, Bridge Design-Long Span Systems area, which can be considered a specialized area of practice. The increases in achievement levels expected to be reached during the initial experience-in-practice are fairly uniform for the other topics, with increases of 2, 3, or 4 levels most often occurring for D12, Earthquake-High Risk Areas (20 times), and for D2, Structural Steel-More Advanced Topics; D6, Masonry Design; and D15, Condition of Structures/Repair, Renovation, Reuse: with each of these assigned increases of 2, 3 or 4 levels by 18 of the participants.

For the Group E, Management and Professional Tools, the subtask with the lowest modification trend is E7, International Design and Construction Practices. For all other topics in Group E, all but one or two participants assigned higher expected achievement levels after 5 Years of experience; with the highest increasing achievement level value being for the E1, Design Office Organization/Management/Office Ethics sub-topic, for which an increase of 2, 3 or 4 levels was assigned by 24 of the 31 participants. Several other subtopics showed a large increase in expectations by this “increases of 2, 3, or 4 levels” measure, including E5, Working with Architects, Contractors and Others (23 times); E3, Design/Build and Other Project Methods (21 times); E2, Business Development and Practices, and E4, Leadership Skills/Adaptation to Changes, each with 19 cases. These large increases in expectations for the Professional Practice topics reflect the expected importance of, what can be considered the intern period.

The Additional Topics (Area F) questions were specifically recommended for addition by panel participants and the individual topics can be viewed as additional topics which could be placed into one of the A through E groups. The minimum expectation level change in the first five years for this mixed group of topics is for F6, Bridge Design Codes, with the highest change being for the F4, Working as a Team sub-topic, which along with the C1, Project Plans & Specifications subtopic, are the only subtopics for which a four or more achievement level increase was assigned more than four times.

As noted before, the high correlation values (all tau-b≥0.85) in Round 2 and the extremely small change in correlation and opinion throughout the topics, allowed Round 3 to be focused on the Importance Level the questionnaire participants assigned to each of five identified primary modes for achieving the increased achievement levels discussed in this section. Results of Round 3 are presented in Section 5.4.5.

5.4.4 Expectations of Elective Offerings

The first two rounds included an additional individual evaluation item (besides the At Graduation and After 5 Years Experience achievement level), namely the achievement level possible with the use of available electives (if any) expected to be typically offered at the top fifty U.S. institutions offering graduate level structural engineering degree/emphasis.

This third evaluation condition was included both to clarify the survey participants expectations for the typical Masters-Level program graduate, given the limits on typical program credit content, should be less than would be provided by taking all available classes and to help quantify the expected potential of electives to provide specialized and additional capabilities.

The findings of this research regarding the expectations of the elective course offerings in a Masters-Level structural engineering program in the top fifty academic institutions in U.S. are summarized in Table 5-7, and in Figure 5-9 for Topic Group A, Figure 5-12 for Topic Group B, Figure 5-15 for Topic Group C, Figure 5-18 for Topic Group D, Figure 5-21 for Topic Group E, and Figure 5-24 for Topic Group F. Although a comparison of the individual subtask achievement level in each of these stacked bar charts with those of the corresponding plots for the "At Graduation" time can be used to discern the additional content and proficiency available through the electives, a useful summary of the potential expected to be offered by the electives is given by the differences (Δ) between the competency expectations with elective course offering and the general (without elective) expectations at graduation from a Masters-Level structural engineering program. These differences are shown in Table 5-7, using the same measures of percentages of assessments at the Bloom's levels at ≥ Level 3 and ≥ Level 5 contained in Table 5-5.

The differences (Δ) between the "achievable with electives" and the "expected at time of graduation may be considered more significant than are the levels of "achievable with electives" themselves as this difference, Δ, can be interpreted "these are important topics, but they cannot fit in the time/resources of the typical M.S. Degree", as they are quite specialized or maybe more often at the PhD level, as "electives should be available in these areas". A low difference (Δ) may indicate that an initial academic course is not expected in the specific subject or that all of the available courses on the subject should be included in the Masters-Level work.

Table 5-7: Change in Expected Competency with Elective Offerings

Question	At Graduation		Elective Offerings		Differences (△)	
	≥ 5 Level	≥ 3 Level	≥ 5 Level	≥ 3 Level	≥ 5 Level	≥ 3 Level
A. Basic Mechanics and Engineering Tools						
A1. Advanced Mechanics of Materials	9	75	16	84	7	9
A2. Structural Analysis – Framed Structures	28	97	45	97	17	0
A3. Finite Element Analysis/Modeling	6	75	22	88	16	13
A4. Elastic Stability	3	66	16	84	13	19
A5. Structural Dynamics	3	75	23	84	19	9
A6. Analysis of Plates and Shells	3	31	13	66	9	34
A7. Properties & Behavior of CE Materials	6	66	23	81	16	15
A8. Numerical Methods	3	44	9	66	6	22
B. General Structural Engineering Tools						
B1. Behavior of Structural Systems. Load Path.	28	81	31	97	3	16
B2. Building Codes & General Requirements	3	53	9	70	6	17
B3. Architectural/Aesthetics Considerations	0	31	3	41	3	9
B4. Conceptual & Preliminary Planning	3	41	6	47	3	6
B5. Design Loads, Including Evaluation	19	81	16	88	-3	6
B6. Foundations & Geotechnical Topics	0	63	13	75	13	13
C. Technology and Communication Tools						
C1. Project Plans & Specifications	0	28	6	41	6	13
C2. Communication Software & Tools	16	94	25	88	9	-6
C3. Computer Graphics	0	44	6	61	6	18
C4. Structural Engineering Design Software	0	56	9	72	9	16
C5. Building Information Management (BIM) Systems	0	34	0	34	0	0
C6. Programming Skills	0	34	9	56	9	22
D. Structural Engineering Topics and Tools						
D1. Structural Steel Design – Basics	25	97	38	94	13	-3
D2. Structural Steel – More Advanced Topics	0	66	9	88	9	22
D3. Reinforced Concrete Design Basics	28	97	38	91	9	-6
D4. Prestressed Concrete Design	9	75	25	78	16	3
D5. Reinforced Concrete – Advanced Topics	9	69	13	84	3	16
D6. Masonry Design	0	63	6	72	6	9
D7. Timber Design	0	63	6	69	6	6
D8. Design with Structural Aluminum	0	23	3	39	3	16
D9. Bridge Design – Short/Mid Span	3	55	10	77	6	23
D10. Bridge Design – Long Span Systems	0	26	3	52	3	26
D11. Earthquake Engineering – Basics	13	78	23	84	10	6
D12. Earthquake – High Risk Areas	3	38	9	63	6	25
D13. Design to Resist Unusual Loads/Blast	0	23	6	48	6	26
D14. Special Concerns for High Rise Systems	0	23	3	45	3	22
D15. Condition of Structures/Repair, Renovation, Reuse	0	34	3	45	3	11
D16. Special Requirements – Residential	0	28	0	33	0	6
D17. Special Requirement – Light Commercial	0	28	0	40	0	12
E. Management and Professional Tools						
E1. Design Office Organization/Management/Office Ethics	0	19	0	48	0	29
E2. Business Development and Practices	0	10	0	25	0	15
E3. Design/Build & Other Project Methods	0	13	3	23	3	9
E4. Leadership Skills/Adaptation to Changes	0	32	3	40	3	8
E5. Working with Architects, Contractors, etc.	0	27	3	33	3	7
E6. LEED, Green Buildings, Energy Use	0	23	3	40	3	17
E7. International Design and Construction Practices	0	7	3	14	3	7
F. Additional Topics						
F1. Communication Skills (Oral, Written, Graphical)	4	96	33	100	29	4
F2. Effective Speaking	0	58	20	100	20	42
F3. Financial Assessment	0	8	0	20	0	12
F4. Working as a Team	0	58	8	92	8	34
F5. Total Building Design Project	0	70	4	85	4	15
F6. Bridge Design Codes (as an addition to B2)	0	38	4	65	4	27

The overall results show that the least impact of the elective course offerings at the typical institution with a large Masters program in structural engineering are in the following areas: C2, Communication Software and Tools; C5, Building Information Management (BIM) Systems; D3, Reinforced Concrete Design Basics; D1, Structural Steel Design Basics; B5, Design Loads; E5, Working with Architects, Contractors, etc.; B1, Behavior of Structural Systems-Load Path; A2, Structural Analysis-Framed Structures; F1, Communication Skills; D16, Special Requirements-Residential; E4, Leadership Skills/Adaptation to Changes; F3, Financial Assessment; D17, Special Requirement-Light Commercial; and E3, Design/Build and Other Project Methods.

These topics include a mix of topics for which the Masters-Level graduate is typically expected to have all the program offers (such as in D1, Structural Steel Design-Basics; and D3, Reinforced Concrete Design-Basics; and A2, Structural Analysis. Framed Structures) and those not typically heavily addressed in program electives, which may include such professional practice topics as E5, Working with Architects, Contractors, and Others, and F3, Financial Assessment. The few negative difference values may reflect the survey participant's judgment that these topics are seldom addressed in the electives.

These results indicate that the potential for increased professional preparation through the use of electives is highest in the areas of A5, Structural Dynamics; F4, Working as a Team; A6, Analysis of Plates and Shells; F1, Communication Skills; F2, Effective Speaking; C6, Programming Skills; D13, Design to Resist Unusual Loads/Blast; D9, Bridge Design-Short/Mid Span; D12, Earthquake-High Risk Areas; D2, Structural Steel-More Advanced Topics; D14, Special Concerns for High Rise Systems; A8, Numerical Methods; A7, Properties and Behavior of Civil Engineering Materials, and D10, Bridge Design-Long Span Systems.

These topics of maximum potential include a mix of those which can be considered more usually taken at the PhD level (such as A6, A8, D2, and D12), those in specialty areas (such as D10 and D14), and those available, perhaps in other departments, which address personal skills (such as F1 and F4).

5.4.5 Round 3 Results

As introduced earlier in Table 5-2 of Section 5.1, Round 3 used Key Set #2 to define the importance level of several sources of additional information and abilities for the Masters-Level graduate using a 1 = not important to 4 = extremely important scale. The five primary modes included in Round 3 for additional preparation for the profession are listed in Section 5.2. These assessments are rather general in that no attempt was made to identify these five modes in any detail. For example, rather than attempting to describe in detail for the survey participants what is currently or might in the future be available via short courses, or by in-house training, the survey participants were expected to use their general knowledge, expectations, and experiences with these modes.

The summary of the importance levels shown in detail in Table 5-8, for each main source area grouped by the topic areas is presented in Table 5-9, and is visually summarized in Figure 5-34. The graphic in Figure 5-34 also illustrates the high level of importance given to the experience-in-practice source for the increased achievement levels expected during the first five years of practice.

Table 5-8: Source Importance in Achieving Expected Change

Question	Expected Change	Added Courses	Short Courses	In-House Training	Exper. in Practice	Self Learning
A. Basic Mechanics and Engineering Tools						
A1. Advanced Mechanics of Materials	0.938	2.200	2.000	1.680	2.600	3.042
A2. Structural Analysis – Framed Structures	1.438	1.960	1.880	2.360	3.560	3.292
A3. Finite Element Analysis/Modeling	1.531	2.200	2.200	2.360	2.960	3.042
A4. Elastic Stability	1.344	1.880	2.080	2.080	2.960	2.917
A5. Structural Dynamics	1.344	2.440	2.160	2.160	2.920	2.833
A6. Analysis of Plates and Shells	1.219	2.200	2.040	1.880	2.680	2.875
A7. Properties & Behavior of CE Materials	1.375	1.960	2.200	2.160	3.080	3.000
A8. Numerical Methods	0.500	2.120	1.840	1.720	2.320	2.583
B. General Structural Engineering Tools						
B1. Behavior of Structural Systems. Load-Path.	1.531	1.800	1.880	2.640	3.840	3.087
B2. Building Codes & General Requirements	2.469	1.680	2.480	3.000	3.880	3.217
B3. Architectural/Aesthetics Considerations	1.531	1.440	1.640	2.360	3.560	2.609
B4. Conceptual & Preliminary Planning	1.875	1.480	1.720	2.840	3.720	2.565
B5. Design Loads, Including Evaluation	1.813	1.920	2.360	2.880	3.680	3.130
B6. Foundations & Geotechnical Topics	1.563	2.200	2.480	2.720	3.320	3.000
C. Technology and Communication Tools						
C1. Project Plans & Specifications	2.938	1.240	1.720	2.920	3.800	2.750
C2. Communication Software & Tools	1.188	1.292	1.792	2.400	3.320	3.500
C3. Computer Graphics	1.337	1.667	2.083	2.520	3.200	3.333
C4. Structural Engineering Design Software	2.344	1.400	2.360	3.200	3.640	3.167
C5. Building Information Management (BIM) Systems	1.844	1.760	2.760	2.960	3.160	2.833
C6. Programming Skills	0.719	1.880	1.680	1.520	2.320	2.833
D. Structural Engineering Topics and Tools						
D1. Structural Steel Design – Basics	1.469	1.760	1.640	1.960	3.320	3.083
D2. Structural Steel – More Advanced Topics	1.688	2.400	2.400	2.320	3.400	2.958
D3. Reinforced Concrete Design Basics	1.469	1.720	1.680	1.880	3.360	3.167
D4. Prestressed Concrete Design	1.281	2.280	2.360	2.440	3.400	3.125
D5. Reinforced Concrete – Advanced Topics	1.563	2.320	2.320	2.320	3.520	3.042
D6. Masonry Design	1.719	2.400	2.640	2.360	3.280	3.208
D7. Timber Design	1.563	2.280	2.640	2.360	3.400	3.208
D8. Design with Structural Aluminum	1.290	1.920	2.440	2.120	2.760	2.958
D9. Bridge Design – Short/Mid Span	1.548	2.040	2.440	2.400	3.520	3.042
D10. Bridge Design – Long Span Systems	1.000	2.160	2.400	2.600	3.440	2.583
D11. Earthquake Engineering – Basics	1.375	2.320	2.560	2.440	3.440	3.125
D12. Earthquake – High Risk Areas	1.594	2.160	2.800	2.640	3.440	3.000
D13. Design to Resist Unusual Loads/Blast	1.129	1.920	2.800	2.280	3.240	2.917
D14. Special Concerns for High Rise Systems	1.165	1.840	2.560	2.560	3.520	2.792
D15. Condition of Structures/Repair, Renovation, Reuse	1.615	1.720	2.640	2.600	3.360	2.875
D16. Special Requirements – Residential	1.581	1.400	2.160	2.400	3.280	2.917
D17. Special Requirement – Light Commercial	1.710	1.400	2.000	2.280	3.280	2.958
E. Management and Professional Tools						
E1. Design Office Organization/Management/ Ethics	2.281	1.320	1.680	3.160	3.640	2.458
E2. Business Development and Practices	1.935	1.560	2.040	3.120	3.640	2.583
E3. Design/Build & Other Project Methods	2.012	1.400	2.040	2.720	3.560	2.458
E4. Leadership Skills/Adaptation to Changes	1.716	1.560	1.960	2.840	3.600	2.958
E5. Working with Architects, Contractors, etc.	2.190	1.240	1.520	2.600	3.760	2.708
E6. LEED, Green Buildings, Energy Use	1.649	1.760	2.840	2.600	3.120	3.208
E7. International Design and Construction Practices	1.149	1.440	1.880	2.360	3.280	2.875
F. Additional Topics						
F1. Communication Skills (Oral, Written, Graphical)	1.885	1.957	2.043	2.739	3.696	3.273
F2. Effective Speaking	2.192	1.870	2.087	2.435	3.652	2.864
F3. Financial Assessment	1.731	1.870	2.261	2.870	3.261	2.955
F4. Working as a Team	3.077	1.391	1.478	2.696	3.870	2.364
F5. Total Building Design Project	2.296	1.609	1.783	2.783	3.609	2.545
F6. Bridge Design Codes (as an addition to B2)	1.573	1.957	2.565	2.783	3.478	2.955

Table 5-9: Mean Importance Levels

Topic Group Mean	Added Courses	Short Courses	In-House Training	Experience in Practice	Self Learning
A	2.120	2.050	2.050	2.885	2.948
B	1.735	2.093	2.740	3.667	2.935
C	1.540	2.066	2.587	3.240	3.069
D	2.002	2.381	2.351	3.351	2.998
E	1.469	1.994	2.771	3.514	2.750
F	1.776	2.036	2.718	3.594	2.826
Overall	1.777	2.103	2.536	3.375	2.921

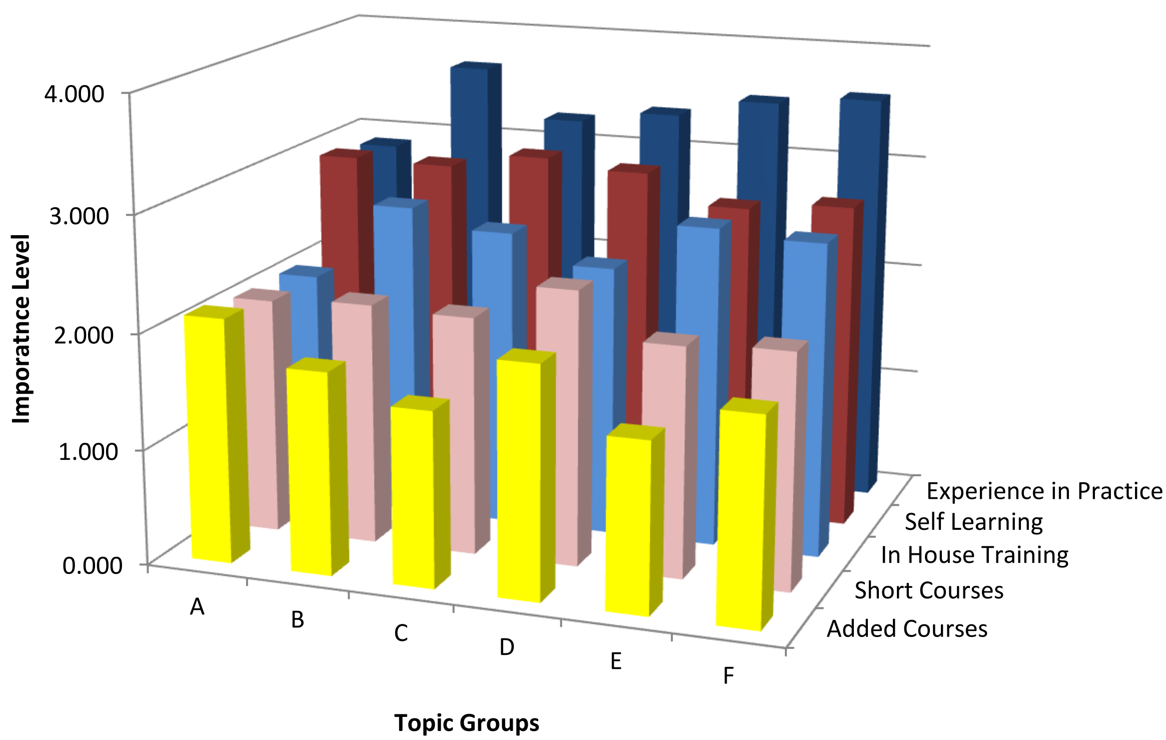


Figure 5-34: Mean Importance Levels by Topic Group and Source

Presented in this section are the results for each of the five primary modes for additional preparation. The mean importance values assigned to each of the five modes for each of the 50 subtasks are presented in Table 5-8. Also included in this table as the first data column is the expected change in achievement level between graduation from Masters-Level program and the completion of the initial five years of professional practice using the approximation of averaging the changes in expectation levels presented earlier in Table 5-8. This column is repeated here as the overall importance, or, alternately stated, the potential, for each mode for the individual topic is a combination of the "expected change", i.e. the overall potential for expected increased achievement level, and the relative importance of the mode. For example, the use of "In-House Training" (relative importance = 1.720) on the subtopic of A8, Numerical Methods (change is 0.500) has little overall importance, while for B2, Building Codes and General Requirements (change =2.469), In-House Training (relative importance= 3.000) has a large potential for better preparing the young professional in structural engineering. The data of Table 5-8 are shown for the individual subtasks for each of the five delivering sources in the five bar charts presented in Figure 5-35 through Figure 5-39.

Added Courses were considered to have the lowest importance of the five sources to bridge the gap between achievement levels at graduation and after five years of experience. This is also true for five of the six topic groups, the exception being Group A. Using assessments for all five modes, the average importance for Added Courses was 1.777 (given in Table 5-9), with the highest average values for Group A (2.120), just above the 2.050 value for both "Short Courses" and "In-House Training", with the lowest for Group E (1.469). The importance of the "Added Courses" for each of the 50 subtasks is shown in Figure 5-35. The highest importance (2.440, between somewhat important and important) was additional coursework in Structural Dynamics

(A5 on Figure 5-35), with D2, Structural Steel –More Advanced Topics (2.400), and D6, Masonry Design (2.400), also among the higher ranked topics. Additional coursework was assigned the least expected importance for C1, Project Plans and Specifications, and E5, Working with Architects, Contractors and Others, both of these topics having an importance value of 1.240.

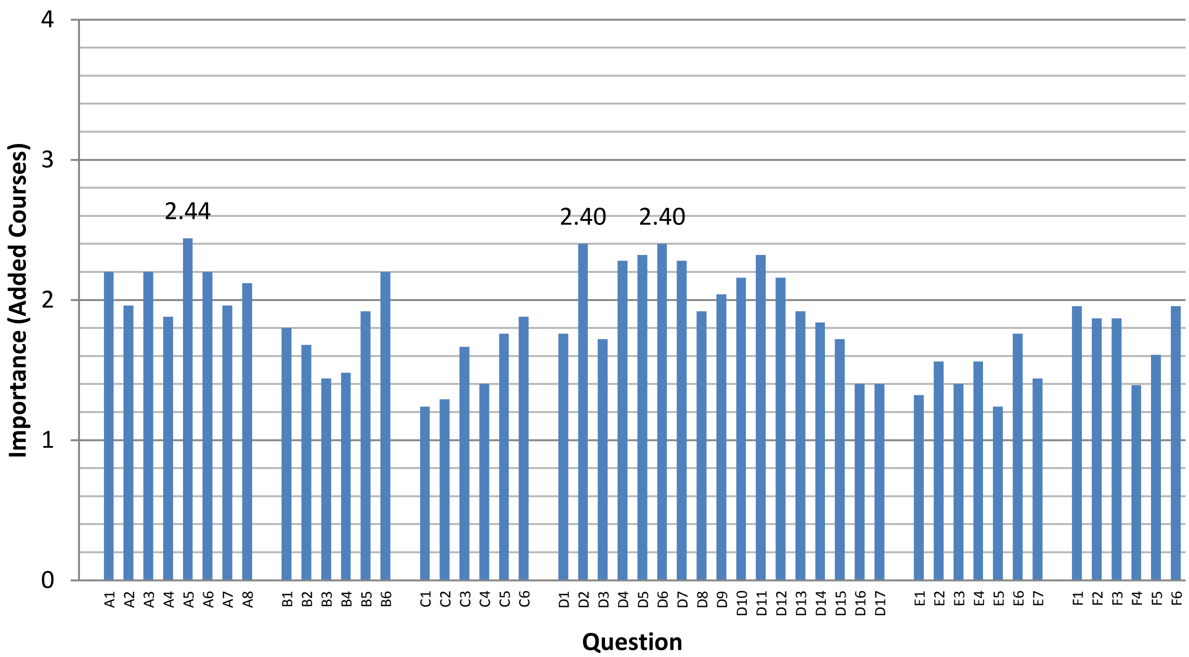


Figure 5-35: Mean Importance Level for the Additional Courses Source

The use of "Short Course" as a source to reach the experience achievement level expected with five years of experience was assigned slightly higher importance than was the use of added courses by the expert panel participants, with a mean of importance values of 2.103 compared to the 1.777 value for added coursework.

The specific topic area expected to most benefit from the "Short Course" source for achievement level improvement was E6, LEED, Green Buildings, Energy Use (Topic E6 on Figure 5-36), with the next three high values given to Topics D12, Earthquake-High Risk Areas

(2.800); D13, Design to Resist Unusual Loads/Blast (2.800), and C5, Building Information Management (BIM) Systems (2.760). The "Short Course" source was given its lowest values for two subtopics dealing with interpersonal skills, those being E5, Working with Architects, Contractors and Others (1.520), and F4, Working as a Team (1.478).

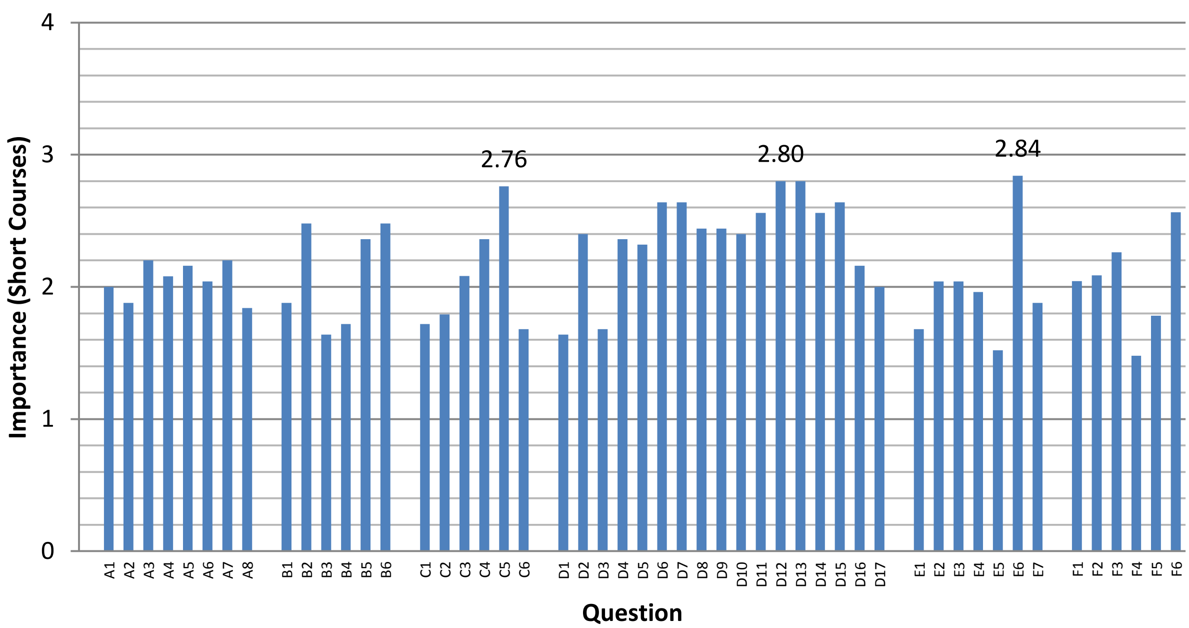


Figure 5-36: Mean Importance Level for the Short Courses Source

The maximum importance assigned to a single topic for the "In-House Training" source of achievement level improvement was C4, Structural Engineering Design Software, with an importance level of 3.200 (See Figure 5-37). Also having a relatively high mean importance level of 2.960 is C5, Building Information Management (BIM) Systems. The high importance assigned these closely-related subtopics is in line with the qualitative comments of the expert participants regarding design software, namely that every company should train their engineers internally on the specific structural design software used by the firm.

Other individual topics for which "In-House Training" was considered among the most important are B2, Building Codes and General Requirements (3.000); E1, Design Office

Organization/Management/Office Ethics (3.160); and E2, Business Development and Practices (3.120).

The In-House Training mode was assigned the lowest expected importance for A1, Advanced Mechanics of Materials (1.520), and subtopic C6, Programming Skills was the subtask with the second lowest expected change in achievement level during the initial five years of experience (1.680).

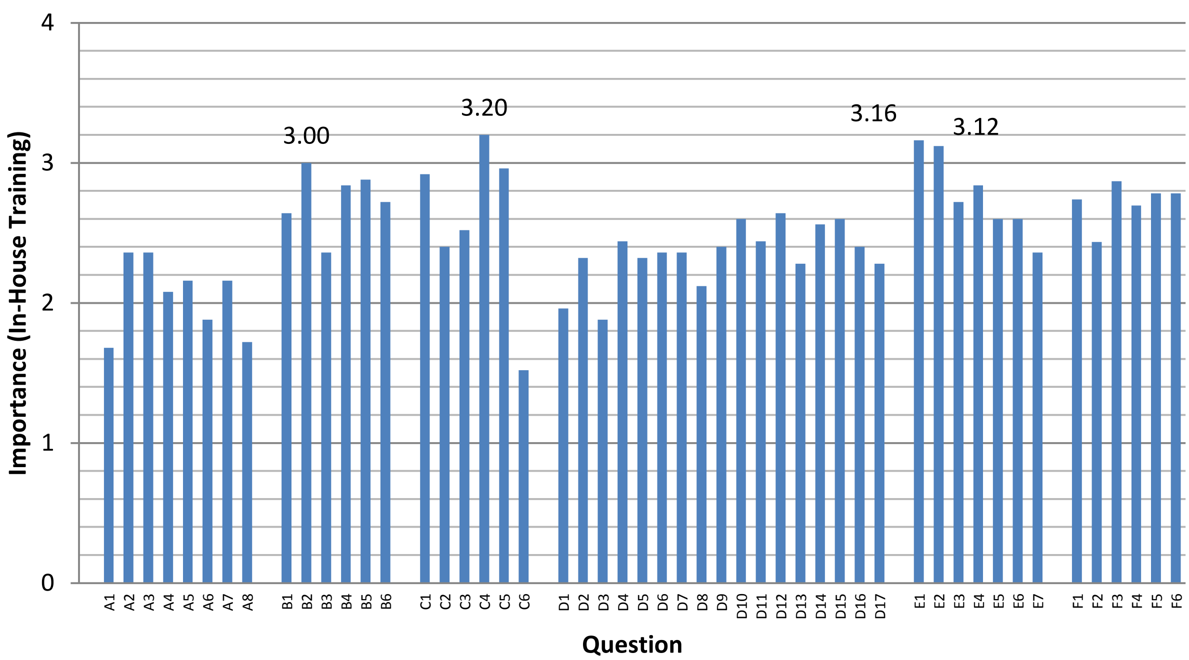


Figure 5-37: Mean Importance Level for the In-House Training Source

As might be predicted, "Experience-in-Practice" mode was found to be the mostly preferred source for achievement level growth during the first five years of experience of a young structural engineer following completion of a Masters degree, with this mode assigned a mean importance of 3.375 (Table 5-9), nearly a half level above the next highest, "Self Learning" with a mean value of 2.921. This trend was not unexpected as learning-by-experience is constantly provided over the entire initial employment period by the work environment of the young structural engineer, is inherently oriented to the professional needs of the young engineer, is sometimes intense and very challenging, and is not an optional activity as can be additional coursework, short courses, and, in some cases, the in-house-training modes. The attention given to this “apprenticeship” phase by both the young engineer and the employer and its effectiveness can certainly vary widely. Often, the experience-in-practice mode, along with Self Learning, is the basic system used to reach the increased achievement levels expected after five years of experience (the time of which the usual experience requirement for licensure has been met), and other modes are used primarily to supplement the experience and self study modes, especially in areas of new developments, new requirements, and new knowledge.

The mean importance value of 3.375 for the “Experience-in-Practice” mode is between important =3 and extremely important =4. All but two topics (C6, Programming Skills (2.320), and D8, Design with Structural Aluminum (2.760) in Categories B through F were assigned a mean value above 3.000 (See Figure 5-38). The topic with the highest value of importance for the Experience in Practice source category was B2, Building Codes and General Requirements, with a mean value of 3.880, the highest importance assigned to any combination of additional learning mode and subtask. The importance of “Experience in Practice” was generally about one-half level lower for the Topic Group A, Basic Mechanics and Engineering Tools, than the average for subtopics B through F, an exception to this trend for the basic academic areas being the high importance of 3.560 assigned to A2, Structural Analysis-Framed Structures. This higher importance assigned to subtopic A2 is consistent with the intense and pervasive use of frame analyses in most structural engineering projects.

A comparison of the trends of Figure 5-38 with the trends shown by Figure 5-35 through Figure 5-37 for added courses, short courses, and in-house training, shows that the average importance level for experience-in-practice is approximately one full level number higher than for the first three sources on the scale of 4. A8, Numerical Methods, and C6, Programming Skills (Figure 5-38) are the subtopics for which experience has the lowest importance in improving the achievement level during the first five years of experience of a young structural engineer by experience in practice (2.320).

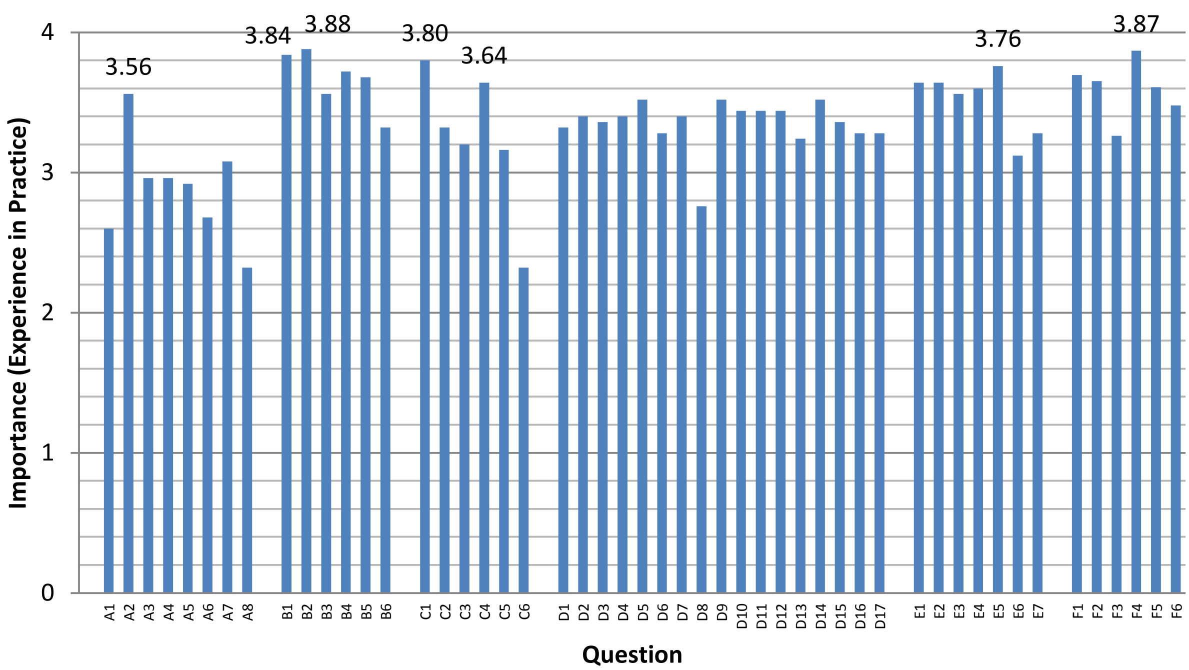


Figure 5-38: Mean Importance Level for the Experience in Practice Source

The “Self Learning” mode was assigned an overall mean importance value of 2.921 for the 50 topics included individually in Figure 5-39, and thus is expected by the study participants to be a more important source for achievement level improvement than added courses, short courses, and “In-House Training”, but less in overall importance than “Experience in Practice”. The importance level assigned to “Self Learning” was highest for C2, Communication Software and Tools topic area, with this area receiving an importance level of 3.500. Subtopic F4, Working as a Team, is not a subject very practical for someone to learn only by self-study, which can explain the lowest importance value of 2.364 (area F4) assigned for this area.

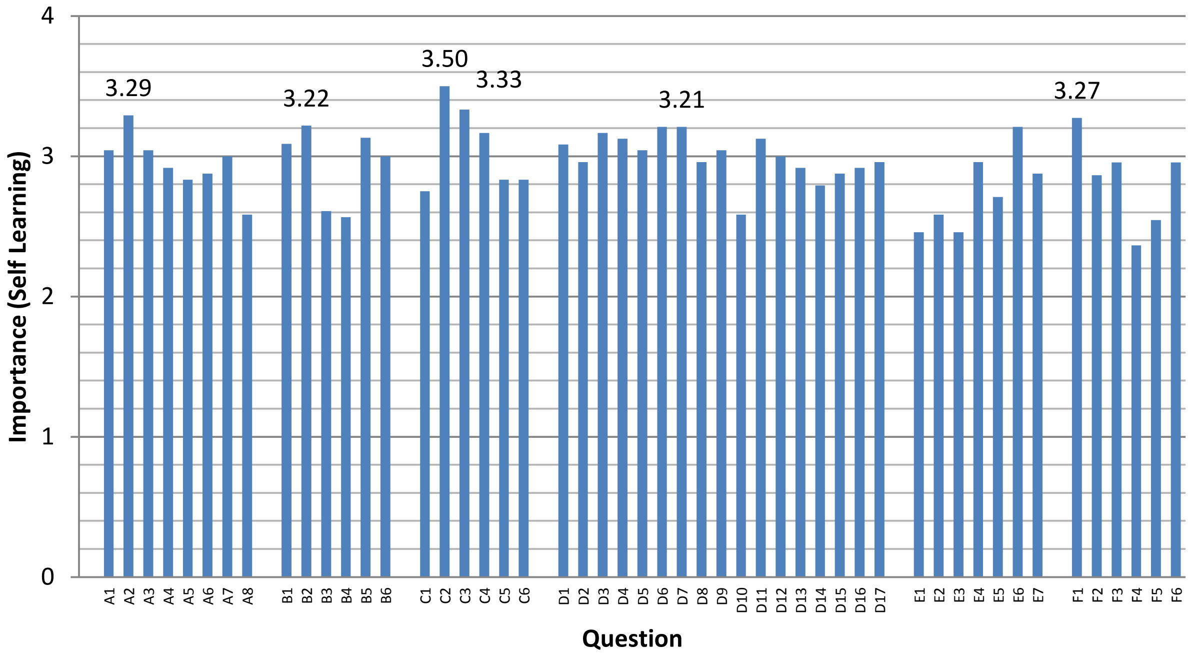


Figure 5-39: Mean Importance Level for the Self Learning Source

5.4.6 Comparison of Results by Affiliation

A question relevant to many practical aspects of facilitating a Masters-Level program best meeting the needs of the structural engineering profession is how similar or differently do those in practice and those in academia rate the achievement levels needed for the various topics. The Expert Panel membership, as presented in Figure 4-3, included individuals from two types of background; participants affiliated with structural engineering firms, and participants from academic institutions and professional societies. For this comparison, individuals with significant involvement in two or three of these affiliations were placed in what was determined from available information to be their primary affiliation.

A comparison of desired achievement level by the two affiliation groups, firms and academic/professional societies (considering academic members and professional society representatives in the same sub-group), is presented on Table 5-10 for every subtopic area at the time of graduation. Table 5-11 and Table 5-12 give the same information for these two groups of participant inputs at the after 5 year of experience time frame and available with elective offerings, respectively.

Some significant differences can be noted among the individual subtasks. Among the largest differences are the following: Conceptual Preliminary Planning (B4) has the maximum difference between the expectations of the two groups for the time at graduation, with most of the academic/professional group having Level 3 expectations, while those in the firms expected Level 2 (See Table 5-10). For the young engineer with 5 years of experience, those in firms had considerably higher expectations for A1, Advanced Mechanics of Materials, with a 33% of their expectations at Level 6 (See Table 5-11). The academic/professional group had significantly higher expectations, with 64% at Level 5 or 6, for the level of achievement possible with electives than did those in practice for A2, Structural Analysis-Framed Structures, with 35% at Level 5 or 6.

Table 5-10: Responses by Affiliation at Graduation

Question	1-Knowledge		2-Comprehension		3-Application		4-Analysis		5-Synthesis		6-Evaluation	
	F %	AP %	F %	AP %	F %	AP %	F %	AP %	F %	AP %	F %	AP %
A1	5	0	19	27	38	45	29	18	5	9	5	0
A2	0	0	5	0	33	18	43	36	14	45	5	0
A3	5	9	19	18	48	36	24	27	0	9	5	0
A4	5	0	24	45	43	18	24	36	0	0	5	0
A5	0	0	24	27	57	55	14	18	0	0	5	0
A6	29	36	43	27	19	27	5	9	0	0	5	0
A7	5	0	38	18	29	36	19	45	5	0	5	0
A8	38	18	19	36	24	27	14	18	0	0	5	0
B1	0	0	19	18	19	18	33	36	19	18	10	9
B2	10	9	48	18	33	64	10	0	0	9	0	0
B3	38	27	43	18	14	55	5	0	0	0	0	0
B4	29	9	52	9	14	73	5	0	0	9	0	0
B5	0	0	24	9	48	27	14	45	10	18	5	0
B6	0	0	43	27	38	36	19	36	0	0	0	0
C1	43	18	38	36	14	36	5	9	0	0	0	0
C2	0	0	10	0	48	36	33	36	5	18	5	9
C3	19	0	52	27	19	55	10	18	0	0	0	0
C4	10	18	43	9	24	45	24	27	0	0	0	0
C5	33	27	38	27	24	36	5	9	0	0	0	0
C6	43	36	29	18	19	45	10	0	0	0	0	0
D1	0	0	0	9	38	27	33	45	24	9	5	9
D2	0	0	33	36	43	27	24	36	0	0	0	0
D3	0	0	0	9	38	27	33	36	24	18	5	9
D4	5	0	19	27	43	55	24	9	5	9	5	0
D5	0	0	29	36	38	36	24	18	5	9	5	0
D6	19	9	24	18	33	45	24	27	0	0	0	0
D7	19	0	29	18	29	55	24	27	0	0	0	0
D8	45	45	35	27	10	27	10	0	0	0	0	0
D9	5	9	50	18	25	64	15	9	5	0	0	0
D10	30	27	50	36	10	36	10	0	0	0	0	0
D11	0	0	19	27	52	36	19	18	5	18	5	0
D12	14	18	48	45	19	18	14	18	5	0	0	0
D13	35	45	40	36	15	18	10	0	0	0	0	0
D14	42	36	32	45	16	18	11	0	0	0	0	0
D15	32	40	37	20	16	40	16	0	0	0	0	0
D16	47	30	26	40	11	20	16	10	0	0	0	0
D17	47	30	26	40	11	20	16	10	0	0	0	0
E1	30	36	50	45	15	9	5	9	0	0	0	0
E2	50	55	44	27	6	18	0	0	0	0	0	0
E3	58	45	26	45	16	0	0	9	0	0	0	0
E4	25	27	50	27	20	45	5	0	0	0	0	0
E5	26	36	47	36	26	27	0	0	0	0	0	0
E6	37	36	42	36	21	27	0	0	0	0	0	0
E7	74	64	21	27	5	9	0	0	0	0	0	0
F1	0	0	11	0	68	89	21	0	0	11	0	0
F2	0	0	47	33	53	56	0	11	0	0	0	0
F3	65	44	29	44	6	11	0	0	0	0	0	0
F4	6	0	41	33	47	56	6	11	0	0	0	0
F5	0	0	28	33	33	22	39	44	0	0	0	0
F6	23	11	31	56	46	33	0	0	0	0	0	0

Note: F% Structural Engineering Firm Representatives answer in %, AP% Academia and Professional Society Representatives answer in %

Table 5-11: Responses by Affiliation after 5 Years of Experience

Question	1-Knowledge		2-Comprehension		3-Application		4-Analysis		5-Synthesis		6-Evaluation	
	F %	AP %	F %	AP %	F %	AP %	F %	AP %	F %	AP %	F %	AP %
A1	0	0	0	9	29	45	29	36	10	9	33	0
A2	0	0	0	0	5	0	10	18	29	18	57	64
A3	0	0	0	0	5	9	48	36	29	36	19	18
A4	0	0	0	0	14	36	43	36	14	27	29	0
A5	0	0	0	9	14	18	48	27	19	36	19	9
A6	14	0	5	27	38	18	24	45	10	9	10	0
A7	0	0	5	0	19	9	29	45	29	27	19	18
A8	29	0	19	36	14	36	29	9	5	18	5	0
B1	0	0	0	0	0	9	10	18	38	18	52	55
B2	0	0	0	0	10	9	19	9	38	36	33	45
B3	5	0	5	27	48	27	24	27	5	18	14	0
B4	0	0	5	9	24	18	43	18	19	36	10	18
B5	0	0	0	0	24	27	0	0	19	36	57	36
B6	0	0	0	0	14	9	33	64	33	27	19	0
C1	0	0	0	0	5	18	19	9	48	45	29	27
C2	0	0	0	0	19	9	10	18	38	55	33	18
C3	5	0	10	0	30	36	30	36	20	18	5	9
C4	0	0	0	0	0	9	24	36	29	36	48	18
C5	0	9	5	9	19	27	52	27	10	18	14	9
C6	24	18	19	36	24	27	24	18	0	0	10	0
D1	0	0	0	0	0	9	5	27	38	9	57	55
D2	0	0	0	0	5	18	33	36	38	45	24	0
D3	0	0	0	0	0	9	5	18	38	18	57	55
D4	0	0	5	9	19	9	24	45	24	27	29	9
D5	0	0	0	9	0	9	33	36	43	36	24	9
D6	5	0	5	0	14	9	24	45	33	18	19	27
D7	10	0	5	9	10	9	24	27	33	36	19	18
D8	15	0	25	18	35	27	10	45	5	9	10	0
D9	5	0	5	9	20	0	20	64	30	18	20	9
D10	10	9	15	18	45	36	25	36	0	0	5	0
D11	0	0	0	9	5	9	48	18	29	36	19	27
D12	5	9	0	9	19	0	48	55	14	18	14	9
D13	15	9	10	18	35	45	35	27	0	0	5	0
D14	10	9	30	9	25	45	25	27	5	9	5	0
D15	5	9	14	0	24	27	29	45	14	18	14	0
D16	5	9	15	9	35	9	30	45	0	27	15	0
D17	5	9	15	0	25	9	40	55	0	27	15	0
E1	0	0	5	9	24	9	33	55	19	27	19	0
E2	0	0	19	18	48	27	14	27	14	27	5	0
E3	0	0	10	18	40	27	35	18	10	36	5	0
E4	5	0	5	9	24	36	48	18	10	36	10	0
E5	0	0	0	0	33	36	33	27	10	36	24	0
E6	0	0	20	9	45	36	20	27	10	18	5	9
E7	25	0	30	45	30	45	10	9	0	0	5	0
F1	0	0	0	0	11	22	0	0	67	56	22	22
F2	0	0	0	0	18	0	0	33	76	56	6	11
F3	0	0	6	11	65	44	24	44	6	0	0	0
F4	0	0	0	0	6	0	6	56	0	0	88	44
F5	0	0	0	0	17	11	0	0	22	44	61	44
F6	15	0	0	0	54	0	0	67	23	33	8	0

Note: F% Structural Engineering Firm Representatives answer in %, AP% Academia and Professional Society Representatives answer in %

Table 5-12: Responses by Affiliation with Elective Offerings

Question	1-Knowledge		2-Comprehension		3-Application		4-Analysis		5-Synthesis		6-Evaluation	
	F %	AP %	F %	AP %	F %	AP %		F %	AP %	F %	AP %	F %
A1	5	0	15	9	25	45	40	27	10	18	5	0
A2	0	0	5	0	35	18	25	18	20	64	15	0
A3	5	0	10	9	33	36	33	27	10	27	10	0
A4	0	0	19	9	33	55	33	18	10	18	5	0
A5	0	0	15	18	30	18	35	36	10	27	10	0
A6	10	0	29	27	29	45	19	18	10	9	5	0
A7	5	0	20	9	20	27	40	27	10	36	5	0
A8	19	0	19	27	29	55	29	0	0	18	5	0
B1	0	0	5	0	38	18	29	45	14	36	14	0
B2	0	9	38	9	33	36	29	27	0	18	0	0
B3	24	18	52	9	19	55	5	9	0	9	0	0
B4	19	9	52	9	10	36	19	27	0	18	0	0
B5	0	0	23	0	41	18	27	55	5	27	5	0
B6	0	0	33	9	29	36	33	27	5	27	0	0
C1	19	9	52	27	19	36	10	9	0	18	0	0
C2	0	0	14	9	38	36	29	18	14	27	5	9
C3	20	0	30	18	20	27	30	36	0	18	0	0
C4	0	9	38	0	29	36	29	36	5	18	0	0
C5	19	9	33	27	33	45	14	0	0	18	0	0
C6	14	18	29	27	33	27	19	9	5	18	0	0
D1	0	0	5	9	33	9	29	36	24	45	10	0
D2	0	0	14	9	29	45	48	36	5	9	5	0
D3	0	0	10	9	29	9	29	36	24	45	10	0
D4	0	0	29	9	29	36	19	27	14	27	10	0
D5	0	0	14	18	29	18	43	55	5	9	10	0
D6	14	9	19	9	33	18	29	55	5	9	0	0
D7	19	0	24	9	24	18	29	64	5	9	0	0
D8	35	9	30	45	25	18	10	18	0	9	0	0
D9	5	0	25	9	25	45	35	36	5	9	5	0
D10	25	9	30	27	30	36	10	27	5	0	0	0
D11	0	0	15	18	45	18	20	36	10	27	10	0
D12	10	9	29	27	24	18	29	36	5	9	5	0
D13	20	18	40	18	20	36	15	18	5	9	0	0
D14	25	18	35	27	20	27	20	18	0	9	0	0
D15	20	18	45	18	15	45	20	9	0	9	0	0
D16	37	18	37	36	5	27	21	18	0	0	0	0
D17	37	18	37	18	5	45	21	18	0	0	0	0
E1	20	27	35	18	40	27	5	27	0	0	0	0
E2	41	27	41	36	18	18	0	18	0	0	0	0
E3	45	27	40	36	15	18	0	9	0	9	0	0
E4	21	18	53	18	21	45	5	9	0	9	0	0
E5	32	27	42	27	26	18	0	18	0	9	0	0
E6	26	18	47	18	26	45	0	9	0	9	0	0
E7	50	36	44	36	6	9	0	9	0	9	0	0
F1	0	0	0	0	61	78	33	11	6	11	0	0
F2	0	0	38	22	38	67	25	0	0	11	0	0
F3	50	33	31	44	13	11	6	11	0	0	0	0
F4	0	0	6	11	63	78	25	0	6	11	0	0
F5	0	0	11	22	22	22	61	56	6	0	0	0
F6	14	11	29	11	50	67	0	11	7	0	0	0

Note: F% Structural Engineering Firm Representatives answer in %, AP% Academia and Professional Society Representatives answer in %

The average expected achievement levels based on participant affiliation (structural engineering firm v. academic/organization) are summarized in Table 5-13. These values have been computed by subtracting the average percentage assigned to each subtask within a Topic Group (A through F) for each achievement level by the participants from structural engineering firms from those for the academic/professional survey participants. For example, the mean percentage of the six subtasks in Group B assigned Level 3 was 45.5% for the academic/professional members and 27.7% for those in the firms (Table 5-10), a decrease of 17.8%, which, when rounded to nearest percentage, gives the -18 value shown in Table 5-13. The negative value indicates that the academic/professional society representatives expect a higher achievement level than do those from the structural engineering firms.

For the time at graduation, the dominance of positive values in Table 5-13 for Levels 1 and 2 and the negative values for Levels 3, 4, and 5 show that the expectations of the academic/professional group was significantly higher than for the those in the structural engineering firms, especially for the Task Groups B and C. Notable for the expectations for the time after five years of experience is the significantly higher number of the top Level 6 values expected by those in the firms. Table 5-11 shows ten subtasks for which at least 12% of the responses of those in the firms is at Level 6, while the academic/professional response for these ten subtasks is zero percent. The dominance of negative numbers to the right side in Table 5-13 for the elective offerings shows that those in the academic/professional community judge that the academic electives offer more opportunity to the young graduate in the early professional years than do those in the structural engineering firms. Because of the relative small number of study participants from the academic/organizational groups and the high level of familiarity or involvement of many of this group with the ASCE “Raise the Bar” effort, the evaluations from this group may be somewhat different from those that a random sample of structural engineering faculty would give, and thus the observations given above should be considered somewhat tentative. Although not explored in this study, some differences in evaluations certainly should be expected depending on whether the participant in the questionnaire project works primarily with bridges or with building or is employed in a government agency, such a state transportation department, or in private practice.

Table 5-13: Differences in Average Expectation Levels, Firms versus Academic/Society, %

At Times	Topic Group	1-Knowledge	2-Comprehension	3-Application	4-Analysis	5-Synthesis	6-Evaluation
At Graduation	A	3	-1	3	-5	-5	5
	B	5	21	-18	-5	-4	1
	C	8	15	-18	-2	-2	-1
	D	3	0	-7	3	0	0
	E	0	5	-4	-1	0	0
	F	6	-2	-2	0	-2	0
After 5 Year Experience	A	5	-7	-4	0	-5	10
	B	1	-4	3	-1	-3	5
	C	0	-2	-5	2	-5	9
	D	1	1	2	-12	-1	8
	E	4	-3	4	2	-16	9
	F	3	-1	15	-28	1	10
Elective Offerings	A	5	3	-8	10	-17	7
	B	1	28	-5	-8	-19	3
	C	4	15	-6	3	-16	-1
	D	7	7	-3	-7	-7	4
	E	8	16	-4	-13	-6	0
	F	3	1	-13	10	-1	0

6 CONCLUSIONS AND RECOMMENDATIONS

6.1 The Thrust of the Questionnaire and Study Content

The major steps in the formulation and implementation of a Body of Knowledge for a profession, such as the ASCE Body of Knowledge described in 2.3.2 and shown in Table 2-3 (American Society of Civil Engineers (ASCE) Body of Knowledge Committee of the CAP3, 2008), are well summarized in the paper entitled "Sociology of Professions: Application to the Civil Engineering "Raise the Bar" Initiative" (Ressler, 2011). Because the current study addresses elements of the ASCE Body of Knowledge (BOK) as it could apply to structural engineering, it is relevant to examine the steps involved in defining and implementing this BOK and how the current study fits within these steps. The paper by Ressler is a basic reference paper describing requirements for professions in general and the adaptation of these requirements to the profession of civil engineering. He describes the progression of defining and delivering the knowledge and skill sets needed by the young professional civil engineer as having the steps listed below:

1. The profession establishes and states a "Body of Knowledge" (BOK). Ideally, this defines the nature of the expert knowledge which is the domain of the profession. The BOK should be based on abstract concepts or theories, not dependent upon details, adaptable to change, and the application of the BOK must entail the exercise of discretionary judgment. ASCE has chosen to state the BOK for Civil Engineering in terms of outcomes and minimum levels of achievement.
2. Allocation of the preparation period and associated resources among the relevant topics needing to be explored. Perhaps this process can be described as the "Topic Specific Framework of Knowledge" or "The specialty-specific BOK".

3. Design a specific curriculum and overall educational program to deliver the "Topic Specific Framework of Knowledge" consistent with the overall "Body of Knowledge". Within the Masters-Level academic program, this would entail the definition of required and elective courses. This process is very much influenced by the resources, philosophy, expertise, and judgment of the educational institution and academic unit.
4. Implementation – design of the individual classes, delivery, assessment, evaluation, and possible modification to the individual classes.

The ASCE BOK certainly applies to the civil engineering specialty area of structural engineering as well as to the overall civil engineering area, even though the 2008 ASCE BOK report emphasizes the undergraduate program. The current study addresses this hierarchy of steps in preparing the young engineer for practice in the structural engineering profession at the second level. This level represents a vital step in which the expectations and needs of the profession are defined in more specific terms than they are in the overall BOK, but the study does not seek to address the myriad of details and varying conditions and resources that the providers of these knowledge sets have to work with. It is a step directed towards assisting the structural engineering profession and the associated educational communities in their planning of the programs needed to deliver the overall BOK within one of the many practice areas of the civil engineer. Like the ASCE BOK report, this study has given considerable attention to the importance of the early period in the profession, a time which has many attributes of an apprenticeship, in the preparation of the young professional, as the overall preparation structural engineer is very much a collaborative effort of the educational programs, the structural engineering design and construction community, and the overall structural engineering profession.

It is proposed that a similar set of studies addressing the topic areas and appropriate level of achievement in each could and should be carried out in the other practice areas (geotechnical, transportation, environmental, etc.) within civil engineering.

6.2 General Observations, Conclusions, and Recommendations

The output of this Delphi study analysis, the literature, and other input from professionals lead to the major findings, conclusions and recommendations of the study. These results are the main elements supporting a proposed framework to be prepared regarding the Masters-Level structural engineering preparedness for the changing structural engineering professional field.

1. The knowledge level expectations identified by this research would allow for the development of a recommended curriculum for Masters-Level structural engineering education, similar to the ASCE BOK2 but more specifically addressing the civil engineering specialization of structural engineering.
2. Reviews of current practices and the survey's findings in the project, as well as the review of literature, suggest that structural engineering education should include additional information than it does in present, including more basic coverage of the professional, technical tools, and management topics which are very dependent on the early professional experience of the young engineer in order to be further developed to the level needed for effective independent professional practice. Some of these topics not traditionally emphasized in the academic classes may need to be infused into existing courses and student activities, some classes may need to emphasize breadth rather than depth in a traditional academic subject, and additional ways for engineers-in-design and faculty members to work effectively together are all needed. This study does not have a goal of defining an extremely prescribed curriculum, as a single model curriculum would be overly restrictive, especially at the graduate level.

Individual program characteristics, program size, resource limitation, department and university goals, local and regional environments, population of the university setting (urban or small city, which can greatly affect the proximity of engineers-in- practice), and other factors must be considerations in formulating the individual graduate programs.

3. Elements of research have to be part of a graduate study in structural engineering within the U.S. environment even if the student chooses to pursue the M.S. degree without the Thesis option. How the research element, which can be a major source of developing self-study, information gathering, problem solving and organizational skills, can best serve the student planning to enter structural engineering practice needs to be explored in a future project.
4. A practicum/internship as a part of the core graduate curriculum would both assist the student progress in the professional areas not emphasized in the academic courses and, perhaps at least as import, and to give this student a better understanding of what is involved in structural engineering professional practice so that this student can better discern how well this profession fits with his/her interests, priorities, and abilities and so they can have a better perspective on how best to plan their formal and informal preparation for this profession. However, such programs are not often considered to be practical or possible at the graduate level. Formal co-operative programs are generally at the undergraduate engineering level and are only available at some schools. Some graduate students obtain some attributes of an internship through a combination of employment and often part-time graduate studies. Sometimes interns are treated by the employer as an inexperienced employee able to fulfill a well-defined low-level task or tasks in an economical way. A requirement for an internship within the graduate level structural engineering program would require the academic institution to both assist the student in finding an appropriate position and to work with the

employer on expectations for this experience so that it can a have a strong role in the overall preparation of the young aspiring professional.

5. It is generally accepted that some of the young structural engineer's preparation needs to be provided by the profession, especially the initial employer. The graduate program is not long enough or comprehensive enough in all the necessary areas to make it possible for the graduate to immediately begin an independent professional practice in traditional structural engineering. Although the scope of this research did not include a complete review of this phase of the structural engineer's preparation for practice, some observations of present and possible future early-career educational opportunities were within the project's scope, especially in the Round 3 study of the perceived importance of five primary modes for obtaining additional capabilities beyond those expected from the formal graduate programs.
6. For the structural engineering professional to have the capabilities, recognition, and respect needed both to more effectively provide structural/physical infrastructure to society and to obtain a larger role in the planning and managing these facilities, the general call of the civil engineering profession is that we have to "Raise the Bar". Two of the key steps in reaching this goal are to increase the formal post-undergraduate academic requirements and to correspondingly increase the professional licensure requirements. Structural engineering groups (e.g. NCSEA, SEI) and structural engineers active in engineering groups (e.g. ASCE, NCEES) are currently very involved in these efforts and can help make these changes happen.
7. The academic program planning a revised Masters-Level program more supportive of the structural engineering professional has several important sources of information in addition to the experience, perspectives, and professional knowledge and experiences of its faculty,

graduates, and local professional community. The results of this study is among these sources of information, along with the Recommended Basic Structural Engineering Curriculum as defined by the National Council of Structural Engineering Associations (given earlier in Table 2-4) and the contents of the NCEES (National Council of Examiners for Engineering and Surveying) national-level Structural Engineering Examination (NCEES, 2011). The taking and passing of this SE Exam is a key requirement for obtaining registration as a Structural Engineer (abbreviated as S. E.).

Some states now have the requirement of professional licensure specifically as a Structural Engineer as a requirement for engineers conducting structural engineering work, and the number of states (professional licensing in the U.S. is done at the state level) adopting or considering this requirement is growing. Thus, a growing proportion of structural engineers in practice are seeking and obtaining licensure as a S.E., either because they are located in a state requiring this credential or they want or need to be able to work with projects located in one of the states with this requirement. For these and other reasons, the NCEES Structural Engineering Examination (SE Exam) and its contents can be expected to have a growing impact on the graduate education programs in structural engineering. It is thus appropriate to examine its general content in more detail. The general format and subject areas in this two-day examination is given in Table 6-1. Although there is only a single morning (breadth) track each day for the exam, for the afternoon (depth) portion, the examinee may choose a track emphasizing bridges or one addressing buildings. As the SE exam contains a well-described set of topics, supplemented now by study guides and manuals, the subject areas the aspiring licensed structural engineer will encounter in the examination, along with the relative weights of each, are quite well described.

Table 6-1: Summary of the Structural Engineering (SE) Examination Requirements

Day	Day 1		Day 2	
AM BREADTH	Vertical Forces (Gravity /Other) and Incidental Lateral with Approximate %		Lateral Forces (Wind/Earthquake) with Approximate %	
	Analysis of Structures 30%	Loads 10%	Analysis of Structures 37%	Lateral Forces-10%
		Methods 20%		Lateral Force Distribution-22%
				Methods-5%
	Design and Details of Structures 65%	General Structural Considerations-7.5%	Design and Details of Structures 60%	General Structural Considerations-7.5%
		Structural Systems Integration-2.5%		Structural Systems Integration-5%
		Structural Steel-12.5%		Structural Steel-10%
		Light Gage/Cold-Formed Steel-2.5%		Light Gage/Cold-Formed Steel-2.5%
		Concrete-12.5%		Concrete-12.5%
		Wood—10%		Wood—7.5%
		Masonry-7.5%		Masonry-7.5%
		Foundations and Retaining Structures-10%		Foundations and Retaining Structures-7.5%
	Construction Administration 5%		Construction Administration 3%	
PM DEPTH	Choice of		Choice of	
	Buildings or	Steel Structure-25%	Buildings or	Steel Structure-25%
		Concrete Structure 25%		Concrete Structure-25%
		Wood Structure 25%		Wood and /or Masonry Structure-25%
		Masonry Structure 25%		General Analysis-25%
	Bridges	Concrete Superstructure-25%	Bridges	Columns-25%
		Other Elements of Bridges-25%		Footings-25%
		Steel Superstructure-50%		General Analysis-50%

6.3 Use of the Survey Results to Various Stakeholders in Structural Engineering

The results of this research can contribute to the structural engineering profession on several levels and in several different ways for the various stakeholder groups in the structural engineering areas. These many stakeholder groups include academic institutions, providers of structural engineering services, the taxpayers, and a wide variety of general interest groups. Six stakeholder communities most directly involved in structural engineering, and thus potentially most directly able to utilize the results of this research, are next listed and discussed.

6.3.1 Academic Institutions offering Masters-Level Structural Engineering Programs

A primary set of information which should be of interest to the educational institutions is the identity of the subject areas (i.e. subtasks) for which the graduates are expected to have the higher levels of abilities. It is suggested that the structural/civil engineering programs examine the ways in which their graduate program can best build upon the undergraduate engineering program to most effectively deliver these desired competencies.

Among the subject areas for which the profession has the highest expectations are:

Area A, Basic Mechanics and Engineering Tools: Advanced Mechanics of Materials, Structural Analysis-Framed Structures, Finite Element Analysis/Modeling, and Structural Dynamics.

Area B, General Structural Engineering Tools: Behavior of Structural Systems – Load Path; Design Loads, including Evaluation.

Area C, Technology and Communication Tools: Communication Software and Tools, Structural Engineering Design Software.

Area D, Structural Engineering Topics and Tools: Structural Steel Design Basics, Reinforced Concrete Design Basics, Earthquake Engineering – Basics, Pre-stressed Concrete

Design, with Masonry Design, Timber Design, and more advanced topics in both steel and reinforced concrete also with quite high expectations.

Area E, Management and Professional Tools: The two with the highest expectations are Leadership Skills/Adaptation to Change, Working with Architects, Contractors, etc., although both of these were assigned lower expectations than for about two thirds of topics in Area D, including those mentioned above.

Area F, Additional Topics: Communication Skills (Oral, Written, Graphical), Total Building Project Design.

Decisions within the academic programs include how to organize the many topics and subject areas into a practical number of well-defined courses, decisions on who will teach the individual classes and the preparation and background they need, and the methods and mechanics of effectively and efficiently delivering the educational classes and components. Some observations and suggestions will be made at the first two levels.

Academic programs have several options for packaging academic content, the default mode being a well-defined course dedicated to a single topic. Other modes include a single class addressing in sequence two or more topics, a class addressing two or more topics together, and a class with the inclusion of a secondary topics within a primary topic. Logical candidates for a dedicated course at the graduate level are most of the topics listed above for Areas A, B and D. Some of the topics assigned the highest expectations are topics usually supported by one or more undergraduate classes – topics such as structural analysis of frames, basic structural steel design, and basic reinforced concrete design. Given the limitation of the number of courses or credits in the typical Masters-Level programs, some of the topics may need to be combined into a single class. Some possible pairs include (a) timber and masonry design, (b) structural dynamics and earthquake engineering fundamentals, (c) elastic stability and advanced steel design topics, and (d) structural loads, security/safety considerations and risk analysis, and design principles to resist disproportionate damage/collapse. An efficient approach may be to place three or more topics in a survey course providing breadth instead of depth, with one possible group of topics being green buildings and LEED, building inspection and monitoring, and building repair, renovation and reuse. A well-organized survey course, perhaps taught by a local structural engineer with extensive experience in project and office management, addressing many of the management and professional topics, could be very effective in building on the undergraduates limited abilities in these areas to reach the expected proficiency levels. Structural engineering design software may be best taught as an integral tool in a building design project class emphasizing one or more structural materials. Ethics, a critical topic not specifically addressed in the questionnaire, leadership skills, management topics, and construction/architectural concerns may be best addressed by these topics being infused into other classes as secondary but important considerations often noted in the conduct of the class.

6.3.2 Employers Hiring Masters-Level Graduates in Structural Engineering

It is no surprise to most employers of recent Masters-Level graduate in structural engineering that they, along with the overall structural engineering profession, have a very large task and obligation to provide this young engineer with many of the basic abilities needed for this individual to become a highly productive professional within the firm, agency, or group. Although many of the results are primarily confirmation of general trends already known to many or most senior structural engineers in the design firms and agencies, there can be significant differences among the professional work environments for young structural engineers.

Employers can use the survey results in several ways. The listing of expected achievement levels upon completion of the Masters-Level program provides a general description of abilities the typical new engineering employee should be able to bring to the employer.

The abilities found to be generally expected within the profession after the initial employment period can serve as a useful check and planning list starting with an examination of whether the young engineer is being provided with sufficient opportunities and learning experiences in the needed areas. Employer needs and staff management practices are not always the same, and how and to what extent work assignments and opportunities can be modified to facilitate the professional development of the entry-level engineer will differ. The important principle is that this professional development is critical, needs to be a significant consideration in the planning and assignment of work tasks and opportunities, and is overall an investment by the firm and by the profession.

The additional competencies documented in the results as being expected to be achieved in the early employment years can be used to help define the general professional development needs within the firm that extend beyond that which follow from appropriate work assignments. Those in the firm responsible for personnel management and professional development should find these results relevant in their planning of in-house training, use and scheduling of technical seminars, and in the planning of employee educational support. The assessment of the importance of the various primary modes of development after the Masters-Level program also should be of assistance by showing general expectations and findings of the profession.

All of the above can serve as useful input for periodic formal and informal discussions involving the young engineer and more senior engineers on his/her professional development, including a review of the individual's progress as observed by both the young engineer and by his/her mentor, a discussion of the individual's professional goals and the needs of the organization, opportunities and limitations of the present work assignments and responsibilities, and plans for the future professional development.

6.3.3 Young Structural Engineers Planning their Professional Growth

The description of the expectations of the structural engineering profession for identified subject areas can be effectively used at several points along the individual's formal education and early career years. Any electives in Masters-Level program can be chosen with one major consideration being how well the elective courses address the expectations of the profession and the topics included in the professional (P.E. and S.E.) licensure exams. Involvement in activities outside of the formal classes, including self-study, can be planned considering the available information on the expectations of the structural engineering profession.

The individual's professional development becomes a joint responsibility of the young engineer and the employer, both as a structural engineering provider and as a representative of the overall profession. Especially during the initial years, but continuing on, the developing structural engineer is advised to take an active role in the planning and carrying out of professional development. Steps include actively participating in mentoring and opportunities provided by the employer, a self-review of the individual's perceived progress in professional development, and a self-comparison of this progress relative to goals and needs as defined by the professional experience and observation and considering information such as that provided by this study of what is needed. The young professional needs to invite additional assistance and career development opportunities from the employer to help him or her reach personal professional goals.

The survey findings on the importance of major information/learning sources beyond the Masters-Level work can inform the young professional in his/her own planning of overall career development. Notable for this young structural engineering is the importance assigned to Self Learning (see Table 5-8), found to be second only to experience-in-practice as a source. Self learning was found to be the most important source for additional basic mechanics and engineering tools (Group A topics in this study) and second to experience-in-practice for Group C, Technology and Communication Tools, and Group D, Structural Engineering Topics and Tools. These finding clearly communicate to the young aspiring structural engineering that life-long learning, perhaps especially during the first several years, is an inherent component of this professional career and thus it needs to be included in expectations, be carefully planned, and then diligently carried out.

6.3.4 Institution/Firms/Organizations Involved in Post Masters Degrees Education

An increasing number of educational institutions, professional organizations, industry sources, and private firms are sources for information/education beyond the Masters-Level work, especially in the areas of added courses, short courses and seminars, and in assisting employers in in-house training programs. The organization and configuration of many of these resources are now rapidly changing, especially as more are becoming web-based. The role of information technology, including the web, on how these resources are delivered to the professional is an increasingly important topic but beyond the scope of this study.

Both the study findings of expected achievement levels in the various subjects and the assessment of importance levels of the primarily early-career educational sources can be useful to those providing these services. As previously noted, the overall importance and thus the opportunity for a given source for a given topic is related to the amount of professional growth in the early career years, indicated in this study by the increase in the level of competency during this period, and the observed importance of the source for that subject. Inherent in this second type of information is that some sources are more effective in some areas than in others. For example, short courses and seminars, along with in-house training can be very appropriate for addressing building code revisions and changes, while additional courses are not needed.

6.3.5 Licensing Boards and Professional Exam Providers

The study provides for both the individual state boards and NCEES, the professional society which provides the standard professional exams adopted by the individual licensing jurisdictions, with information on what the structural engineering profession expects of its members, especially in the early career years and at the time these individuals typically can first seek professional registration.

The increasing use of the NCEES structural engineering examination and specific professional registration in structural engineering will result in this examination and its inclusion and allocation of topics having increased influence in the planning of the entering engineers academic programs and professional development plans. The results of this study may be useful to NCEES and those working within this professional organization as one input considered in determining the level of competency that should be required to demonstrate an acceptable performance on this examination.

6.3.6 ASCE and Other Professional Societies Addressing Structural Engineering

The American Society of Civil Engineers (ASCE), its Structural Engineering Institute (SEI), along with large number of other professional organizations such as the American Concrete Institute (ACI) and the American Institute for Steel Construction (AISC), are important sources of seminars, short course and other professional development programs, and the observations made above about the providers of such services certainly apply to these groups.

Notable activities of most of these groups not directly addressed in this study include meetings ranging from national and international conferences to local chapter meetings, publications containing a combination of professional and research information, and technical committees which provide a combination of professional service and significant professional development for the committee members. Participation in appropriate professional activities is an important additional source of professional development not directly addressed in this study, but one that all young structural engineers should choose.

The actions of ASCE in leading the call for additional preparation of young engineers and its further definition of this need through its "Raise the Bar" initiative and activities, including the Body of Knowledge (BOK) report (American Society of Civil Engineers (ASCE) Body of Knowledge Committee of the CAP3, 2008) are very notable and a major motivation for this study. The ASCE BOK addresses the breath of the civil engineering profession rather than the specialties of civil engineering. Although it includes the importance of early professional experience, it addresses more the basic educational programs for the young civil engineer. In many ways, this study extends the findings of the BOK Report to the large specialty area of structural engineering. As increased emphasis is being given to the Masters-Level or equivalent preparation as an future expectation of licensure and the overall profession, there appears to be an increasing need for information on a number of civil engineering specialties to be generated in a format similar to that used in this study. Thus, encouragement is offered to ASCE to include in their current plans and activities studies such as the reported project to give an increased description and assessment of professional expectations in other sub-disciplines/specialties of civil engineering. The present study should be able to serve as one model or starting point for these types of studies. Through the ASCE organization, such studies can be conducted with the intense level of planning and the high level of participation by members of the profession not possible in this initial study. The profession would greatly benefit by having this type of description of needs and expectations, including for structural engineering, with the depth and credibility that can be provided best by ASCE.

7 SUMMARY AND FUTURE RESEARCH

7.1 Summary

This study focused on the Masters-Level preparedness in the structural engineering area within the civil engineering field. The objective of the research is to create a Framework of Knowledge identifying and recognizing the needs of the structural engineering profession, along with some recommendations of how those needs could be achieved in the academic setting, in practice environment, from the initial period of (approximately five years) of professional employment. This was accomplished with a modified Delphi three-round study conducted by e-mail and using questionnaire content developed with the assistance of individual interviews with a panel of very experience practicing structural engineers and the use of this questionnaire by a participant group including design structural engineering from around the U.S. and a smaller group of structural engineers in academia and professional organizations.

In applying the Delphi method for this study, two different types of questionnaires were developed, one for Round 1 and Round 2 of the modified Delphi study, and another one for Round 3. Through the three rounds, the study obtained the critical information necessary to describe and help advance the preparedness of the young Masters graduates in structural engineering for professional practice and licensing from the responses of expert panels members of the structural engineering profession responding to the questionnaires. The structural engineering professionals' expectations of young engineers were determined at graduation from a Masters-Level structural engineering program and after the initial five years of experience. The strong correlation of the expert panel input for the individual questions and subject areas which was found to exist between the Round 1 and Round 2 responses allowed the Round 2 responses to be used for the balance of the study and the planned Round 3 to be used to explore the importance of professional development sources for the young professional. The comparison of the responses by the active practicing group and by the academia/professional society engineers at both times indicated some systematic differences but no major disagreement between the expectations of these two groups. The importance levels of five primary sources to reach the desired additional achievement levels during the initial professional employment period were obtained in Round 3 and analyzed. The expected role of the elective course offerings at the larger institutions offering Masters-Level structural engineering degrees was also addressed. The findings set up the Framework of Knowledge for the Masters-Level and early career structural engineering.

The Framework of Knowledge developed in this research can serve the academic programs, appropriate employer/practice groups, and the relevant professional organizations in their task of ensuring better preparedness of the young structural engineers. The study results could also be of high interest, including as input, to any professional committees or groups addressing in more detail the Body of Knowledge at the graduate level focusing on the structural engineering field.

7.2 Future Research Recommendations

As previously discussed, this research could serve as reference for future related research in the area of structural engineering education. Many identifiable factors affecting professional preparedness could not be included within the scope of this project, but warrant study. Possible future research areas related to general aspects of structural engineering education and professional preparedness related to this study include:

1. Based on the Framework of Knowledge developed herein, build appropriate model curriculums for Masters-Level education in structural engineering.

2. Incorporate the Framework of Knowledge described in this dissertation into the recommendations of increasing licensure requirements for structural engineers nationwide.
3. Describe the ongoing extension of the traditional academic study environment from the on-campus settings to different and alternative delivery modes such as online, hybrid, distance, web and video-based graduate degree programs or courses.
4. Expand the study or conduct similar studies for other civil engineering areas, for the PhD level programs, or for various types of professional practice (i. e., researchers, academics, scientists, administrators).
5. Survey the levels of knowledge expected by the structural engineering profession at the time of entrance into the Masters-Level (or, nearly equivalent, at the time of the Bachelors-level graduation).
6. Address in more detail the international-global aspects (culture, language, business practices, design philosophies), as they are expected to become more essential to the structural engineering community in the more highly integrated commerce in tomorrow’s increasingly connected world.

8 REFERENCES

Abbott, A. (1988). *The System of Professions: An Essay on the Division of Expert Labor*. Chicago: University of Chicago Press.

Abdi, H. (2007). The Kendall Rank Correlation Coefficient. In N. Salkind, *Encyclopedia of Measurement and Statistics.* Thousands Oaks, CA: Sage.

Adelman, C. (2008). *Learning Accountability from Bologna: A Higher Education Policy Primer.* Washington, DC: Institute for Higher Education Policy.

Adelman, C. (2009). *The Bologna Process for U.S. Eyes: Re-learning Higher Education in the Age of Convergence* . Washington, DC: Institute for Higher Education Policy.

Adler, M., & Ziglio, E. (1996). *Gazing into the Oracle: The Delphi Method and its Application to Social Policy and Public Health.* London: Jessica Kingsley Publishers.

American Society of Civil Engineering. (2007). *The Vision for Civil Engineering in 2025.* Reston: ASCE.

American Society of Civil Engineers (ASCE) Body of Knowledge Committee of the CAP3. (2008). *Civil Engineering Body of Knowledge for the 21st Century.* Reston: American Society of Civil Engineers.

American Society of Civil Engineers. (2009). *Achieving the Vision for Civil Engineering in 2025: A Roadmap for the Profession.* Reston: ASCE.

American Society of Civil Engineers. (2012). *ASCE Mebership Grades*. Retrieved from www.asce.org: www.asce.org/membership/ASCE-mebership-grades-and-guidelines

American Society of Civil Engineers. (1998). *ASCE Policy Statement 465: Academic Prerequisites for Licensure and Professional Practice*. Retrieved from www.asce.org:

http://www.asce.org/Public-Policies-and-Priorities/Public-Policy-Statements/Policy-Statement-465---Academic-Prerequisites-for-Licensure-and-Professional-Practice/

American Society of Civil Engineers, A. L. (2005). *Levels of Achievement applicable to the Body of Knowledge Required for entry into the Practice of Civil Engineering at the Professional Level.* ASCE.

Anderson, L. W., & Krathwohl, D. R. (2001). *A Taxonomy for Learning, Teaching, and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives.* New York: Longman.

Augustine, N. R. (2009, February). Reengineering Engineering. *Prism Magazine: American Society for Engineering Education* .

Barnes, C. E. (2004, February). Education for the Structural Engineer - Basic Course Curriculum and Content. *Structure Magazine* .

Bell, G. R. (2012). Developing the Next Generation of Structural Engineers. *43rd Structures Congress, Closing Plenary Session, Keynote.* Chicago.

Bloom, B. S., Engehart, M. D., Furst, E. J., & Kratwohl, D. (1956). *Taxonomy of Educational Objectives, the Classification of Educational Goals, Handbook I: Cognitive Domain.* New York: David McKay Company.

Coffey, Heather. (2008). Bloom's Taxonomy. Chapel Hill, North Carolina.

Cramer, S. M., & Wheat, D. L. (2011, June). Education in Wood Structural Design: Who Needs It. *Structure Magazine* , p. 5.

Czinkota, M., & Ronkainen. (1997). Internation Business and Trade in the Next Decade: Report from a Delphi Study. *Journal of International Business Studies* , *28* (4), 827-844.

Dalkey, N. C., & Helmer, O. (1963). An Experimental Application of the Delphi Method to the Use of Experts. *Management Science* , *9* (3), 458-467.

Delbeq, A., Van de Ven, A., & Gustavson, D. H. (1975). *Group Techniques for Program Planning: A Guide to Nominal Group and Delphi Processes.* Glenview: Scott Foresman and Company.

Freidson, E. (2001). *Professionalism: The Third Logic - On the Practice of Knowledge* . Chicago: University of Chicago Press.

Galambos, T. V. (2006). Structural Design Codes: The Bridge Between Research and Practice. *International Association for Bridge and Structural Engineers Symposium.* Budapest: IABSE.

Gupta, R., & Gopu, V. (2005). Wood Engineering Education - Trends and Challenges. *Proceedings of the 2005 Structures Congress and the 2005 Forensic Engineering Symposium.* New York: ASCE.

Halal, W. E., Kull, M. D., & Leffmann, A. (1998). The GWU Forecast of Emerging Technologies: A Continuous Assessment of the Technology Revolution. *Technological Forecasting and Social Change , 59*, 89-110.

Hasson, F., Keeney, S., & McKenna, H. (2000). Research Guidelines for the Delphi Survey Technique. *Journal of Advanced Nursing , 32* (4), 1008-1015.

Herrmann, A. (2011, December). *President's Message.* Retrieved from www.asceoc.org: http://www.asceoc.org/index.php/newsletter/article/presidents_message_dec2011

International Association for Bridge and Structural Engineers. (2011). *Definitions*. Retrieved from www.iabse.org: www.iabse.org/association/organisation/index.php

Jamieson, L. H. (2009). *Creating a Culture for Scholarly and Systematic Innovation in Engineering Education - Phase I.* Washington, DC: American Society for Engineering Education.

Jamieson, L. H. (2011). *Creating a Culture for Scholarly and Systematic Innovation in Engineering Education - Phase II.* Washington, DC: American Society for Engineering Education.

Jirsa, J. O. (2004, February). *Structural Engineering Education and Global Issues.* Retrieved from www.ascelibrary.org: ascelibrary.org/proceedings/resource/2/ascecp/103/40492/77_1

Keeney, S., Hasson, F., & McKenna, H. (2006). Consulting the Oracle: Ten Lessons from Using the Delphi Technique in Nursing Research. *Journal of Advanced Nursing , 53* (2), 205-212.

Khosravi, S., & Afshari, H. (2011). A Success Measurement Model for Construction Projects. *IPEDR , 11*, 186.

Linstone, H. A., & Turoff, M. (1975). *The Delphi Method: Techniques and Applications.* Reading: Addison-Wesley Publishing Company.

Lumina Foundation. (2011). *The Degree Qualification Profile.* Indianapolis: Lumina Foundation.

Morgan, G. A., Leech, N. L., Gloeckner, G. W., & Barett, K. C. (2011). *IBM SPSS for Introductory Statistics: Use and Interpretation.* New York: Taylor and Fracis Group, LLC.

National Academies. (2010). *Rising Above the Gathering Storm - Revisited: Rapidly Approaching Category 5.* Washington, DC: National Academies Press.

National Academies. (2005). *Rising Above the Gathering Storm.* Washington, DC: National Academies Press.

National Academy of Engineering. (2005). *Educating the Engineer of 2020 - Adapting Engineering Education to the New Century.* Washington, DC: National Academies Press.

National Academy of Engineering. (2004). *The Engineer of 2020 - Visions of Engineering in the New Century.* Washington, DC: National Academies Press.

National Council of Examiners for Engineering and Surveying. (2011, September). *Model Law*. Retrieved from www.ncees.org.

National Council of Structural Engineering Associations. (2010). NCSEA Basic Education Survey Curriculum Results. *Structure Magazin* .

National Council of Structural Engineering Associations. (2007, April). The Basic Structural Education. *Structure Magazine* , pp. 33-39.

National Science Board. (2007). *Moving Forward to Improve Engineering Education.* Arlington: National Science Foundation.

National Society of Professional Engineers. (1954). *http://www.nspe.org/Ethics/CodeofEthics/Creed/creed.html*. Retrieved from http://www.nspe.org.

NCEES. (2011). *NCEES Structural Sample Questions and Solutions.*

Nelson, E. (2012, February). What is Structural Engineering Exactly? *Structure Magazine* .

Ressler, J. S. (2011). Sociology of Professions: Application to the Civil Engineering "Raise the Bar" Initiative. *Journal of Professional Issues in Engineering Education and Practice , 137* (3), 151-161.

Rowe, G., Wright, G., & Bolger, F. (1991). Delphi: A Reevaluation of Research and Theory. *Technological Forecasting and Social Change , 39*, 235-251.

Russell, J. S., Lenox, T., Rogers, J., & Coward, D. (2010). *Civil Engineering Master's Programs: A Comprehensive Review of Types and Requirements.* Madison: University of Wisconsin - Madison.

Schmidt, J. (2008, September). Philosophy and Engineering. *Structure Magazine* .

Siller, T. J., Criswell, M. E., Fontane, D. G., & Grigg, N. S. (2004). Some Methods to Achieve Changes in Delivered Civil Engineering Body of Knowledge. *Proceeding of the 2004 American Society for Engineering Education Annual Conference & Exposition.* ASEE.

Skumolski, G. J., Hartman, F. T., & Krahn, J. (2007). The Delphi Method for Graduate Research. *Journal of Information Technology Education , 6*.

Sursock, A., & Smidt, H. (2010). *Trends 2010: A Decade of Change in European Higher Education.* European University Association. Brussels: EUA Publications.

Yousuf, M. I. (2007). Using Experts' Opionions Through Delphi Technique. *Practical Assesment Research and Evaluation (PARE) , 12* (4).

A. APPENDICES

Colorado State University
Knowledge to Go Places

Research Integrity & Compliance Review Office
Office of the Vice President for Research
321 General Services Building - Campus Delivery 2011 Fort Collins, CO
TEL: (970) 491-1553
FAX: (970) 491-2293

NOTICE OF APPROVAL FOR HUMAN RESEARCH

DATE:	October 14, 2011	
TO:	Criswell, Marvin, 1372 Civil Engineering	
	Garcia, Luis, 1372 Civil Engineering, Balogh, Zsuzsa, 1372 Civil Engineering	
FROM:	Barker, Janell, , CSU IRB 1	
PROTOCOL TITLE:	Harmonizing the graduate level structural engineering education with the structural engineering professional field.	
FUNDING SOURCE:	NONE	
PROTOCOL NUMBER:	11-2930H	
APPROVAL PERIOD:	Approval Date: October 14, 2011	Expiration Date: September 14, 2012

The CSU Institutional Review Board (IRB) for the protection of human subjects has reviewed the protocol entitled: Harmonizing the graduate level structural engineering education with the structural engineering professional field.. The project has been approved for the procedures and subjects described in the protocol. This protocol must be reviewed for renewal on a yearly basis for as long as the research remains active. Should the protocol not be renewed before expiration, all activities must cease until the protocol has been re-reviewed.

If approval did not accompany a proposal when it was submitted to a sponsor, it is the PI's responsibility to provide the sponsor with the approval notice.

This approval is issued under Colorado State University's Federal Wide Assurance 00000647 with the Office for Human Research Protections (OHRP). If you have any questions regarding your obligations under CSU's Assurance, please do not hesitate to contact us.

Please direct any questions about the IRB's actions on this project to:

Janell Barker, Senior IRB Coordinator - (970) 491-1655 Janell.Barker@Colostate.edu
Evelyn Swiss, IRB Coordinator - (970) 491-1381 Evelyn.Swiss@Colostate.edu

Barker, Janell

Janell Barker

Barker, Janell

Includes:

Approval is for 80 research participants using the approved electronic cover letter to recruit and obtain consent. Documentation of consent is waived through 117(c)(2). No changes may be made to the protocol without prior IRB approval.

Page: 1

Figure A-1: Institutional Review Board Approval Notice

Date

Dear Participant,

My name is Zsuzsa Balogh, Ph.D. candidate at Colorado State University under the guidance of Dr. Marvin Criswell, Civil and Environmental Engineering Department in the Structural Engineering area. My research is focused on examination of how well the typical graduate program in structural engineering in the United States prepares its graduates for professional practice in structural engineering, then exploring how best the identified gaps between academic preparation and professional needs can be addressed. The tentative title of the project is *Harmonizing the graduate level structural engineering education with the structural engineering professional field*. The Principal Investigator is Dr. Marvin Criswell, Civil and Environmental Engineering Department and the Co-Principal Investigator is Zsuzsa Balogh, Civil and Environmental Engineering Department.

A key component of this study is an e-mail survey (Delphi) of a group of 50 - 80 structural engineers and professionals in closely related areas and located throughout the country.

We invite you to participate in the Delphi study. The time required for you will be approximately one hour per round, (up to maximum four rounds) at different times for the preparation and submission of survey responses via internet/e-mail.

Your participation in the Delphi study is voluntary. If you agree to participate in the study, you may withdraw your consent and stop your participation at any time without penalty.

Your name/company will not be identifiably linked to your answers, comments, and recommendations, as the unrestricted contribution of participant opinions and input of the survey is generally considered to be facilitated by anonymity within the participating members. The researcher will be the one managing and assessing the data. Except for information needed to communicate with you during the survey, for purposes of working with input and results, your name/company will be substituted by a code in order to manage the information from round one to round three (maximum four) of the survey. While there are no direct benefits to you, we hope to gain more knowledge to reach the final goal of the research, which is to create a recommendation for graduate level (Masters) structural engineering education framework similar to the more undergraduate-oriented American Society of Civil Engineers Body of Knowledge (BOK 2) for the 21st Century. This framework would focus on graduate structural engineering technical and professional preparedness.

There are no known risks of participation in this research.

In a quick reply (via e-mail), please let me know if you are or you are not able to accept the invitation for participation in the study.

If you are willing to participate, please fill out the questionnaire attached to this e-mail and send it back to Zsuzsa Balogh by Friday, March 23, 2012. Upon receipt of Round 1 replies from members participating, I will summarize the Round 1 results, including compilation and summary of comments, finalize Round 2 questionnaire, and send out Round 2 survey via e-mail. My target time for this process is shortly (couple of days) after having the Round 1 results. The third round (the last round currently planned) of the survey of the modified Delphi questionnaire will follow the same procedure as the first one described above.

If you have any questions, please contact
Zsuzsa Balogh, Colorado State University/Department of Civil and Environmental Engineering and also Associate Professor/CET Program Coordinator/Department of Engineering Technology Metropolitan State College of Denver at ………… or ……………...

or

Dr. Marvin E Criswell, Professor, Colorado State University/Department of Civil and Environmental Engineering at ……………… or …………………

If you have any questions about your rights as a volunteer in this research, contact Janell Barker, Human Research Administrator, at …………………

Sincerely,

Dr. Marvin E Criswell	Zsuzsa Balogh
Professor, CSU	Ph.D. candidate, CSU
Dept. of Civil and Environmental Engineering	Dept. of Civil and Environmental Engineering

Figure A-2: Invitation Letter of Round 1

Dear…

Thank you for your response in Round 1 of the Delphi Study as part of my research in harmonizing the Masters level structural engineering preparedness with the professional field.

Your participation is extremely valuable and crucial in the success of this research.

This second round provides you with information on how the overall questionnaire group responded in the first round and for you to review and reconsider your response given additional background information from the first round. The topics in Section F were added based on participant comments/requests in Round 1.

If your decision is not to change any of your Round 1 evaluations, you need only to send me a quick, brief e-mail stating: "I have chosen to submit NO modifications to my evaluations made in Round 1", and please add your scores on the six questions in Section F.

Your response to this second round will be used to define the final mean group response and the scatter of responses for each of the items evaluated. The evaluation of levels of achievement expected for the typical Masters graduate is of primary interest in defining the task of the graduate program. The difference in the levels of achievement expect at that time relative to those the young engineering should have after the first five years in structural engineering practice define the additional educational/professional preparation expected beyond what the Masters program provides. The third and last round of this study will mainly address the relative importance of various primary modes (such as experience in practice, in-house training, additional university courses, short courses ,and self-learning) available for use by the young structural engineering acting to reach the desired "after five years in practice" levels of achievement.

Please send your Round 2 response to ……………….. by Tuesday, May 8, 2012.

Sincerely,

Zsuzsa

Zsuzsa Balogh

PhD Candidate

Colorado State University Civil and Environmental Engineering Department

Figure A-3: Invitation Letter of Round 2

Dear…

Round 3 is the last component of this Delphi research study, regarding harmonizing the structural engineering masters level preparedness with the structural engineering professional field needs.

Please complete the following table (using Key #2) on the importance of the identified primary modes (such as experience in practice, in-house training, additional university courses, short courses, and self-learning) for the young structural engineer to utilize in the task of closing the gaps (as defined by the Round 1 and 2 results, included in the form for your convenience) between what the masters program should provide and what he/she should have after about five years of professional experience.

The educational and professional communities share the task of providing the young structural engineer educational opportunities beyond those they have at graduation from a Masters program. These resources may be needed for them to meet the levels of achievement required for practice or to obtain competency in specialty areas. Professional development and learning in general is certainly a professional (and life-long) responsibility for all structural engineers. Because the spectrum of appropriate topics of interest and professional activities can and do change at various stages of one's career, we ask you to consider only the additional preparation needed in the first five years of the typical structural engineer's career.

A comparison of the Round 2 levels of achievement results at the time of graduation relative to those expected after the first five years of practice for the same topic (information provided to you) show the additional levels of achievement the young engineer needs to obtain beyond the masters programs.

In some areas, the preparation of the young engineer is primarily the responsibility of the graduate program, while in others the professional practice community has a larger role.

The goal of the Round 3 component is to better define the expected roles of the educational and professional communities (including the employer) in providing opportunities and assistance for the young engineer in the period between the masters program and approximately five year in practice.

Results of the Delphi study will be shared with you as the Delphi Expert Panel participant after analyzing and summarizing the results (tentatively in August-September of 2012). Please do not hesitate to contact me with any questions.

I'm looking forward to your e-mail reply with your Round 3 (LAST ROUND) input

by Thursday, May 24, 2012.

Best Regards,
Zsuzsa

Zsuzsa Balogh

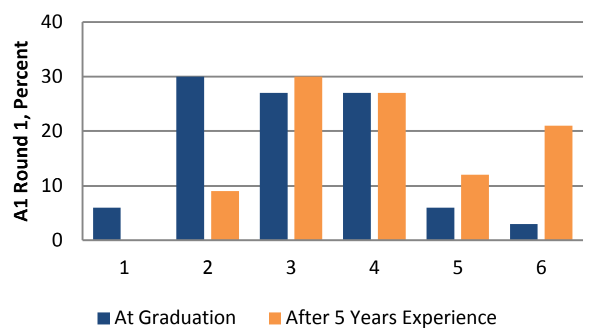
PhD Candidate

Colorado State University/Department of Civil and Environmental Engineering

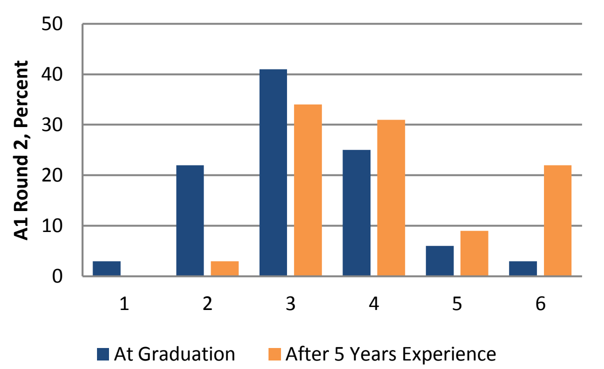
Figure A-4: Invitation Letter of Round 3

Table A-1: Responses to Question A1

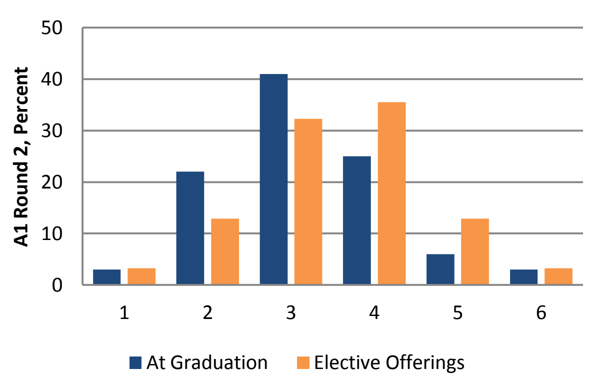
A1. Advanced Mechanics of Materials	Achievement Level	At Graduation		After 5 Years Exp.	
Round 1		Freq	%	Freq	%
	1-Knowledge	2	6	0	0
	2-Comprehension	10	30	3	9
	3-Application	9	27	10	30
	4-Analysis	9	27	9	27
	5-Synthesis	2	6	4	12
	6-Evaluation	1	3	7	21
	Total	33	100	33	100



Round 2		Freq	%	Freq	%
	1-Knowledge	1	3	0	0
	2-Comprehension	7	22	1	3
	3-Application	13	41	11	34
	4-Analysis	8	25	10	31
	5-Synthesis	2	6	3	9
	6-Evaluation	1	3	7	22
	Total	32	100	32	100



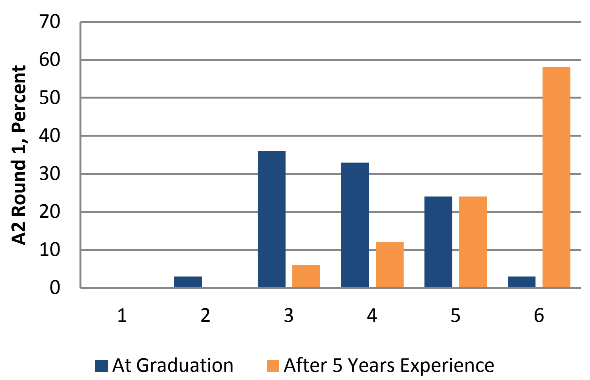
Elective Offerings		Round 1		Round 2	
		Freq	%	Freq	%
	1-Knowledge	1	3	1	3
	2-Comprehension	5	16	4	13
	3-Application	10	31	10	32
	4-Analysis	9	28	11	35
	5-Synthesis	5	16	4	13
	6-Evaluation	2	6	1	3
	Total	32	100	31	100



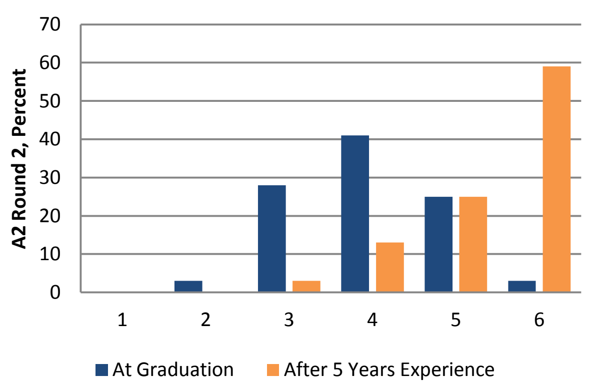
Opinion Movement		
Round 1- to - Round 2	Symmetric Measures	
	Approx. Sig. (p)	Kendall's tau-b (τ-b)
At Graduation	<0.001	0.882
After 5 Years Experience	<0.001	0.950
Elective Offerings	<0.001	0.907

Table A-2: Responses to Question A2

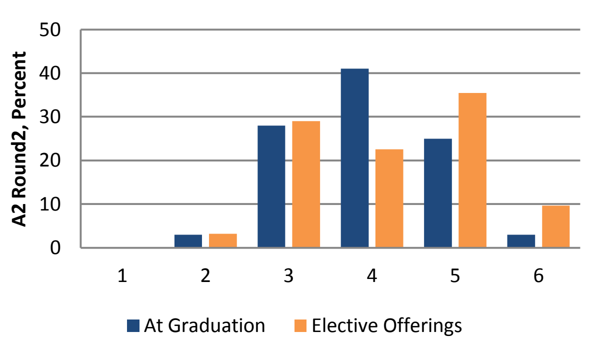
A2. Structural Analysis – Framed Structures	Achievement Level	At Graduation		After 5 Years Exp.	
Round 1		Freq	%	Freq	%
	1-Knowledge	0	0	0	0
	2-Comprehension	1	3	0	0
	3-Application	12	36	2	6
	4-Analysis	11	33	4	12
	5-Synthesis	8	24	8	24
	6-Evaluation	1	3	19	58
	Total	33	100	33	100



Round 2	Achievement Level	Freq	%	Freq	%
	1-Knowledge	0	0	0	0
	2-Comprehension	1	3	0	0
	3-Application	9	28	1	3
	4-Analysis	13	41	4	13
	5-Synthesis	8	25	8	25
	6-Evaluation	1	3	19	59
	Total	32	100	32	100



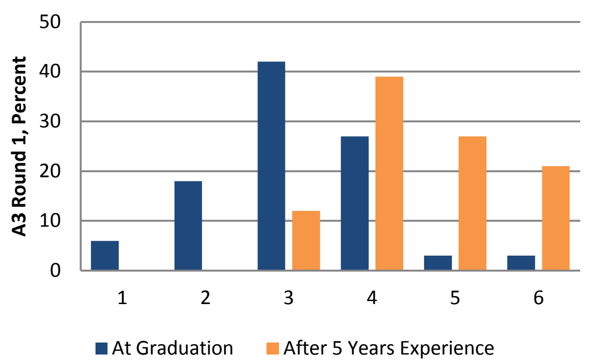
Elective Offerings	Achievement Level	Round 1		Round 2	
		Freq	%	Freq	%
	1-Knowledge	0	0	0	0
	2-Comprehension	1	3	1	3
	3-Application	10	31	9	29
	4-Analysis	7	22	7	23
	5-Synthesis	10	31	11	35
	6-Evaluation	4	13	3	10
	Total	32	100	31	100

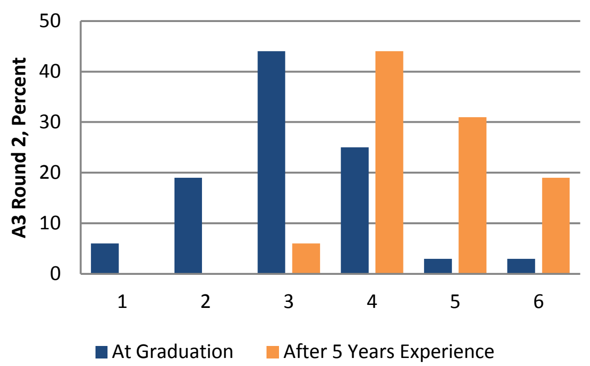


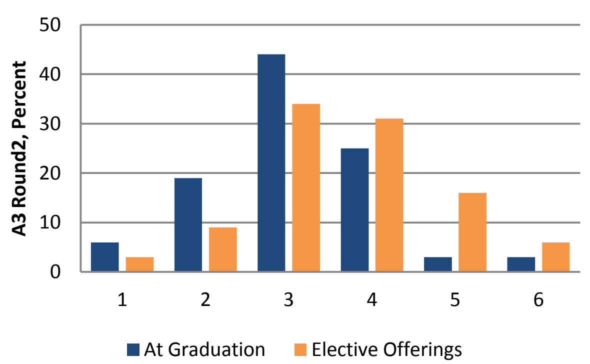
Opinion Movement		
Round 1- to - Round 2	Symmetric Measures	
	Approx. Sig. (p)	Kendall's tau-b (τ-b)
At Graduation	<0.001	0.920
After 5 Years Experience	<0.001	0.889
Elective Offerings	<0.001	0.956

Table A-3: Responses to Question A3

A3. Finite Element Analysis/Modeling	Achievement Level	At Graduation		After 5 Years Exp.	
Round 1		Freq	%	Freq	%
	1-Knowledge	2	6	0	0
	2-Comprehension	6	18	0	0
	3-Application	14	42	4	12
	4-Analysis	9	27	13	39
	5-Synthesis	1	3	9	27
	6-Evaluation	1	3	7	21
	Total	33	100	33	100
Round 2		Freq	%	Freq	%
	1-Knowledge	2	6	0	0
	2-Comprehension	6	19	0	0
	3-Application	14	44	2	6
	4-Analysis	8	25	14	44
	5-Synthesis	1	3	10	31
	6-Evaluation	1	3	6	19
	Total	32	100	32	100
Elective Offerings		Round 1		Round 2	
		Freq	%	Freq	%
	1-Knowledge	1	3	1	3
	2-Comprehension	4	12	3	9
	3-Application	10	30	11	34
	4-Analysis	9	27	10	31
	5-Synthesis	6	18	5	16
	6-Evaluation	3	9	2	6
	Total	33	100	32	100

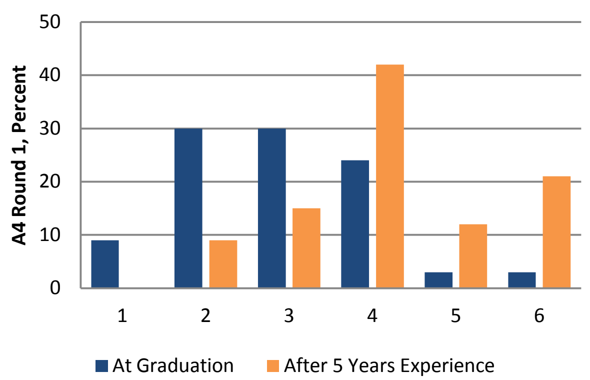
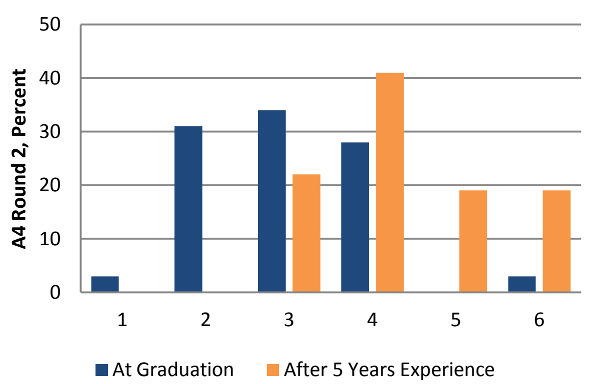
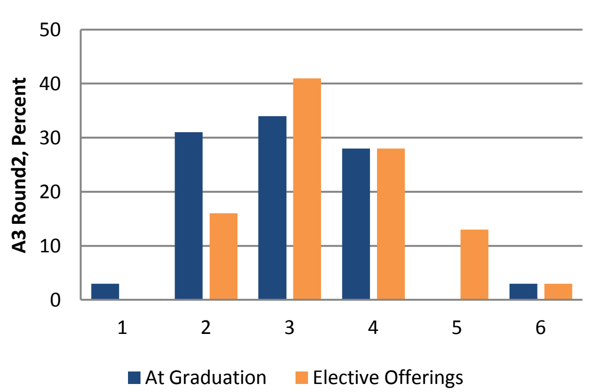






Opinion Movement		
Round 1- to - Round 2	Symmetric Measures	
	Approx. Sig. (p)	Kendall's tau-b (τ-b)
At Graduation	<0.001	0.971
After 5 Years Experience	<0.001	0.940
Elective Offerings	<0.001	0.965

Table A-4: Responses to Question A4

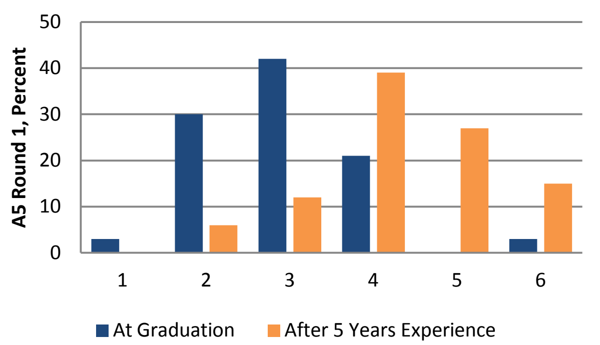
A4. Elastic Stability	Achievement Level	At Graduation		After 5 Years Exp.	
Round 1		Freq	%	Freq	%
	1-Knowledge	3	9	0	0
	2-Comprehension	10	30	3	9
	3-Application	10	30	5	15
	4-Analysis	8	24	14	42
	5-Synthesis	1	3	4	12
	6-Evaluation	1	3	7	21
	Total	33	100	33	100
Round 2		Freq	%	Freq	%
	1-Knowledge	1	3	0	0
	2-Comprehension	10	31	0	0
	3-Application	11	34	7	22
	4-Analysis	9	28	13	41
	5-Synthesis	0	0	6	19
	6-Evaluation	1	3	6	19
	Total	32	100	32	100
Elective Offerings		Round 1		Round 2	
		Freq	%	Freq	%
	1-Knowledge	0	0	0	0
	2-Comprehension	7	21	5	16
	3-Application	11	33	13	41
	4-Analysis	8	24	9	28
	5-Synthesis	5	15	4	13
	6-Evaluation	2	6	1	3
	Total	33	100	32	100

Opinion Movement		
Round 1- to - Round 2	Symmetric Measures	
	Approx. Sig. (p)	Kendall's tau-b (τ-b)
At Graduation	<0.001	0.920
After 5 Years Experience	<0.001	0.926
Elective Offerings	<0.001	0.941

Table A-5: Responses to Question A5

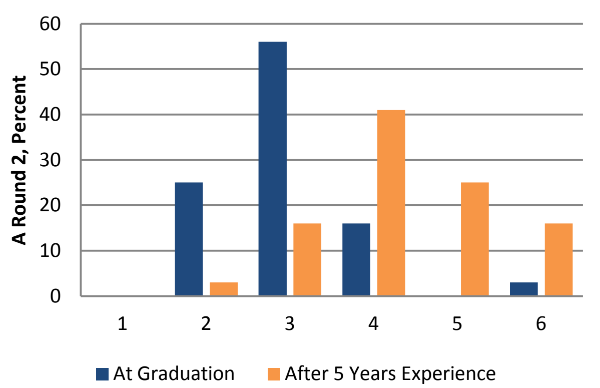
A5. Structural Dynamics

Round 1



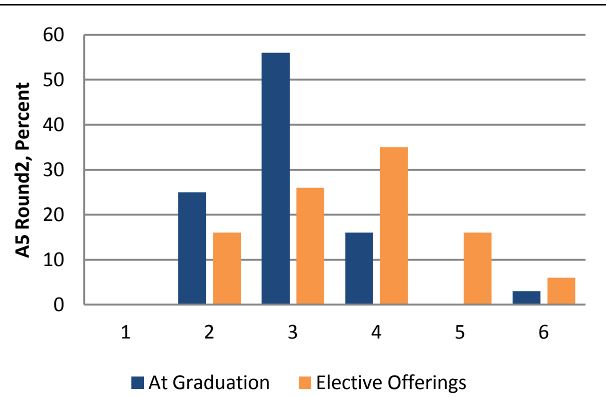
Achievement Level	At Graduation Freq	At Graduation %	After 5 Years Exp. Freq	After 5 Years Exp. %
1-Knowledge	1	3	0	0
2-Comprehension	10	30	2	6
3-Application	14	42	4	12
4-Analysis	7	21	13	39
5-Synthesis	0	0	9	27
6-Evaluation	1	3	5	15
Total	33	100	33	100

Round 2



Achievement Level	At Graduation Freq	At Graduation %	After 5 Years Exp. Freq	After 5 Years Exp. %
1-Knowledge	0	0	0	0
2-Comprehension	8	25	1	3
3-Application	18	56	5	16
4-Analysis	5	16	13	41
5-Synthesis	0	0	8	25
6-Evaluation	1	3	5	16
Total	32	100	32	100

Elective Offerings

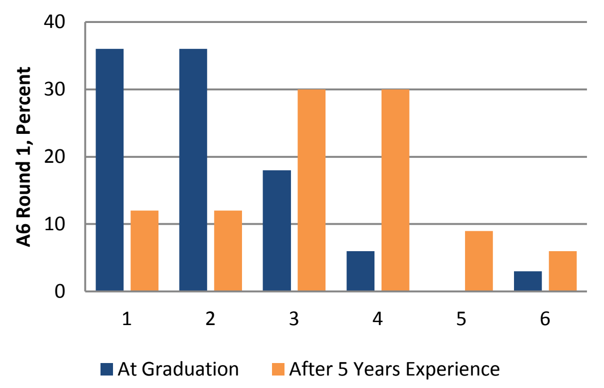
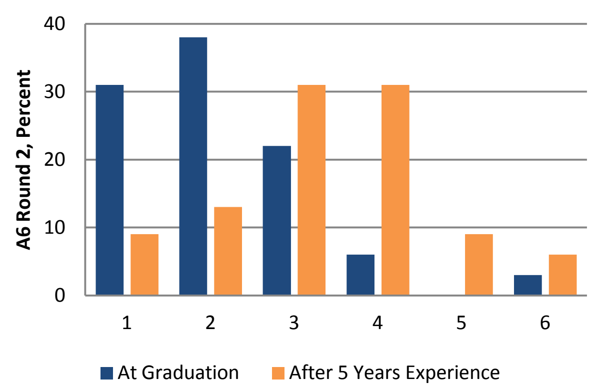
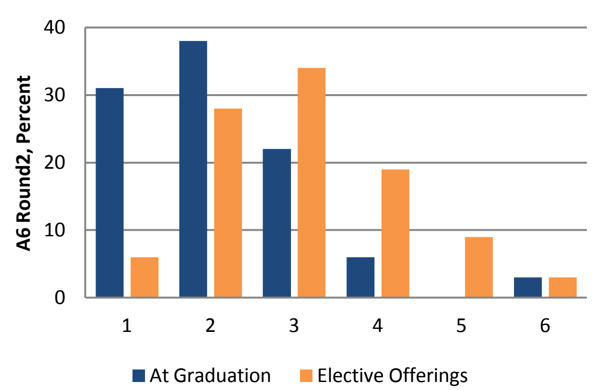


Achievement Level	Round 1 Freq	Round 1 %	Round 2 Freq	Round 2 %
1-Knowledge	0	0	0	0
2-Comprehension	6	19	5	16
3-Application	7	22	8	26
4-Analysis	10	31	11	35
5-Synthesis	6	19	5	16
6-Evaluation	3	9	2	6
Total	32	100	31	100

Opinion Movement

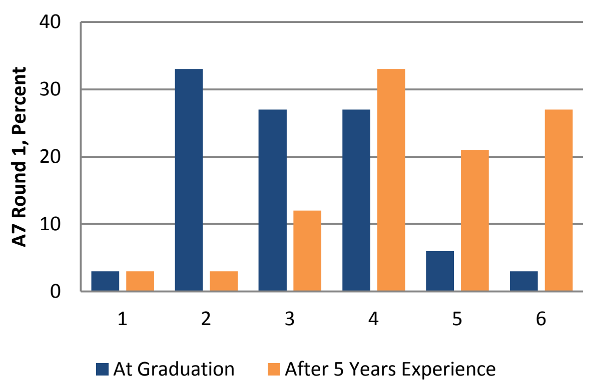
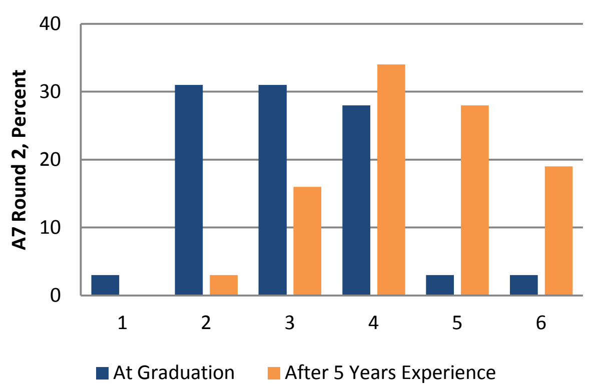
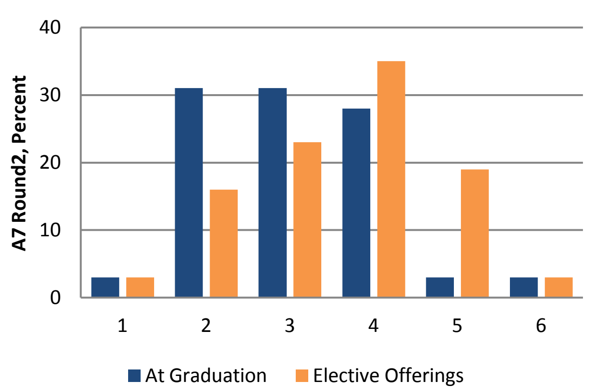
Round 1- to - Round 2	Symmetric Measures: Approx. Sig. (p)	Symmetric Measures: Kendall's -b (τ-b)
At Graduation	<0.001	0.860
After 5 Years Experience	<0.001	0.993
Elective Offerings	<0.001	0.963

Table A-6: Responses to Question A6

A6. Analysis of Plates and Shells	Achievement Level	At Graduation		After 5 Years Exp.	
Round 1		Freq	%	Freq	%
	1-Knowledge	12	36	4	12
	2-Comprehension	12	36	4	12
	3-Application	6	18	10	30
	4-Analysis	2	6	10	30
	5-Synthesis	0	0	3	9
	6-Evaluation	1	3	2	6
	Total	33	100	33	100
Round 2		Freq	%	Freq	%
	1-Knowledge	10	31	3	9
	2-Comprehension	12	38	4	13
	3-Application	7	22	10	31
	4-Analysis	2	6	10	31
	5-Synthesis	0	0	3	9
	6-Evaluation	1	3	2	6
	Total	32	100	32	100
Elective Offerings		Round 1		Round 2	
		Freq	%	Freq	%
	1-Knowledge	3	9	2	6
	2-Comprehension	8	24	9	28
	3-Application	10	30	11	34
	4-Analysis	8	24	6	19
	5-Synthesis	3	9	3	9
	6-Evaluation	1	3	1	3
	Total	33	100	32	100

Opinion Movement		
Round 1- to - Round 2	Symmetric Measures	
	Approx. Sig. (p)	Kendall's tau-b (τ-b)
At Graduation	<0.001	0.922
After 5 Years Experience	<0.001	0.992
Elective Offerings	<0.001	0.967

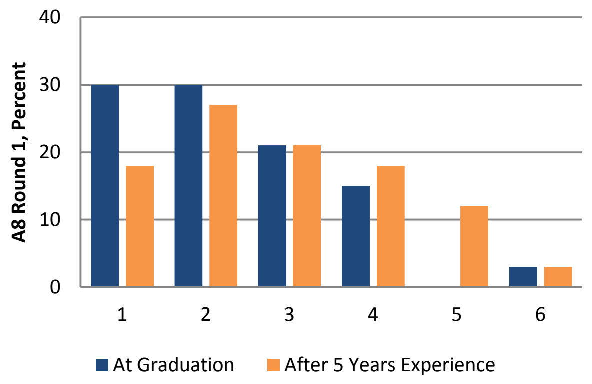
Table A-7: Responses to Question A7

A7. Properties & Behavior of CE Materials	Achievement Level	At Graduation		After 5 Years Exp.	
Round 1		Freq	%	Freq	%
	1-Knowledge	1	3	1	3
	2-Comprehension	11	33	1	3
	3-Application	9	27	4	12
	4-Analysis	9	27	11	33
	5-Synthesis	2	6	7	21
	6-Evaluation	1	3	9	27
	Total	33	100	33	100
Round 2		Freq	%	Freq	%
	1-Knowledge	1	3	0	0
	2-Comprehension	10	31	1	3
	3-Application	10	31	5	16
	4-Analysis	9	28	11	34
	5-Synthesis	1	3	9	28
	6-Evaluation	1	3	6	19
	Total	32	100	32	100
Elective Offerings		Round 1		Round 2	
		Freq	%	Freq	%
	1-Knowledge	2	6	1	3
	2-Comprehension	4	13	5	16
	3-Application	7	22	7	23
	4-Analysis	9	28	11	35
	5-Synthesis	8	25	6	19
	6-Evaluation	2	6	1	3
	Total	32	100	31	100

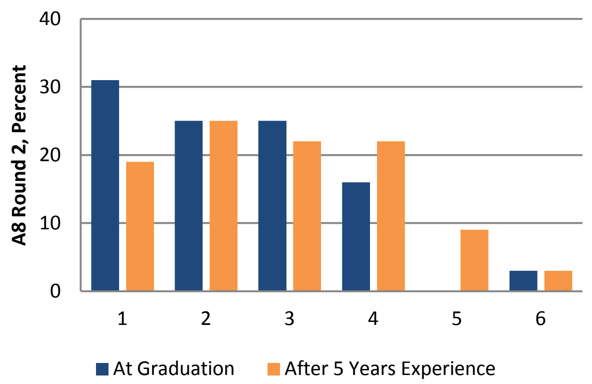
Opinion Movement		
Round 1- to - Round 2	Symmetric Measures	
	Approx. Sig. (p)	Kendall's tau-b (τ-b)
At Graduation	<0.001	0.962
After 5 Years Experience	<0.001	0.961
Elective Offerings	<0.001	0.953

Table A-8: Responses to Question A8

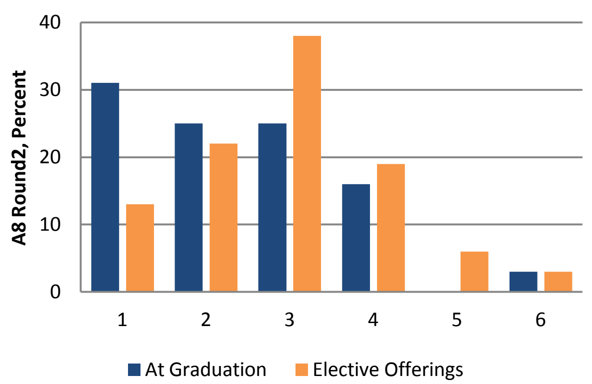
A8. Numerical Methods	Achievement Level	At Graduation		After 5 Years Exp.	
Round 1		Freq	%	Freq	%
	1-Knowledge	10	30	6	18
	2-Comprehension	10	30	9	27
	3-Application	7	21	7	21
	4-Analysis	5	15	6	18
	5-Synthesis	0	0	4	12
	6-Evaluation	1	3	1	3
	Total	33	100	33	100



Round 2	Achievement Level	Freq	%	Freq	%
	1-Knowledge	10	31	6	19
	2-Comprehension	8	25	8	25
	3-Application	8	25	7	22
	4-Analysis	5	16	7	22
	5-Synthesis	0	0	3	9
	6-Evaluation	1	3	1	3
	Total	32	100	32	100



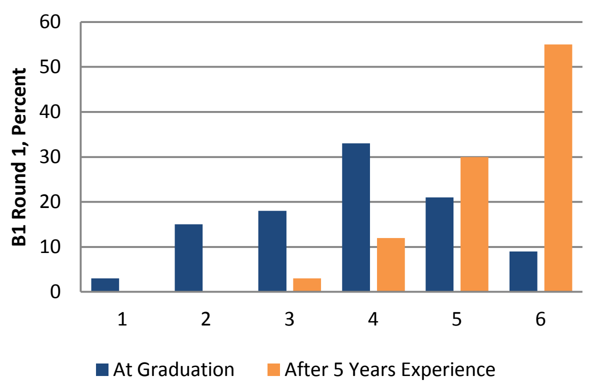
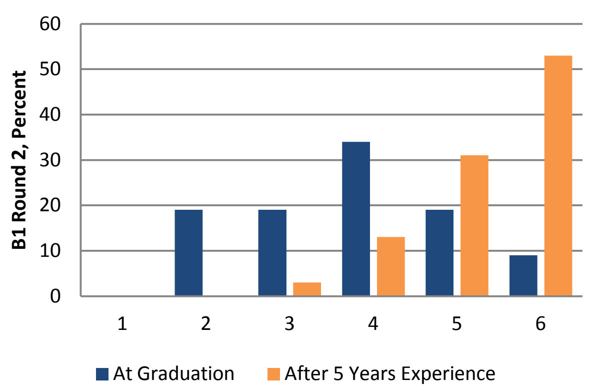
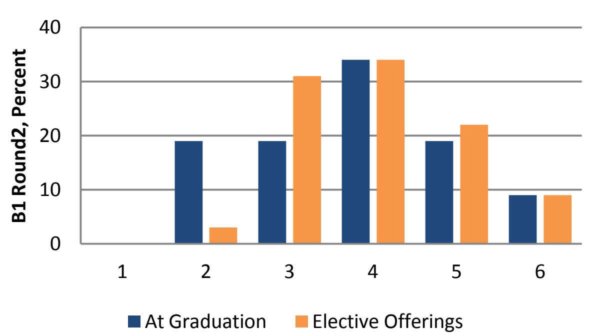
Elective Offerings	Achievement Level	Round 1		Round 2	
		Freq	%	Freq	%
	1-Knowledge	4	12	4	13
	2-Comprehension	7	21	7	22
	3-Application	10	30	12	38
	4-Analysis	7	21	6	19
	5-Synthesis	3	9	2	6
	6-Evaluation	2	6	1	3
	Total	33	100	32	100



Opinion Movement

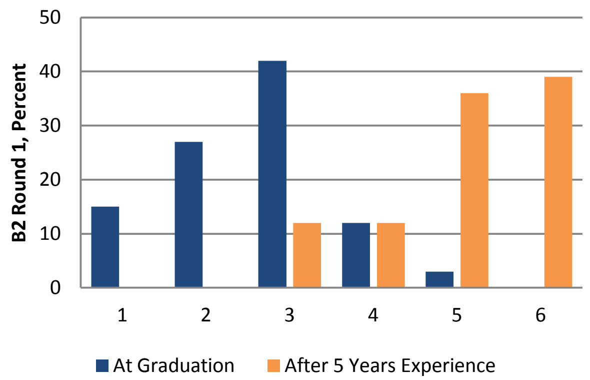
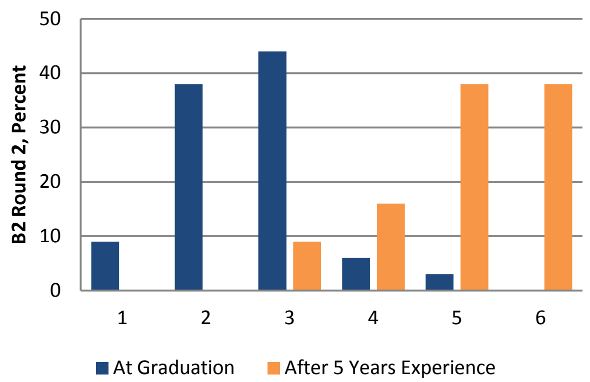
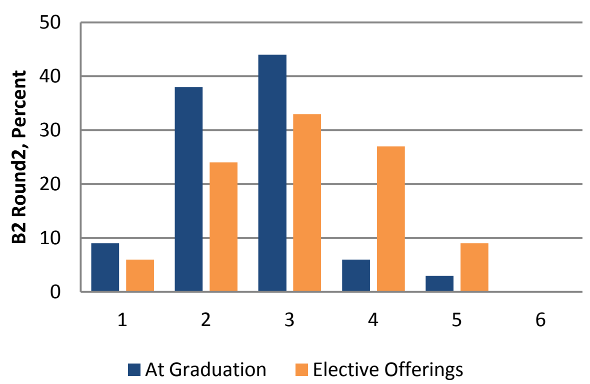
Round 1- to - Round 2	Symmetric Measures	
	Approx. Sig. (p)	Kendall's tau-b (τ-b)
At Graduation	<0.001	0.980
After 5 Years Experience	<0.001	0.989
Elective Offerings	<0.001	0.922

Table A-9: Responses to Question B1

B1. Behavior of Structural Systems, Load Path	Achievement Level	At Graduation		After 5 Years Exp.	
Round 1		Freq	%	Freq	%
	1-Knowledge	1	3	0	0
	2-Comprehension	5	15	0	0
	3-Application	6	18	1	3
	4-Analysis	11	33	4	12
	5-Synthesis	7	21	10	30
	6-Evaluation	3	9	18	55
	Total	33	100	33	100
Round 2		Freq	%	Freq	%
	1-Knowledge	0	0	0	0
	2-Comprehension	6	19	0	0
	3-Application	6	19	1	3
	4-Analysis	11	34	4	13
	5-Synthesis	6	19	10	31
	6-Evaluation	3	9	17	53
	Total	32	100	32	100
Elective Offerings		Round 1		Round 2	
		Freq	%	Freq	%
	1-Knowledge	0	0	0	0
	2-Comprehension	1	3	1	3
	3-Application	10	30	10	31
	4-Analysis	11	33	11	34
	5-Synthesis	6	18	7	22
	6-Evaluation	5	15	3	9
	Total	33	100	32	100

Opinion Movement		
Round 1- to - Round 2	Symmetric Measures	
	Approx. Sig. (p)	Kendall's tau-b (τ-b)
At Graduation	<0.001	0.994
After 5 Years Experience	<0.001	1.000
Elective Offerings	<0.001	0.988

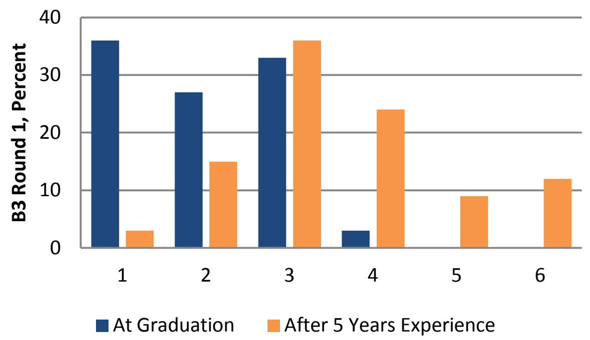
Table A-10: Responses to Question B2

B2. Building Codes and General Requirements	Achievement Level	At Graduation		After 5 Years Exp.	
Round 1		Freq	%	Freq	%
	1-Knowledge	5	15	0	0
	2-Comprehension	9	27	0	0
	3-Application	14	42	4	12
	4-Analysis	4	12	4	12
	5-Synthesis	1	3	12	36
	6-Evaluation	0	0	13	39
	Total	33	100	33	100
Round 2		Freq	%	Freq	%
	1-Knowledge	3	9	0	0
	2-Comprehension	12	38	0	0
	3-Application	14	44	3	9
	4-Analysis	2	6	5	16
	5-Synthesis	1	3	12	38
	6-Evaluation	0	0	12	38
	Total	32	100	32	100
Elective Offerings		Round 1		Round 2	
		Freq	%	Freq	%
	1-Knowledge	1	3	2	6
	2-Comprehension	9	28	8	24
	3-Application	11	34	11	33
	4-Analysis	9	28	9	27
	5-Synthesis	2	6	3	9
	6-Evaluation	0	0	0	0
	Total	32	100	33	100

Opinion Movement		
Round 1- to - Round 2	Symmetric Measures	
	Approx. Sig. (p)	Kendall's tau-b (τ-b)
At Graduation	<0.001	0.924
After 5 Years Experience	<0.001	0.990
Elective Offerings	<0.001	0.975

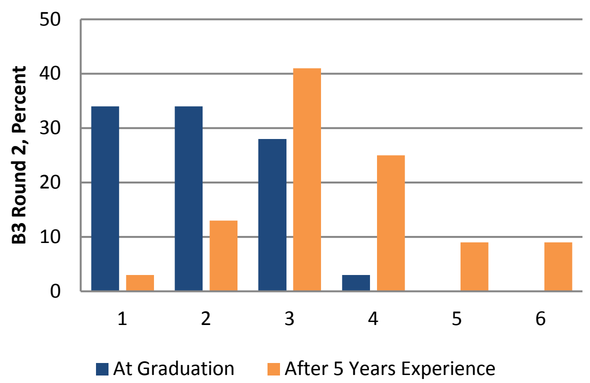
Table A-11: Responses to Question B3

B3. Architectural/Aesthetics Considerations	Achievement Level	At Graduation		After 5 Years Exp.	
Round 1		Freq	%	Freq	%



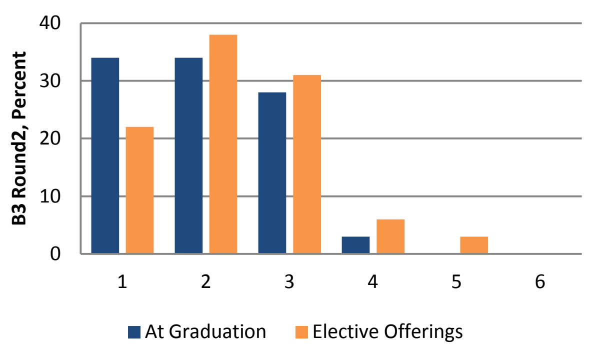
Achievement Level	Freq	%	Freq	%
1-Knowledge	12	36	1	3
2-Comprehension	9	27	5	15
3-Application	11	33	12	36
4-Analysis	1	3	8	24
5-Synthesis	0	0	3	9
6-Evaluation	0	0	4	12
Total	33	100	33	100

Round 2	Freq	%	Freq	%



Achievement Level	Freq	%	Freq	%
1-Knowledge	11	34	1	3
2-Comprehension	11	34	4	13
3-Application	9	28	13	41
4-Analysis	1	3	8	25
5-Synthesis	0	0	3	9
6-Evaluation	0	0	3	9
Total	32	100	32	100

Elective Offerings	Round 1		Round 2	
	Freq	%	Freq	%

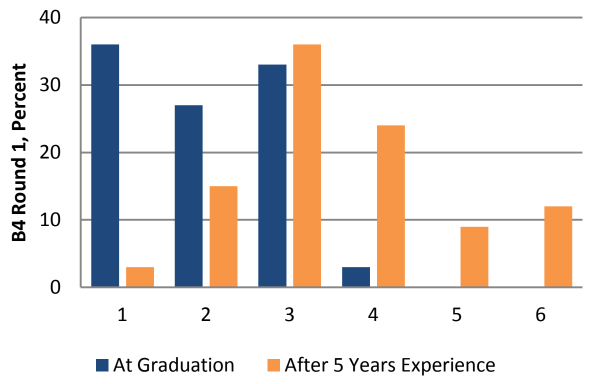


Achievement Level	Freq	%	Freq	%
1-Knowledge	7	21	7	22
2-Comprehension	12	36	12	38
3-Application	10	30	10	31
4-Analysis	3	9	2	6
5-Synthesis	1	3	1	3
6-Evaluation	0	0	0	0
Total	33	100	32	100

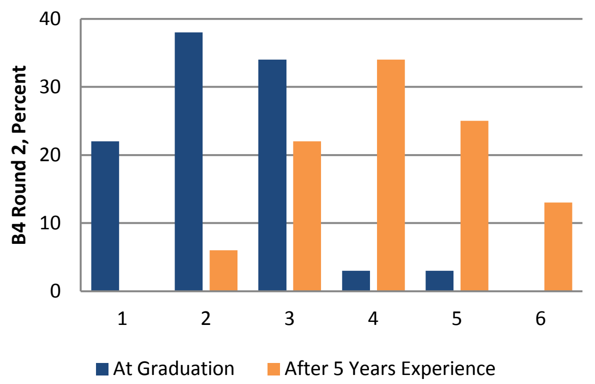
Opinion Movement		
Round 1- to - Round 2	Symmetric Measures	
	Approx. Sig. (p)	Kendall's tau-b (τ-b)
At Graduation	<0.001	0.944
After 5 Years Experience	<0.001	0.973
Elective Offerings	<0.001	1.000

Table A-12: Responses to Question B4

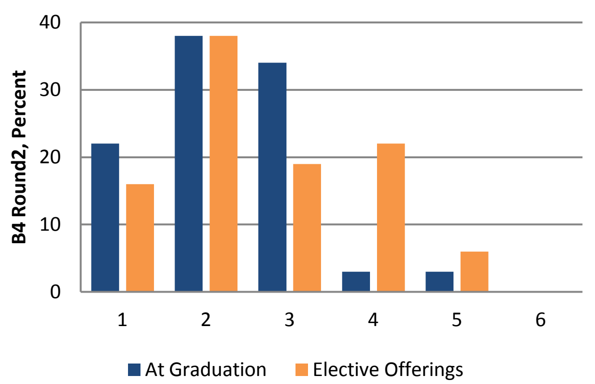
B4. Conceptual and Preliminary Planning	Achievement Level	At Graduation		After 5 Years Exp.	
Round 1		Freq	%	Freq	%
	1-Knowledge	8	36	0	3
	2-Comprehension	11	27	3	15
	3-Application	11	33	7	36
	4-Analysis	2	3	11	24
	5-Synthesis	1	0	8	9
	6-Evaluation	0	0	4	12
	Total	33	100	33	100



	Achievement Level	At Graduation		After 5 Years Exp.	
Round 2		Freq	%	Freq	%
	1-Knowledge	7	22	0	0
	2-Comprehension	12	38	2	6
	3-Application	11	34	7	22
	4-Analysis	1	3	11	34
	5-Synthesis	1	3	8	25
	6-Evaluation	0	0	4	13
	Total	32	100	32	100



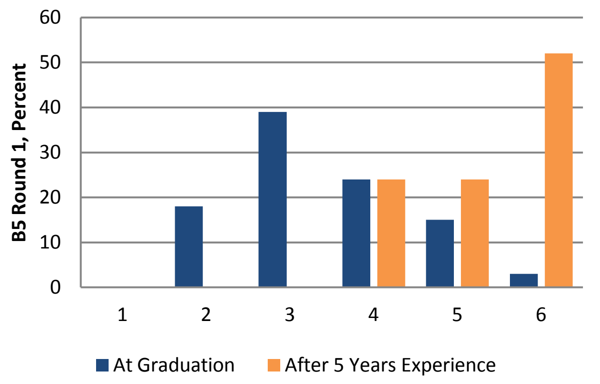
Elective Offerings		Round 1		Round 2	
		Freq	%	Freq	%
	1-Knowledge	5	15	5	16
	2-Comprehension	12	36	12	38
	3-Application	6	18	6	19
	4-Analysis	7	21	7	22
	5-Synthesis	3	9	2	6
	6-Evaluation	0	0	0	0
	Total	33	100	32	100



Opinion Movement		
Round 1- to - Round 2	Symmetric Measures	
	Approx. Sig. (p)	Kendall's tau-b (τ-b)
At Graduation	<0.001	0.960
After 5 Years Experience	<0.001	0.969
Elective Offerings	<0.001	0.990

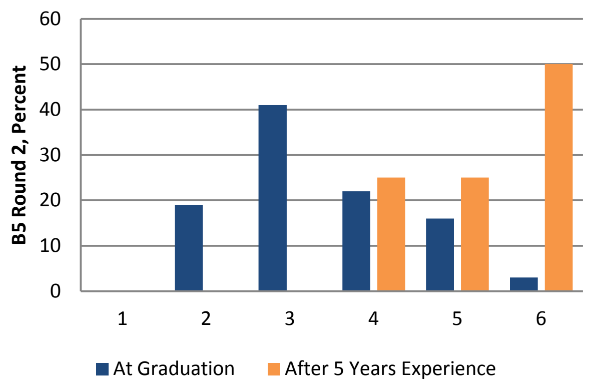
Table A-13: Responses to Question B5

B5. Design Loads, Including Evaluation	Achievement Level	At Graduation		After 5 Years Exp.	
Round 1		Freq	%	Freq	%



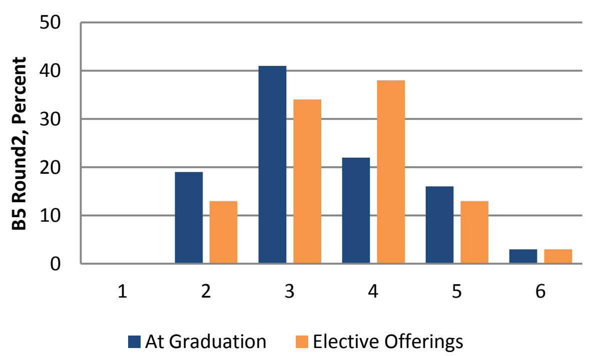
Achievement Level	Freq	%	Freq	%
1-Knowledge	0	0	0	0
2-Comprehension	6	18	0	0
3-Application	13	39	0	0
4-Analysis	8	24	8	24
5-Synthesis	5	15	8	24
6-Evaluation	1	3	17	52
Total	33	100	33	100

Round 2	Freq	%	Freq	%



Achievement Level	Freq	%	Freq	%
1-Knowledge	0	0	0	0
2-Comprehension	6	19	0	0
3-Application	13	41	0	0
4-Analysis	7	22	8	25
5-Synthesis	5	16	8	25
6-Evaluation	1	3	16	50
Total	32	100	32	100

Elective Offerings	Round 1		Round 2	
	Freq	%	Freq	%

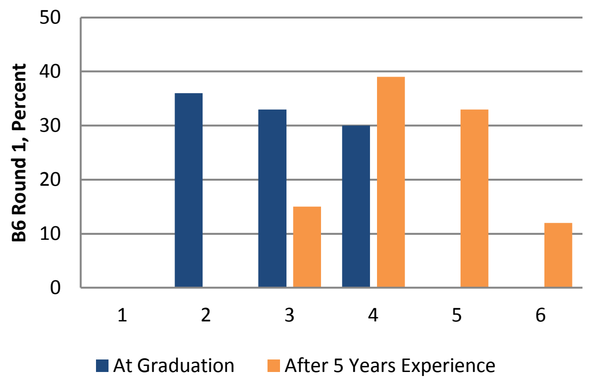


Achievement Level	Freq	%	Freq	%
1-Knowledge	0	0	0	0
2-Comprehension	4	12	4	13
3-Application	11	33	11	34
4-Analysis	10	30	12	38
5-Synthesis	5	15	4	13
6-Evaluation	3	9	1	3
Total	33	100	32	100

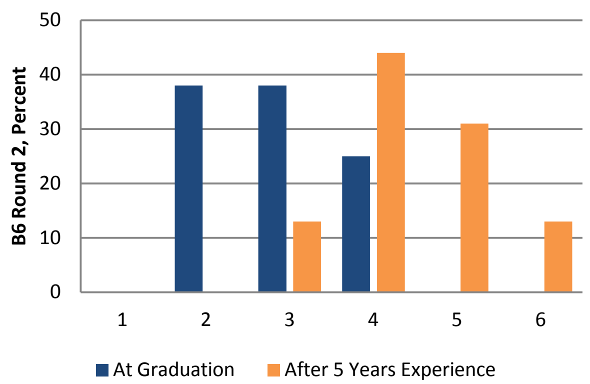
Opinion Movement		
Round 1- to - Round 2	Symmetric Measures	
	Approx. Sig. (p)	Kendall's tau-b (τ-b)
At Graduation	<0.001	0.959
After 5 Years Experience	<0.001	1.000
Elective Offerings	<0.001	0.944

Table A-14: Responses to Question B6

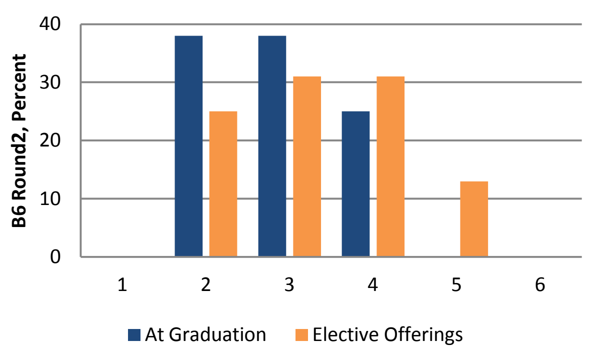
B6. Foundations and Geotechnical	Achievement Level	At Graduation		After 5 Years Exp.	
Round 1		Freq	%	Freq	%
	1-Knowledge	0	0	0	0
	2-Comprehension	12	36	0	0
	3-Application	11	33	5	15
	4-Analysis	10	30	13	39
	5-Synthesis	0	0	11	33
	6-Evaluation	0	0	4	12
	Total	33	100	33	100



Round 2		Freq	%	Freq	%
	1-Knowledge	0	0	0	0
	2-Comprehension	12	38	0	0
	3-Application	12	38	4	13
	4-Analysis	8	25	14	44
	5-Synthesis	0	0	10	31
	6-Evaluation	0	0	4	13
	Total	32	100	32	100



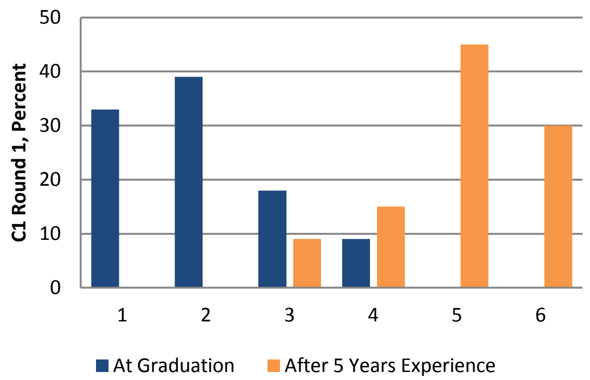
Elective Offerings		Round 1		Round 2	
		Freq	%	Freq	%
	1-Knowledge	0	0	0	0
	2-Comprehension	9	27	8	25
	3-Application	8	24	10	31
	4-Analysis	10	30	10	31
	5-Synthesis	4	12	4	13
	6-Evaluation	2	6	0	0
	Total	33	100	32	100



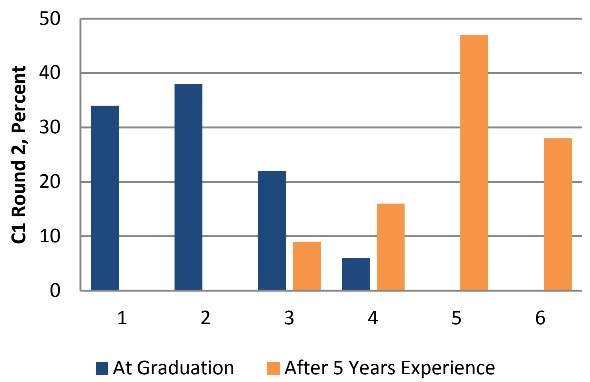
Opinion Movement		
Round 1- to - Round 2	Symmetric Measures	
	Approx. Sig. (p)	Kendall's tau-b (τ-b)
At Graduation	<0.001	0.939
After 5 Years Experience	<0.001	0.976
Elective Offerings	<0.001	0.922

Table A-15: Responses to Question C1

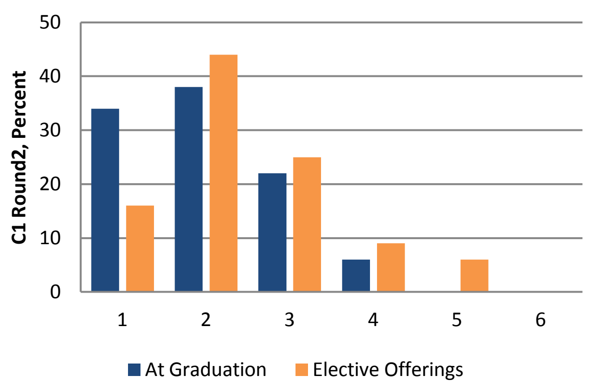
C1. Project Plans and Specifications	Achievement Level	At Graduation		After 5 Years Exp.	
Round 1		Freq	%	Freq	%
	1-Knowledge	11	33	0	0
	2-Comprehension	13	39	0	0
	3-Application	6	18	3	9
	4-Analysis	3	9	5	15
	5-Synthesis	0	0	15	45
	6-Evaluation	0	0	10	30
	Total	33	100	33	100



Round 2	Achievement Level	Freq	%	Freq	%
	1-Knowledge	11	34	0	0
	2-Comprehension	12	38	0	0
	3-Application	7	22	3	9
	4-Analysis	2	6	5	16
	5-Synthesis	0	0	15	47
	6-Evaluation	0	0	9	28
	Total	32	100	32	100



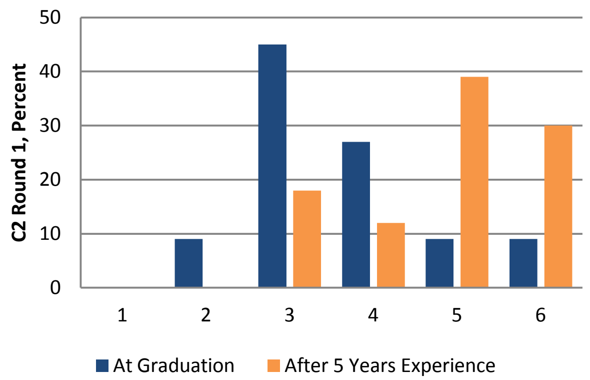
Elective Offerings	Achievement Level	Round 1		Round 2	
		Freq	%	Freq	%
	1-Knowledge	6	18	5	16
	2-Comprehension	13	39	14	44
	3-Application	8	24	8	25
	4-Analysis	4	12	3	9
	5-Synthesis	2	6	2	6
	6-Evaluation	0	0	0	0
	Total	33	100	32	100



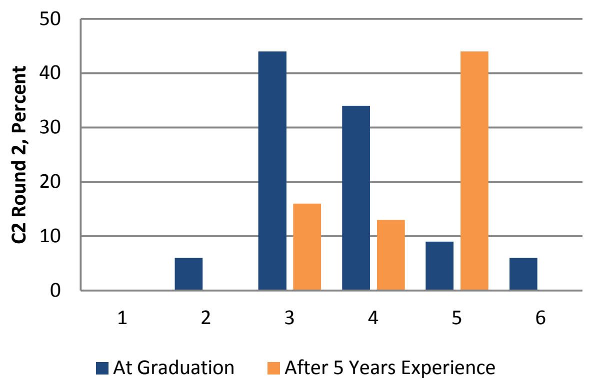
Opinion Movement		
Round 1- to - Round 2	Symmetric Measures	
	Approx. Sig. (p)	Kendall's tau-b (τ-b)
At Graduation	<0.001	1.000
After 5 Years Experience	<0.001	1.000
Elective Offerings	<0.001	0.962

Table A-16: Responses to Question C2

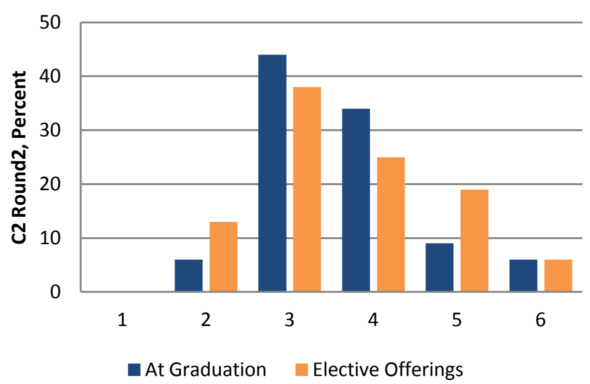
C2. Communication Software & Tools	Achievement Level	At Graduation		After 5 Years Exp.	
Round 1		Freq	%	Freq	%
	1-Knowledge	0	0	0	0
	2-Comprehension	3	9	0	0
	3-Application	15	45	6	18
	4-Analysis	9	27	4	12
	5-Synthesis	3	9	13	39
	6-Evaluation	3	9	10	30
	Total	33	100	33	100



Round 2	Achievement Level	Freq	%	Freq	%
	1-Knowledge	0	0	0	0
	2-Comprehension	2	6	0	0
	3-Application	14	44	5	16
	4-Analysis	11	34	4	13
	5-Synthesis	3	9	14	44
	6-Evaluation	2	6	9	28
	Total	32	100	32	100



Elective Offerings		Round 1		Round 2	
		Freq	%	Freq	%
	1-Knowledge	0	0	0	0
	2-Comprehension	4	12	4	13
	3-Application	12	36	12	38
	4-Analysis	6	18	8	25
	5-Synthesis	6	18	6	19
	6-Evaluation	5	15	2	6
	Total	33	100	32	100

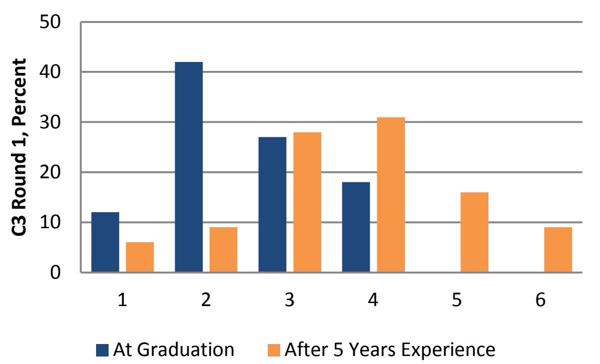


Opinion Movement

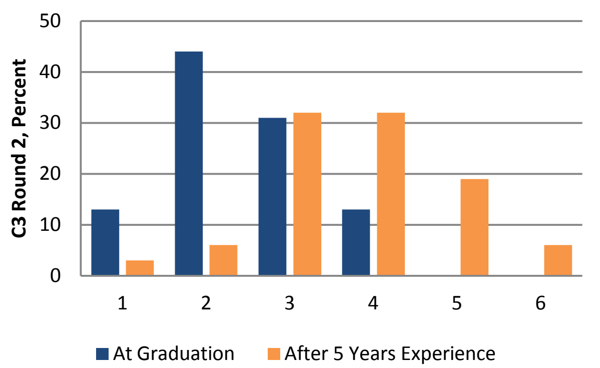
Round 1- to - Round 2	Symmetric Measures	
	Approx. Sig. (p)	Kendall's tau-b (τ-b)
At Graduation	<0.001	0.913
After 5 Years Experience	<0.001	0.952
Elective Offerings	<0.001	0.936

Table A-17: Responses to Question C3

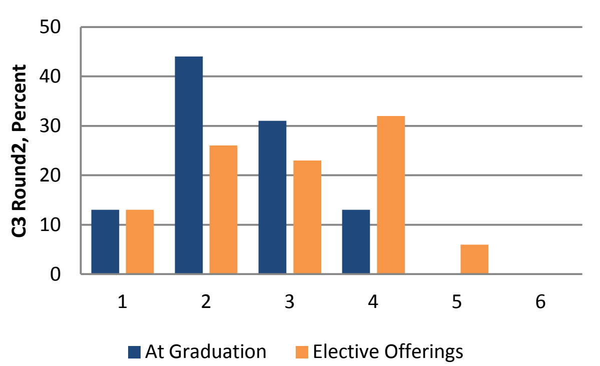
C3. Computer Graphics	Achievement Level	At Graduation		After 5 Years Exp.	
Round 1		Freq	%	Freq	%
	1-Knowledge	4	12	2	6
	2-Comprehension	14	42	3	9
	3-Application	9	27	9	28
	4-Analysis	6	18	10	31
	5-Synthesis	0	0	5	16
	6-Evaluation	0	0	3	9
	Total	33	100	32	100



Round 2		Freq	%	Freq	%
	1-Knowledge	4	13	1	3
	2-Comprehension	14	44	2	6
	3-Application	10	31	10	32
	4-Analysis	4	13	10	32
	5-Synthesis	0	0	6	19
	6-Evaluation	0	0	2	6
	Total	32	100	31	100



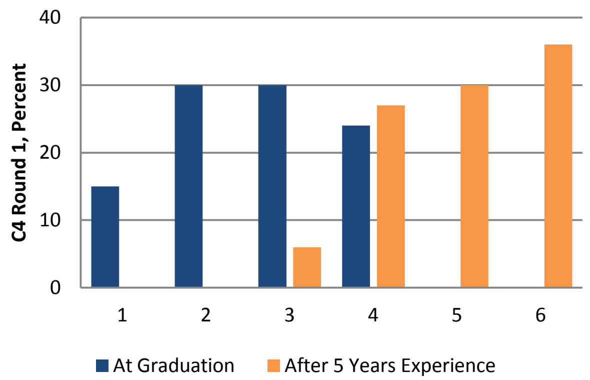
Elective Offerings		Round 1		Round 2	
		Freq	%	Freq	%
	1-Knowledge	4	13	4	13
	2-Comprehension	8	25	8	26
	3-Application	7	22	7	23
	4-Analysis	9	28	10	32
	5-Synthesis	3	9	2	6
	6-Evaluation	1	3	0	0
	Total	32	100	31	100



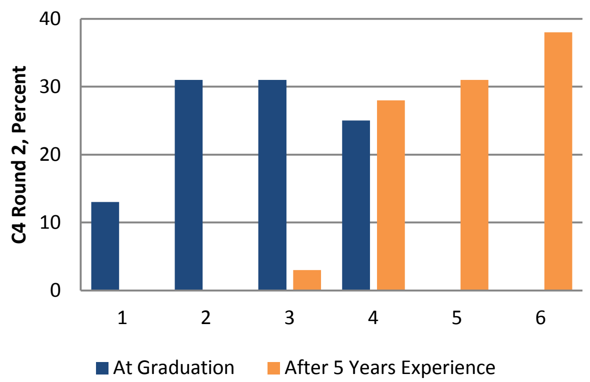
Opinion Movement		
Round 1- to - Round 2	Symmetric Measures	
	Approx. Sig. (p)	Kendall's tau-b (τ-b)
At Graduation	<0.001	0.981
After 5 Years Experience	<0.001	0.939
Elective Offerings	<0.001	0.985

Table A-18: Responses to Question C4

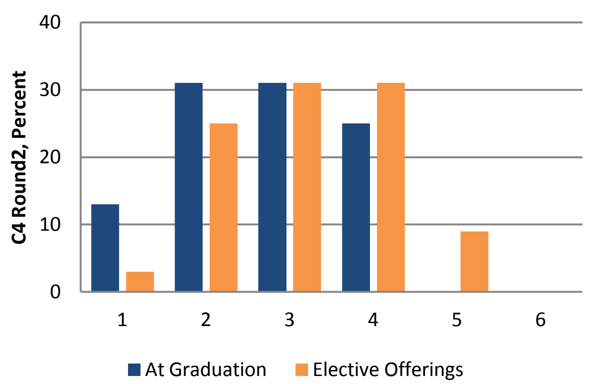
C4. Structural Engineering Design Software	Achievement Level	At Graduation		After 5 Years Exp.	
Round 1		Freq	%	Freq	%
	1-Knowledge	5	15	0	0
	2-Comprehension	10	30	0	0
	3-Application	10	30	2	6
	4-Analysis	8	24	9	27
	5-Synthesis	0	0	10	30
	6-Evaluation	0	0	12	36
	Total	33	100	33	100



Round 2	Achievement Level	Freq	%	Freq	%
	1-Knowledge	4	13	0	0
	2-Comprehension	10	31	0	0
	3-Application	10	31	1	3
	4-Analysis	8	25	9	28
	5-Synthesis	0	0	10	31
	6-Evaluation	0	0	12	38
	Total	32	100	32	100



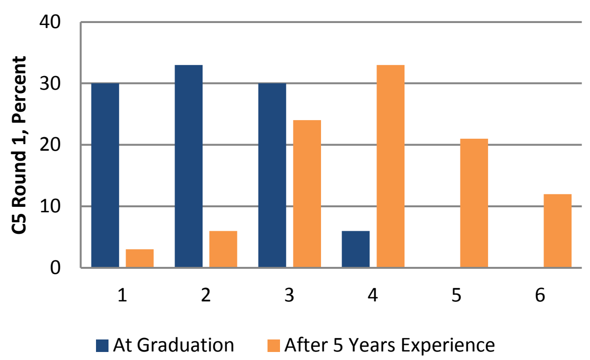
Elective Offerings	Achievement Level	Round 1		Round 2	
		Freq	%	Freq	%
	1-Knowledge	3	9	1	3
	2-Comprehension	6	18	8	25
	3-Application	10	30	10	31
	4-Analysis	8	24	10	31
	5-Synthesis	5	15	3	9
	6-Evaluation	1	3	0	0
	Total	33	100	32	100



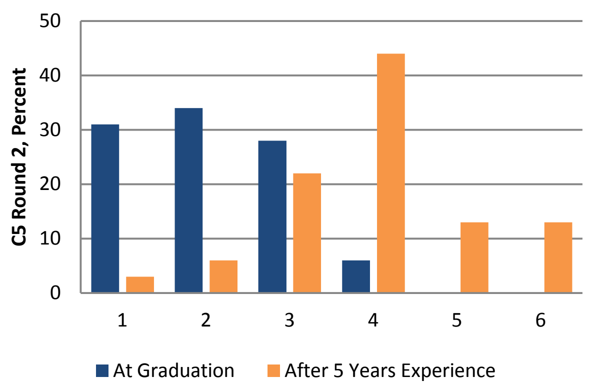
Opinion Movement		
Round 1- to - Round 2	Symmetric Measures	
	Approx. Sig. (p)	Kendall's tau-b (τ-b)
At Graduation	<0.001	0.937
After 5 Years Experience	<0.001	0.987
Elective Offerings	<0.001	0.941

Table A-19: Responses to Question C5

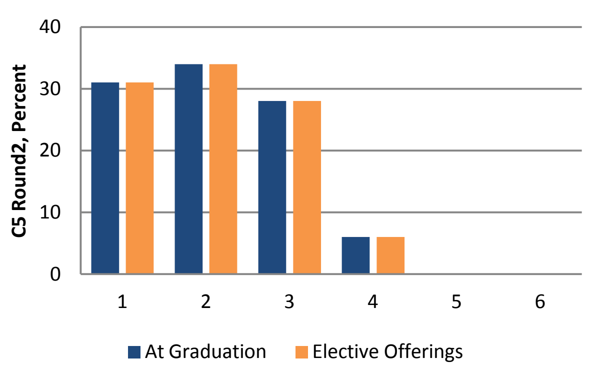
C5. Building Information Management (BIM) Systems	Achievement Level	At Graduation		After 5 Years Exp.	
Round 1		Freq	%	Freq	%



	Achievement Level	Freq	%	Freq	%
	1-Knowledge	10	30	1	3
	2-Comprehension	11	33	2	6
	3-Application	10	30	8	24
	4-Analysis	2	6	11	33
	5-Synthesis	0	0	7	21
	6-Evaluation	0	0	4	12
	Total	33	100	33	100
Round 2		Freq	%	Freq	%



	Achievement Level	Freq	%	Freq	%
	1-Knowledge	10	31	1	3
	2-Comprehension	11	34	2	6
	3-Application	9	28	7	22
	4-Analysis	2	6	14	44
	5-Synthesis	0	0	4	13
	6-Evaluation	0	0	4	13
	Total	32	100	32	100
Elective Offerings		Round 1		Round 2	
		Freq	%	Freq	%

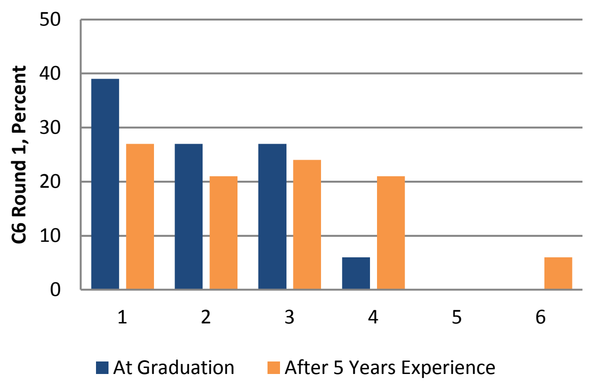


	Achievement Level	Freq	%	Freq	%
	1-Knowledge	7	21	10	31
	2-Comprehension	9	27	11	34
	3-Application	9	27	9	28
	4-Analysis	5	15	2	6
	5-Synthesis	2	6	0	0
	6-Evaluation	1	3	0	0
	Total	33	100	32	100

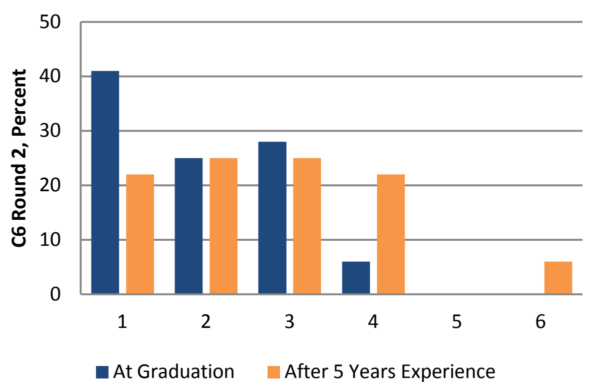
Opinion Movement		
Round 1- to - Round 2	Symmetric Measures	
	Approx. Sig. (p)	Kendall's tau-b (τ-b)
At Graduation	<0.001	0.961
After 5 Years Experience	<0.001	0.953
Elective Offerings	<0.001	0.910

Table A-20: Responses to Question C6

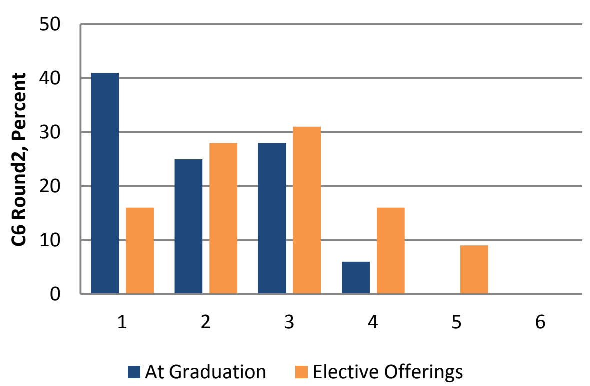
C6. Programming Skills	Achievement Level	At Graduation		After 5 Years Exp.	
Round 1		Freq	%	Freq	%
	1-Knowledge	13	39	9	27
	2-Comprehension	9	27	7	21
	3-Application	9	27	8	24
	4-Analysis	2	6	7	21
	5-Synthesis	0	0	0	0
	6-Evaluation	0	0	2	6
	Total	33	100	33	100



Round 2		Freq	%	Freq	%
	1-Knowledge	13	41	7	22
	2-Comprehension	8	25	8	25
	3-Application	9	28	8	25
	4-Analysis	2	6	7	22
	5-Synthesis	0	0	0	0
	6-Evaluation	0	0	2	6
	Total	32	100	32	100



Elective Offerings		Round 1		Round 2	
		Freq	%	Freq	%
	1-Knowledge	7	21	5	16
	2-Comprehension	7	21	9	28
	3-Application	10	30	10	31
	4-Analysis	5	15	5	16
	5-Synthesis	3	9	3	9
	6-Evaluation	1	3	0	0
	Total	33	100	32	100

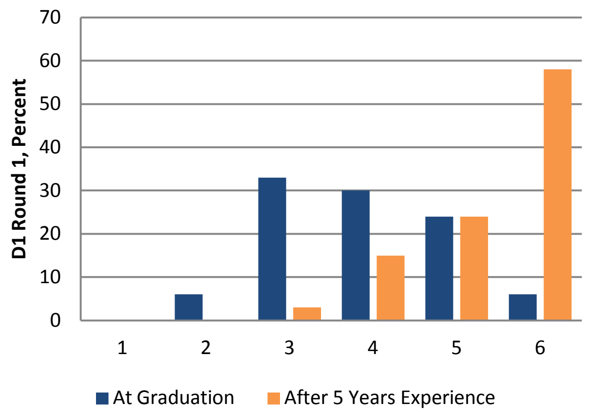


Opinion Movement

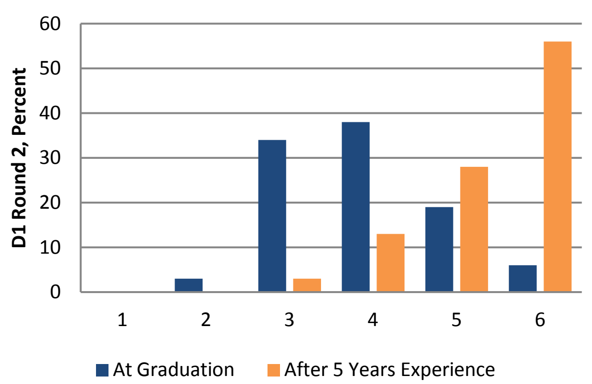
Round 1- to - Round 2	Symmetric Measures	
	Approx. Sig. (p)	Kendall's tau-b (τ-b)
At Graduation	<0.001	0.941
After 5 Years Experience	<0.001	0.967
Elective Offerings	<0.001	0.970

Table A-21: Responses to Question D1

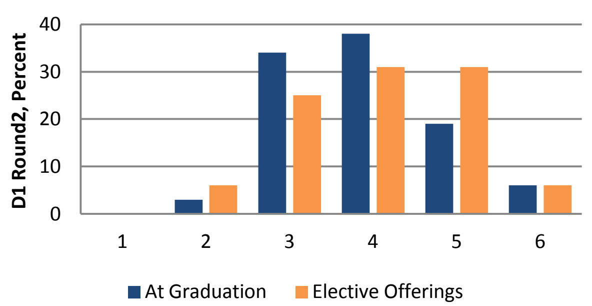
D1. Structural Steel Design - Basics	Achievement Level	At Graduation Freq	At Graduation %	After 5 Years Exp. Freq	After 5 Years Exp. %
Round 1		Freq	%	Freq	%
	1-Knowledge	0	0	0	0
	2-Comprehension	2	6	0	0
	3-Application	11	33	1	3
	4-Analysis	10	30	5	15
	5-Synthesis	8	24	8	24
	6-Evaluation	2	6	19	58
	Total	33	100	33	100



Round 2	Achievement Level	At Graduation Freq	At Graduation %	After 5 Years Exp. Freq	After 5 Years Exp. %
	1-Knowledge	0	0	0	0
	2-Comprehension	1	3	0	0
	3-Application	11	34	1	3
	4-Analysis	12	38	4	13
	5-Synthesis	6	19	9	28
	6-Evaluation	2	6	18	56
	Total	32	100	32	100



Elective Offerings	Achievement Level	Round 1 Freq	Round 1 %	Round 2 Freq	Round 2 %
	1-Knowledge	0	0	0	0
	2-Comprehension	3	9	2	6
	3-Application	7	21	8	25
	4-Analysis	10	30	10	31
	5-Synthesis	10	30	10	31
	6-Evaluation	3	9	2	6
	Total	33	100	32	100

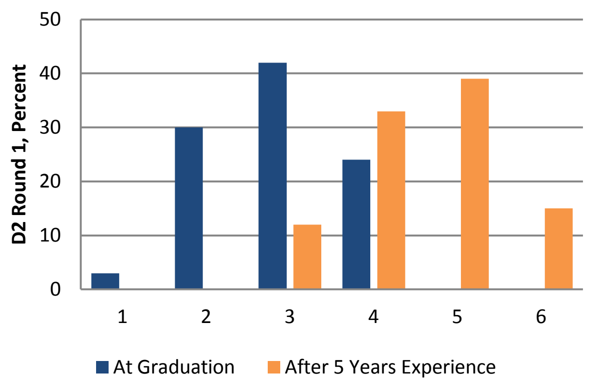


Opinion Movement

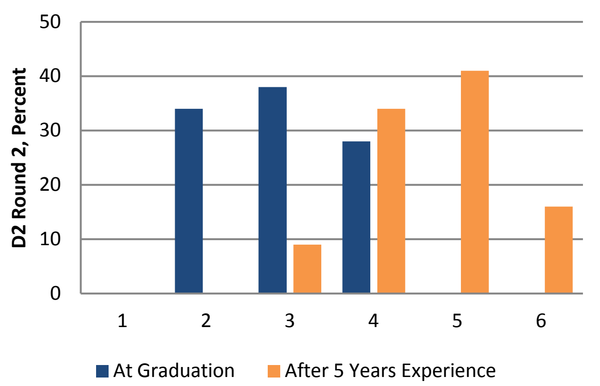
Round 1- to - Round 2	Symmetric Measures: Approx. Sig. (p)	Symmetric Measures: Kendall's tau-b (τ-b)
At Graduation	<0.001	0.935
After 5 Years Experience	<0.001	0.980
Elective Offerings	<0.001	0.974

Table A-22: Responses to Question D2

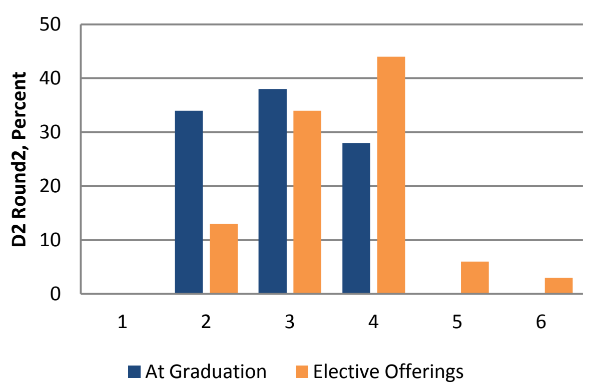
D2. Structural Steel – Advanced	Achievement Level	At Graduation		After 5 Years Exp.	
Round 1		Freq	%	Freq	%
	1-Knowledge	1	3	0	0
	2-Comprehension	10	30	0	0
	3-Application	14	42	4	12
	4-Analysis	8	24	11	33
	5-Synthesis	0	0	13	39
	6-Evaluation	0	0	5	15
	Total	33	100	33	100



Round 2	Achievement Level	Freq	%	Freq	%
	1-Knowledge	0	0	0	0
	2-Comprehension	11	34	0	0
	3-Application	12	38	3	9
	4-Analysis	9	28	11	34
	5-Synthesis	0	0	13	41
	6-Evaluation	0	0	5	16
	Total	32	100	32	100



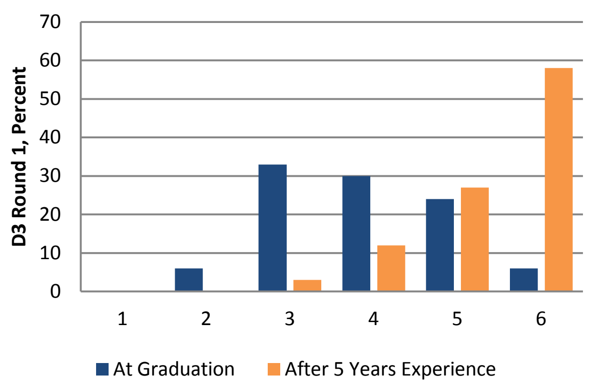
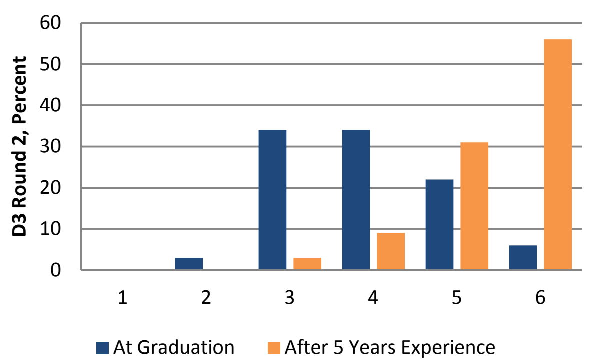
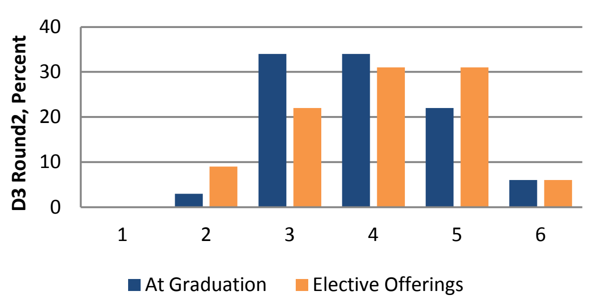
Elective Offerings	Achievement Level	Round 1		Round 2	
		Freq	%	Freq	%
	1-Knowledge	0	0	0	0
	2-Comprehension	5	15	4	13
	3-Application	10	30	11	34
	4-Analysis	12	36	14	44
	5-Synthesis	4	12	2	6
	6-Evaluation	2	6	1	3
	Total	33	100	32	100



Opinion Movement

Round 1- to - Round 2	Symmetric Measures	
	Approx. Sig. (p)	Kendall's tau-b (τ-b)
At Graduation	<0.001	0.956
After 5 Years Experience	<0.001	0.982
Elective Offerings	<0.001	0.942

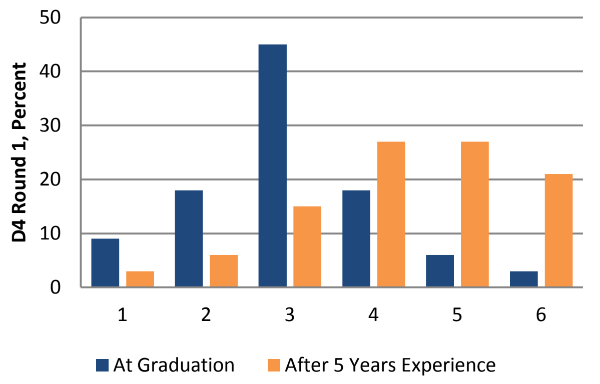
Table A-23: Responses to Question D3

D3. Reinforced Concrete Design - Basics	Achievement Level	At Graduation		After 5 Years Exp.	
Round 1		Freq	%	Freq	%
	1-Knowledge	0	0	0	0
	2-Comprehension	2	6	0	0
	3-Application	11	33	1	3
	4-Analysis	10	30	4	12
	5-Synthesis	8	24	9	27
	6-Evaluation	2	6	19	58
	Total	33	100	33	100
Round 2		Freq	%	Freq	%
	1-Knowledge	0	0	0	0
	2-Comprehension	1	3	0	0
	3-Application	11	34	1	3
	4-Analysis	11	34	3	9
	5-Synthesis	7	22	10	31
	6-Evaluation	2	6	18	56
	Total	32	100	32	100
Elective Offerings		Round 1		Round 2	
		Freq	%	Freq	%
	1-Knowledge	0	0	0	0
	2-Comprehension	3	9	3	9
	3-Application	7	21	7	22
	4-Analysis	10	30	10	31
	5-Synthesis	10	30	10	31
	6-Evaluation	3	9	2	6
	Total	33	100	32	100

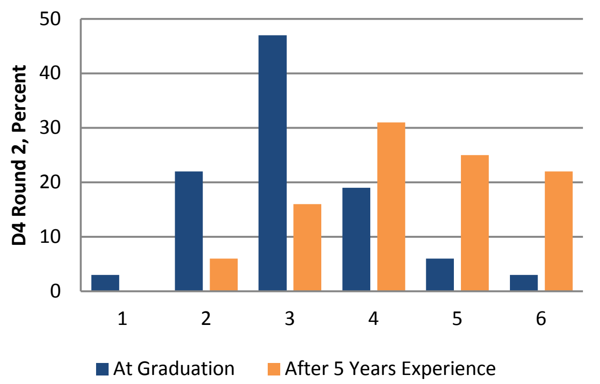
Opinion Movement		
Round 1- to - Round 2	Symmetric Measures	
	Approx. Sig. (p)	Kendall's tau-b (τ-b)
At Graduation	<0.001	0.958
After 5 Years Experience	<0.001	0.980
Elective Offerings	<0.001	0.986

Table A-24: Responses to Question D4

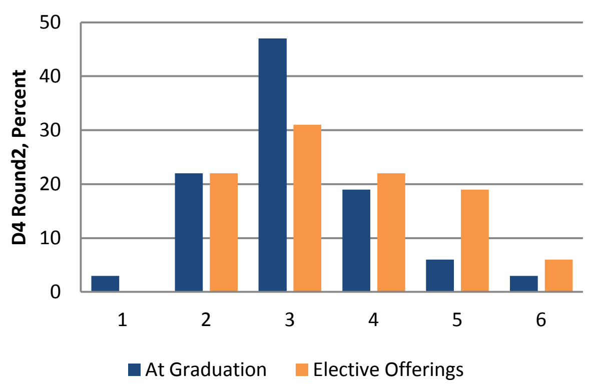
D4. Prestressed Concrete Design	Achievement Level	At Graduation		After 5 Years Exp.	
Round 1		Freq	%	Freq	%
	1-Knowledge	3	9	1	3
	2-Comprehension	6	18	2	6
	3-Application	15	45	5	15
	4-Analysis	6	18	9	27
	5-Synthesis	2	6	9	27
	6-Evaluation	1	3	7	21
	Total	33	100	33	100



D4. Prestressed Concrete Design	Achievement Level	At Graduation		After 5 Years Exp.	
Round 2		Freq	%	Freq	%
	1-Knowledge	1	3	0	0
	2-Comprehension	7	22	2	6
	3-Application	15	47	5	16
	4-Analysis	6	19	10	31
	5-Synthesis	2	6	8	25
	6-Evaluation	1	3	7	22
	Total	32	100	32	100



Elective Offerings	Achievement Level	Round 1		Round 2	
		Freq	%	Freq	%
	1-Knowledge	1	3	0	0
	2-Comprehension	7	21	7	22
	3-Application	9	27	10	31
	4-Analysis	7	21	7	22
	5-Synthesis	6	18	6	19
	6-Evaluation	3	9	2	6
	Total	33	100	32	100

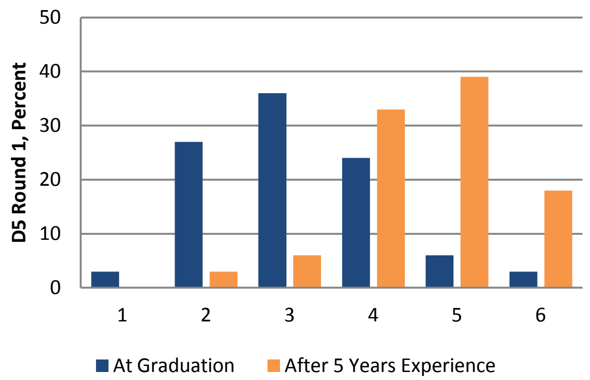


Opinion Movement

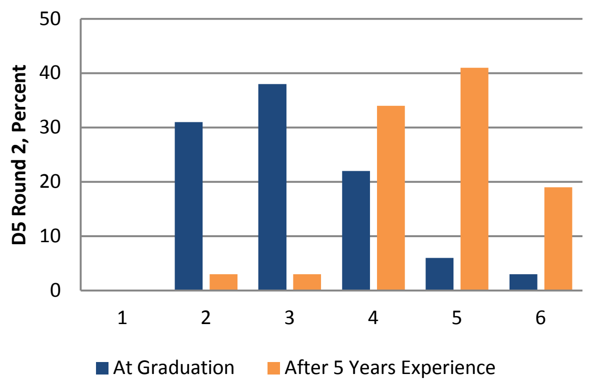
Round 1- to - Round 2	Symmetric Measures	
	Approx. Sig. (p)	Kendall's tau-b (τ-b)
At Graduation	<0.001	0.958
After 5 Years Experience	<0.001	0.968
Elective Offerings	<0.001	0.965

Table A-25: Responses to Question D5

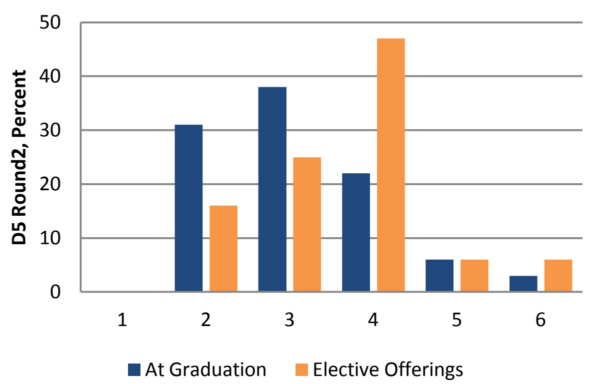
D5. Reinforced Concrete – Advanced	Achievement Level	At Graduation		After 5 Years Exp.	
Round 1		Freq	%	Freq	%
	1-Knowledge	1	3	0	0
	2-Comprehension	9	27	1	3
	3-Application	12	36	2	6
	4-Analysis	8	24	11	33
	5-Synthesis	2	6	13	39
	6-Evaluation	1	3	6	18
	Total	33	100	33	100



Round 2	Achievement Level	Freq	%	Freq	%
	1-Knowledge	0	0	0	0
	2-Comprehension	10	31	1	3
	3-Application	12	38	1	3
	4-Analysis	7	22	11	34
	5-Synthesis	2	6	13	41
	6-Evaluation	1	3	6	19
	Total	32	100	32	100



Elective Offerings		Round 1		Round 2	
		Freq	%	Freq	%
	1-Knowledge	0	0	0	0
	2-Comprehension	5	15	5	16
	3-Application	8	24	8	25
	4-Analysis	12	36	15	47
	5-Synthesis	5	15	2	6
	6-Evaluation	3	9	2	6
	Total	33	100	32	100

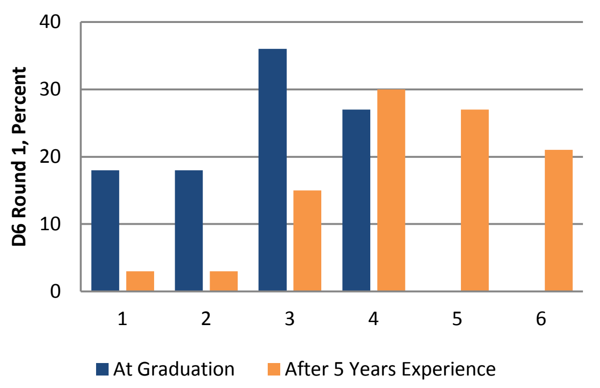


Opinion Movement		
Round 1- to - Round 2	Symmetric Measures	
	Approx. Sig. (p)	Kendall's tau-b (τ-b)
At Graduation	<0.001	0.964
After 5 Years Experience	<0.001	0.984
Elective Offerings	<0.001	0.944

Table A-26: Responses to Question D6

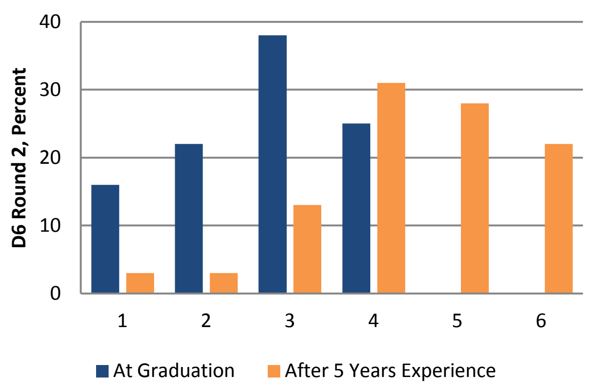
D6. Masonry Design

Round 1



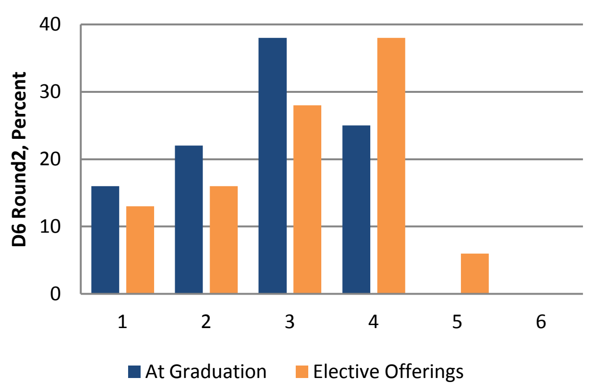
Achievement Level	At Graduation Freq	At Graduation %	After 5 Years Exp. Freq	After 5 Years Exp. %
1-Knowledge	6	18	1	3
2-Comprehension	6	18	1	3
3-Application	12	36	5	15
4-Analysis	9	27	10	30
5-Synthesis	0	0	9	27
6-Evaluation	0	0	7	21
Total	33	100	33	100

Round 2



Achievement Level	At Graduation Freq	At Graduation %	After 5 Years Exp. Freq	After 5 Years Exp. %
1-Knowledge	5	16	1	3
2-Comprehension	7	22	1	3
3-Application	12	38	4	13
4-Analysis	8	25	10	31
5-Synthesis	0	0	9	28
6-Evaluation	0	0	7	22
Total	32	100	32	100

Elective Offerings

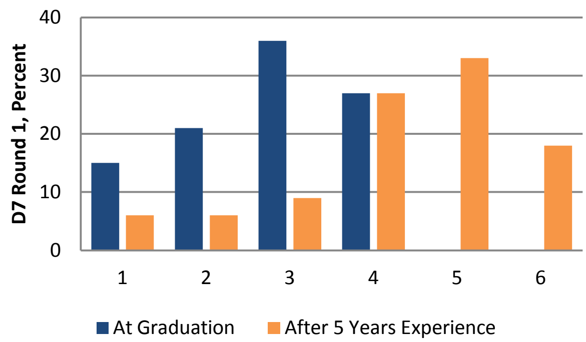
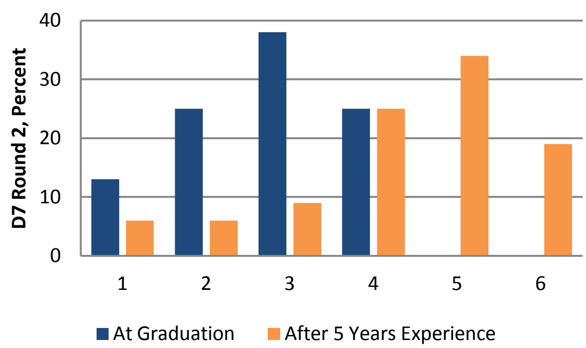
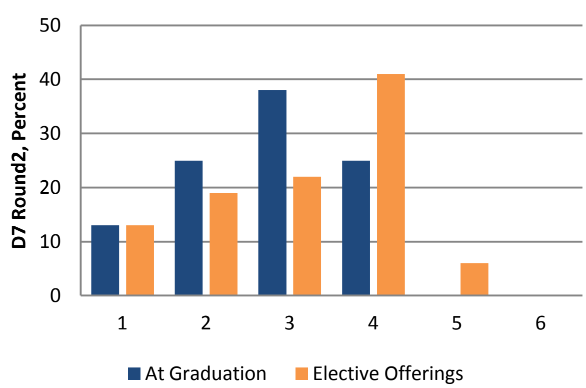


Achievement Level	Round 1 Freq	Round 1 %	Round 2 Freq	Round 2 %
1-Knowledge	5	15	4	13
2-Comprehension	4	12	5	16
3-Application	9	27	9	28
4-Analysis	12	36	12	38
5-Synthesis	2	6	2	6
6-Evaluation	1	3	0	0
Total	33	100	32	100

Opinion Movement

Round 1- to - Round 2	Symmetric Measures: Approx. Sig. (p)	Symmetric Measures: Kendall’s tau-b (τ-b)
At Graduation	<0.001	0.985
After 5 Years Experience	<0.001	0.962
Elective Offerings	<0.001	0.965

Table A-27: Responses to Question D7

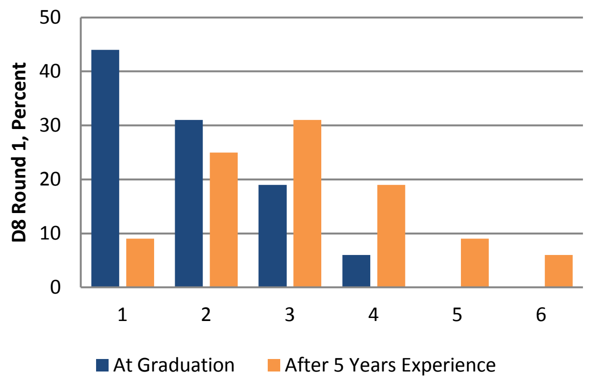
D7. Timber Design	Achievement Level	At Graduation		After 5 Years Exp.	
Round 1		Freq	%	Freq	%
	1-Knowledge	5	15	2	6
	2-Comprehension	7	21	2	6
	3-Application	12	36	3	9
	4-Analysis	9	27	9	27
	5-Synthesis	0	0	11	33
	6-Evaluation	0	0	6	18
	Total	33	100	33	100
Round 2		Freq	%	Freq	%
	1-Knowledge	4	13	2	6
	2-Comprehension	8	25	2	6
	3-Application	12	38	3	9
	4-Analysis	8	25	8	25
	5-Synthesis	0	0	11	34
	6-Evaluation	0	0	6	19
	Total	32	100	32	100
Elective Offerings		Round 1		Round 2	
		Freq	%	Freq	%
	1-Knowledge	5	15	4	13
	2-Comprehension	5	15	6	19
	3-Application	7	21	7	22
	4-Analysis	13	39	13	41
	5-Synthesis	2	6	2	6
	6-Evaluation	1	3	0	0
	Total	33	100	32	100

Opinion Movement

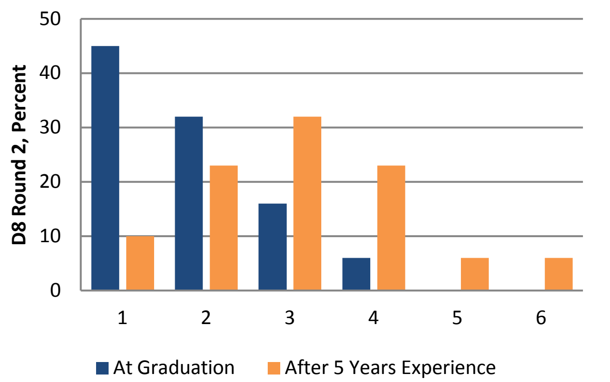
Round 1- to - Round 2	Symmetric Measures: Approx. Sig. (p)	Symmetric Measures: Kendall's tau-b (τ-b)
At Graduation	<0.001	0.985
After 5 Years Experience	<0.001	0.977
Elective Offerings	<0.001	0.962

Table A-28: Responses to Question D8

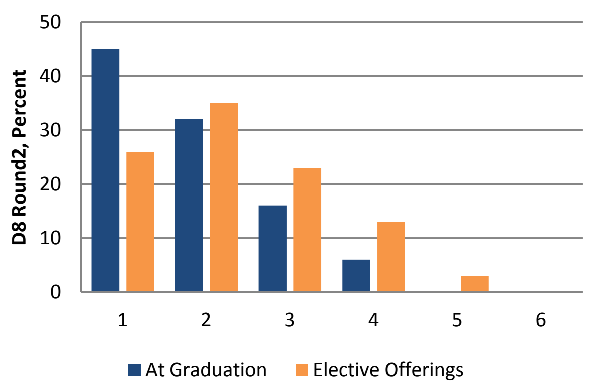
D8. Design with Structural Aluminum	Achievement Level	At Graduation		After 5 Years Exp.	
Round 1		Freq	%	Freq	%
	1-Knowledge	14	44	3	9
	2-Comprehension	10	31	8	25
	3-Application	6	19	10	31
	4-Analysis	2	6	6	19
	5-Synthesis	0	0	3	9
	6-Evaluation	0	0	2	6
	Total	32	100	32	100



D8. Design with Structural Aluminum	Achievement Level	At Graduation		After 5 Years Exp.	
Round 2		Freq	%	Freq	%
	1-Knowledge	14	45	3	10
	2-Comprehension	10	32	7	23
	3-Application	5	16	10	32
	4-Analysis	2	6	7	23
	5-Synthesis	0	0	2	6
	6-Evaluation	0	0	2	6
	Total	31	100	31	100



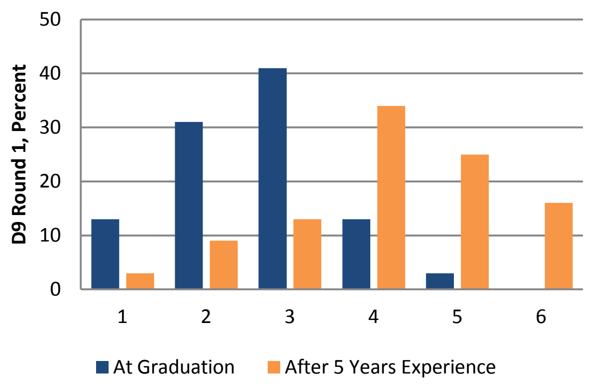
Elective Offerings	Achievement Level	Round 1		Round 2	
		Freq	%	Freq	%
	1-Knowledge	8	25	8	26
	2-Comprehension	11	34	11	35
	3-Application	6	19	7	23
	4-Analysis	5	16	4	13
	5-Synthesis	2	6	1	3
	6-Evaluation	0	0	0	0
	Total	32	100	31	100



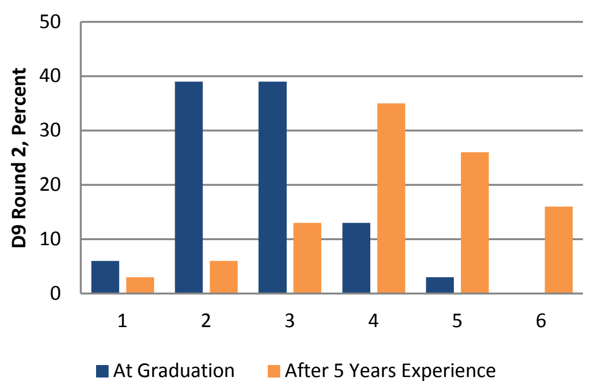
Opinion Movement		
Round 1- to - Round 2	Symmetric Measures	
	Approx. Sig. (p)	Kendall's tau-b (τ-b)
At Graduation	<0.001	0.953
After 5 Years Experience	<0.001	0.968
Elective Offerings	<0.001	0.986

Table A-29: Responses to Question D9

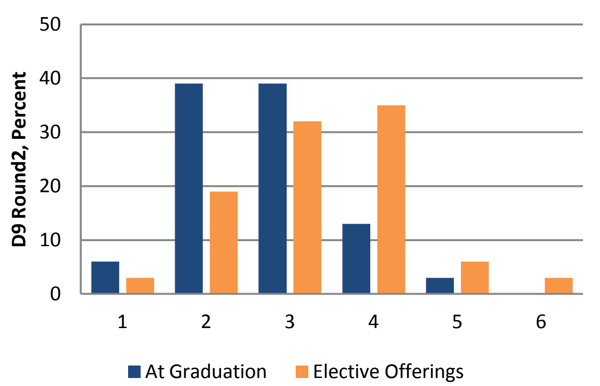
D9. Bridge Design – Short/Mid Span	Achievement Level	At Graduation		After 5 Years Exp.	
Round 1		Freq	%	Freq	%
	1-Knowledge	4	13	1	3
	2-Comprehension	10	31	3	9
	3-Application	13	41	4	13
	4-Analysis	4	13	11	34
	5-Synthesis	1	3	8	25
	6-Evaluation	0	0	5	16
	Total	32	100	32	100



D9. Bridge Design – Short/Mid Span	Achievement Level	At Graduation		After 5 Years Exp.	
Round 2		Freq	%	Freq	%
	1-Knowledge	2	6	1	3
	2-Comprehension	12	39	2	6
	3-Application	12	39	4	13
	4-Analysis	4	13	11	35
	5-Synthesis	1	3	8	26
	6-Evaluation	0	0	5	16
	Total	31	100	31	100



Elective Offerings		Round 1		Round 2	
		Freq	%	Freq	%
	1-Knowledge	1	3	1	3
	2-Comprehension	6	19	6	19
	3-Application	10	31	10	32
	4-Analysis	9	28	11	35
	5-Synthesis	4	13	2	6
	6-Evaluation	2	6	1	3
	Total	32	100	31	100

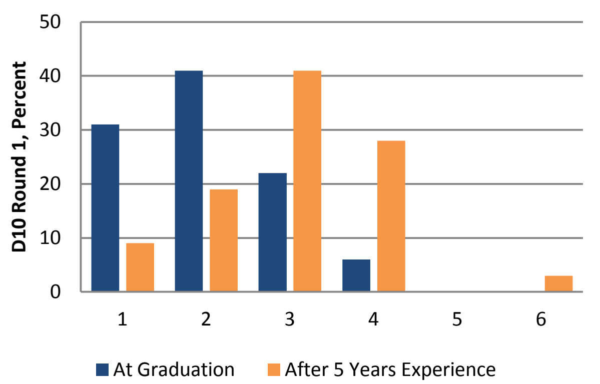


Opinion Movement

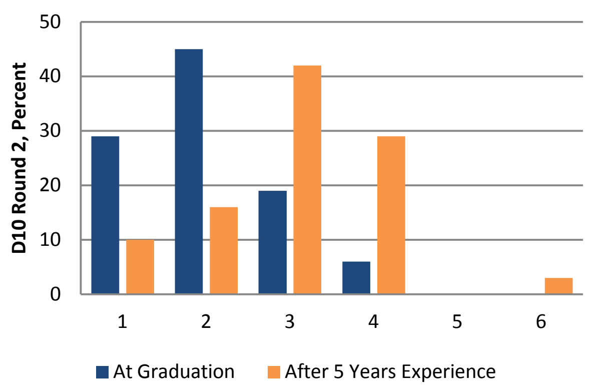
Round 1- to - Round 2	Symmetric Measures	
	Approx. Sig. (p)	Kendall's tau-b (τ-b)
At Graduation	<0.001	0.964
After 5 Years Experience	<0.001	0.993
Elective Offerings	<0.001	0.958

Table A-30: Responses to Question D10

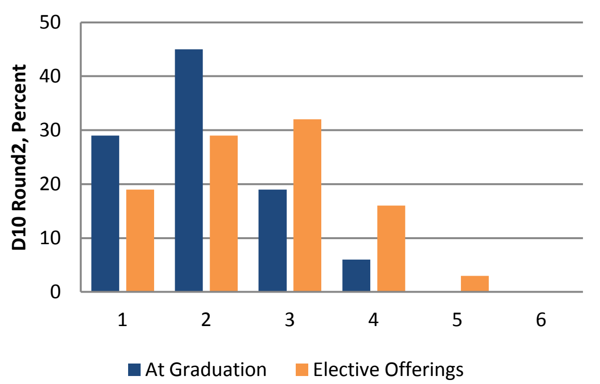
D10. Bridge Design – Long Span	Achievement Level	At Graduation		After 5 Years Exp.	
Round 1		Freq	%	Freq	%
	1-Knowledge	10	31	3	9
	2-Comprehension	13	41	6	19
	3-Application	7	22	13	41
	4-Analysis	2	6	9	28
	5-Synthesis	0	0	0	0
	6-Evaluation	0	0	1	3
	Total	32	100	32	100



Round 2	Achievement Level	At Graduation Freq	At Graduation %	After 5 Years Exp. Freq	After 5 Years Exp. %
	1-Knowledge	9	29	3	10
	2-Comprehension	14	45	5	16
	3-Application	6	19	13	42
	4-Analysis	2	6	9	29
	5-Synthesis	0	0	0	0
	6-Evaluation	0	0	1	3
	Total	31	100	31	100



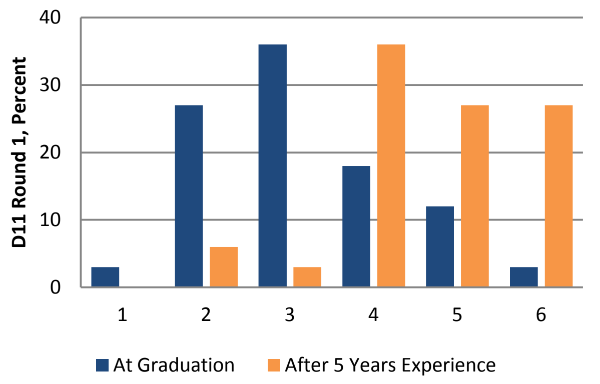
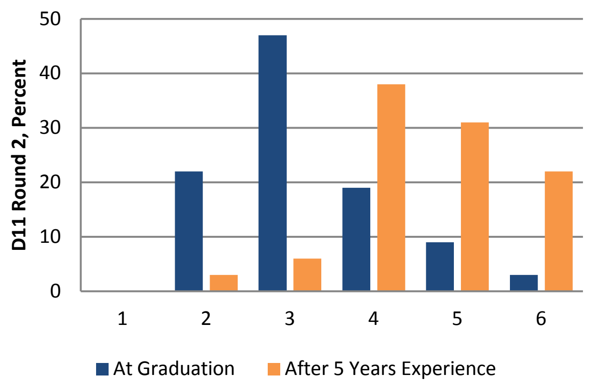
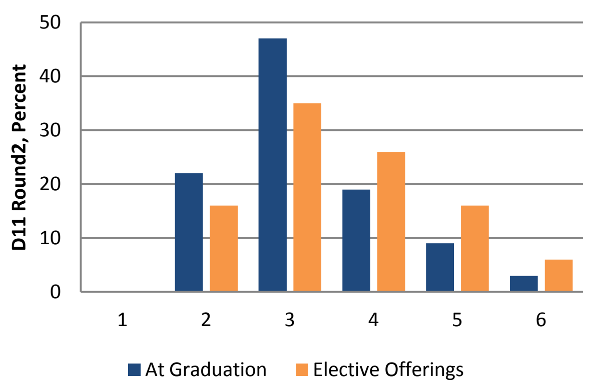
Elective Offerings		Round 1		Round 2	
		Freq	%	Freq	%
	1-Knowledge	6	19	6	19
	2-Comprehension	9	28	9	29
	3-Application	9	28	10	32
	4-Analysis	6	19	5	16
	5-Synthesis	2	6	1	3
	6-Evaluation	0	0	0	0
	Total	32	100	31	100



Opinion Movement

Round 1- to - Round 2	Symmetric Measures	
	Approx. Sig. (p)	Kendall's tau-b (τ-b)
At Graduation	<0.001	0.966
After 5 Years Experience	<0.001	0.975
Elective Offerings	<0.001	0.981

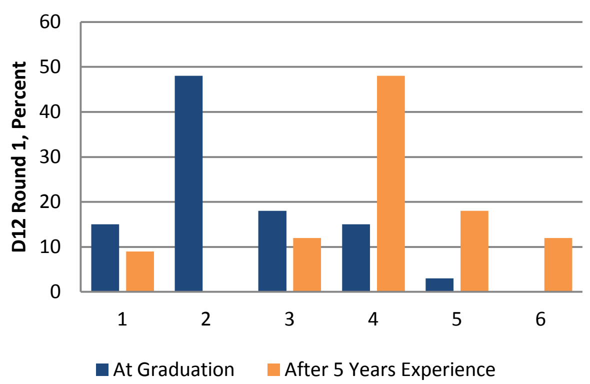
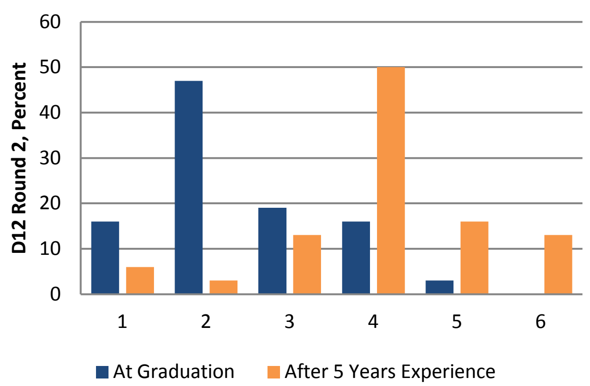
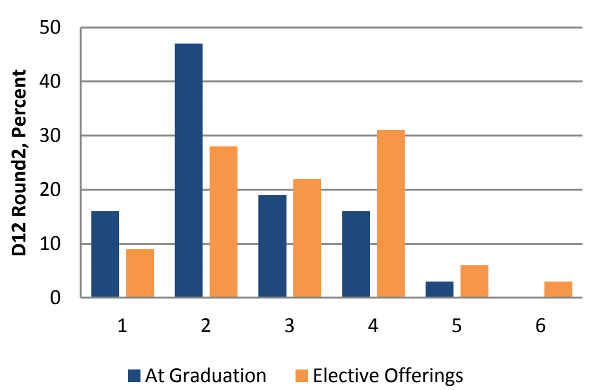
Table A-31: Responses to Question D11

D11. Earthquake Engineering – Basics	Achievement Level	At Graduation		After 5 Years Exp.	
Round 1		Freq	%	Freq	%
	1-Knowledge	1	3	0	0
	2-Comprehension	9	27	2	6
	3-Application	12	36	1	3
	4-Analysis	6	18	12	36
	5-Synthesis	4	12	9	27
	6-Evaluation	1	3	9	27
	Total	33	100	33	100
Round 2		Freq	%	Freq	%
	1-Knowledge	0	0	0	0
	2-Comprehension	7	22	1	3
	3-Application	15	47	2	6
	4-Analysis	6	19	12	38
	5-Synthesis	3	9	10	31
	6-Evaluation	1	3	7	22
	Total	32	100	32	100
Elective Offerings		Round 1		Round 2	
		Freq	%	Freq	%
	1-Knowledge	1	3	0	0
	2-Comprehension	5	16	5	16
	3-Application	10	31	11	35
	4-Analysis	6	19	8	26
	5-Synthesis	7	22	5	16
	6-Evaluation	3	9	2	6
	Total	32	100	31	100

Opinion Movement

Round 1- to - Round 2	Symmetric Measures	
	Approx. Sig. (p)	Kendall's tau-b (τ-b)
At Graduation	<0.001	0.918
After 5 Years Experience	<0.001	0.975
Elective Offerings	<0.001	0.922

Table A-32: Responses to Question D12

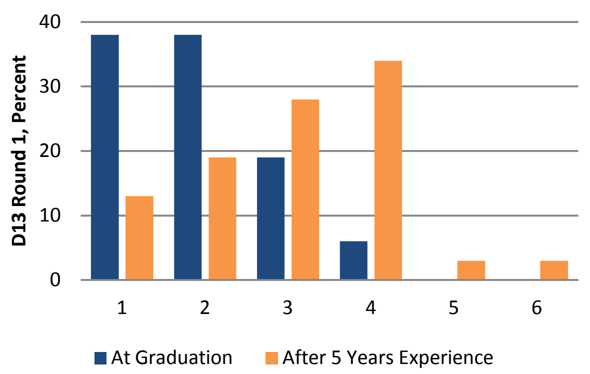
D12. Earthquake Engineering – High Risk Areas	Achievement Level	At Graduation		After 5 Years Exp.	
Round 1		Freq	%	Freq	%
	1-Knowledge	5	15	3	9
	2-Comprehension	16	48	0	0
	3-Application	6	18	4	12
	4-Analysis	5	15	16	48
	5-Synthesis	1	3	6	18
	6-Evaluation	0	0	4	12
	Total	33	100	33	100
Round 2		Freq	%	Freq	%
	1-Knowledge	5	16	2	6
	2-Comprehension	15	47	1	3
	3-Application	6	19	4	13
	4-Analysis	5	16	16	50
	5-Synthesis	1	3	5	16
	6-Evaluation	0	0	4	13
	Total	32	100	32	100
Elective Offerings		Round 1		Round 2	
		Freq	%	Freq	%
	1-Knowledge	3	9	3	9
	2-Comprehension	9	27	9	28
	3-Application	7	21	7	22
	4-Analysis	8	24	10	31
	5-Synthesis	4	12	2	6
	6-Evaluation	2	6	1	3
	Total	33	100	32	100

Opinion Movement

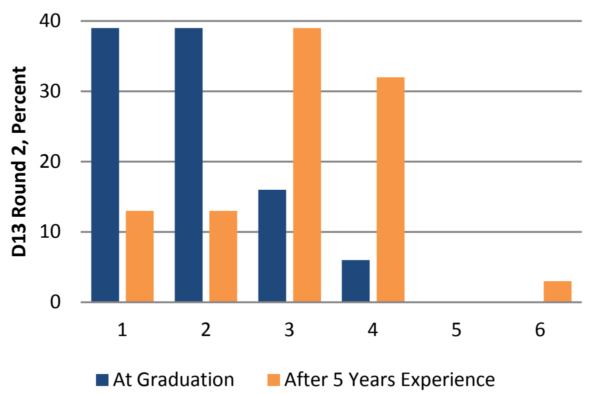
Round 1- to - Round 2	Symmetric Measures	
	Approx. Sig. (p)	Kendall's tau-b (τ-b)
At Graduation	<0.001	0.972
After 5 Years Experience	<0.001	0.997
Elective Offerings	<0.001	0.965

Table A-33: Responses to Question D13

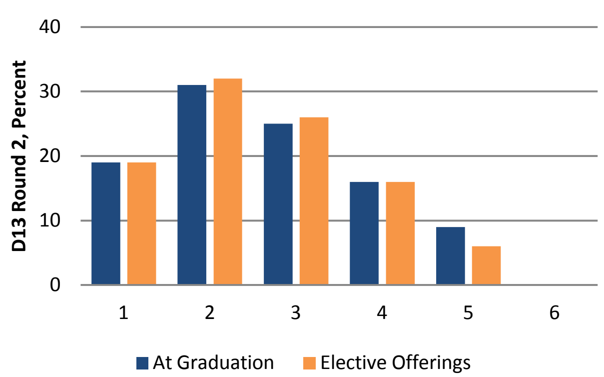
D13. Design to Resist Unusual Loads/Blast	Achievement Level	At Graduation		After 5 Years Exp.	
Round 1		Freq	%	Freq	%
	1-Knowledge	12	38	4	13
	2-Comprehension	12	38	6	19
	3-Application	6	19	9	28
	4-Analysis	2	6	11	34
	5-Synthesis	0	0	1	3
	6-Evaluation	0	0	1	3
	Total	32	100	32	100



Round 2	Achievement Level	Freq	%	Freq	%
	1-Knowledge	12	39	4	13
	2-Comprehension	12	39	4	13
	3-Application	5	16	12	39
	4-Analysis	2	6	10	32
	5-Synthesis	0	0	0	0
	6-Evaluation	0	0	1	3
	Total	31	100	31	100



Elective Offerings	Achievement Level	Round 1		Round 2	
		Freq	%	Freq	%
	1-Knowledge	6	19	6	19
	2-Comprehension	10	31	10	32
	3-Application	8	25	8	26
	4-Analysis	5	16	5	16
	5-Synthesis	3	9	2	6
	6-Evaluation	0	0	0	0
	Total	32	100	31	100

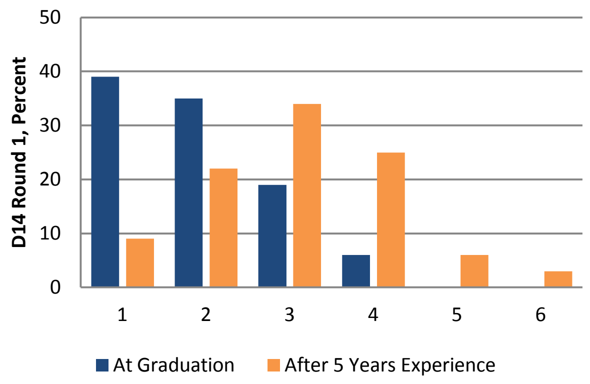


Opinion Movement

Round 1- to - Round 2	Symmetric Measures: Approx. Sig. (p)	Symmetric Measures: Kendall's tau-b (τ-b)
At Graduation	<0.001	1.000
After 5 Years Experience	<0.001	0.932
Elective Offerings	<0.001	1.000

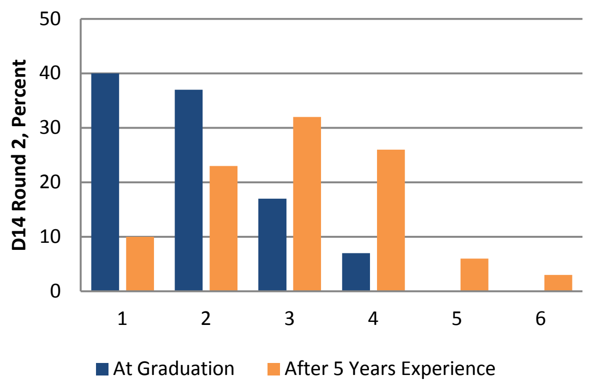
Table A-34: Responses to Question D14

D14. Special Concerns for High Rise Systems	Achievement Level	At Graduation		After 5 Years Exp.	
Round 1		Freq	%	Freq	%



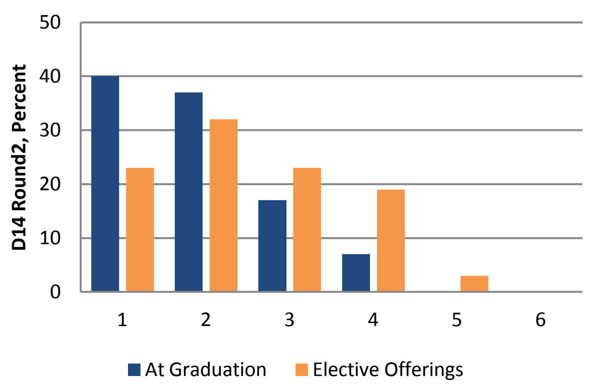
Achievement Level	Freq	%	Freq	%
1-Knowledge	12	39	3	9
2-Comprehension	11	35	7	22
3-Application	6	19	11	34
4-Analysis	2	6	8	25
5-Synthesis	0	0	2	6
6-Evaluation	0	0	1	3
Total	31	100	32	100

Round 2	Freq	%	Freq	%



Achievement Level	Freq	%	Freq	%
1-Knowledge	12	40	3	10
2-Comprehension	11	37	7	23
3-Application	5	17	10	32
4-Analysis	2	7	8	26
5-Synthesis	0	0	2	6
6-Evaluation	0	0	1	3
Total	30	100	31	100

Elective Offerings	Round 1		Round 2	
	Freq	%	Freq	%



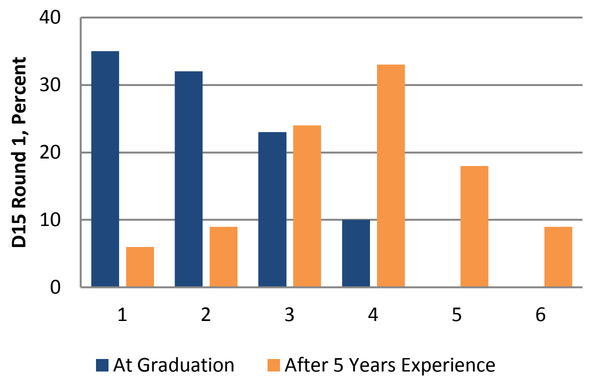
Achievement Level	Freq	%	Freq	%
1-Knowledge	7	22	7	23
2-Comprehension	10	31	10	32
3-Application	7	22	7	23
4-Analysis	7	22	6	19
5-Synthesis	1	3	1	3
6-Evaluation	0	0	0	0
Total	32	100	31	100

Opinion Movement

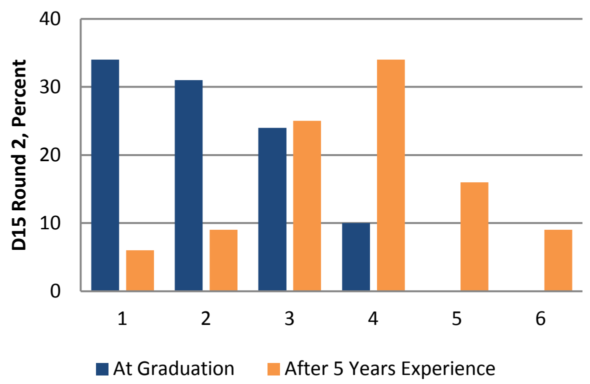
Round 1- to - Round 2	Symmetric Measures	
	Approx. Sig. (p)	Kendall's tau-b (τ-b)
At Graduation	<0.001	1.000
After 5 Years Experience	<0.001	1.000
Elective Offerings	<0.001	1.000

Table A-35: Responses to Question D15

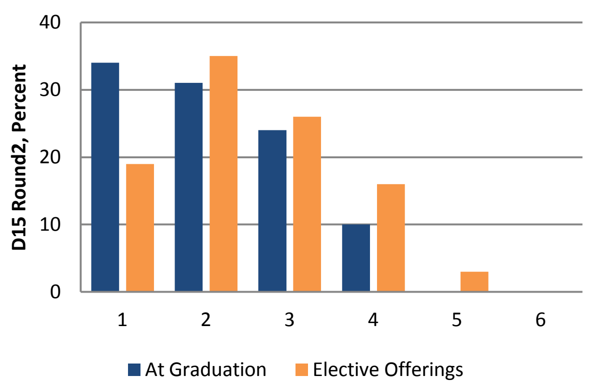
D15. Condition of Structures/Repair, Renovation, Reuse	Achievement Level	At Graduation		After 5 Years Exp.	
Round 1		Freq	%	Freq	%
	1-Knowledge	11	35	2	6
	2-Comprehension	10	32	3	9
	3-Application	7	23	8	24
	4-Analysis	3	10	11	33
	5-Synthesis	0	0	6	18
	6-Evaluation	0	0	3	9
	Total	31	100	33	100



Round 2		Freq	%	Freq	%
	1-Knowledge	10	34	2	6
	2-Comprehension	9	31	3	9
	3-Application	7	24	8	25
	4-Analysis	3	10	11	34
	5-Synthesis	0	0	5	16
	6-Evaluation	0	0	3	9
	Total	29	100	32	100



Elective Offerings		Round 1		Round 2	
		Freq	%	Freq	%
	1-Knowledge	6	19	6	19
	2-Comprehension	11	34	11	35
	3-Application	7	22	8	26
	4-Analysis	5	16	5	16
	5-Synthesis	3	9	1	3
	6-Evaluation	0	0	0	0
	Total	32	100	31	100

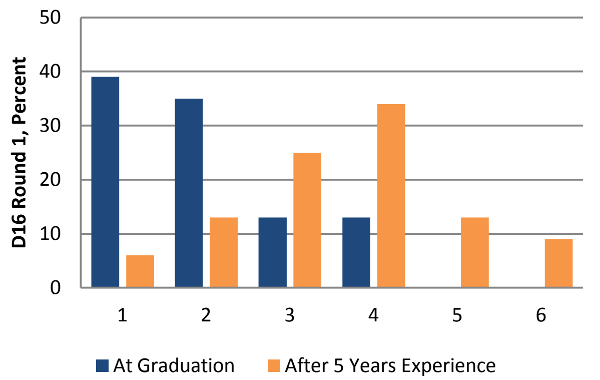


Opinion Movement

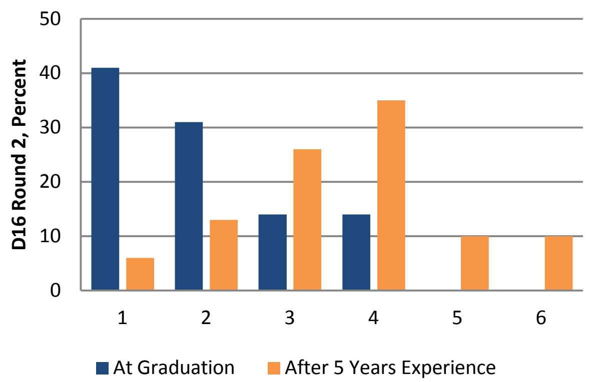
Round 1- to - Round 2	Symmetric Measures	
	Approx. Sig. (p)	Kendall's tau-b (τ-b)
At Graduation	<0.001	1.000
After 5 Years Experience	<0.001	1.000
Elective Offerings	<0.001	0.961

Table A-36: Responses to Question D16

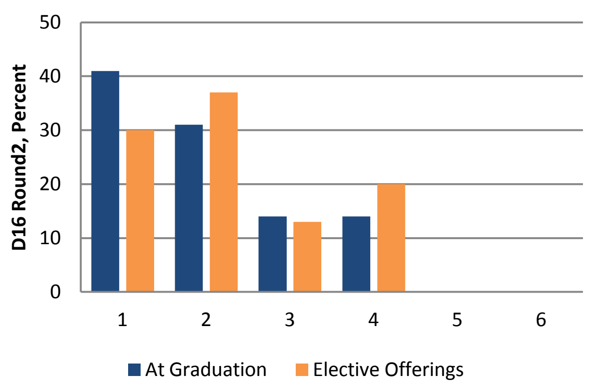
D16. Special Requirements - Residential	Achievement Level	At Graduation		After 5 Years Exp.	
Round 1		Freq	%	Freq	%
	1-Knowledge	12	39	2	6
	2-Comprehension	11	35	4	13
	3-Application	4	13	8	25
	4-Analysis	4	13	11	34
	5-Synthesis	0	0	4	13
	6-Evaluation	0	0	3	9
	Total	31	100	32	100



	Achievement Level	At Graduation		After 5 Years Exp.	
Round 2		Freq	%	Freq	%
	1-Knowledge	12	41	2	6
	2-Comprehension	9	31	4	13
	3-Application	4	14	8	26
	4-Analysis	4	14	11	35
	5-Synthesis	0	0	3	10
	6-Evaluation	0	0	3	10
	Total	29	100	31	100



Elective Offerings		Round 1		Round 2	
		Freq	%	Freq	%
	1-Knowledge	9	29	9	30
	2-Comprehension	11	35	11	37
	3-Application	4	13	4	13
	4-Analysis	7	23	6	20
	5-Synthesis	0	0	0	0
	6-Evaluation	0	0	0	0
	Total	31	100	30	100

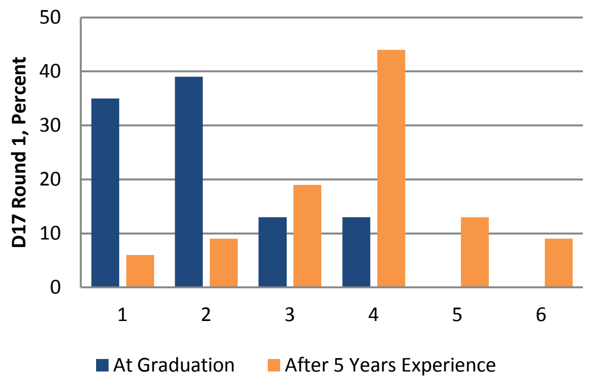


Opinion Movement

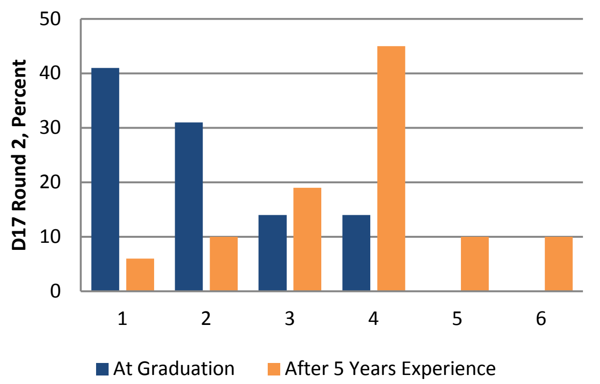
Round 1- to - Round 2	Symmetric Measures	
	Approx. Sig. (p)	Kendall's tau-b (τ-b)
At Graduation	<0.001	0.966
After 5 Years Experience	<0.001	0.983
Elective Offerings	<0.001	1.000

Table A-37: Responses to Question D17

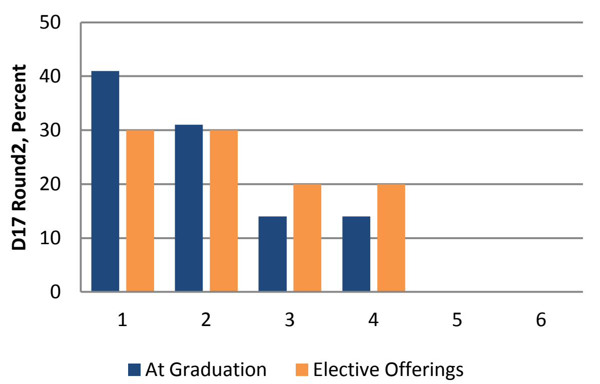
D17. Special Requirements - Light Commercial	Achievement Level	At Graduation		After 5 Years Exp.	
Round 1		Freq	%	Freq	%
	1-Knowledge	11	35	2	6
	2-Comprehension	12	39	3	9
	3-Application	4	13	6	19
	4-Analysis	4	13	14	44
	5-Synthesis	0	0	4	13
	6-Evaluation	0	0	3	9
	Total	31	100	32	100



Round 2		Freq	%	Freq	%
	1-Knowledge	12	41	2	6
	2-Comprehension	9	31	3	10
	3-Application	4	14	6	19
	4-Analysis	4	14	14	45
	5-Synthesis	0	0	3	10
	6-Evaluation	0	0	3	10
	Total	29	100	31	100



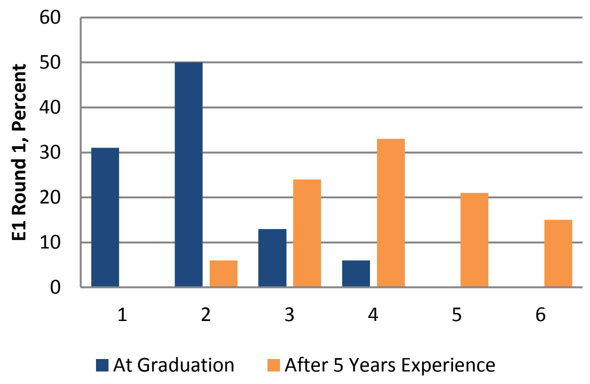
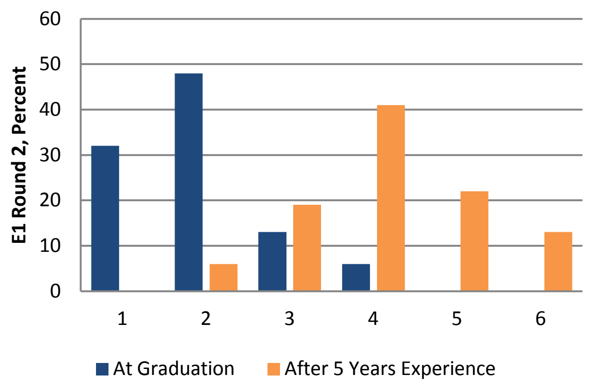
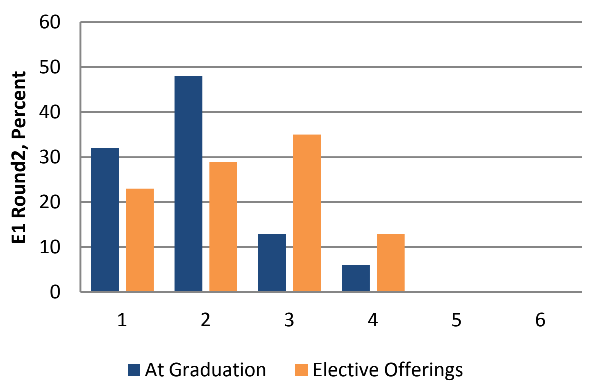
Elective Offerings		Round 1		Round 2	
		Freq	%	Freq	%
	1-Knowledge	9	29	9	30
	2-Comprehension	10	32	9	30
	3-Application	5	16	6	20
	4-Analysis	7	23	6	20
	5-Synthesis	0	0	0	0
	6-Evaluation	0	0	0	0
	Total	31	100	30	100



Opinion Movement

Round 1- to - Round 2	Symmetric Measures	
	Approx. Sig. (p)	Kendall's tau-b (τ-b)
At Graduation	<0.001	0.966
After 5 Years Experience	<0.001	0.977
Elective Offerings	<0.001	0.979

Table A-38: Responses to Question E1

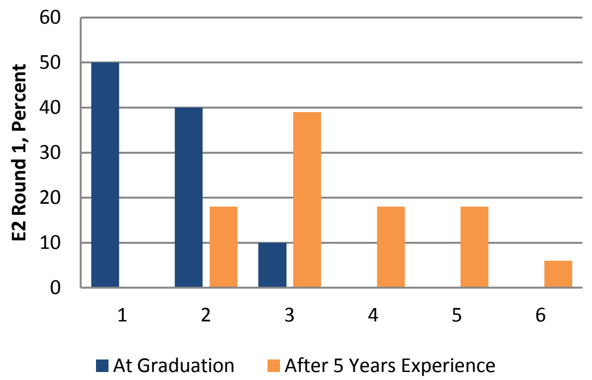
E1. Design Office Organization/Management/Office Ethics	Achievement Level	At Graduation		After 5 Years Exp.	
Round 1		Freq	%	Freq	%
	1-Knowledge	10	31	0	0
	2-Comprehension	16	50	2	6
	3-Application	4	13	8	24
	4-Analysis	2	6	11	33
	5-Synthesis	0	0	7	21
	6-Evaluation	0	0	5	15
	Total	32	100	33	100
Round 2		Freq	%	Freq	%
	1-Knowledge	10	32	0	0
	2-Comprehension	15	48	2	6
	3-Application	4	13	6	19
	4-Analysis	2	6	13	41
	5-Synthesis	0	0	7	22
	6-Evaluation	0	0	4	13
	Total	31	100	32	100
Elective Offerings		Round 1		Round 2	
		Freq	%	Freq	%
	1-Knowledge	7	22	7	23
	2-Comprehension	9	28	9	29
	3-Application	12	38	11	35
	4-Analysis	4	13	4	13
	5-Synthesis	0	0	0	0
	6-Evaluation	0	0	0	0
	Total	32	100	31	100

Opinion Movement

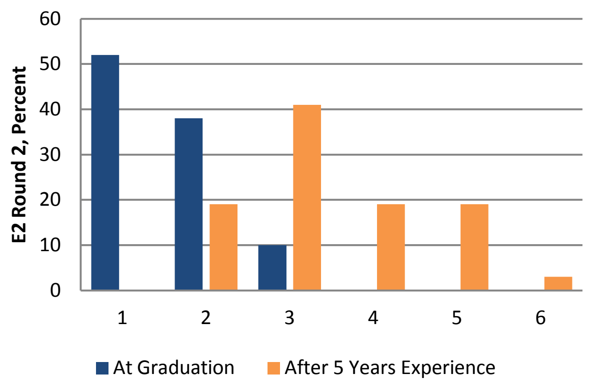
Round 1- to - Round 2	Symmetric Measures: Approx. Sig. (p)	Symmetric Measures: Kendall's tau-b (τ-b)
At Graduation	<0.001	1.000
After 5 Years Experience	<0.001	0.942
Elective Offerings	<0.001	1.000

Table A-39: Responses to Question E2

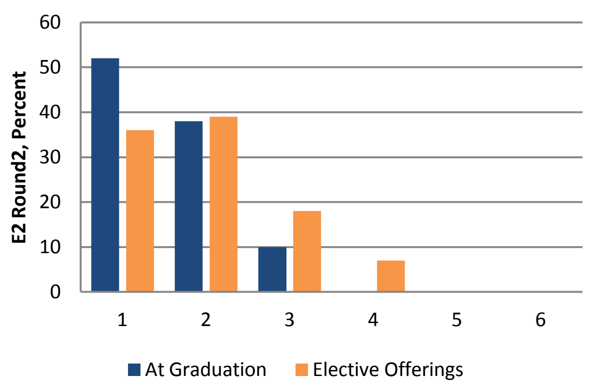
E2. Business Development and Practices	Achievement Level	At Graduation		After 5 Years Exp.	
Round 1		Freq	%	Freq	%
	1-Knowledge	15	50	0	0
	2-Comprehension	12	40	6	18
	3-Application	3	10	13	39
	4-Analysis	0	0	6	18
	5-Synthesis	0	0	6	18
	6-Evaluation	0	0	2	6
	Total	30	100	33	100



Round 2		Freq	%	Freq	%
	1-Knowledge	15	52	0	0
	2-Comprehension	11	38	6	19
	3-Application	3	10	13	41
	4-Analysis	0	0	6	19
	5-Synthesis	0	0	6	19
	6-Evaluation	0	0	1	3
	Total	29	100	32	100



Elective Offerings		Round 1		Round 2	
		Freq	%	Freq	%
	1-Knowledge	9	31	10	36
	2-Comprehension	12	41	11	39
	3-Application	6	21	5	18
	4-Analysis	2	7	2	7
	5-Synthesis	0	0	0	0
	6-Evaluation	0	0	0	0
	Total	29	100	28	100

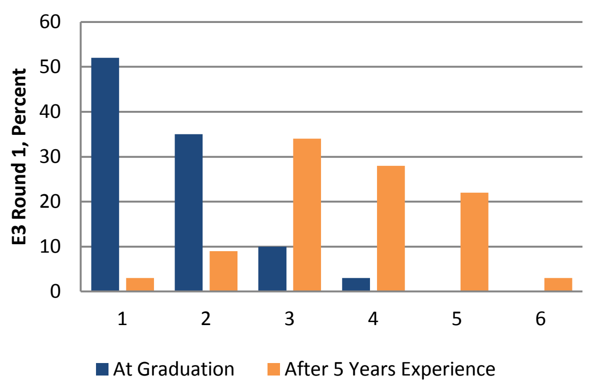


Opinion Movement

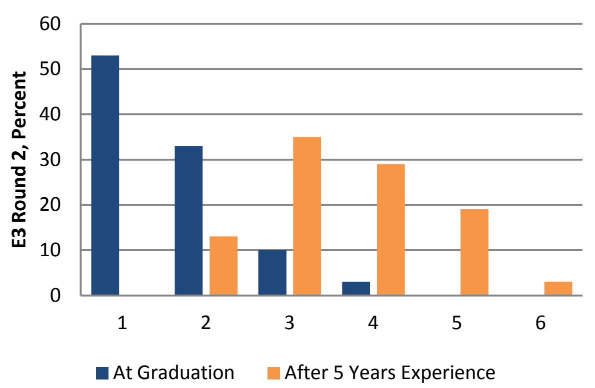
Round 1- to - Round 2	Symmetric Measures	
	Approx. Sig. (p)	Kendall's tau-b (τ-b)
At Graduation	<0.001	1.000
After 5 Years Experience	<0.001	0.979
Elective Offerings	<0.001	0.937

Table A-40: Responses to Question E3

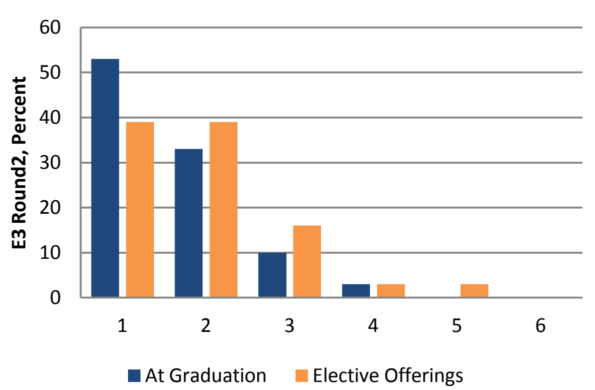
E3. Design/Build & Other Project Methods	Achievement Level	At Graduation		After 5 Years Exp.	
Round 1		Freq	%	Freq	%
	1-Knowledge	16	52	1	3
	2-Comprehension	11	35	3	9
	3-Application	3	10	11	34
	4-Analysis	1	3	9	28
	5-Synthesis	0	0	7	22
	6-Evaluation	0	0	1	3
	Total	31	100	32	100



Round 2		Freq	%	Freq	%
	1-Knowledge	16	53	0	0
	2-Comprehension	10	33	4	13
	3-Application	3	10	11	35
	4-Analysis	1	3	9	29
	5-Synthesis	0	0	6	19
	6-Evaluation	0	0	1	3
	Total	30	100	31	100



Elective Offerings		Round 1		Round 2	
		Freq	%	Freq	%
	1-Knowledge	12	38	12	39
	2-Comprehension	13	41	12	39
	3-Application	5	16	5	16
	4-Analysis	1	3	1	3
	5-Synthesis	1	3	1	3
	6-Evaluation	0	0	0	0
	Total	32	100	31	100

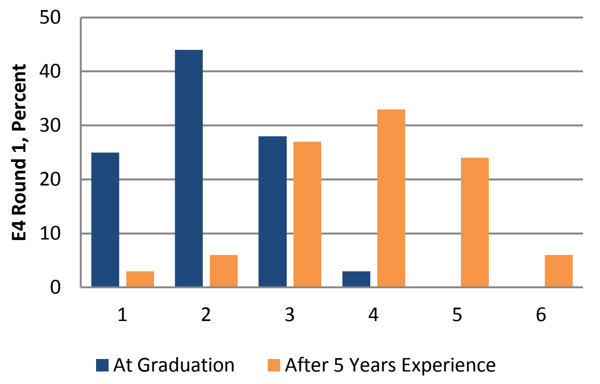


Opinion Movement

Round 1- to - Round 2	Symmetric Measures	
	Approx. Sig. (p)	Kendall's tau-b (τ-b)
At Graduation	<0.001	1.000
After 5 Years Experience	<0.001	0.996
Elective Offerings	<0.001	1.000

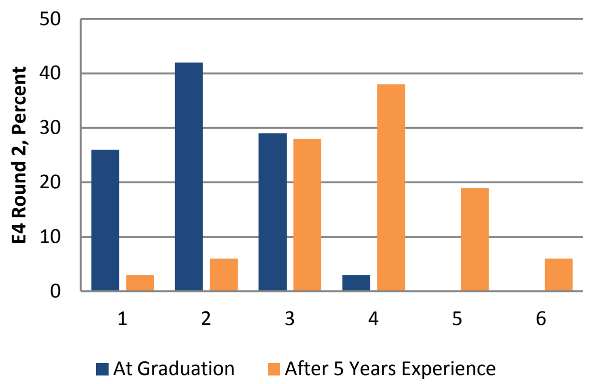
Table A-41: Responses to Question E4

E4. Leadership Skills/Adaptation to Changes	Achievement Level	At Graduation		After 5 Years Exp.	
Round 1		Freq	%	Freq	%



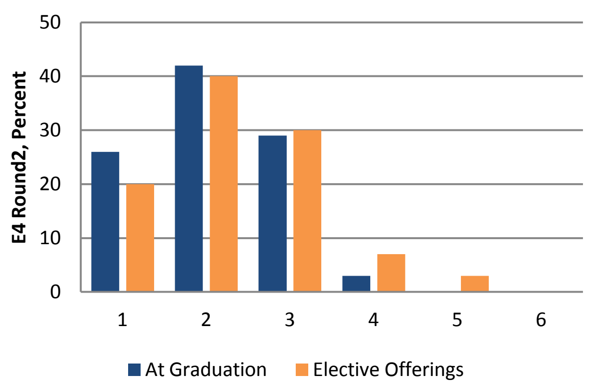
Achievement Level	At Graduation Freq	At Graduation %	After 5 Years Exp. Freq	After 5 Years Exp. %
1-Knowledge	8	25	1	3
2-Comprehension	14	44	2	6
3-Application	9	28	9	27
4-Analysis	1	3	11	33
5-Synthesis	0	0	8	24
6-Evaluation	0	0	2	6
Total	32	100	33	100

Round 2	Freq	%	Freq	%



Achievement Level	At Graduation Freq	At Graduation %	After 5 Years Exp. Freq	After 5 Years Exp. %
1-Knowledge	8	26	1	3
2-Comprehension	13	42	2	6
3-Application	9	29	9	28
4-Analysis	1	3	12	38
5-Synthesis	0	0	6	19
6-Evaluation	0	0	2	6
Total	31	100	32	100

Elective Offerings	Round 1		Round 2	
	Freq	%	Freq	%

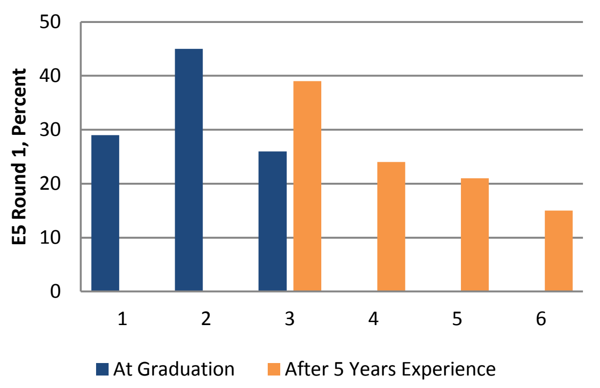


Achievement Level	Round 1 Freq	Round 1 %	Round 2 Freq	Round 2 %
1-Knowledge	6	19	6	20
2-Comprehension	12	39	12	40
3-Application	8	26	9	30
4-Analysis	3	10	2	7
5-Synthesis	2	6	1	3
6-Evaluation	0	0	0	0
Total	31	100	30	100

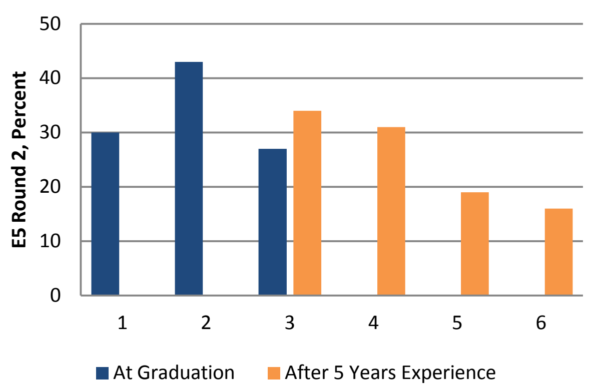
Opinion Movement		
Round 1- to - Round 2	Symmetric Measures	
	Approx. Sig. (p)	Kendall's tau-b (τ-b)
At Graduation	<0.001	1.000
After 5 Years Experience	<0.001	0.978
Elective Offerings	<0.001	0.984

Table A-42: Responses to Question E5

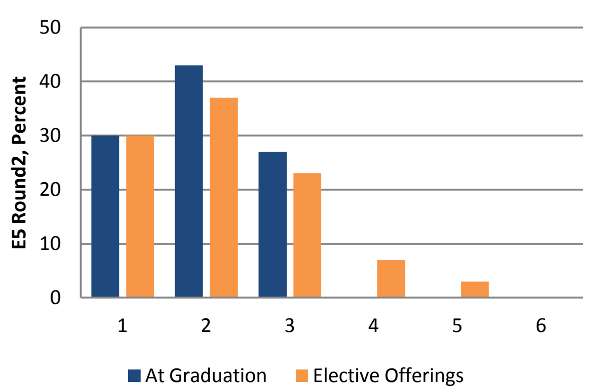
E5. Working with Architects, Contractors, etc.	Achievement Level	At Graduation		After 5 Years Exp.	
Round 1		Freq	%	Freq	%
	1-Knowledge	9	29	0	0
	2-Comprehension	14	45	0	0
	3-Application	8	26	13	39
	4-Analysis	0	0	8	24
	5-Synthesis	0	0	7	21
	6-Evaluation	0	0	5	15
	Total	31	100	33	100



Round 2		Freq	%	Freq	%
	1-Knowledge	9	30	0	0
	2-Comprehension	13	43	0	0
	3-Application	8	27	11	34
	4-Analysis	0	0	10	31
	5-Synthesis	0	0	6	19
	6-Evaluation	0	0	5	16
	Total	30	100	32	100



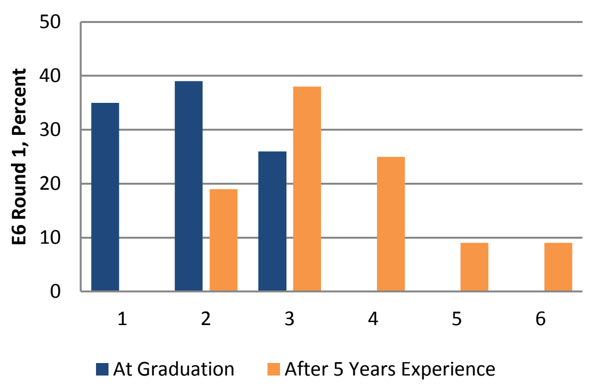
Elective Offerings		Round 1		Round 2	
		Freq	%	Freq	%
	1-Knowledge	9	29	9	30
	2-Comprehension	11	35	11	37
	3-Application	8	26	7	23
	4-Analysis	2	6	2	7
	5-Synthesis	1	3	1	3
	6-Evaluation	0	0	0	0
	Total	31	100	30	100



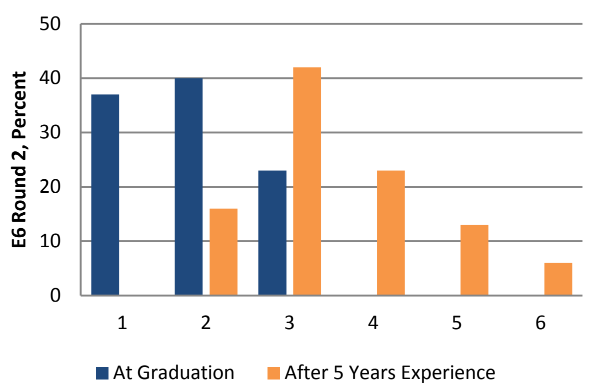
Opinion Movement		
Round 1- to - Round 2	Symmetric Measures	
	Approx. Sig. (p)	Kendall's tau-b (τ-b)
At Graduation	<0.001	1.000
After 5 Years Experience	<0.001	0.948
Elective Offerings	<0.001	1.000

Table A-43: Responses to Question E6

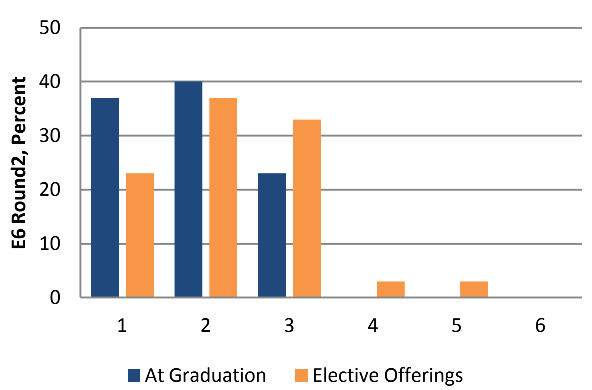
E6. LEED, Green Buildings, Energy Use	Achievement Level	At Graduation		After 5 Years Exp.	
Round 1		Freq	%	Freq	%
	1-Knowledge	11	35	0	0
	2-Comprehension	12	39	6	19
	3-Application	8	26	12	38
	4-Analysis	0	0	8	25
	5-Synthesis	0	0	3	9
	6-Evaluation	0	0	3	9
	Total	31	100	32	100



Round 2		Freq	%	Freq	%
	1-Knowledge	11	37	0	0
	2-Comprehension	12	40	5	16
	3-Application	7	23	13	42
	4-Analysis	0	0	7	23
	5-Synthesis	0	0	4	13
	6-Evaluation	0	0	2	6
	Total	30	100	31	100



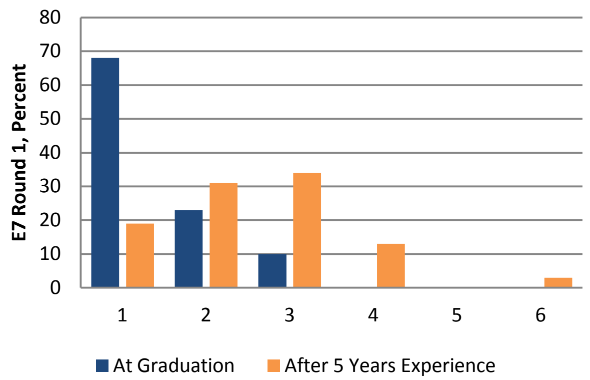
Elective Offerings		Round 1		Round 2	
		Freq	%	Freq	%
	1-Knowledge	7	23	7	23
	2-Comprehension	10	32	11	37
	3-Application	11	35	10	33
	4-Analysis	1	3	1	3
	5-Synthesis	2	6	1	3
	6-Evaluation	0	0	0	0
	Total	31	100	30	100



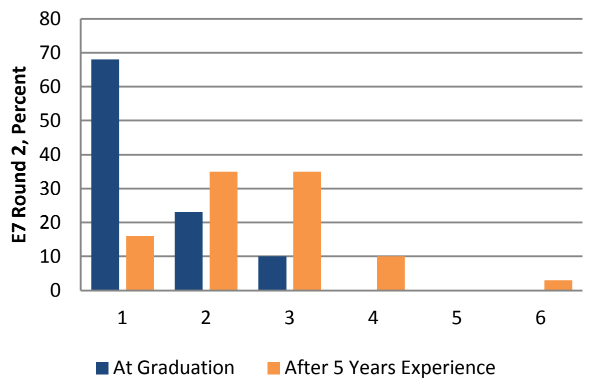
Opinion Movement		
Round 1- to - Round 2	Symmetric Measures	
	Approx. Sig. (p)	Kendall's tau-b (τ-b)
At Graduation	<0.001	1.000
After 5 Years Experience	<0.001	0.961
Elective Offerings	<0.001	0.968

Table A-44: Responses to Question E7

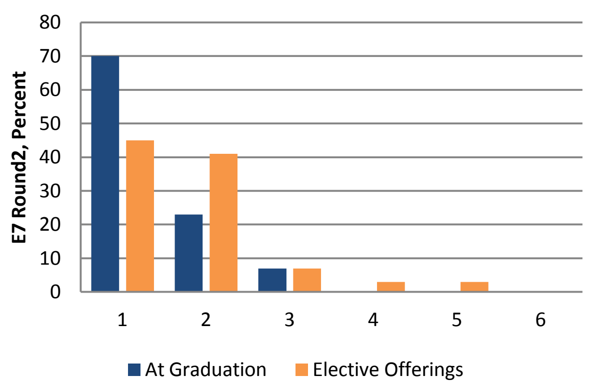
E7. International Design and Construction Practices	Achievement Level	At Graduation		After 5 Years Exp.	
Round 1		Freq	%	Freq	%
	1-Knowledge	21	68	6	19
	2-Comprehension	7	23	10	31
	3-Application	3	10	11	34
	4-Analysis	0	0	4	13
	5-Synthesis	0	0	0	0
	6-Evaluation	0	0	1	3
	Total	31	100	32	100



Round 2		Freq	%	Freq	%
	1-Knowledge	21	70	5	16
	2-Comprehension	7	23	11	35
	3-Application	2	7	11	35
	4-Analysis	0	0	3	10
	5-Synthesis	0	0	0	0
	6-Evaluation	0	0	1	3
	Total	30	100	31	100



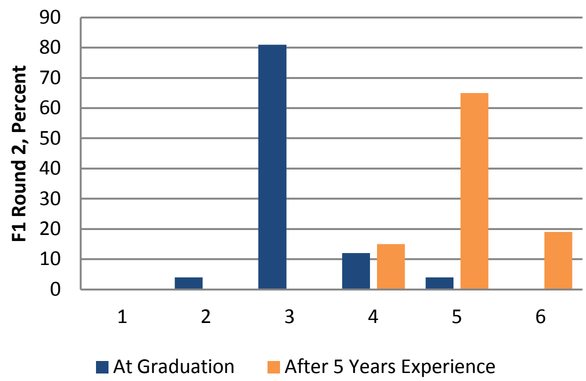
Elective Offerings		Round 1		Round 2	
		Freq	%	Freq	%
	1-Knowledge	14	47	13	45
	2-Comprehension	11	37	12	41
	3-Application	2	7	2	7
	4-Analysis	1	3	1	3
	5-Synthesis	2	7	1	3
	6-Evaluation	0	0	0	0
	Total	30	100	29	100



Opinion Movement

Round 1- to - Round 2	Symmetric Measures	
	Approx. Sig. (p)	Kendall's tau-b (τ-b)
At Graduation	<0.001	1.000
After 5 Years Experience	<0.001	0.978
Elective Offerings	<0.001	0.954

Table A-45: Responses to Question F1

F1. Communication Skills (Oral, Written, Graphical)	Achievement Level	At Graduation		After 5 Years Exp.	
Round 2		Freq	%	Freq	%
	1-Knowledge	0	0	0	0
	2-Comprehension	1	4	0	0
	3-Application	21	81	0	0
	4-Analysis	3	12	4	15
	5-Synthesis	1	4	17	65
	6-Evaluation	0	0	5	19
	Total	26	100	26	100

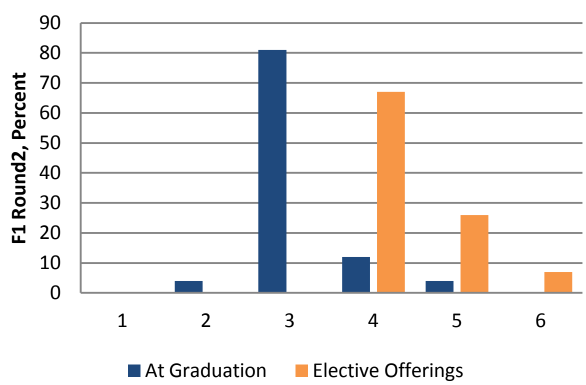
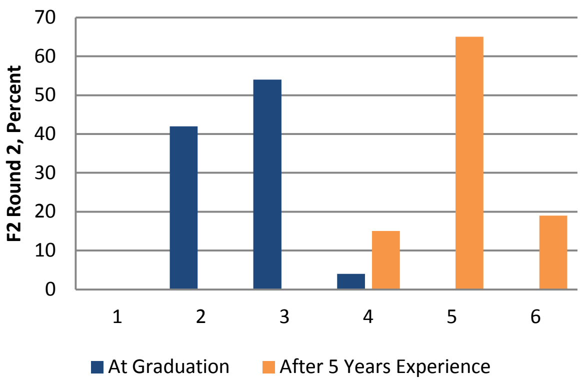
Elective Offerings		Round 2	
		Freq.	%
	1-Knowledge	0	0
	2-Comprehension	0	0
	3-Application	0	0
	4-Analysis	18	67
	5-Synthesis	7	26
	6-Evaluation	2	7
	Total	27	100

Table A-46: Responses to Question F2

F2. Effective Speaking	Achievement Level	At Graduation		After 5 Years Exp.	
Round 2		Freq	%	Freq	%
	1-Knowledge	0	0	0	0
	2-Comprehension	11	42	0	0
	3-Application	14	54	3	12
	4-Analysis	1	4	3	12
	5-Synthesis	0	0	17	68
	6-Evaluation	0	0	2	8
	Total	26	100	25	100



Elective Offerings		Round 2	
		Freq.	%
	1-Knowledge	0	0
	2-Comprehension	0	0
	3-Application	8	32
	4-Analysis	12	48
	5-Synthesis	4	16
	6-Evaluation	1	4
	Total	25	100

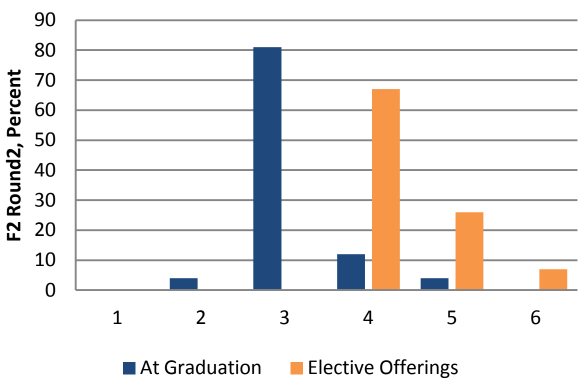


Table A-47: Responses to Question F3

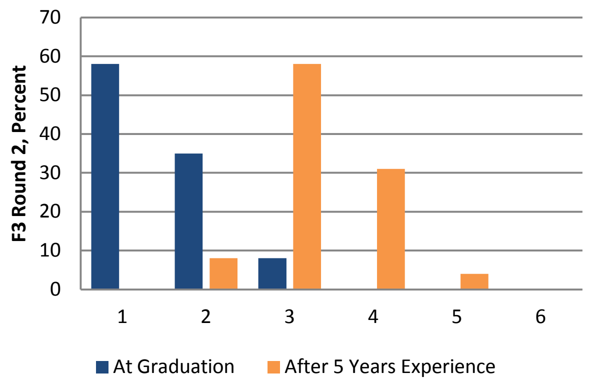
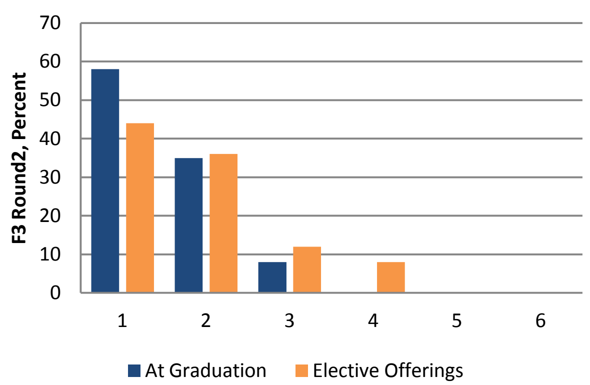
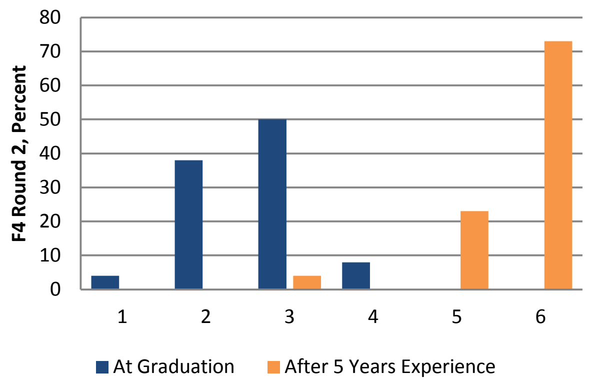
<table>
<tr><td>F3. Financial Assessment</td><td>Achievement Level</td><td colspan="2">At Graduation</td><td colspan="2">After 5 Years Exp.</td></tr>
<tr><td colspan="2">Round 2</td><td>Freq</td><td>%</td><td>Freq</td><td>%</td></tr>
<tr><td rowspan="7">
</td><td>1-Knowledge</td><td>15</td><td>58</td><td>0</td><td>0</td></tr>
<tr><td>2-Comprehension</td><td>9</td><td>35</td><td>2</td><td>8</td></tr>
<tr><td>3-Application</td><td>2</td><td>8</td><td>15</td><td>58</td></tr>
<tr><td>4-Analysis</td><td>0</td><td>0</td><td>8</td><td>31</td></tr>
<tr><td>5-Synthesis</td><td>0</td><td>0</td><td>1</td><td>4</td></tr>
<tr><td>6-Evaluation</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Total</td><td>26</td><td>100</td><td>26</td><td>100</td></tr>
<tr><td colspan="2" rowspan="2">Elective Offerings</td><td colspan="4">Round 2</td></tr>
<tr><td colspan="2">Freq.</td><td colspan="2">%</td></tr>
<tr><td rowspan="7">
</td><td>1-Knowledge</td><td colspan="2">11</td><td colspan="2">44</td></tr>
<tr><td>2-Comprehension</td><td colspan="2">9</td><td colspan="2">36</td></tr>
<tr><td>3-Application</td><td colspan="2">3</td><td colspan="2">12</td></tr>
<tr><td>4-Analysis</td><td colspan="2">2</td><td colspan="2">8</td></tr>
<tr><td>5-Synthesis</td><td colspan="2">0</td><td colspan="2">0</td></tr>
<tr><td>6-Evaluation</td><td colspan="2">0</td><td colspan="2">0</td></tr>
<tr><td>Total</td><td colspan="2">25</td><td colspan="2">100</td></tr>
</table>

Table A-48: Responses to Question F4

F4. Working as a Team	Achievement Level	At Graduation		After 5 Years Exp.	
Round 2		Freq	%	Freq	%
	1-Knowledge	1	4	0	0
	2-Comprehension	10	38	0	0
	3-Application	13	50	1	4
	4-Analysis	2	8	0	0
	5-Synthesis	0	0	6	23
	6-Evaluation	0	0	19	73
	Total	26	100	26	100



Elective Offerings		Round 2	
		Freq.	%
	1-Knowledge	0	0
	2-Comprehension	2	8
	3-Application	17	68
	4-Analysis	4	16
	5-Synthesis	2	8
	6-Evaluation	0	0
	Total	25	100

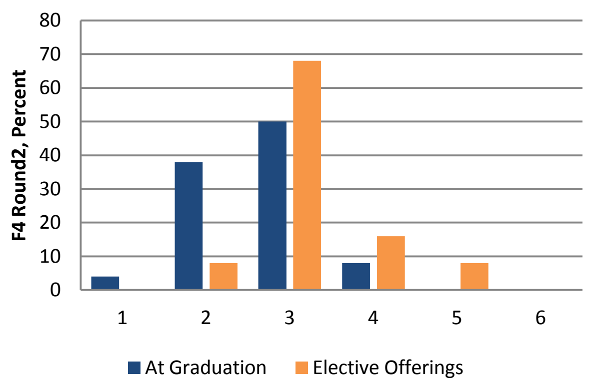


Table A-49: Responses to Question F5

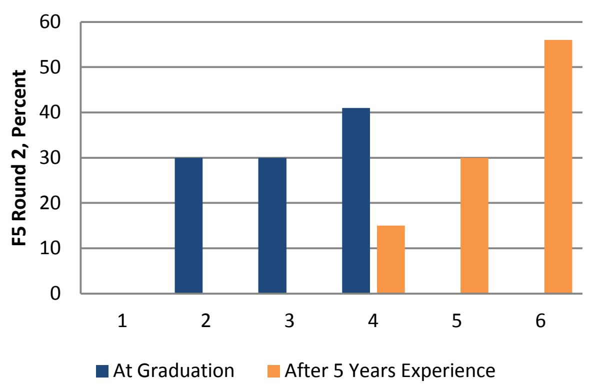
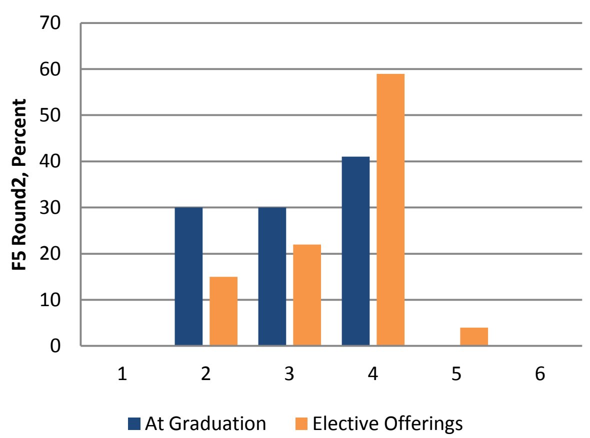
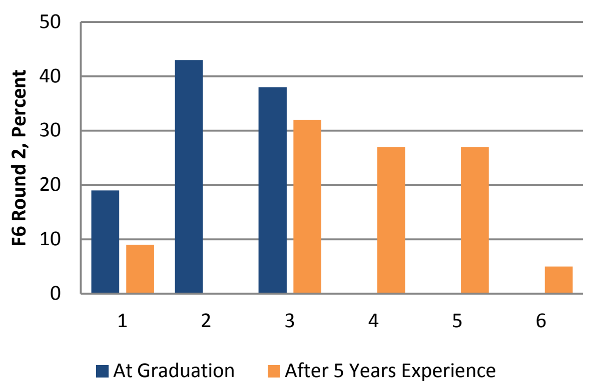
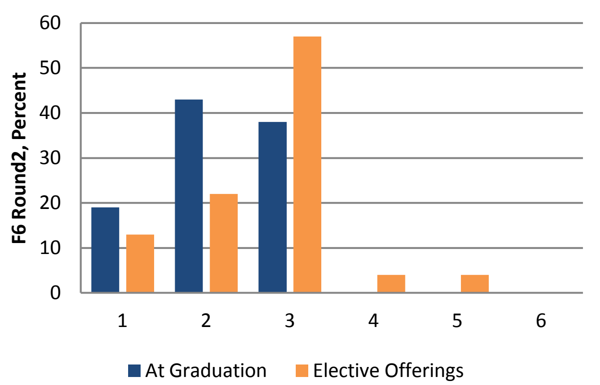
<table>
<tr><td colspan="2">F5. Total Building Design Project</td><td>Achievement Level</td><td colspan="2">At Graduation</td><td colspan="2">After 5 Years Exp.</td></tr>
<tr><td colspan="3">Round 2</td><td>Freq</td><td>%</td><td>Freq</td><td>%</td></tr>
<tr><td colspan="2" rowspan="7">
</td><td>1-Knowledge</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>2-Comprehension</td><td>8</td><td>30</td><td>0</td><td>0</td></tr>
<tr><td>3-Application</td><td>8</td><td>30</td><td>0</td><td>0</td></tr>
<tr><td>4-Analysis</td><td>11</td><td>41</td><td>4</td><td>15</td></tr>
<tr><td>5-Synthesis</td><td>0</td><td>0</td><td>8</td><td>30</td></tr>
<tr><td>6-Evaluation</td><td>0</td><td>0</td><td>15</td><td>56</td></tr>
<tr><td>Total</td><td>27</td><td>100</td><td>27</td><td>100</td></tr>
<tr><td colspan="3" rowspan="2">Elective Offerings</td><td colspan="4">Round 2</td></tr>
<tr><td colspan="2">Freq.</td><td colspan="2">%</td></tr>
<tr><td colspan="2" rowspan="7">
</td><td>1-Knowledge</td><td colspan="2">0</td><td colspan="2">0</td></tr>
<tr><td>2-Comprehension</td><td colspan="2">4</td><td colspan="2">15</td></tr>
<tr><td>3-Application</td><td colspan="2">6</td><td colspan="2">22</td></tr>
<tr><td>4-Analysis</td><td colspan="2">16</td><td colspan="2">59</td></tr>
<tr><td>5-Synthesis</td><td colspan="2">1</td><td colspan="2">4</td></tr>
<tr><td>6-Evaluation</td><td colspan="2">0</td><td colspan="2">0</td></tr>
<tr><td>Total</td><td colspan="2">27</td><td colspan="2">100</td></tr>
</table>

Table A-50: Responses to Question F6

F6. Bridge Design Codes (as an addition to B2)	Achievement Level	At Graduation		After 5 Years Exp.	
Round 2		Freq	%	Freq	%
	1-Knowledge	4	19	2	9
	2-Comprehension	9	43	0	0
	3-Application	8	38	7	32
	4-Analysis	0	0	6	27
	5-Synthesis	0	0	6	27
	6-Evaluation	0	0	1	5
	Total	21	100	22	100



Elective Offerings		Round 2	
		Freq.	%
	1-Knowledge	3	13
	2-Comprehension	5	22
	3-Application	13	57
	4-Analysis	1	4
	5-Synthesis	1	4
	6-Evaluation	0	0
	Total	23	100



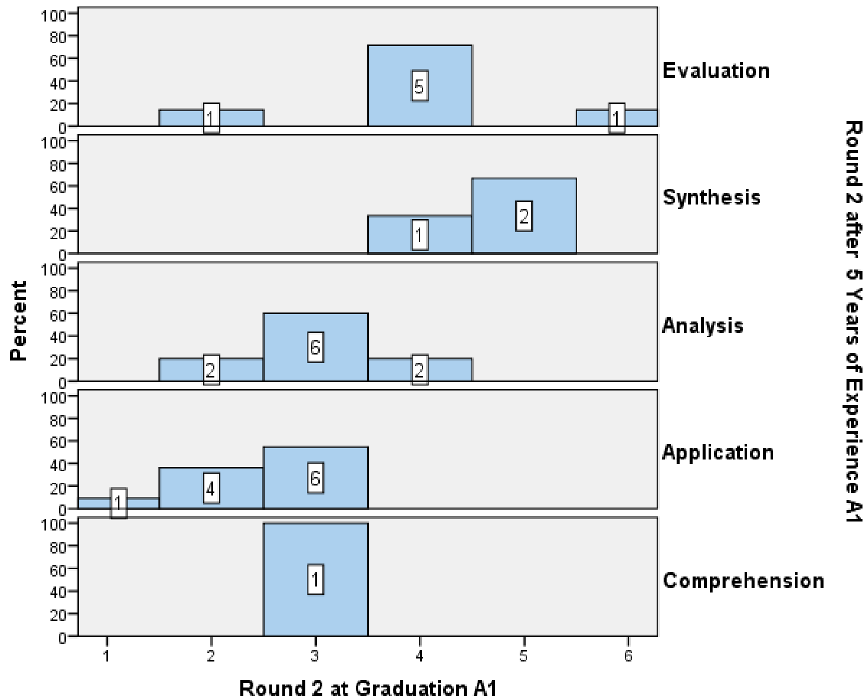


Figure A-5: Change in Expected Achievement Level, Question A1

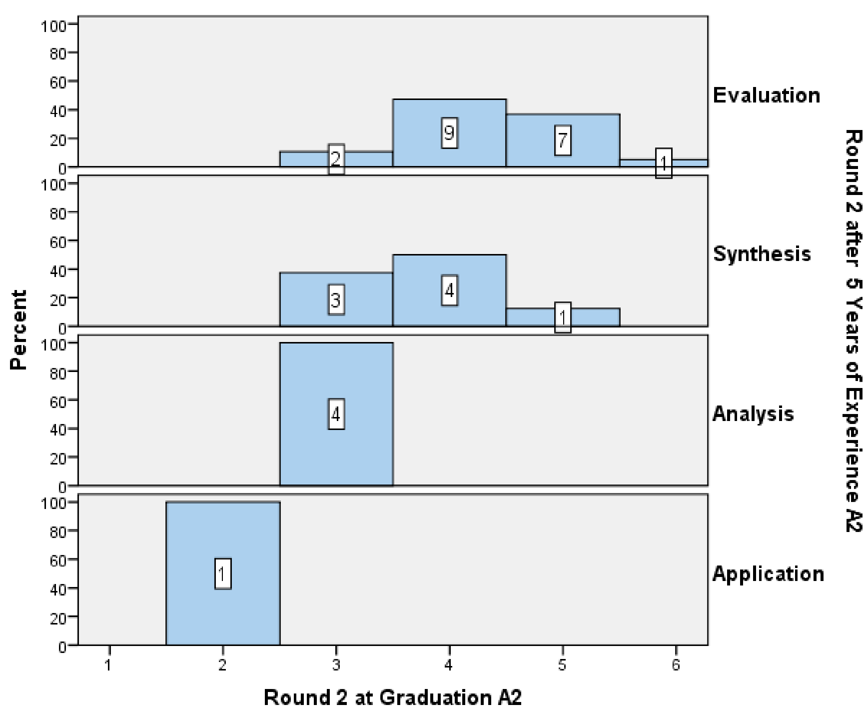


Figure A-6: Change in Expected Achievement Level, Question A2

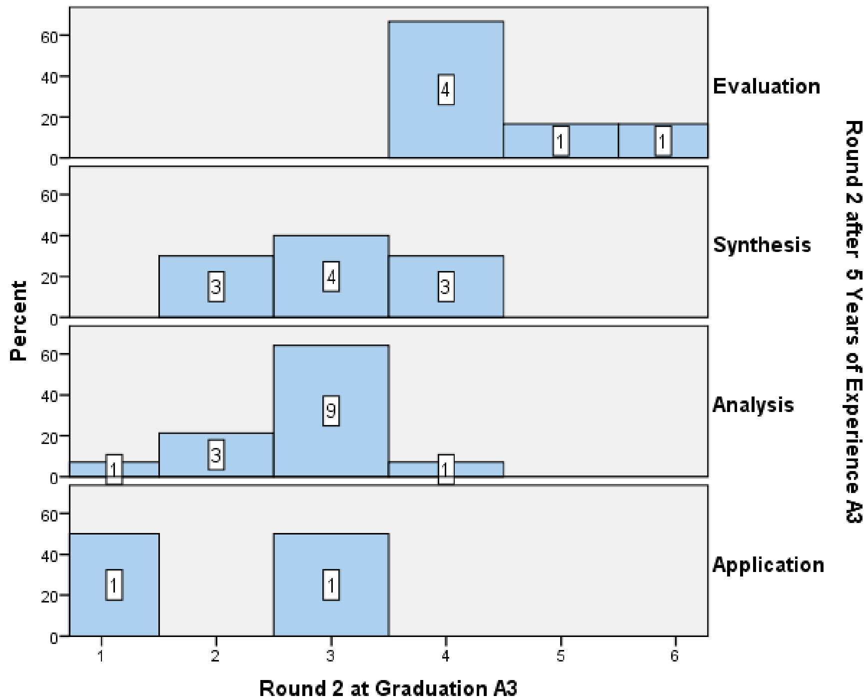


Figure A-7: Change in Expected Achievement Level, Question A3

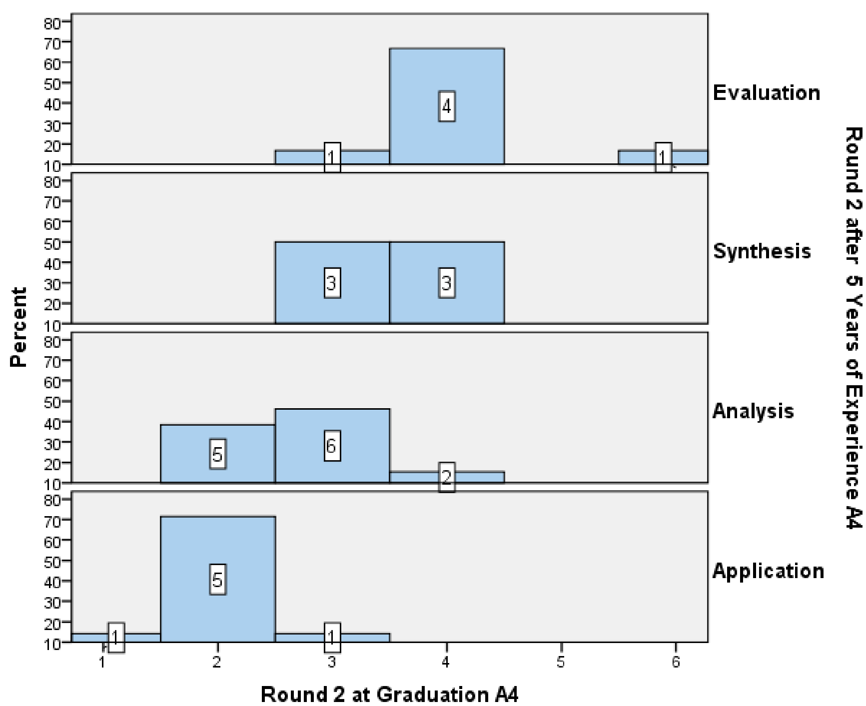


Figure A-8: Change in Expected Achievement Level, Question A4

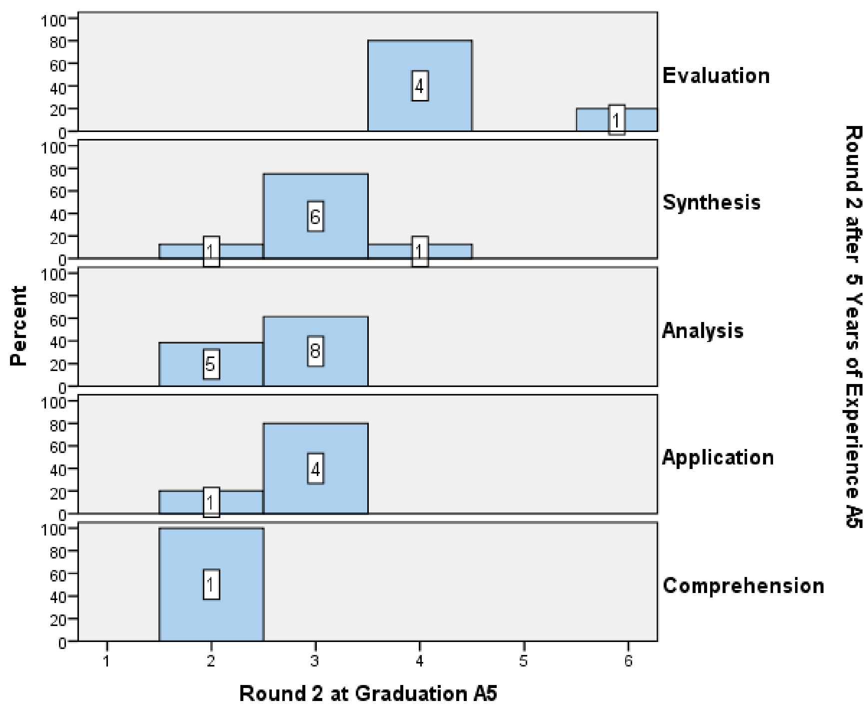


Figure A-9: Change in Expected Achievement Level, Question A5

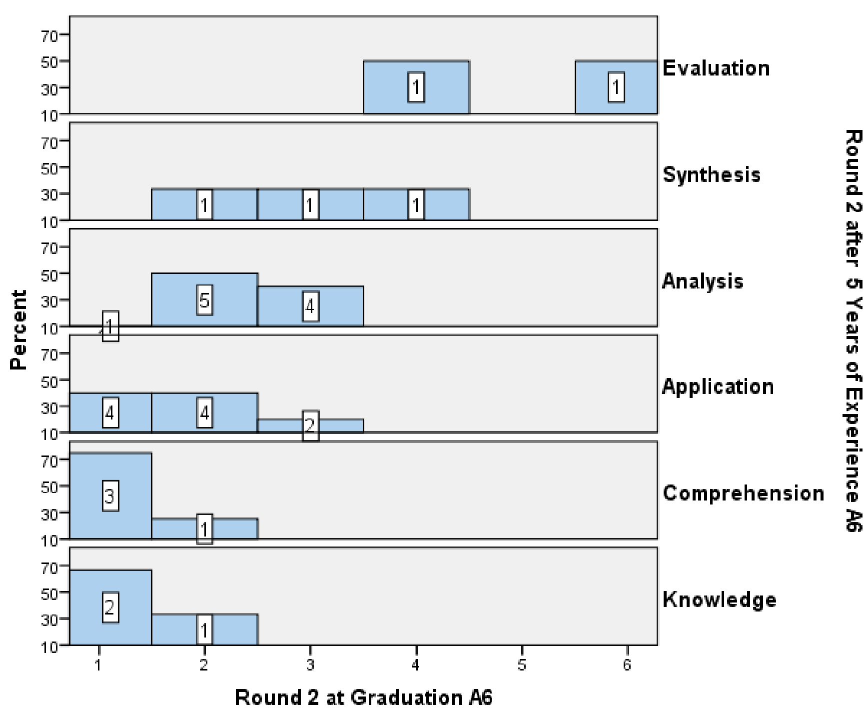


Figure A-10: Change in Expected Achievement Level, Question A6

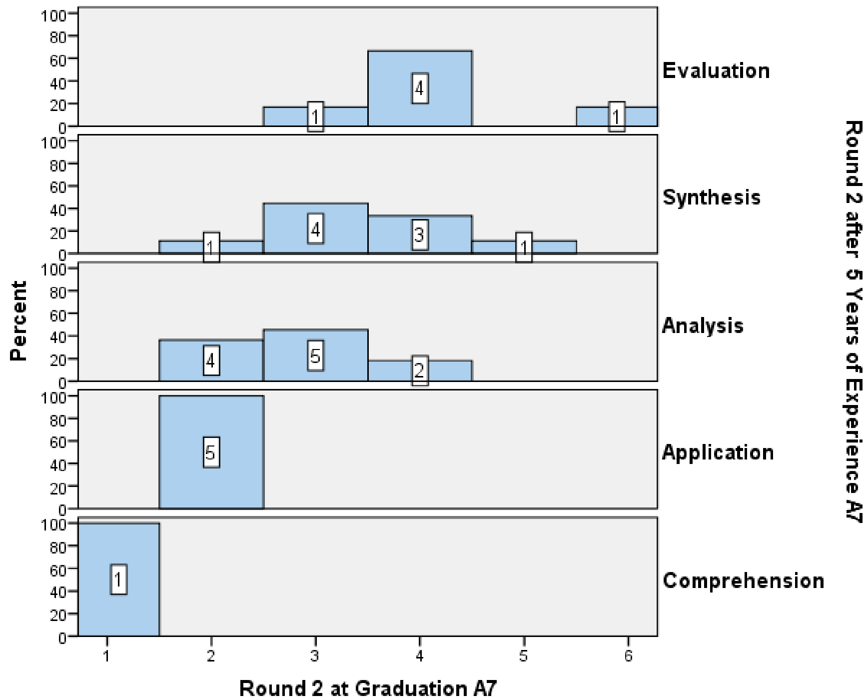


Figure A-11: Change in Expected Achievement Level, Question A7

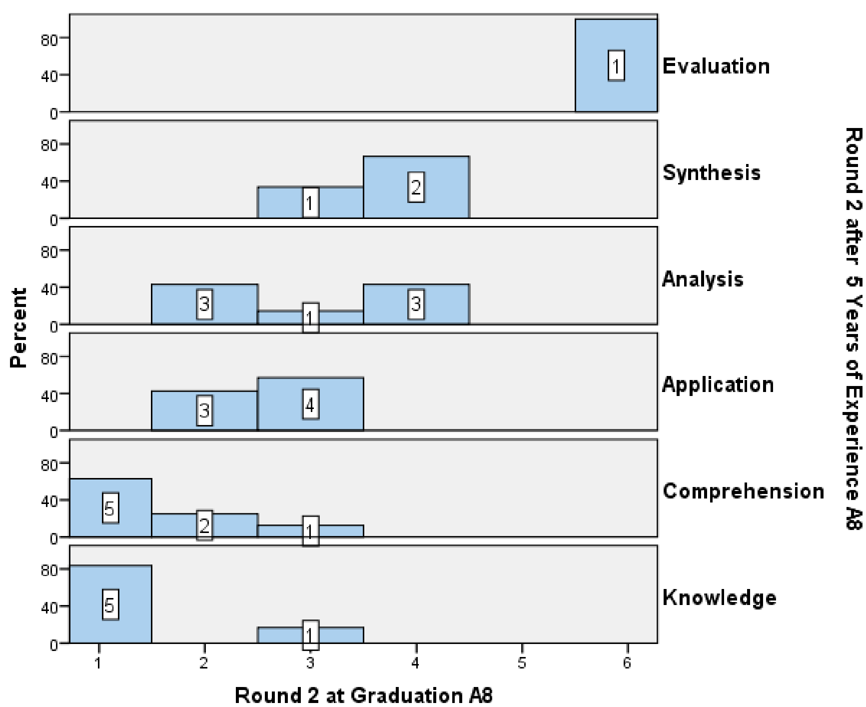


Figure A-12: Change in Expected Achievement Level, Question A8

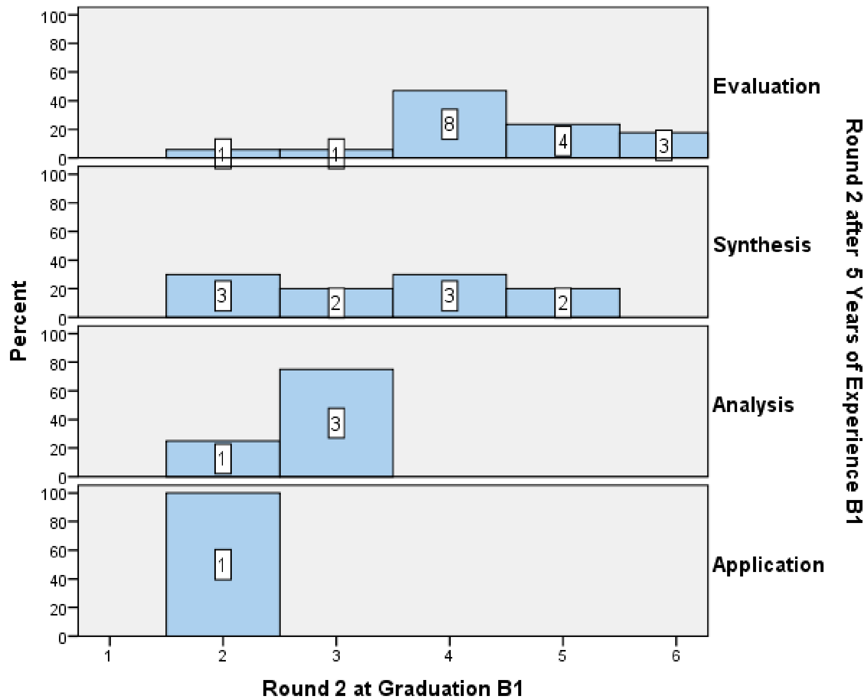


Figure A-13: Change in Expected Achievement Level, Question B1

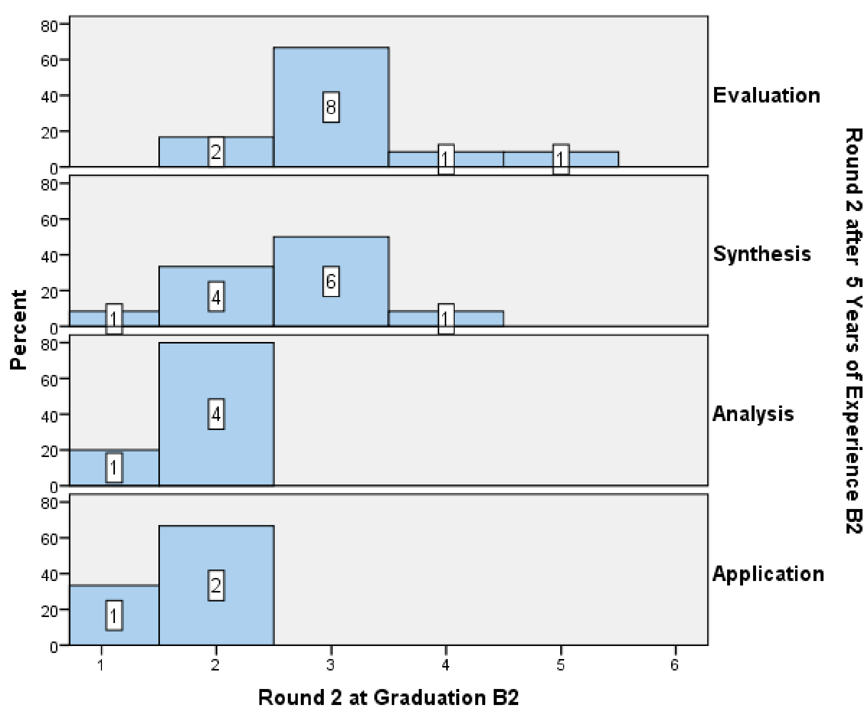


Figure A-14: Change in Expected Achievement Level, Question B2

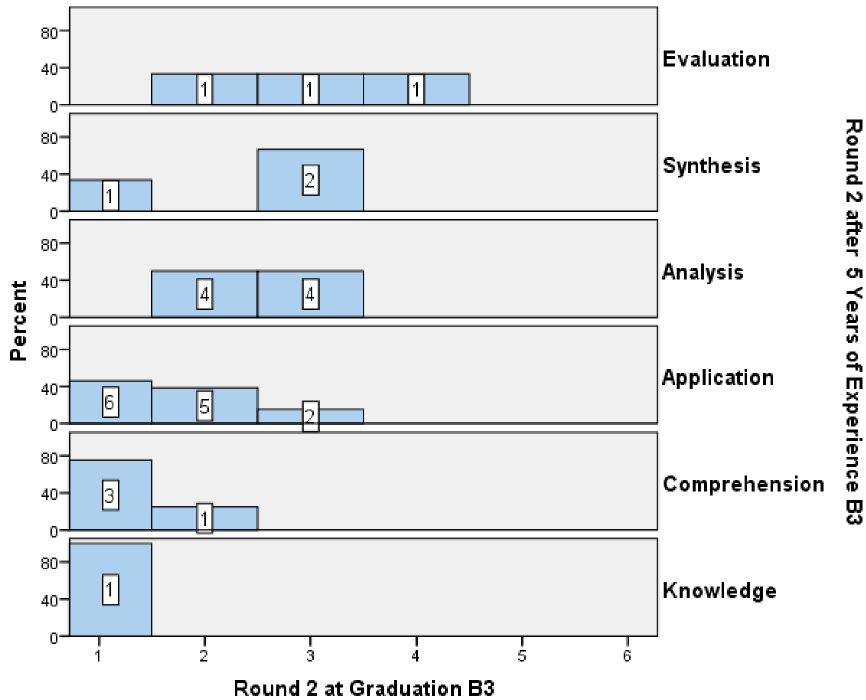


Figure A-15: Change in Expected Achievement Level, Question B3

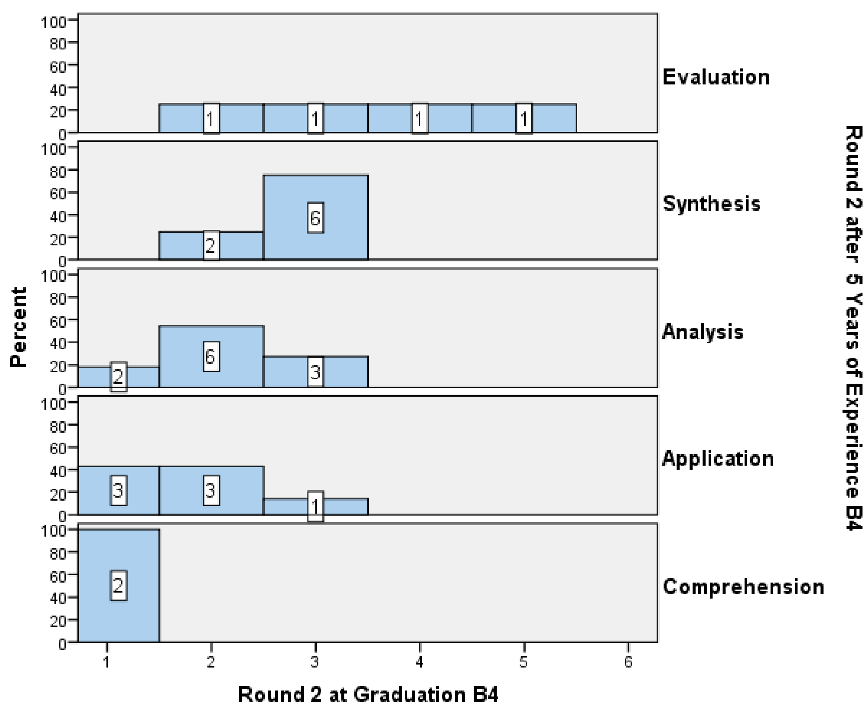


Figure A-16: Change in Expected Achievement Level, Question B4

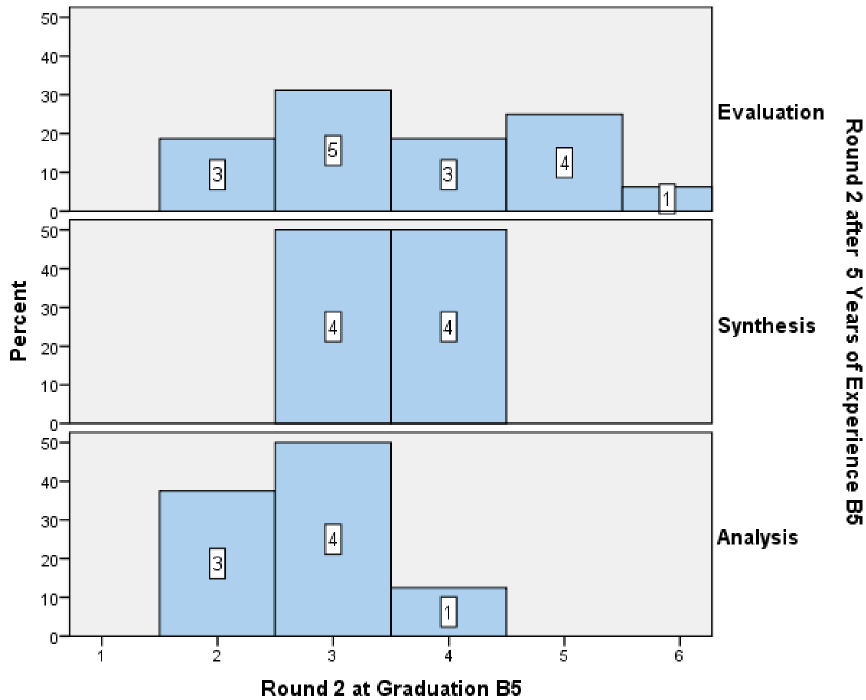


Figure A-17: Change in Expected Achievement Level, Question B5

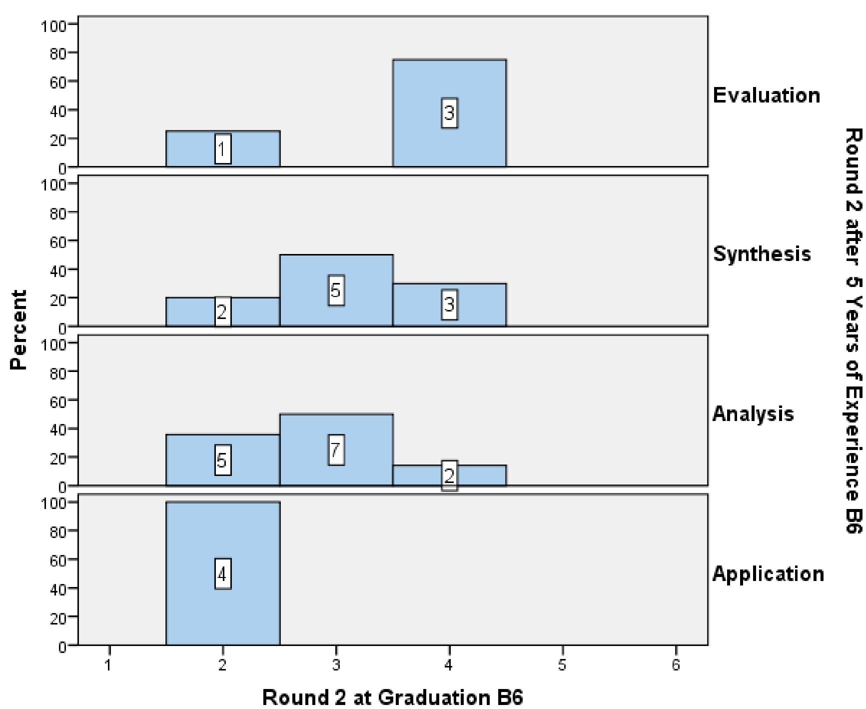


Figure A-18: Change in Expected Achievement Level, Question B6

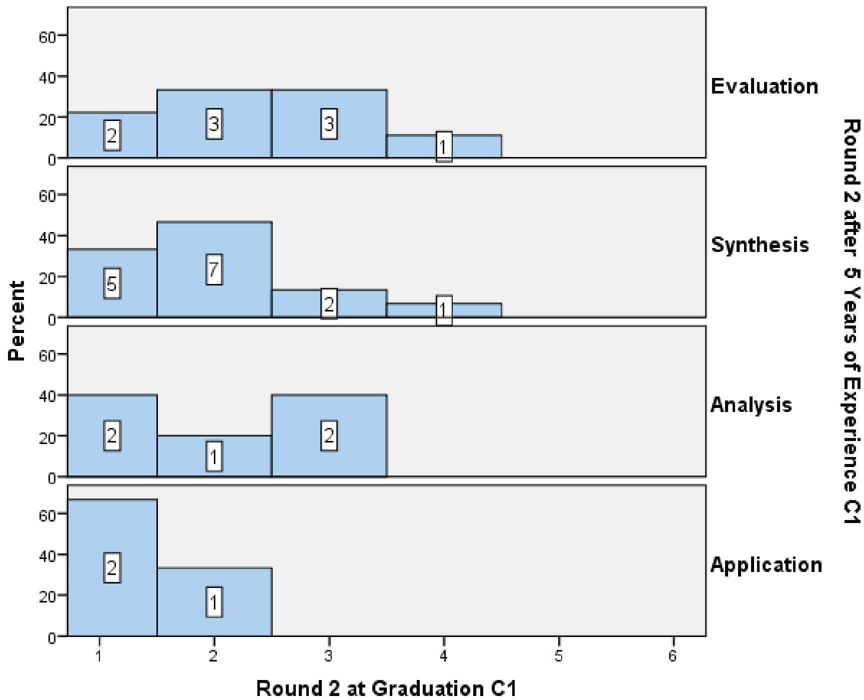


Figure A-19: Change in Expected Achievement Level, Question C1

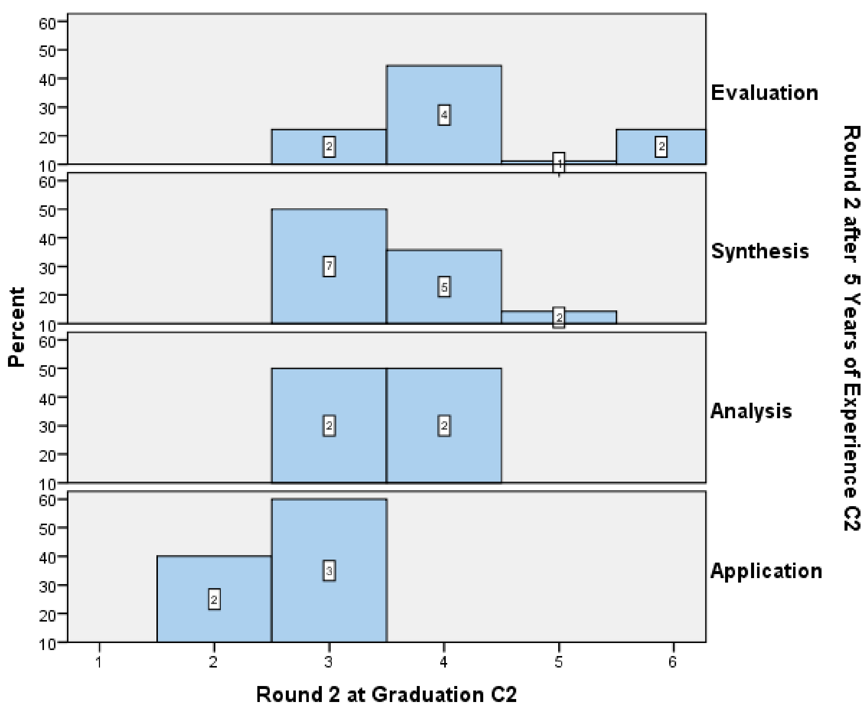


Figure A-20: Change in Expected Achievement Level, Question C2

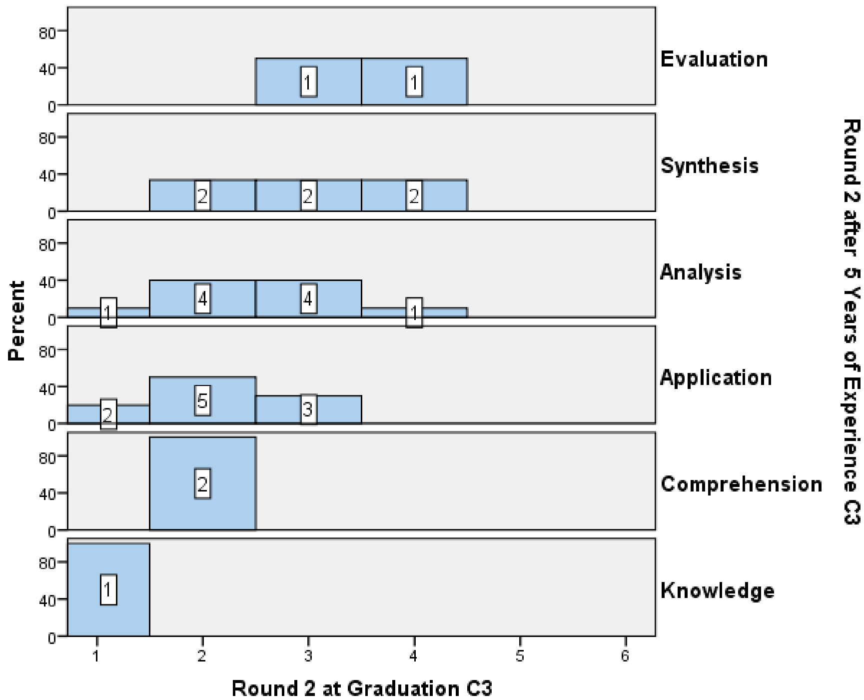


Figure A-21: Change in Expected Achievement Level, Question C3

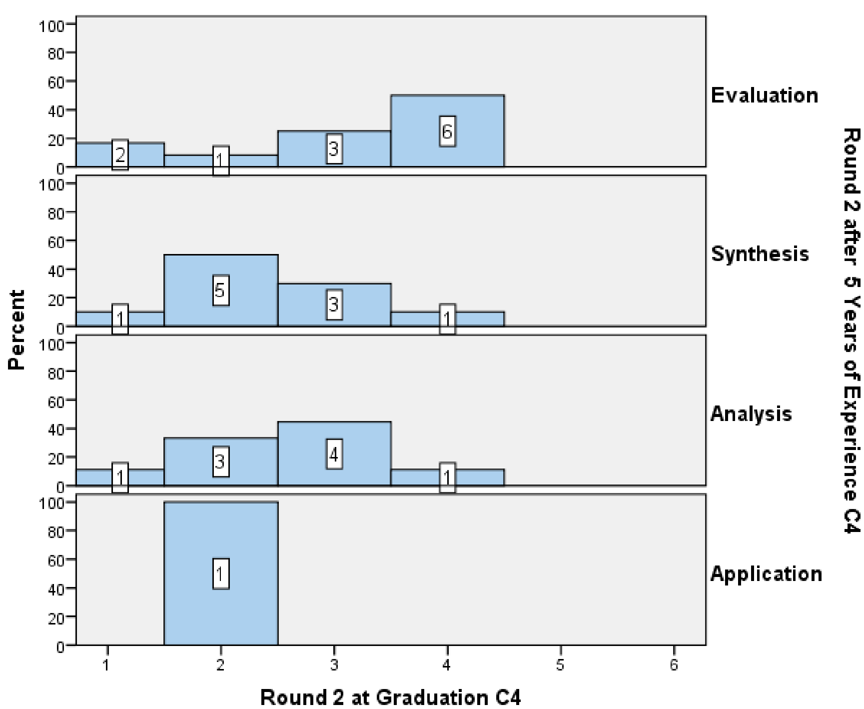


Figure A-22: Change in Expected Achievement Level, Question C4

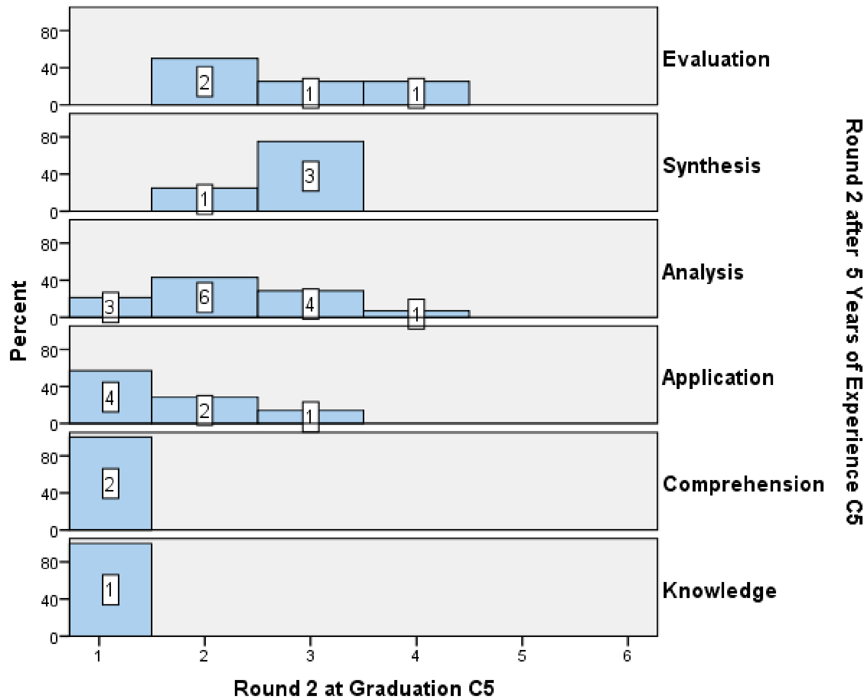


Figure A-23: Change in Expected Achievement Level, Question C5

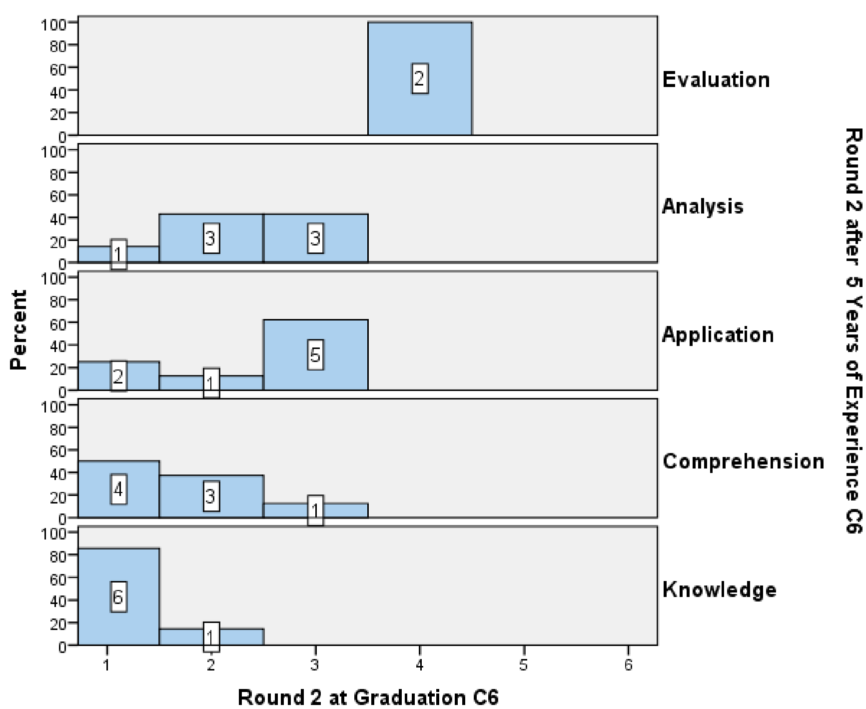


Figure A-24: Change in Expected Achievement Level, Question C6

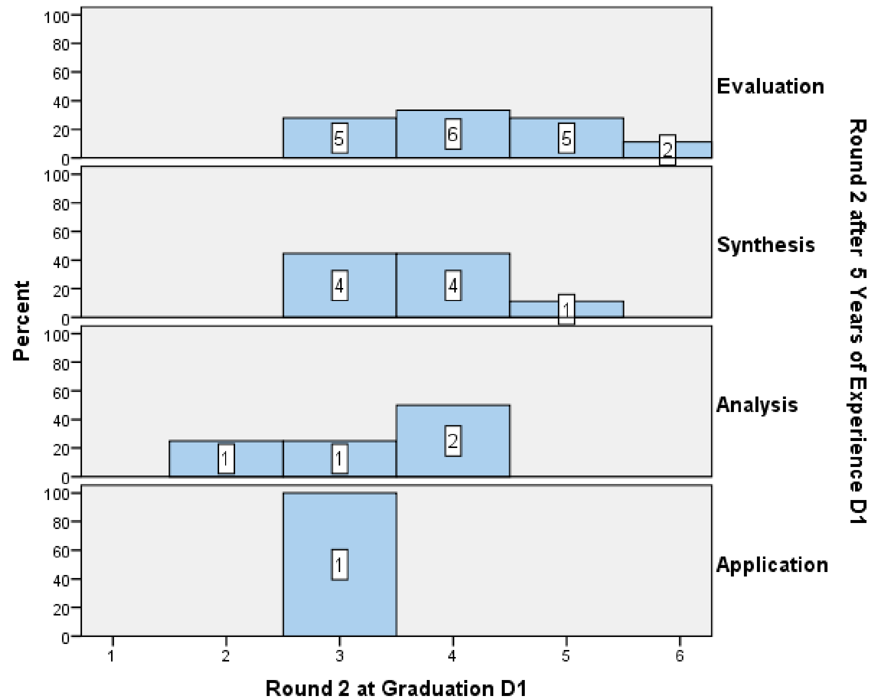


Figure A-25: Change in Expected Achievement Level, Question D1

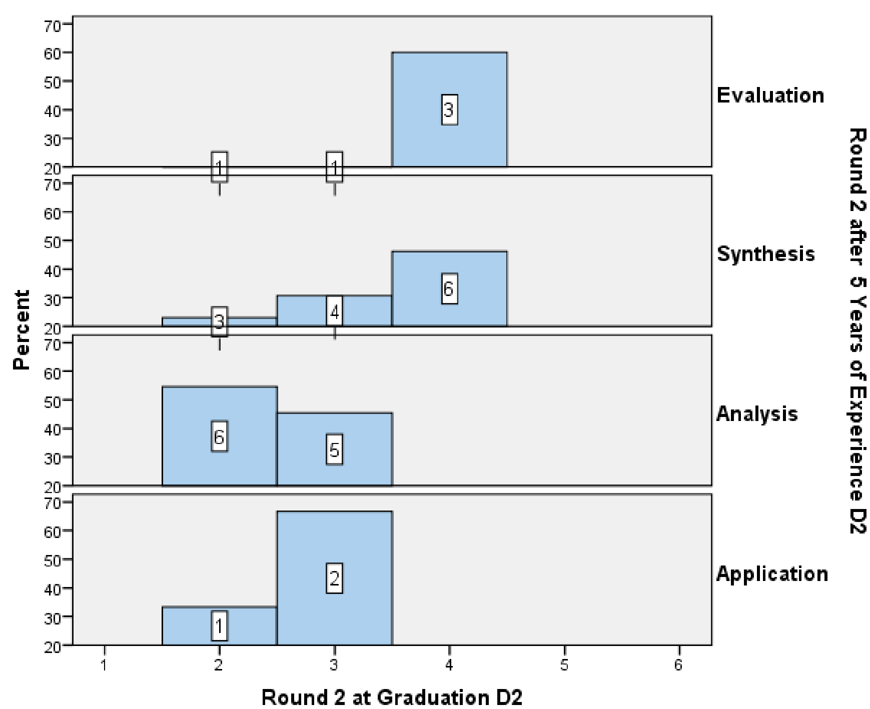


Figure A-26: Change in Expected Achievement Level, Question D2

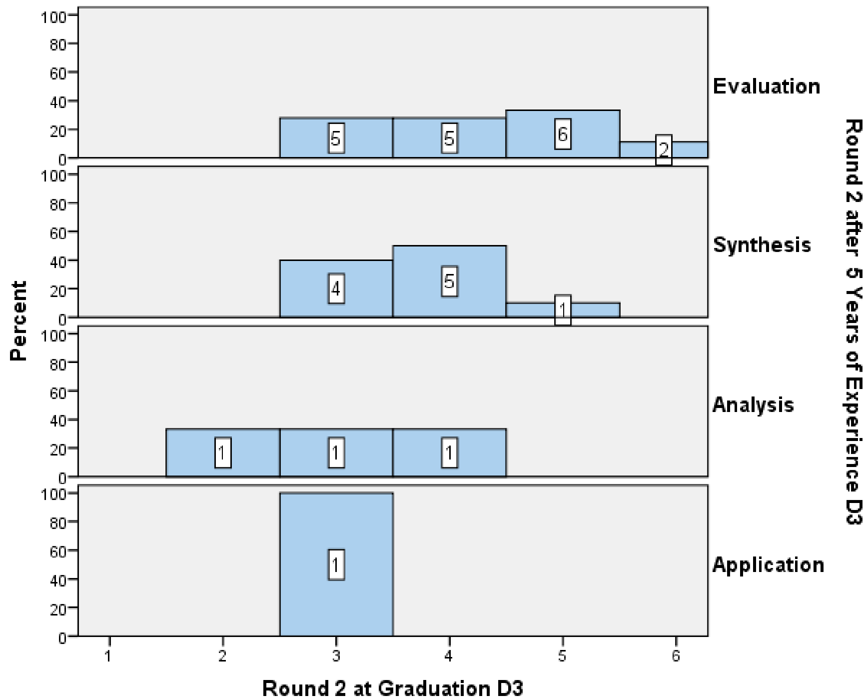


Figure A-27: Change in Expected Achievement Level, Question D3

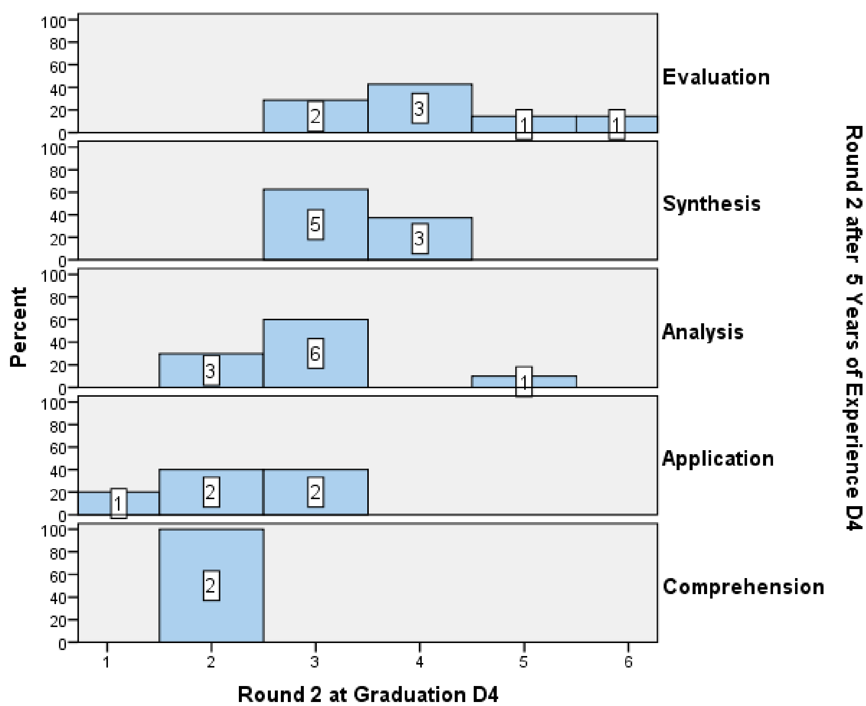


Figure A-28: Change in Expected Achievement Level, Question D4

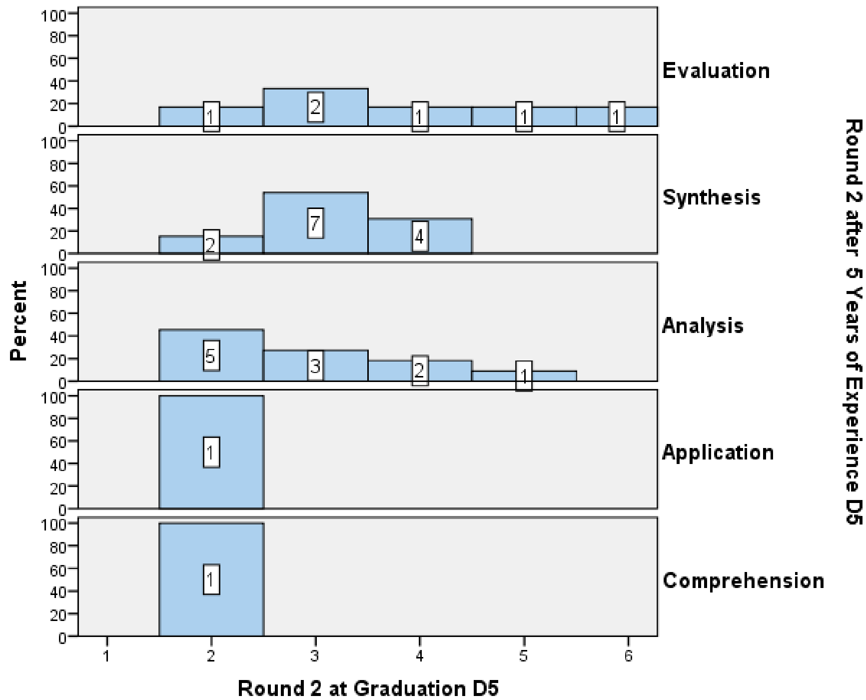


Figure A-29: Change in Expected Achievement Level, Question D5

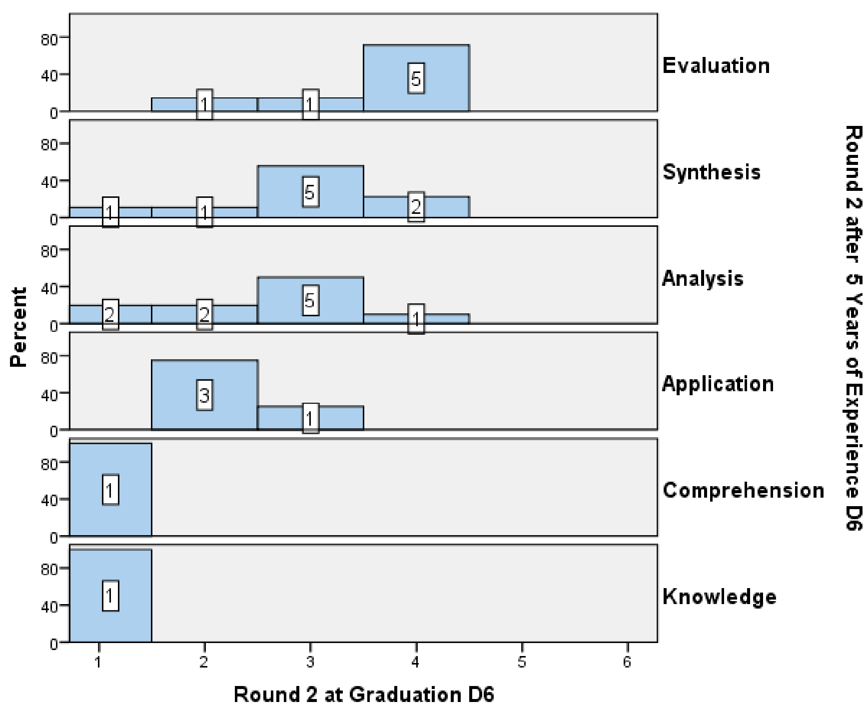


Figure A-30: Change in Expected Achievement Level, Question D6

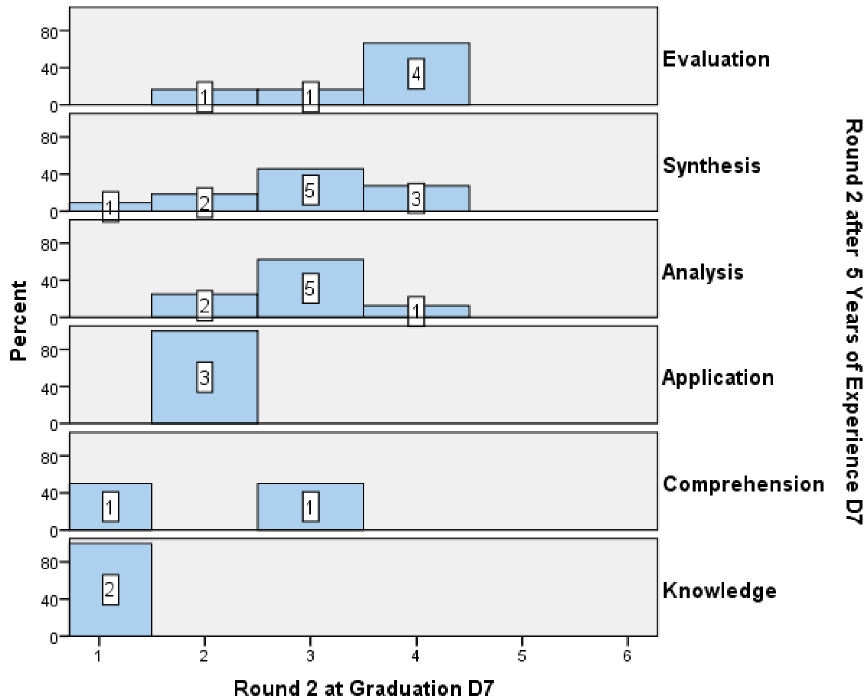


Figure A-31: Change in Expected Achievement Level, Question D7

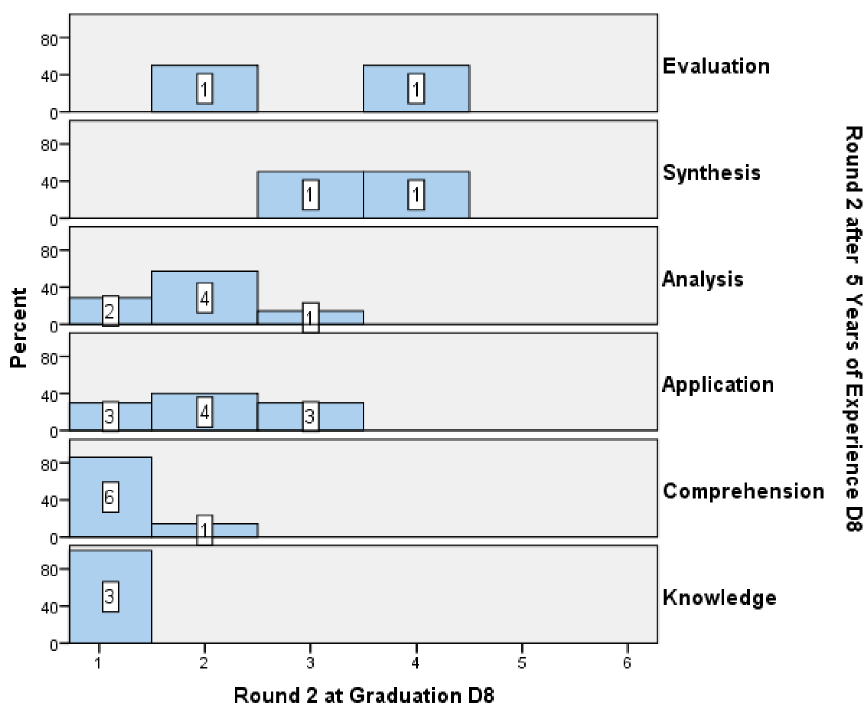


Figure A-32: Change in Expected Achievement Level, Question D8

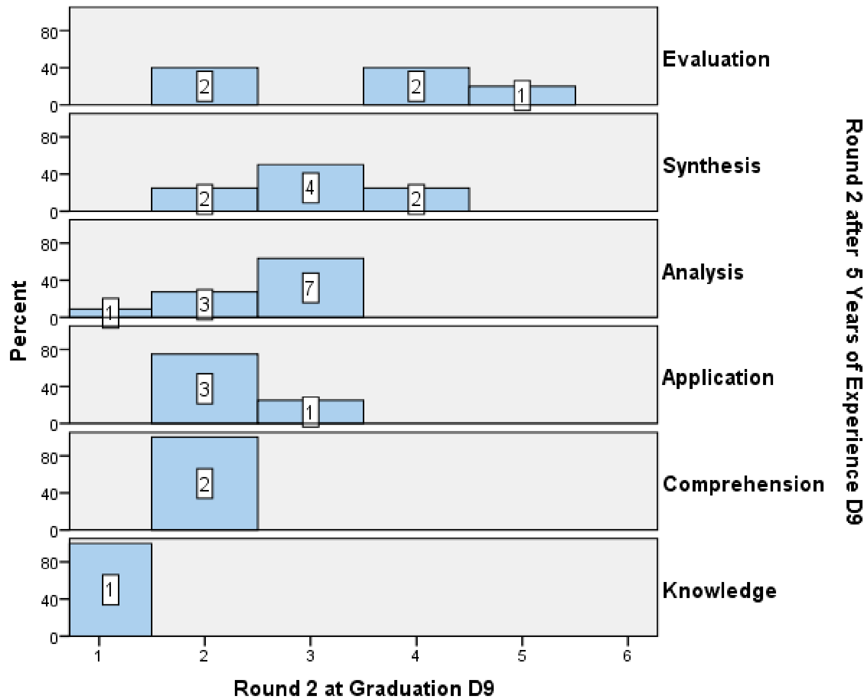


Figure A-33: Change in Expected Achievement Level, Question D9

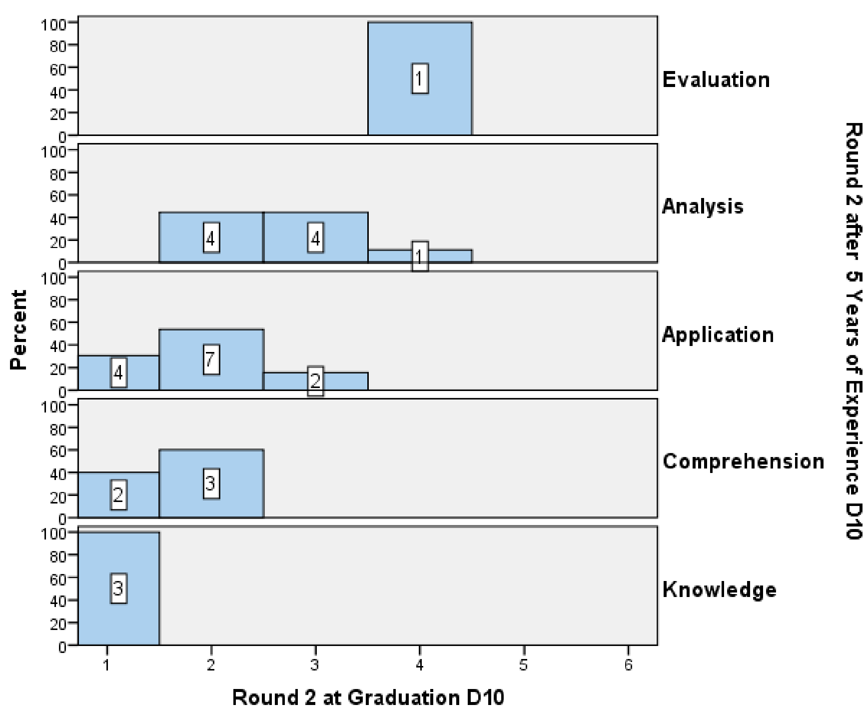


Figure A-34: Change in Expected Achievement Level, Question D10

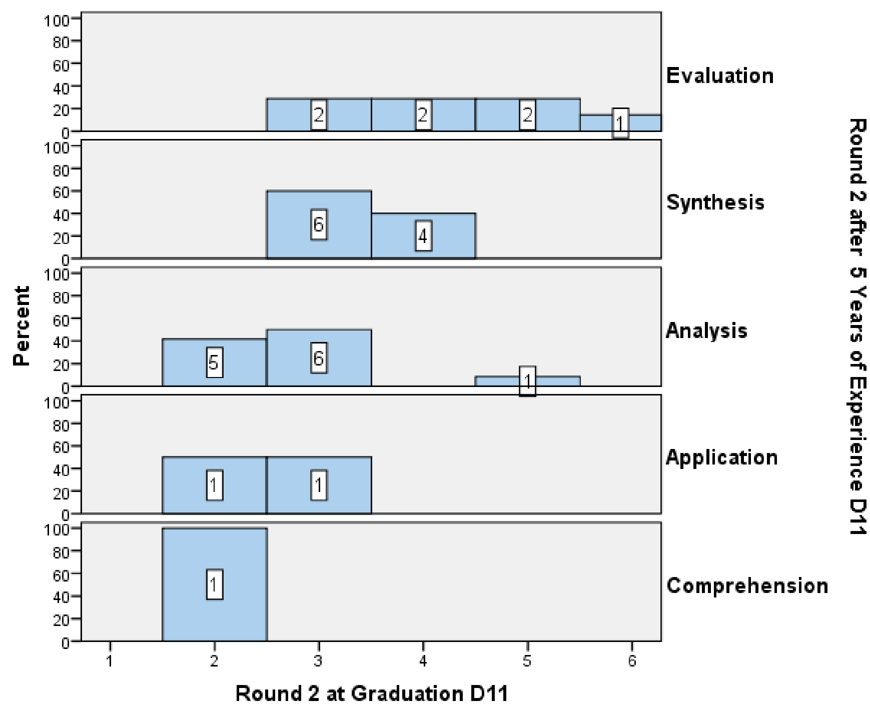


Figure A-35: Change in Expected Achievement Level, Question D11

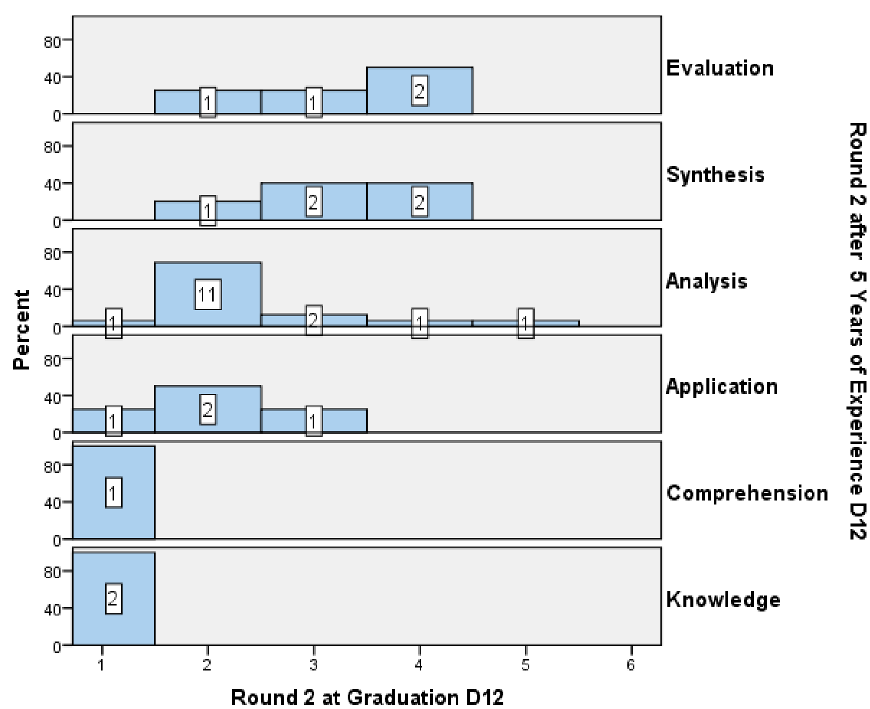


Figure A-36: Change in Expected Achievement Level, Question D12

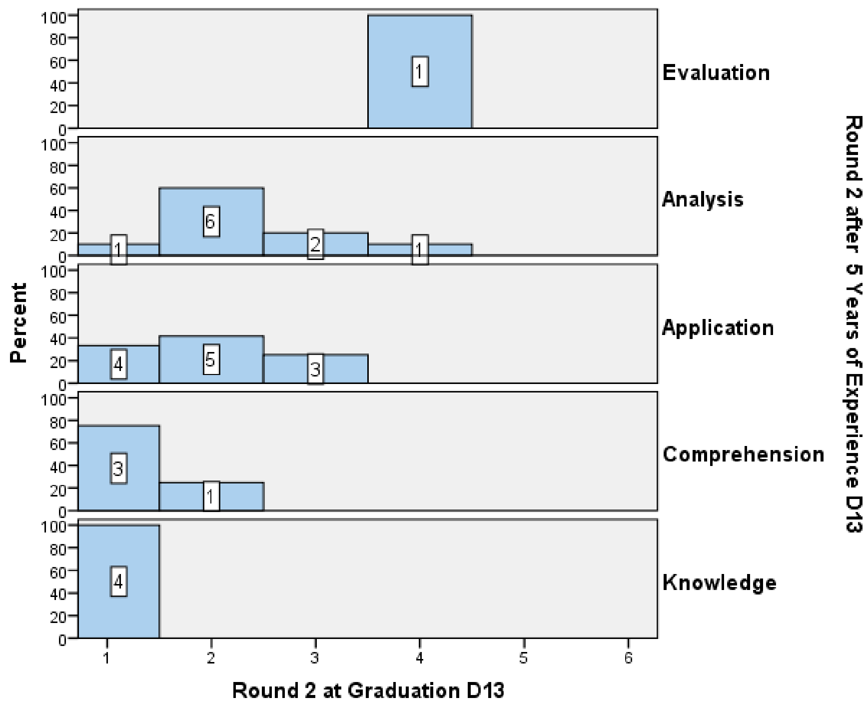


Figure A-37: Change in Expected Achievement Level, Question D13

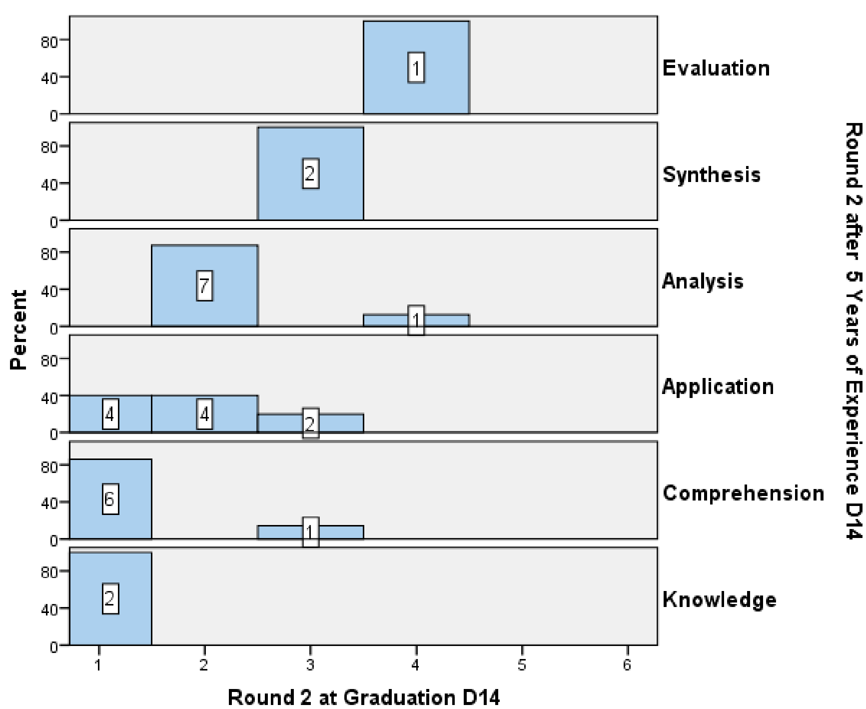


Figure A-38: Change in Expected Achievement Level, Question D14

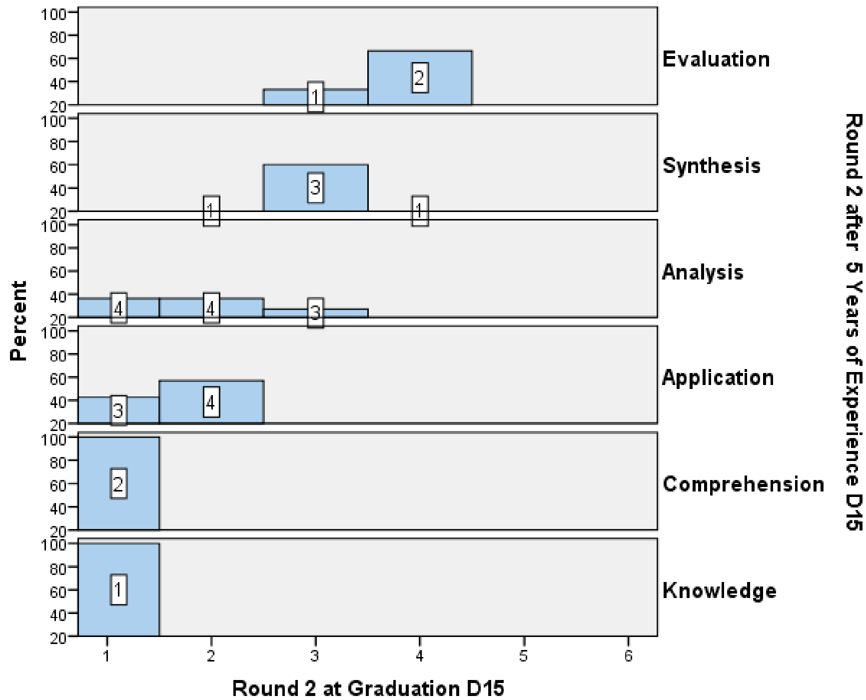


Figure A-39: Change in Expected Achievement Level, Question D15

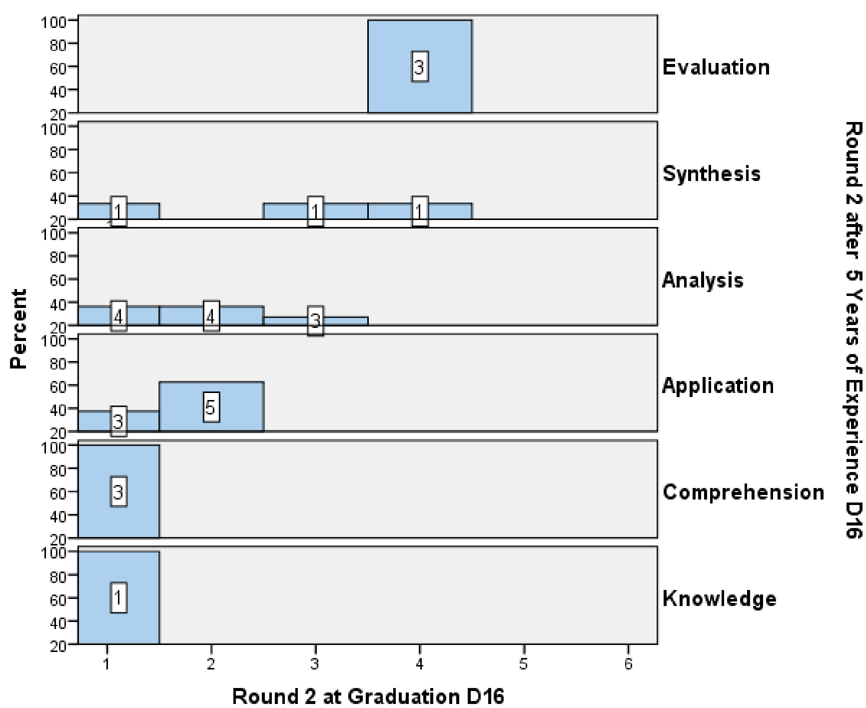


Figure A-40: Change in Expected Achievement Level, Question D16

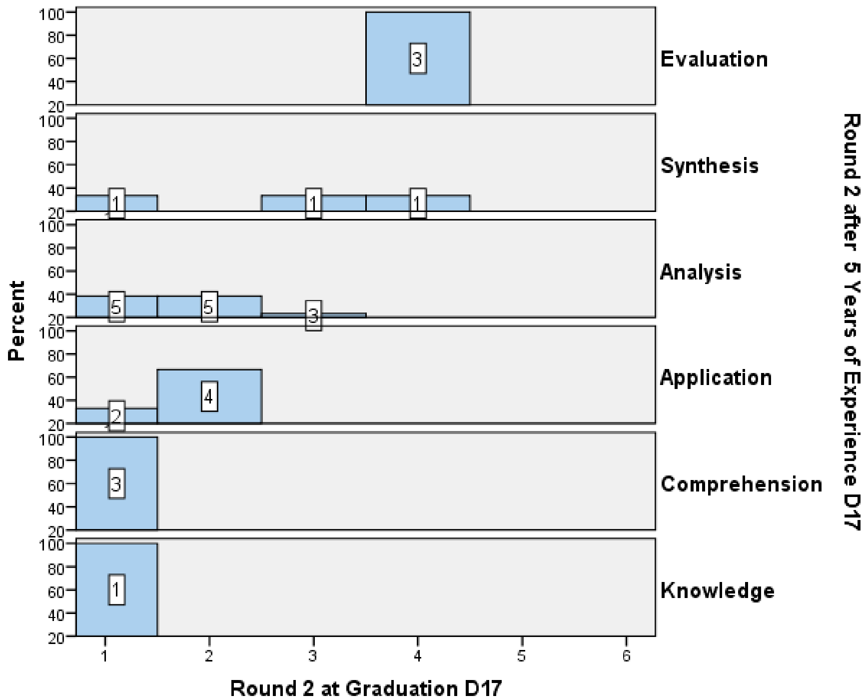


Figure A-41: Change in Expected Achievement Level, Question D17

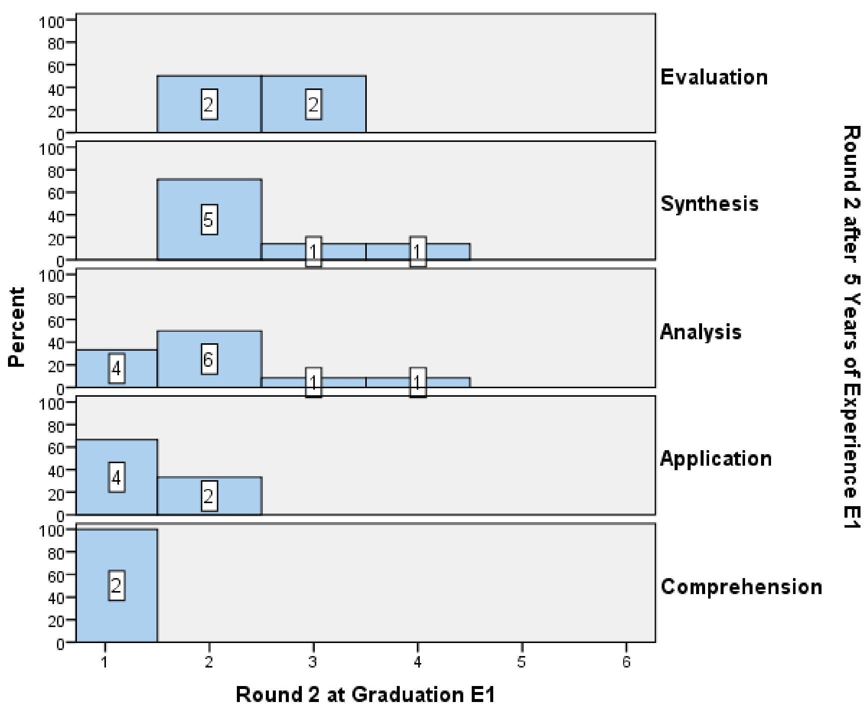


Figure A-42: Change in Expected Achievement Level, Question E1

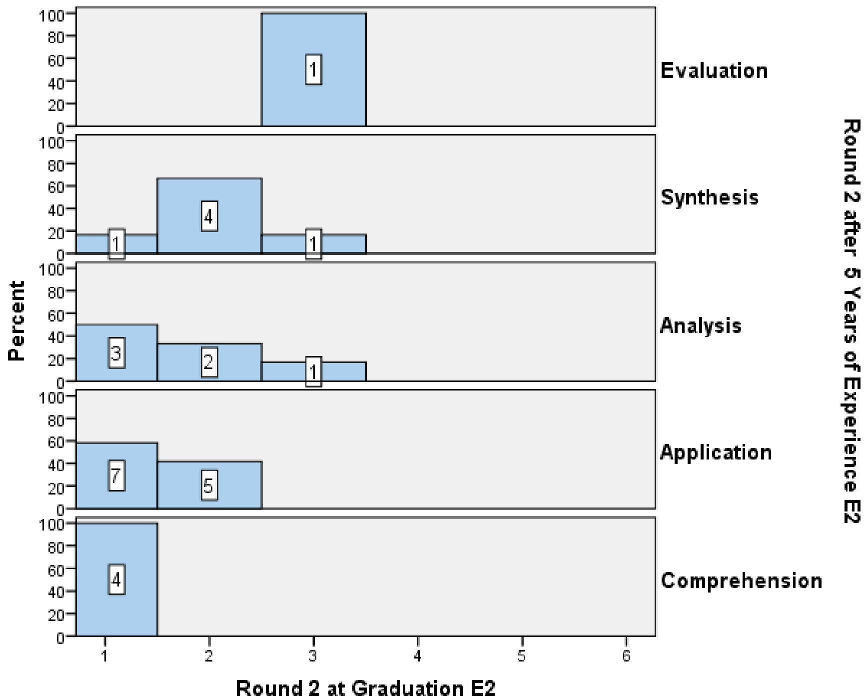


Figure A-43: Change in Expected Achievement Level, Question E2

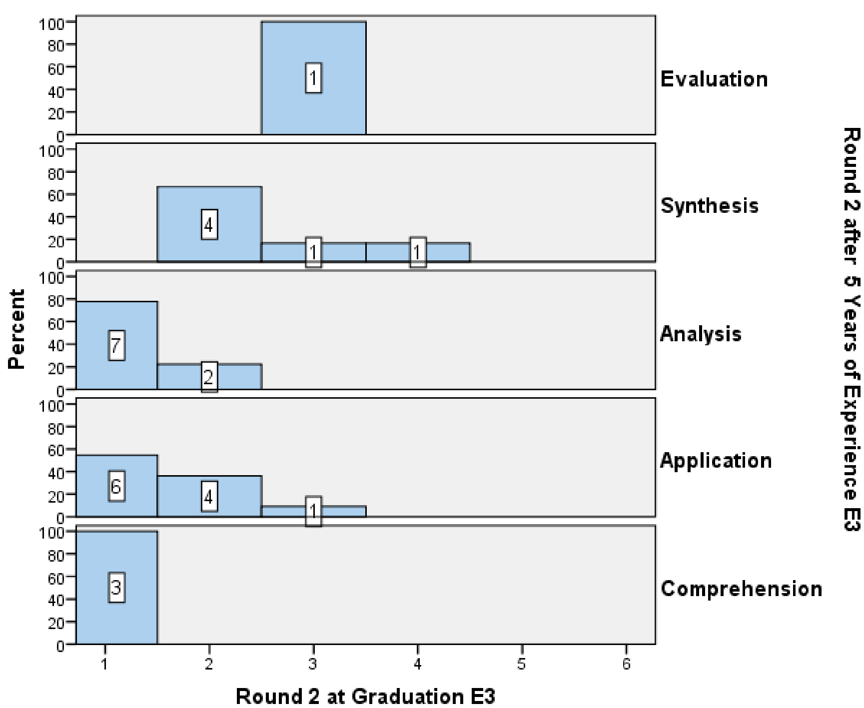


Figure A-44: Change in Expected Achievement Level, Question E3

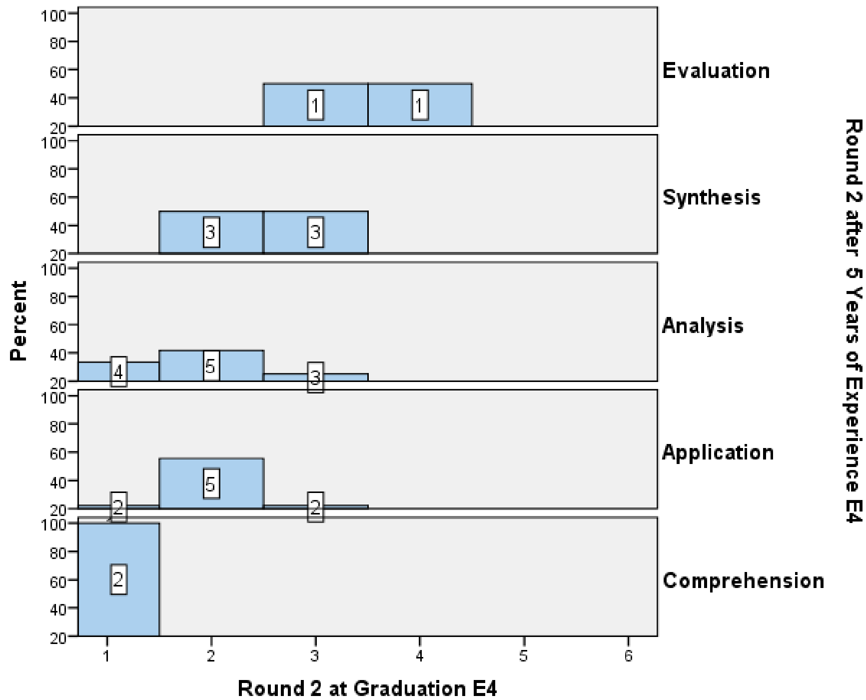


Figure A-45: Change in Expected Achievement Level, Question E4

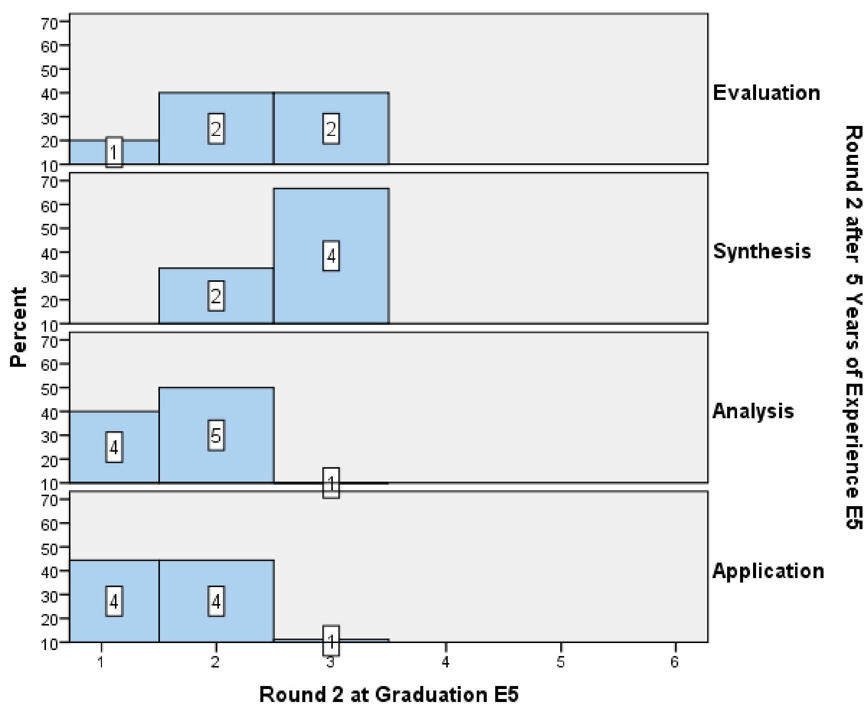


Figure A-46: Change in Expected Achievement Level, Question E5

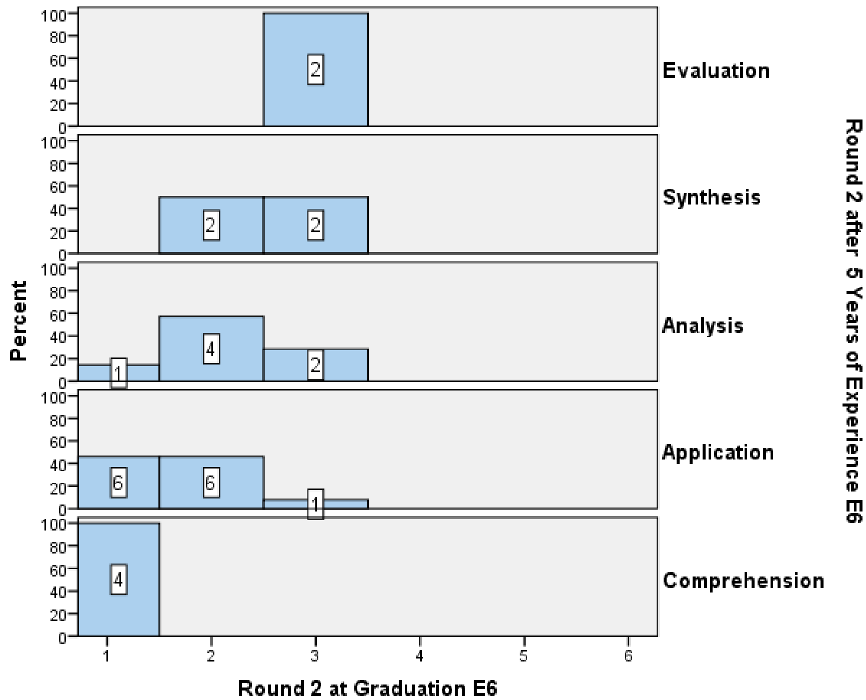


Figure A-47: Change in Expected Achievement Level, Question E6

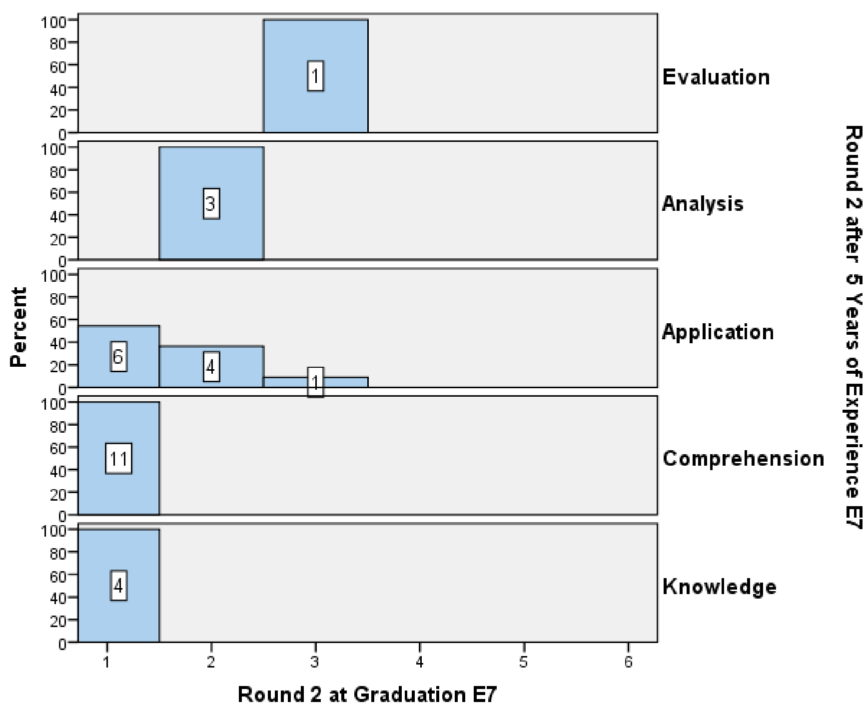


Figure A-48: Change in Expected Achievement Level, Question E7

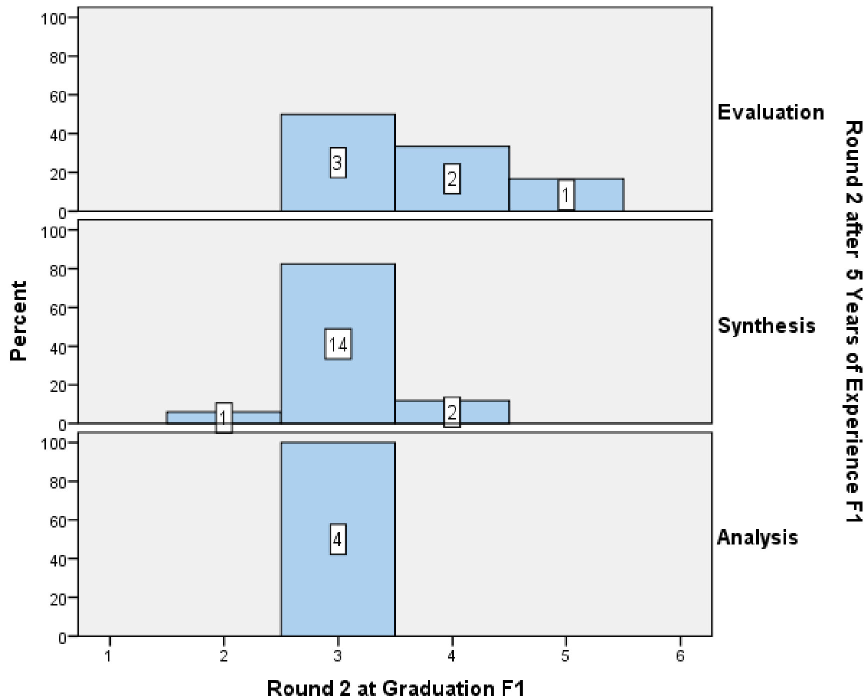


Figure A-49: Change in Expected Achievement Level, Question F1

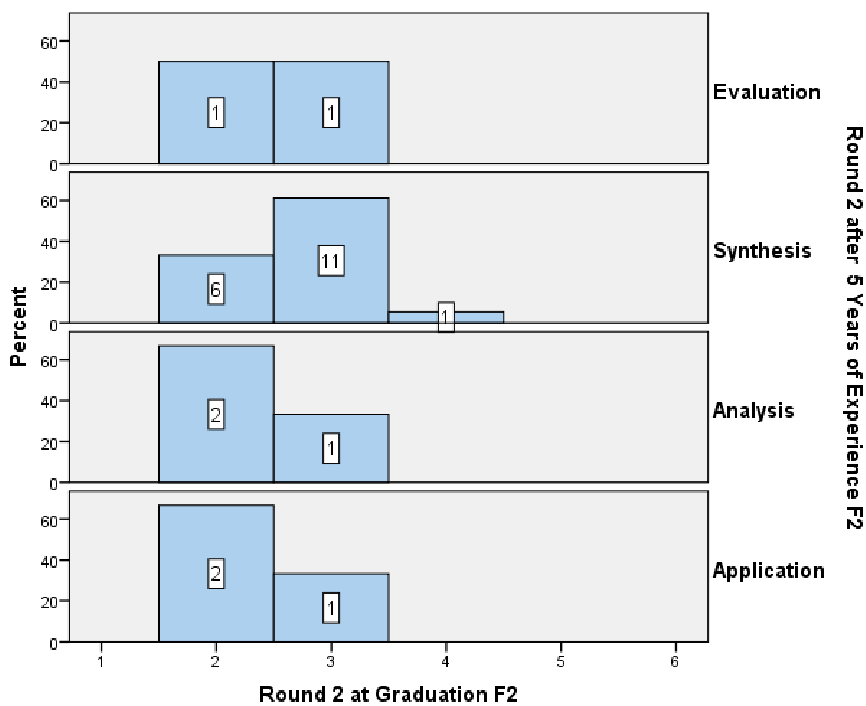


Figure A-50: Change in Expected Achievement Level, Question F2

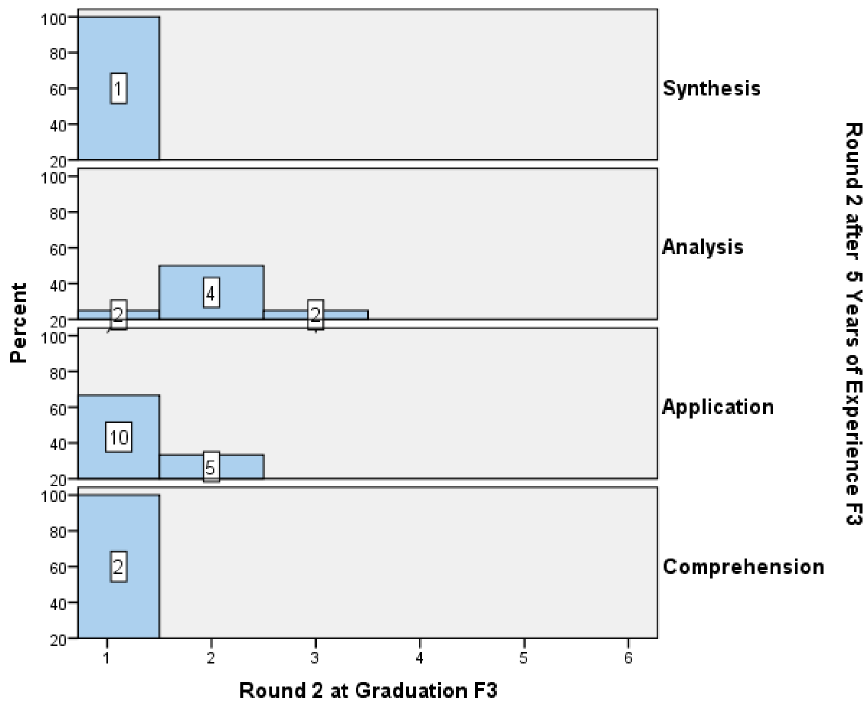


Figure A-51: Change in Expected Achievement Level, Question F3

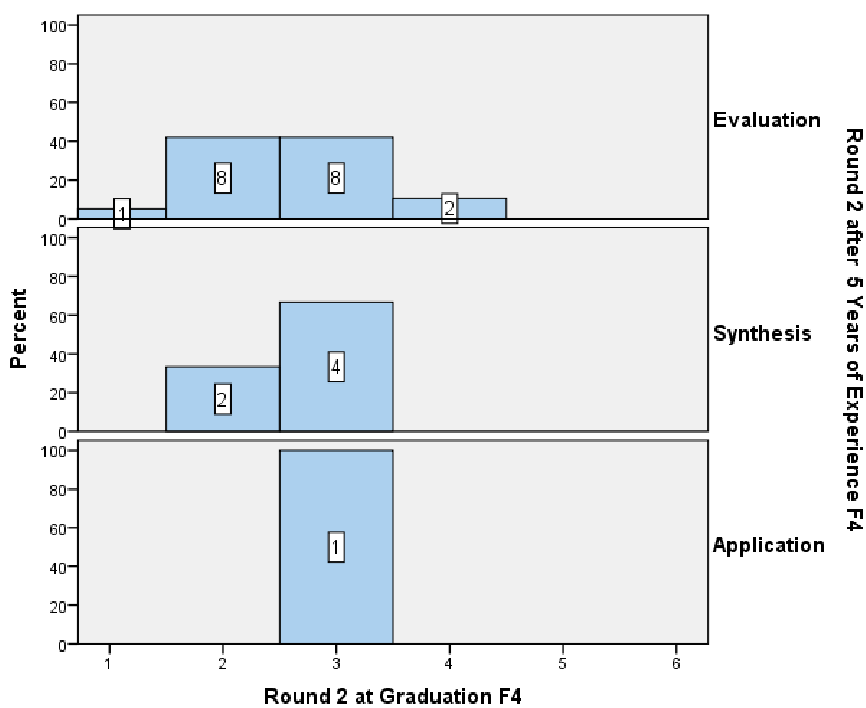


Figure A-52: Change in Expected Achievement Level, Question F4

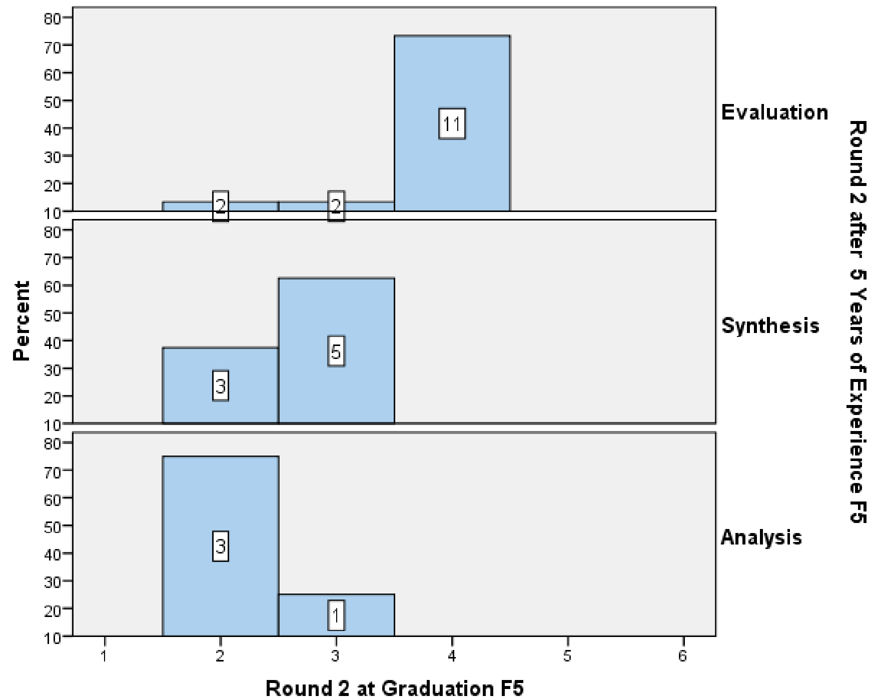


Figure A-53: Change in Expected Achievement Level, Question F5

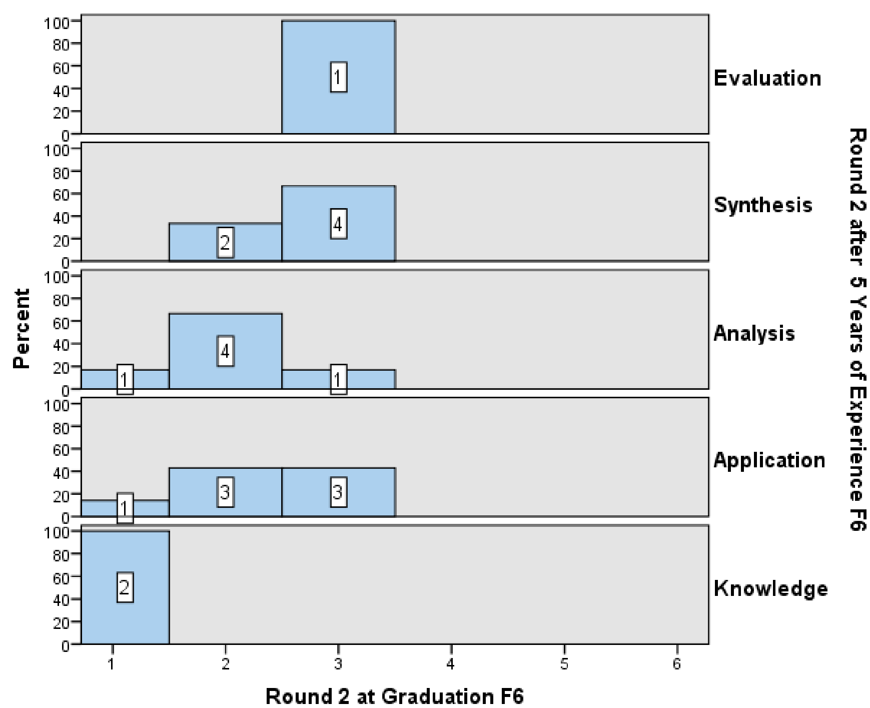


Figure A-54: Change in Expected Achievement Level, Question F6

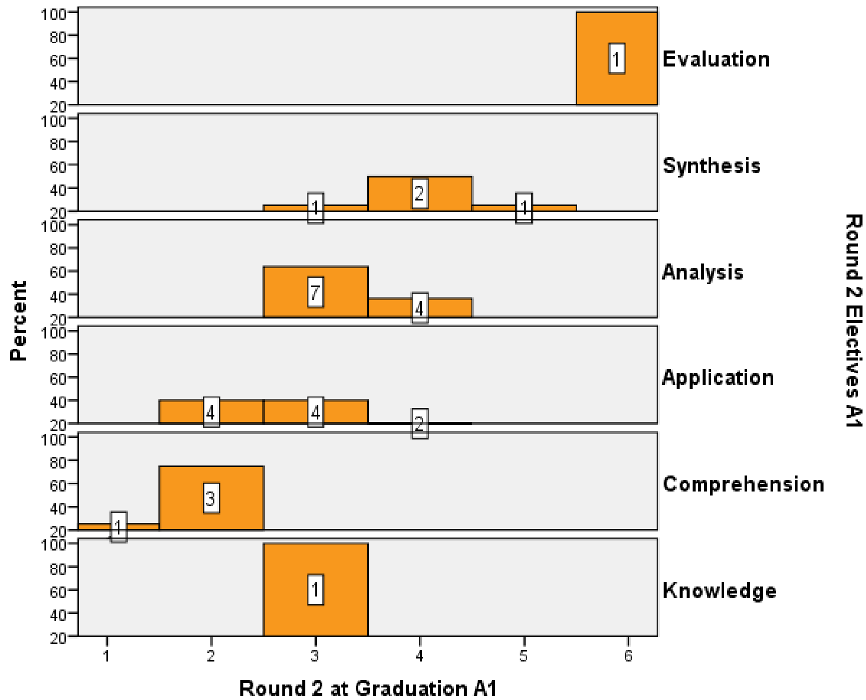


Figure A-55: Change in Expected Achievement Level, Question A1

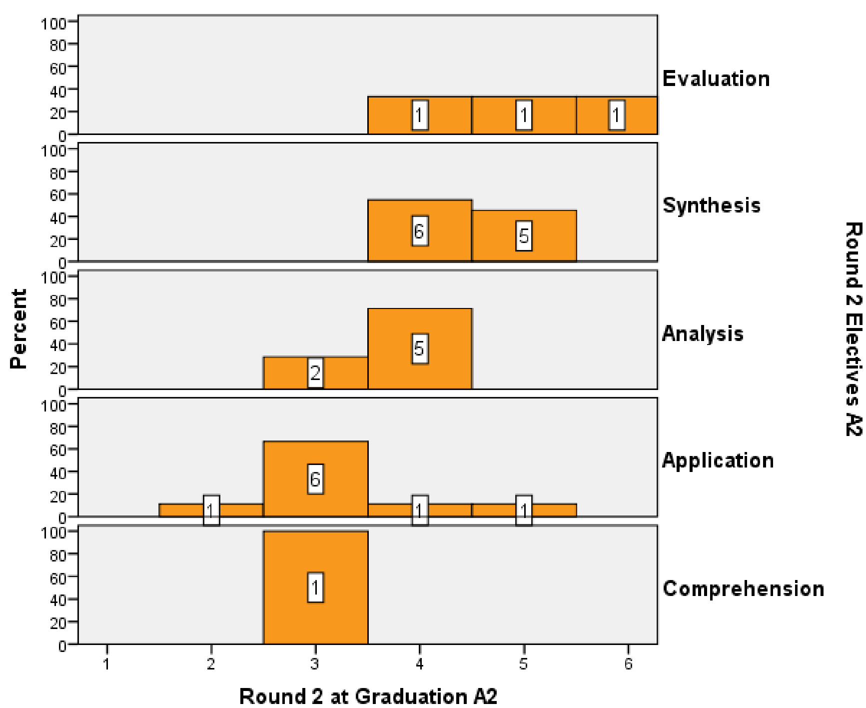


Figure A-56: Change in Expected Achievement Level, Question A2

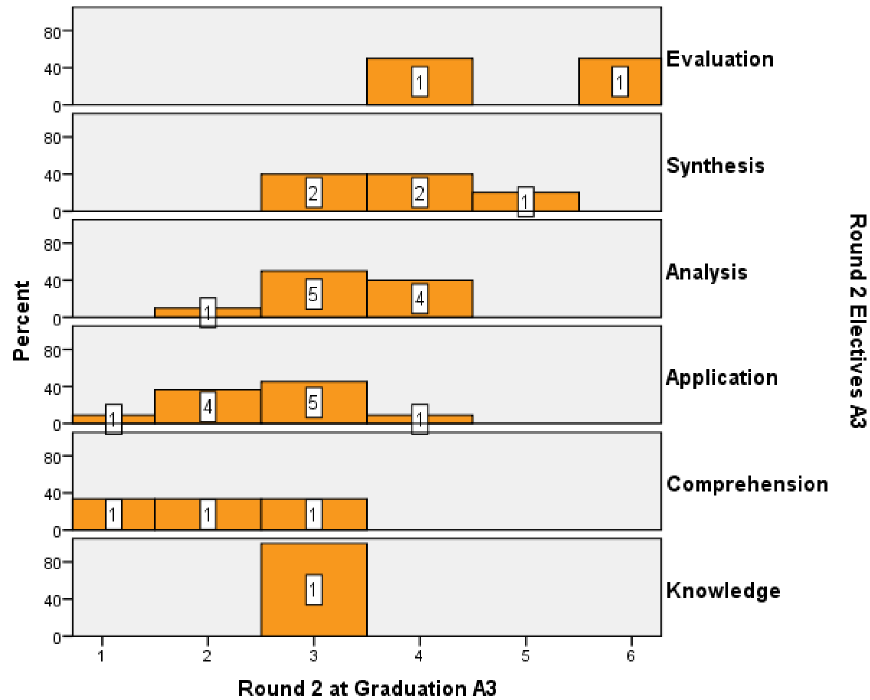


Figure A-57: Change in Expected Achievement Level, Question A3

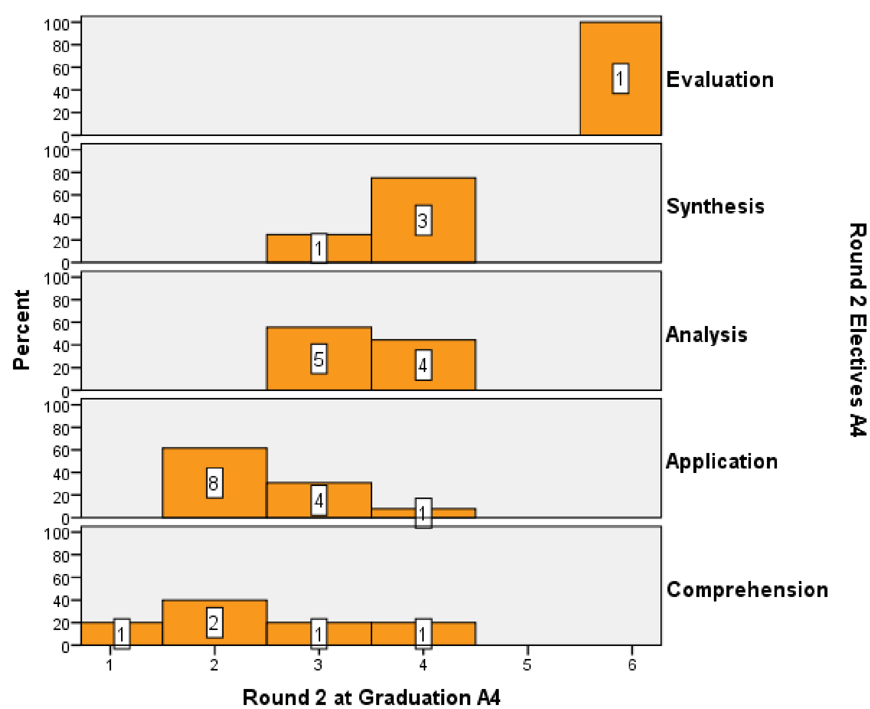


Figure A-58: Change in Expected Achievement Level, Question A4

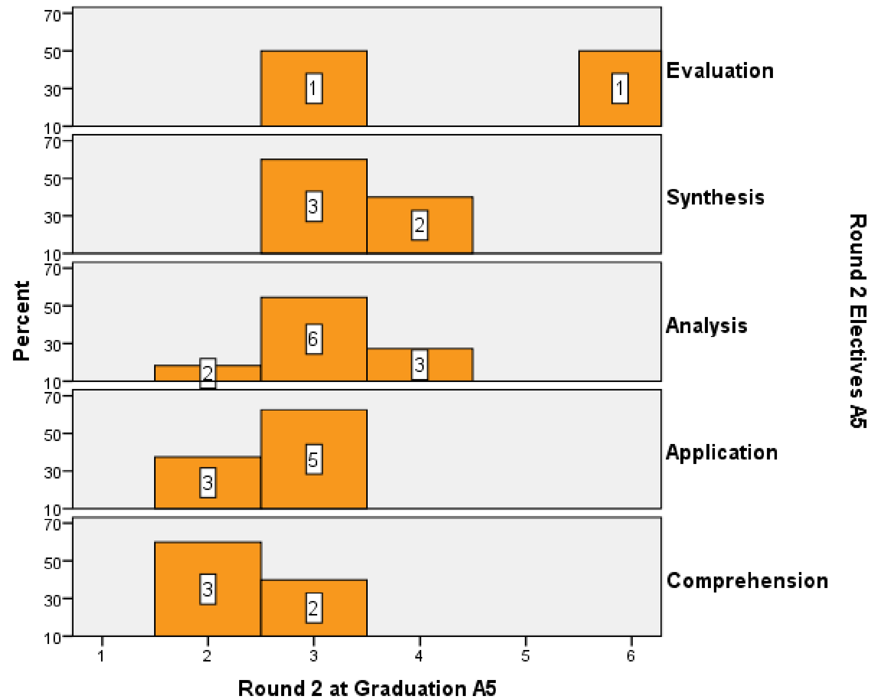


Figure A-59: Change in Expected Achievement Level, Question A5

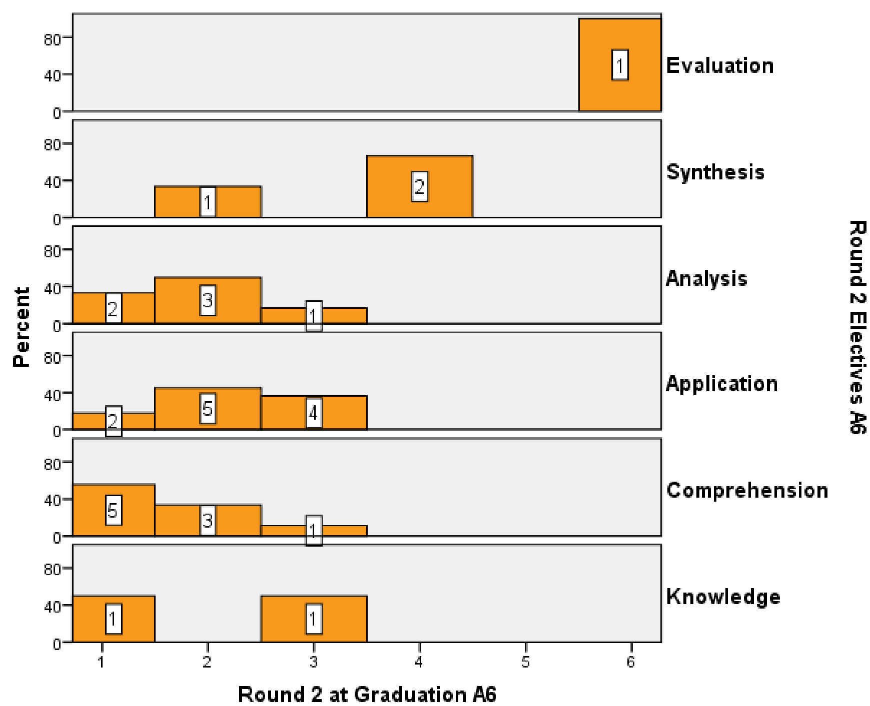


Figure A-60: Change in Expected Achievement Level, Question A6

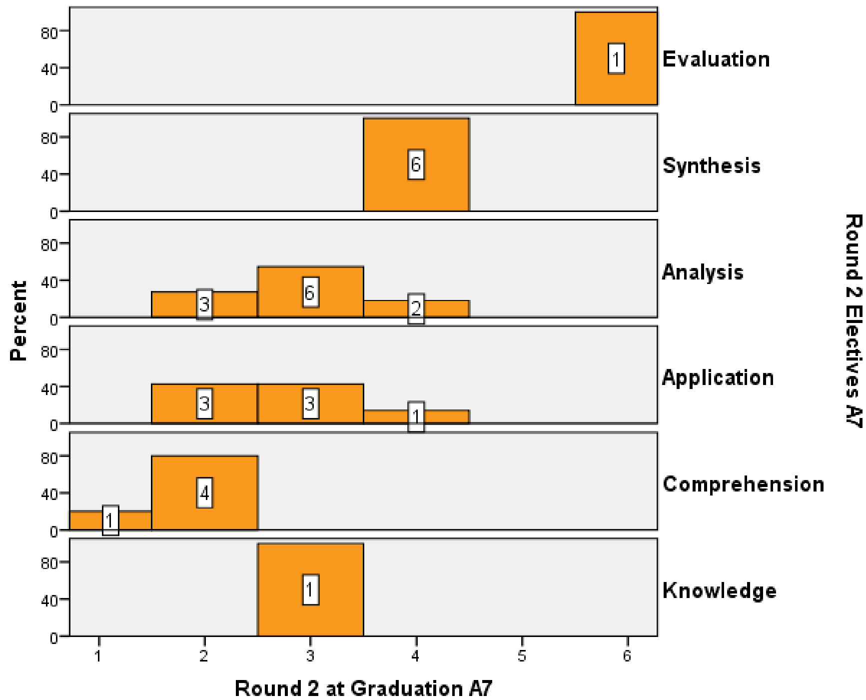


Figure A-61: Change in Expected Achievement Level, Question A7

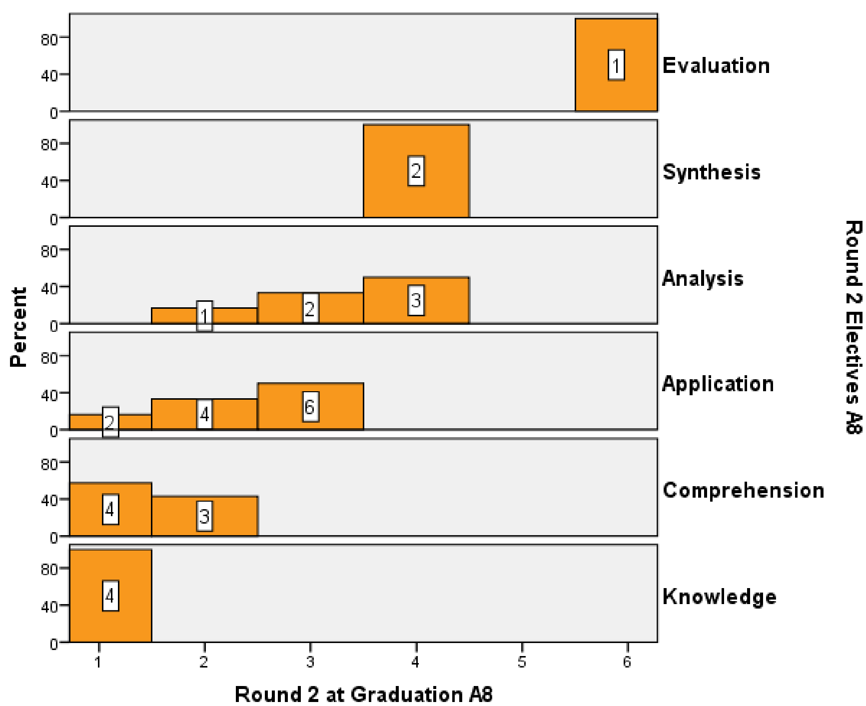


Figure A-62: Change in Expected Achievement Level, Question A8

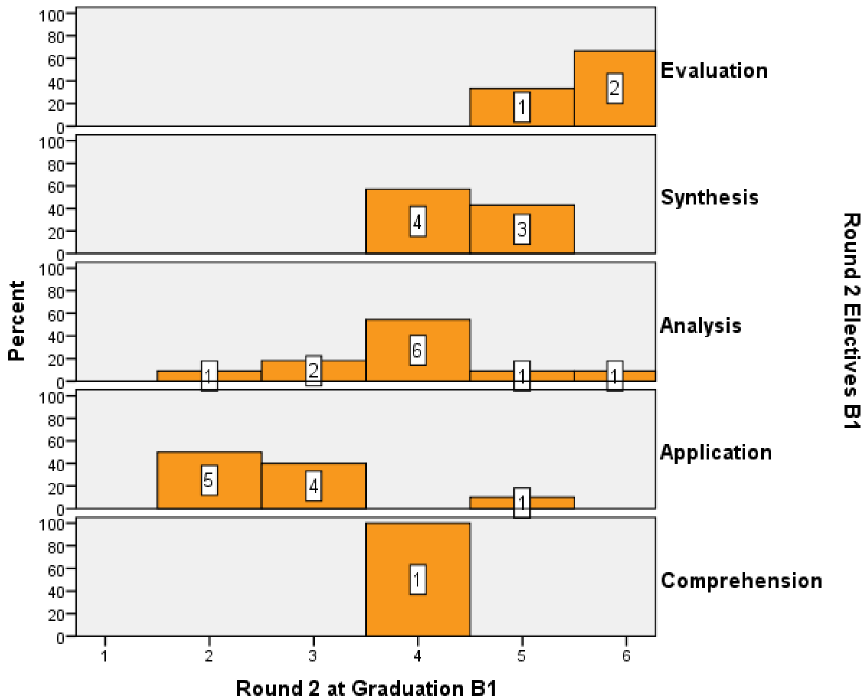


Figure A-63: Change in Expected Achievement Level, Question B1

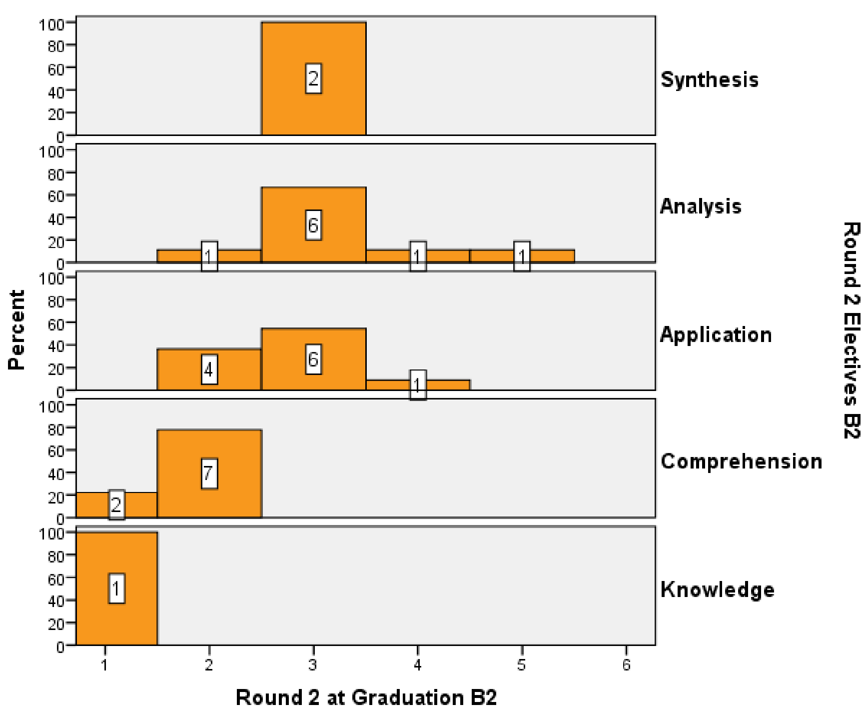


Figure A-64: Change in Expected Achievement Level, Question B2

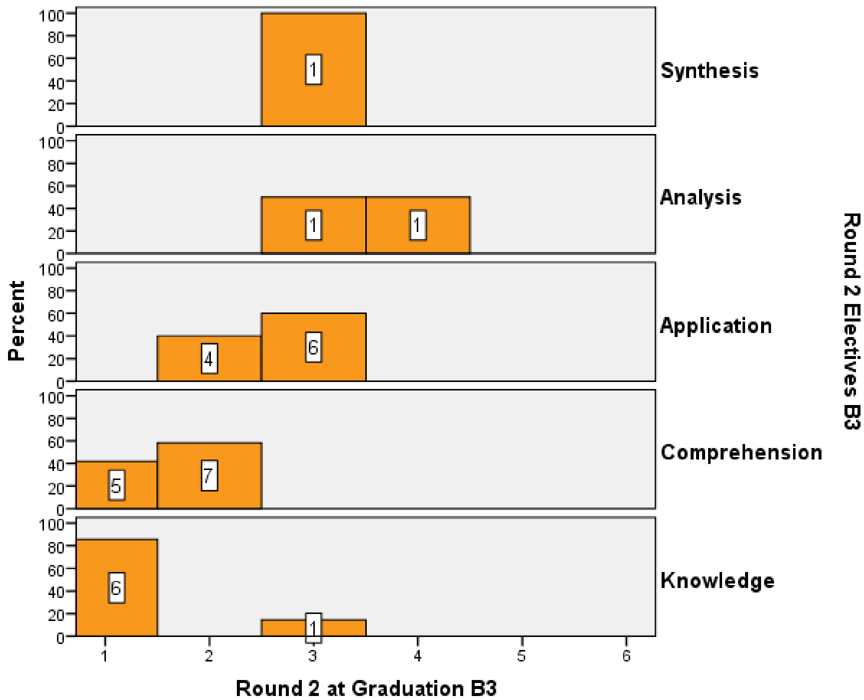


Figure A-65: Change in Expected Achievement Level, Question B3

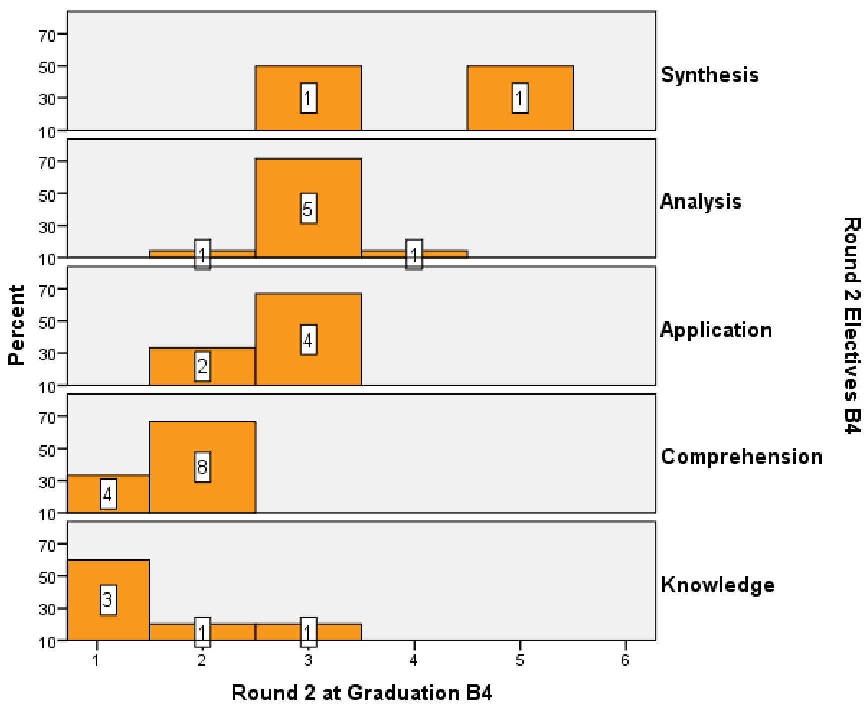


Figure A-66: Change in Expected Achievement Level, Question B4

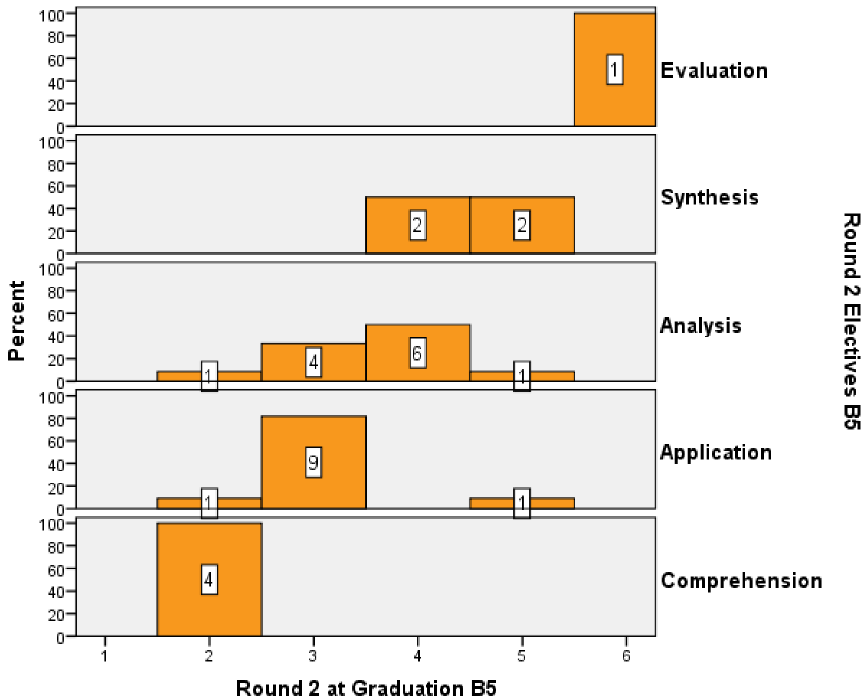


Figure A-67: Change in Expected Achievement Level, Question B5

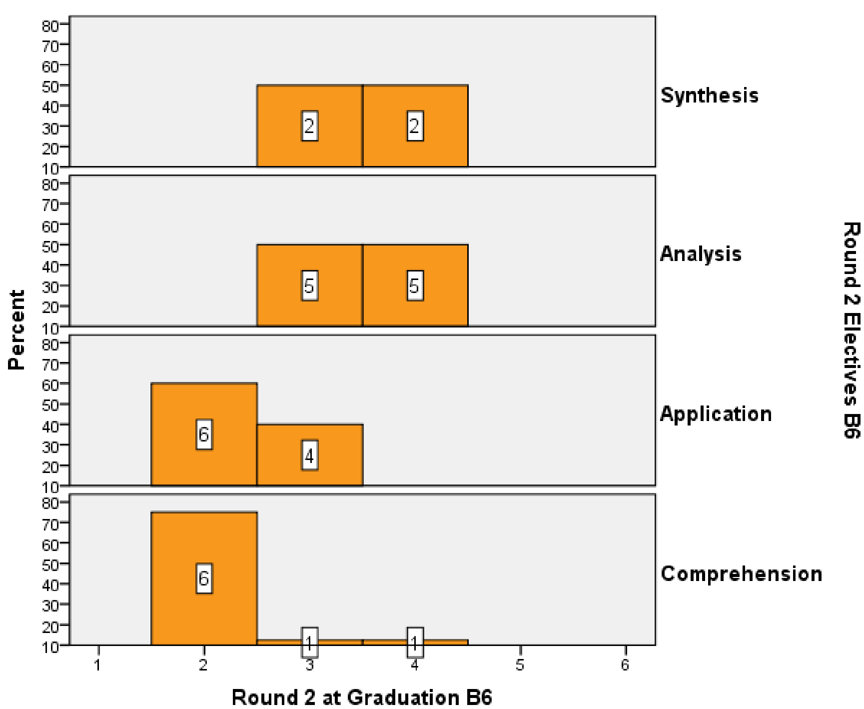


Figure A-68: Change in Expected Achievement Level, Question B6

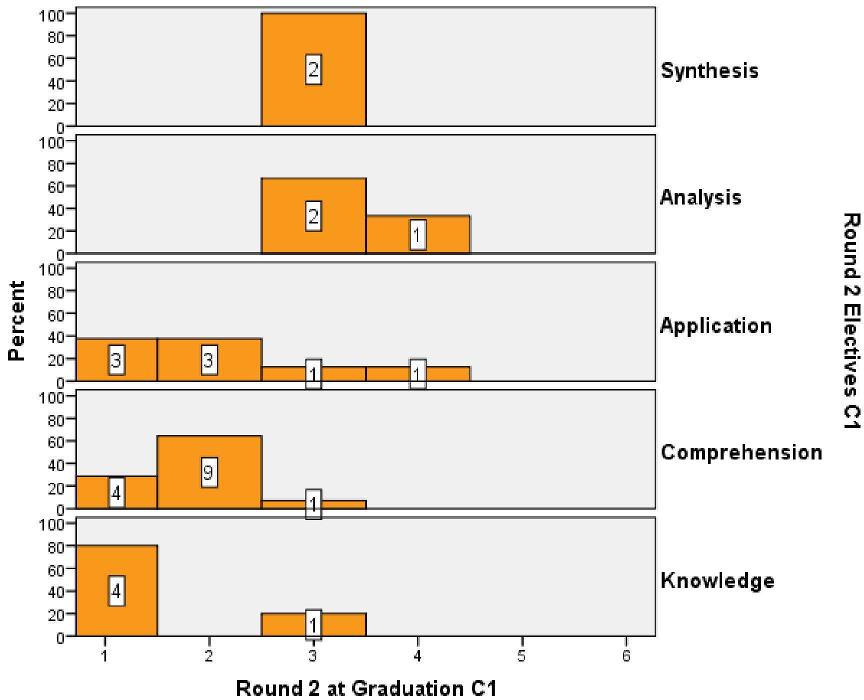


Figure A-69: Change in Expected Achievement Level, Question C1

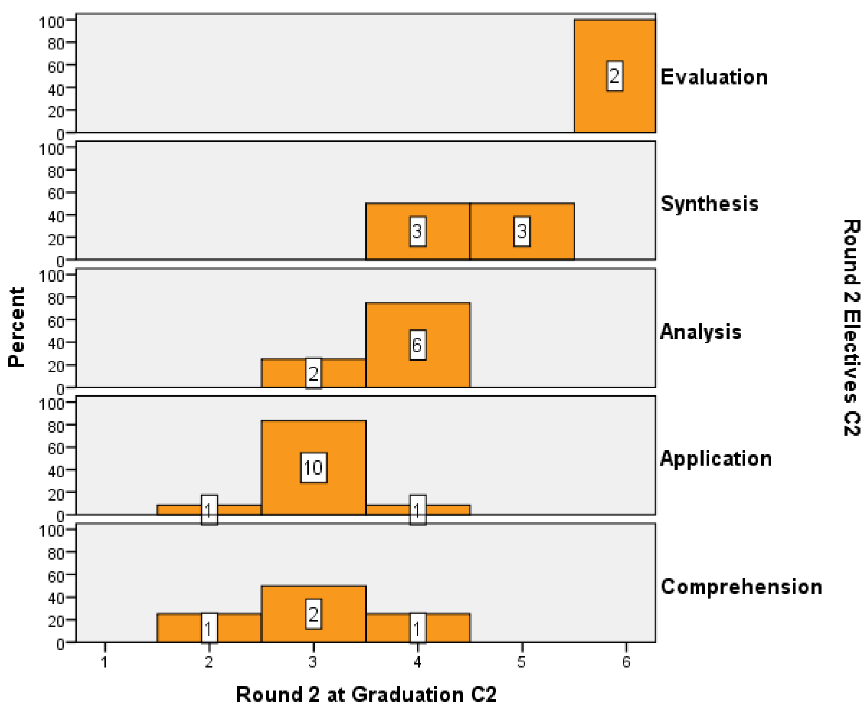


Figure A-70: Change in Expected Achievement Level, Question C2

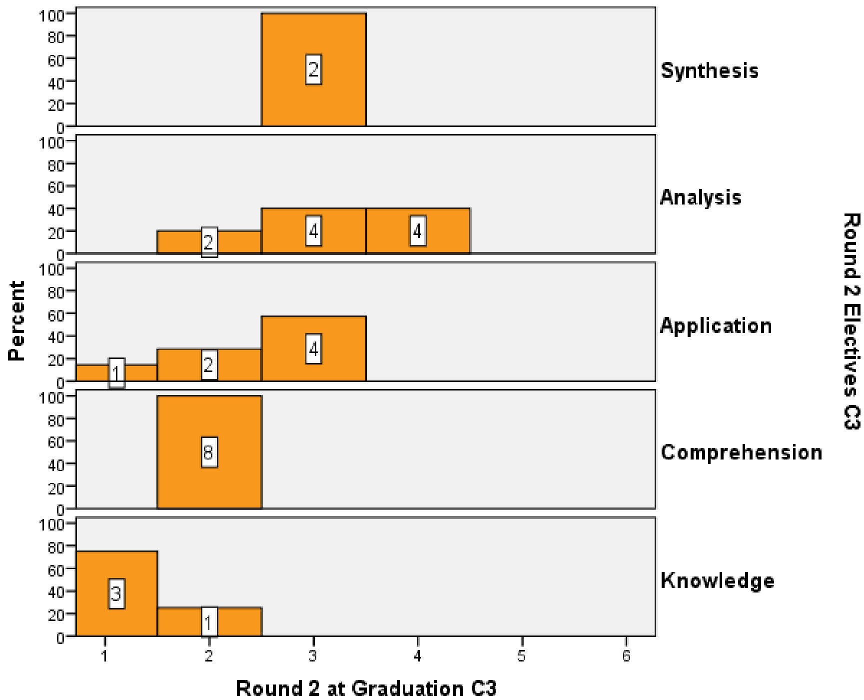


Figure A-71: Change in Expected Achievement Level, Question C3

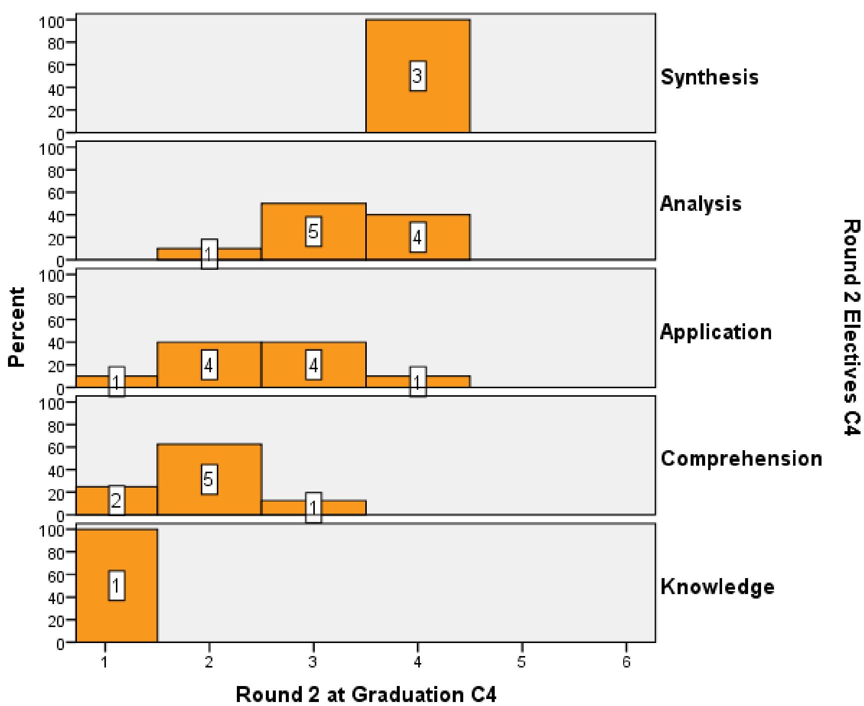


Figure A-72: Change in Expected Achievement Level, Question C4

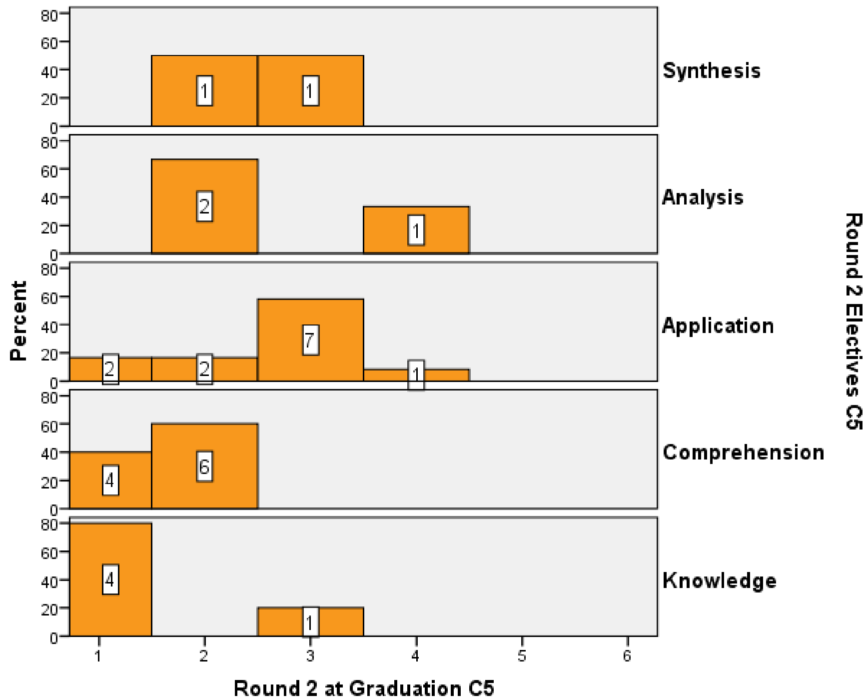


Figure A-73: Change in Expected Achievement Level, Question C5

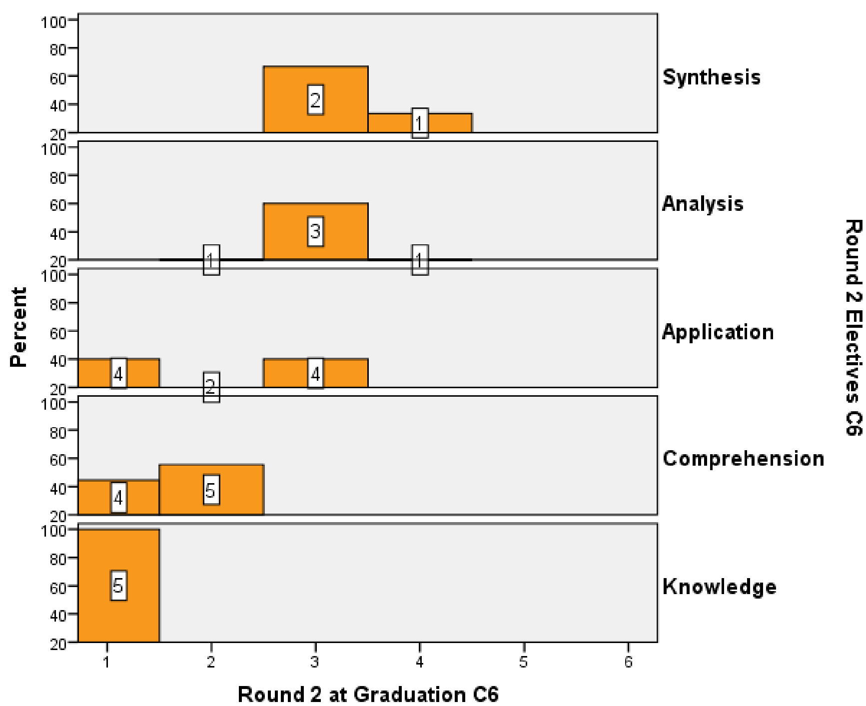


Figure A-74: Change in Expected Achievement Level, Question C6

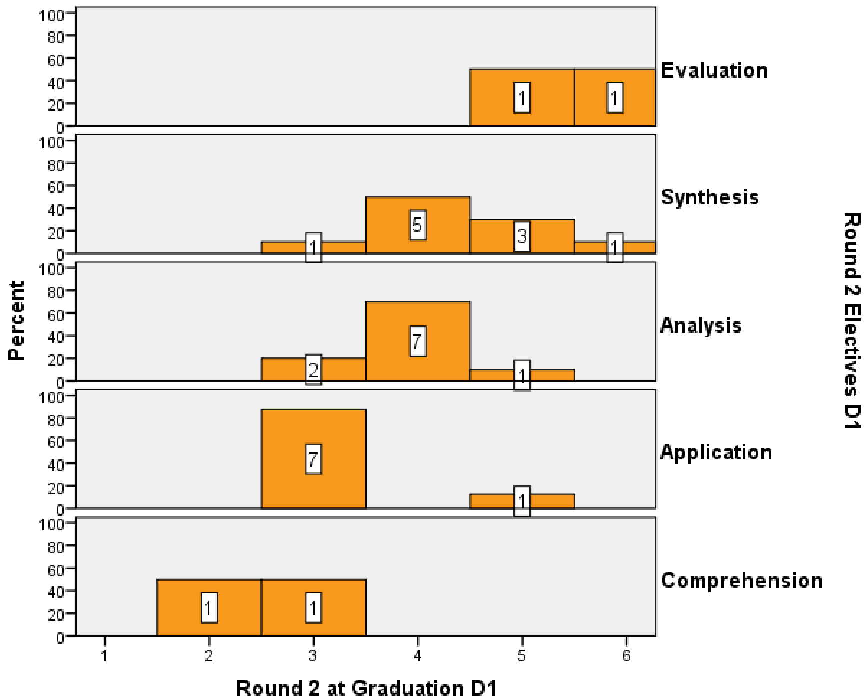


Figure A-75: Change in Expected Achievement Level, Question D1

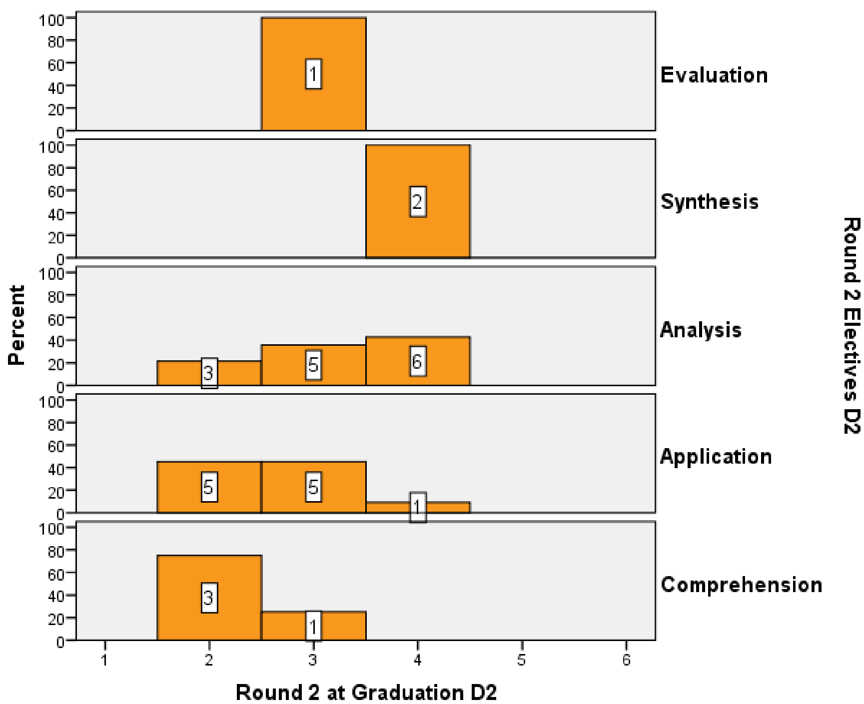


Figure A-76: Change in Expected Achievement Level, Question D2

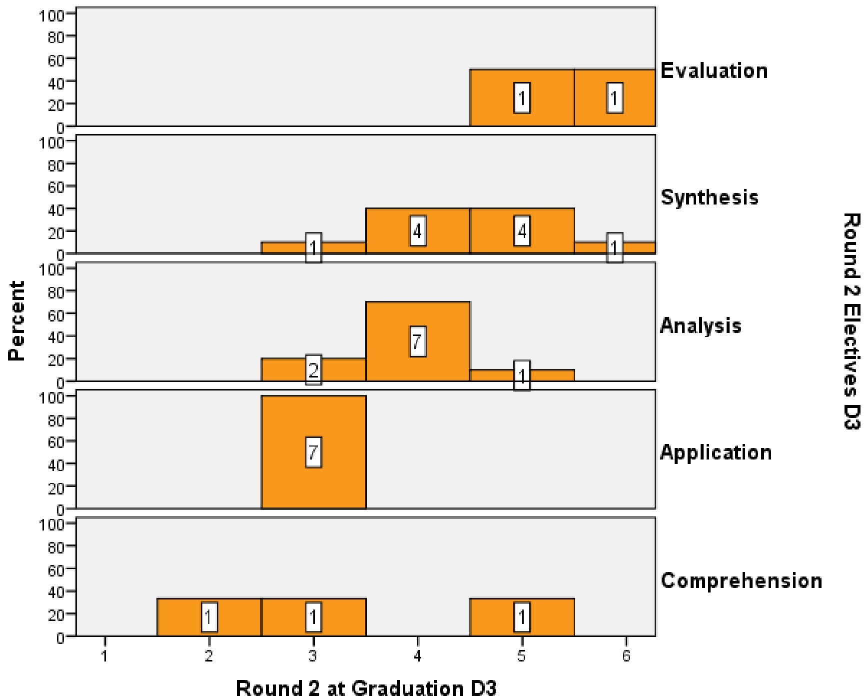


Figure A-77: Change in Expected Achievement Level, Question D3

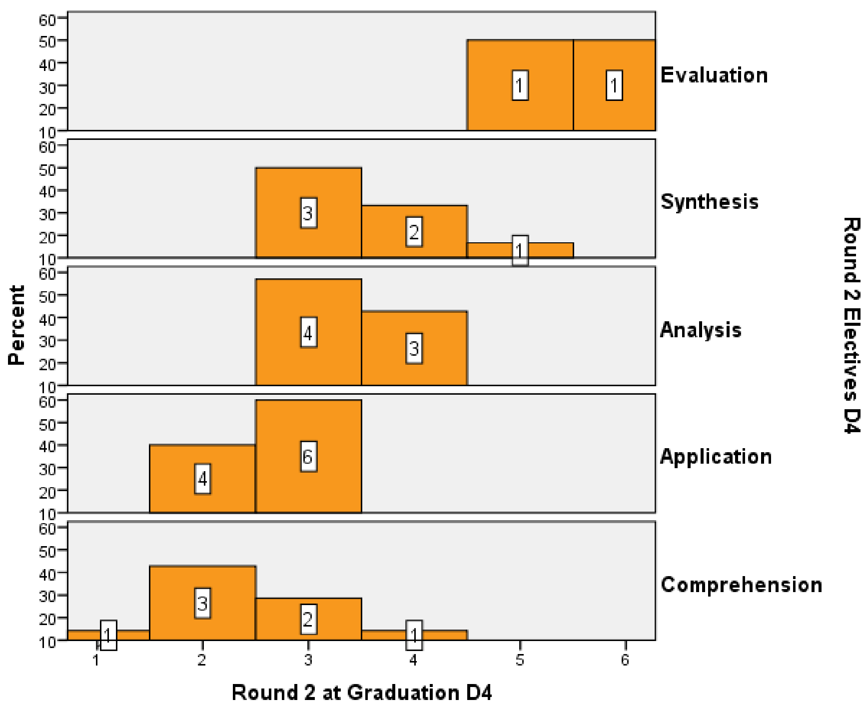


Figure A-78: Change in Expected Achievement Level, Question D4

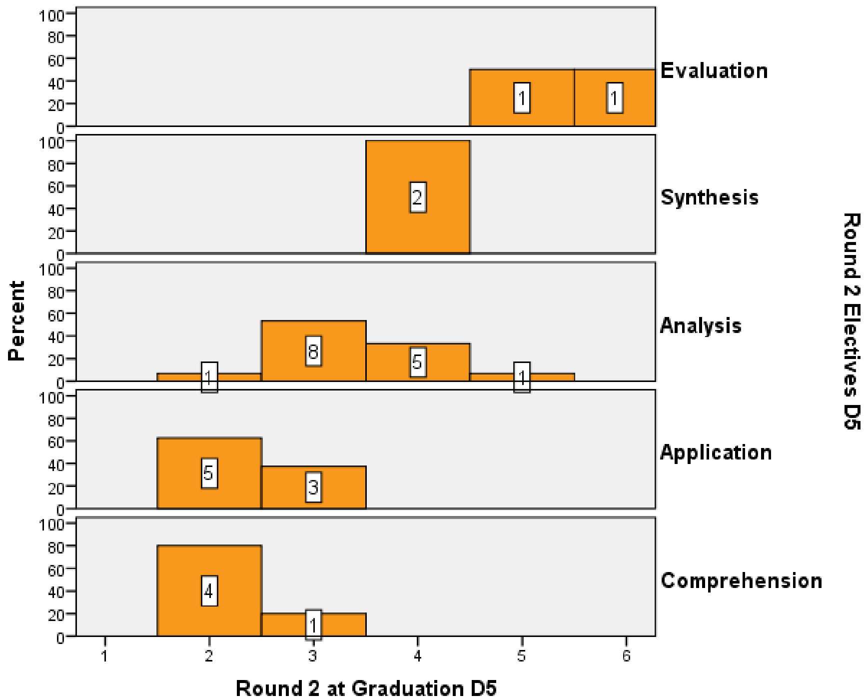


Figure A-79: Change in Expected Achievement Level, Question D5

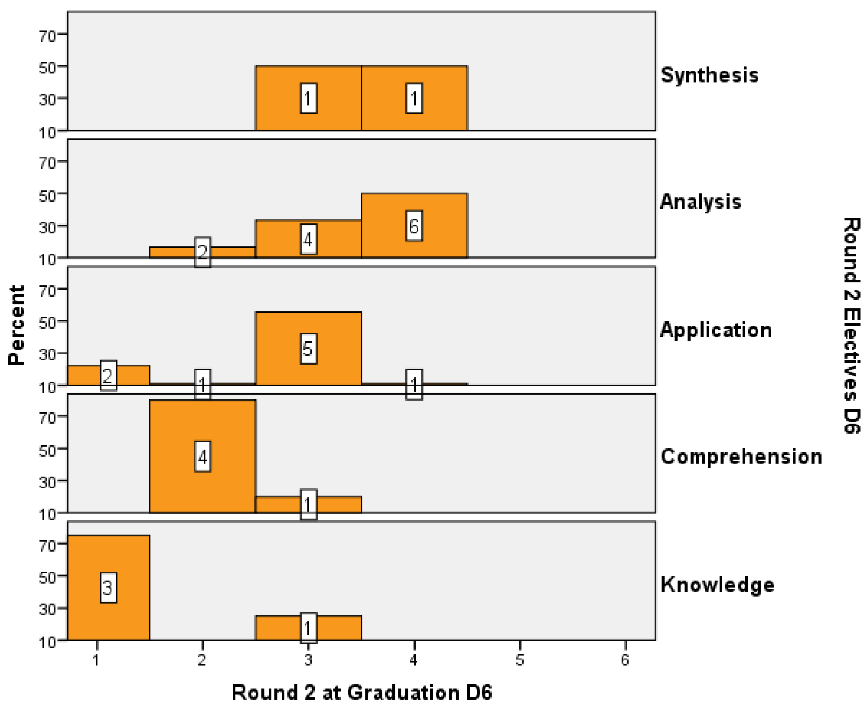


Figure A-80: Change in Expected Achievement Level, Question D6

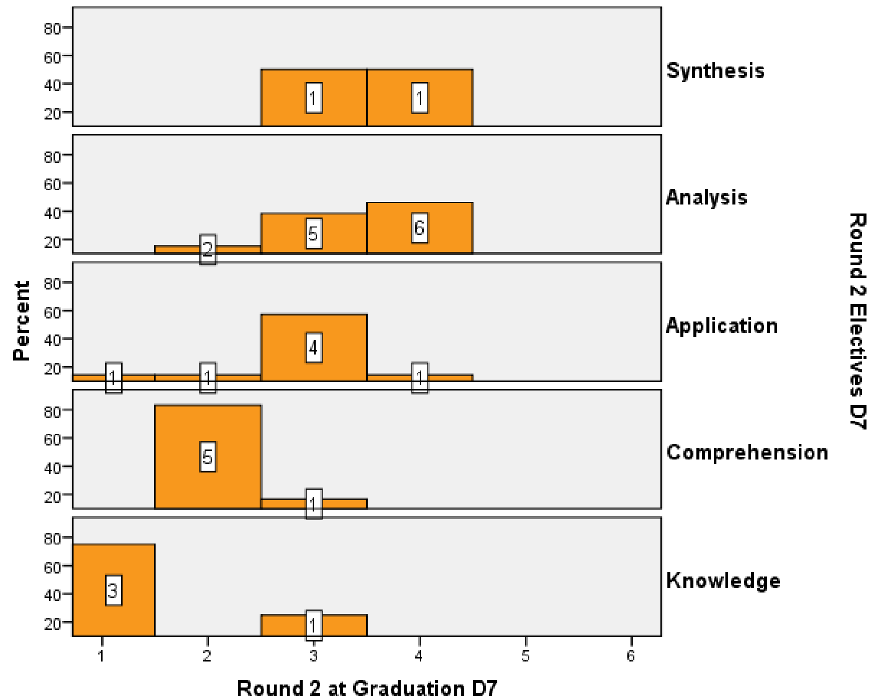


Figure A-81: Change in Expected Achievement Level, Question D7

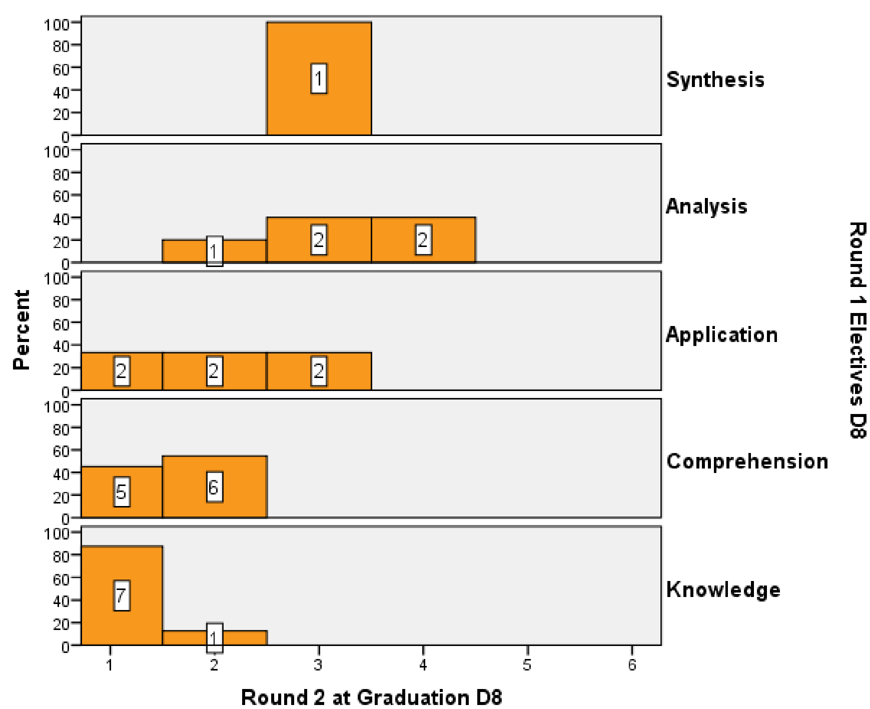


Figure A-82: Change in Expected Achievement Level, Question D8

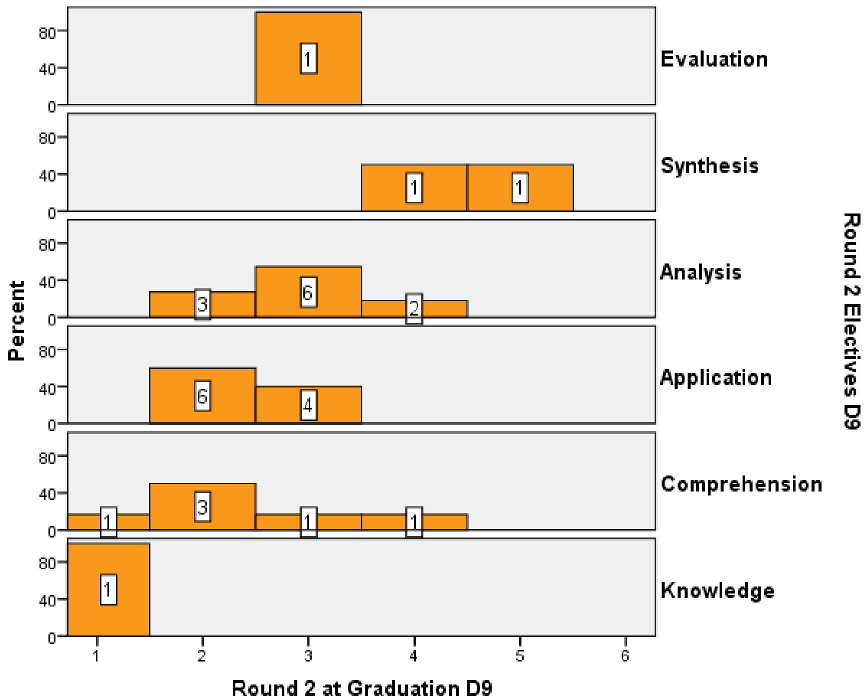


Figure A-83: Change in Expected Achievement Level, Question D9

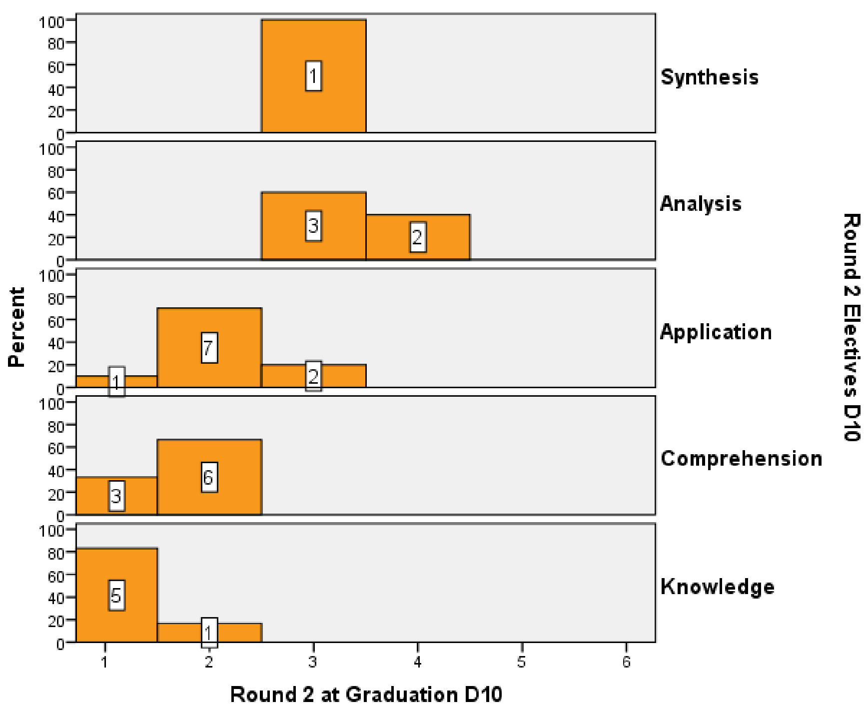


Figure A-84: Change in Expected Achievement Level, Question D10

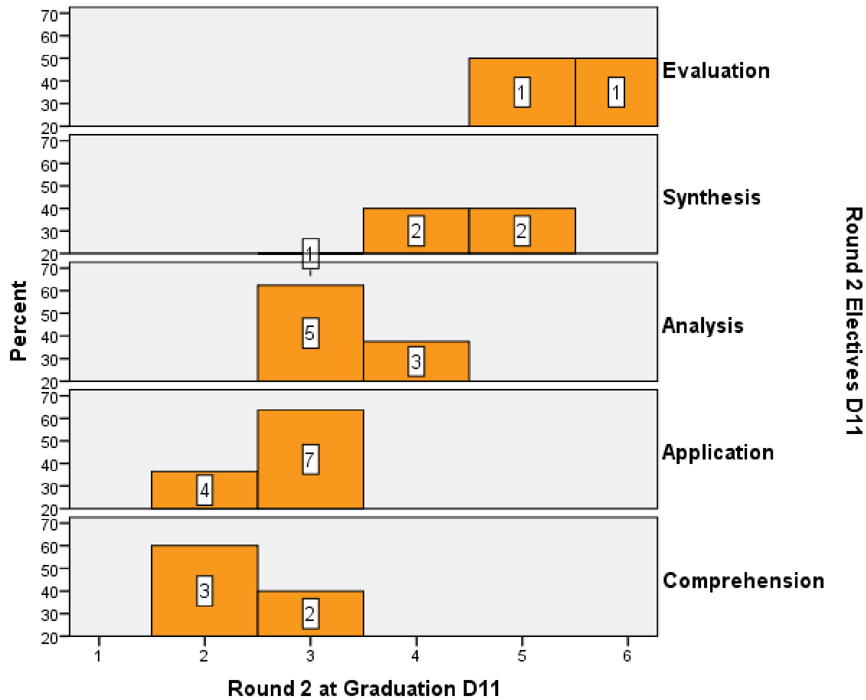


Figure A-85: Change in Expected Achievement Level, Question D11

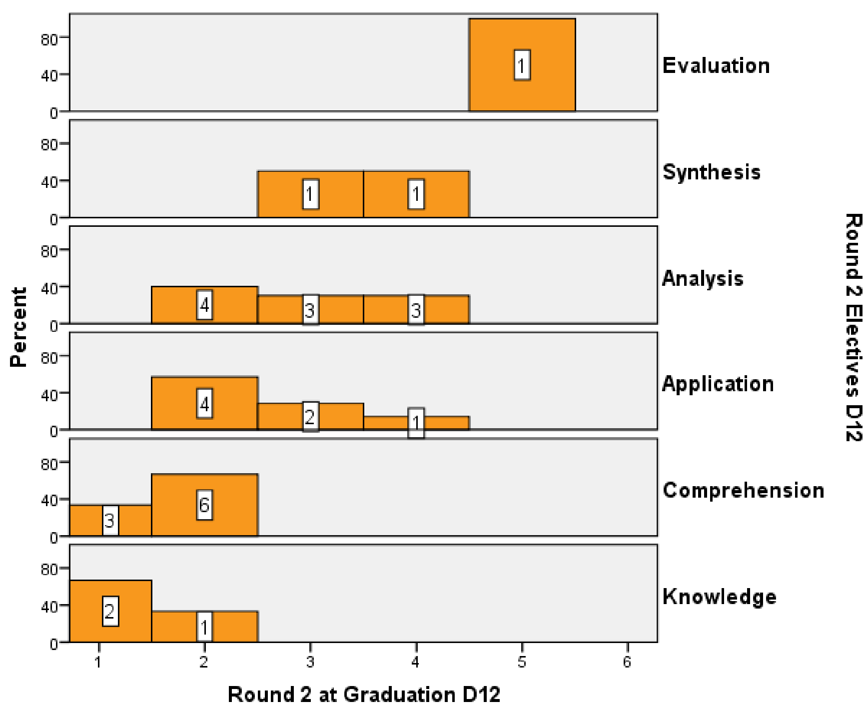


Figure A-86: Change in Expected Achievement Level, Question D12

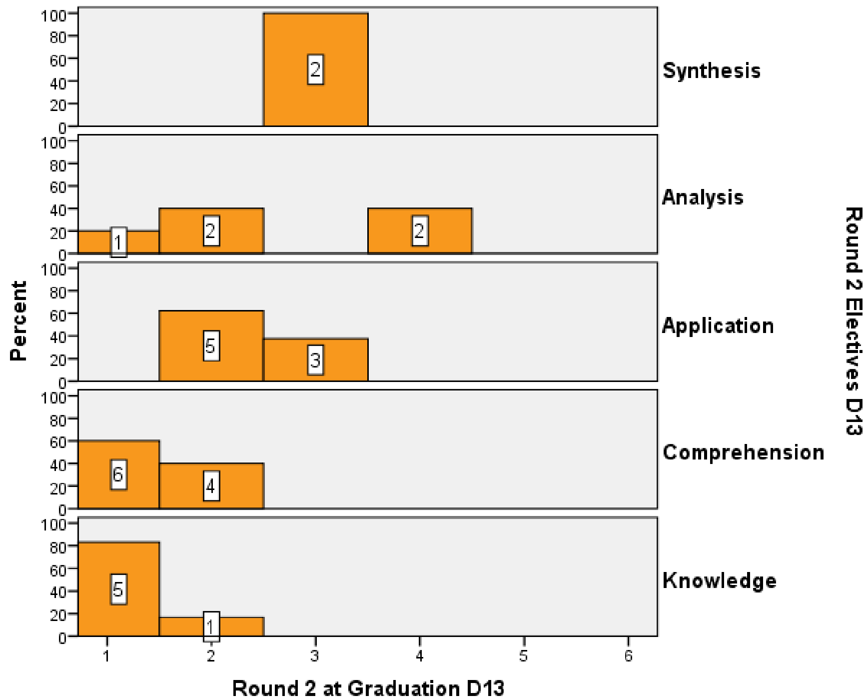


Figure A-87: Change in Expected Achievement Level, Question D13

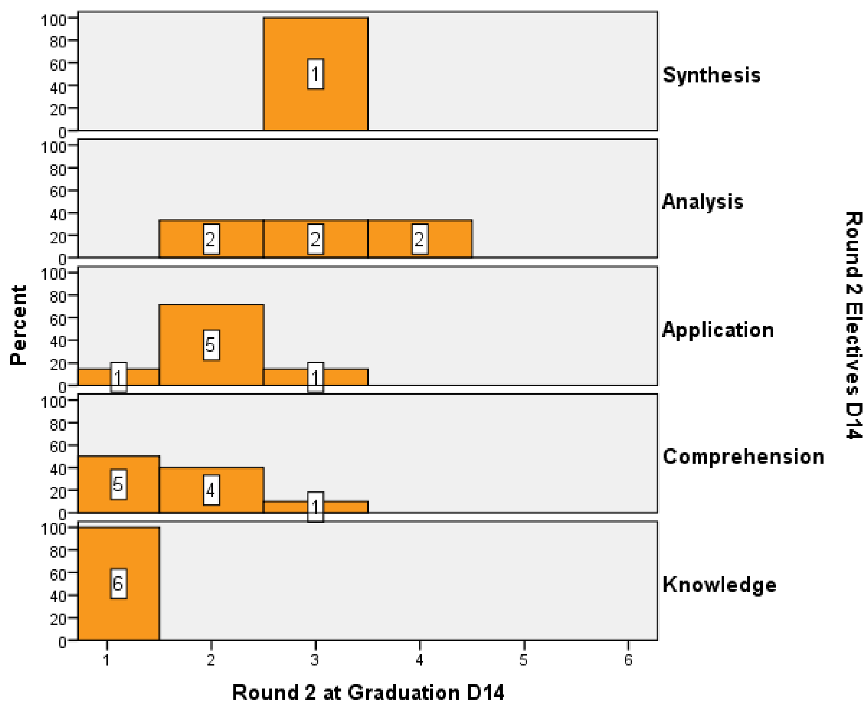


Figure A-88: Change in Expected Achievement Level, Question D14

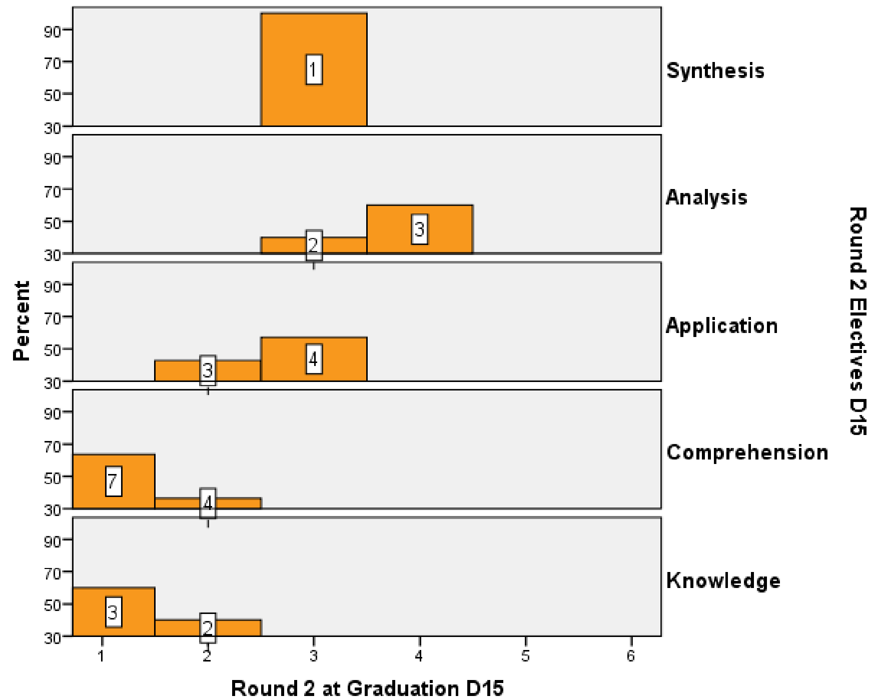


Figure A-89: Change in Expected Achievement Level, Question D15

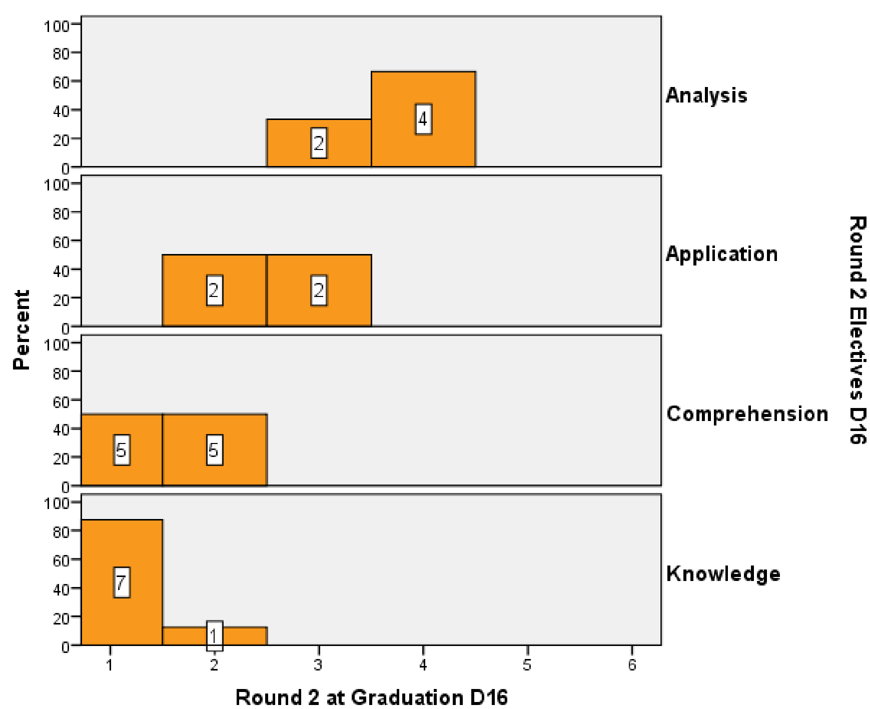


Figure A-90: Change in Expected Achievement Level, Question D16

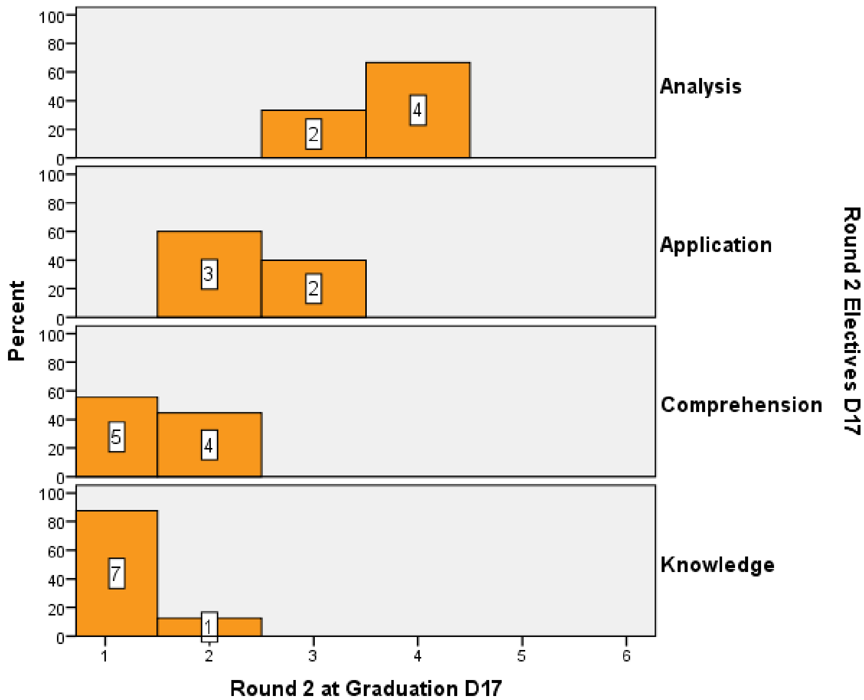


Figure A-91: Change in Expected Achievement Level, Question D17

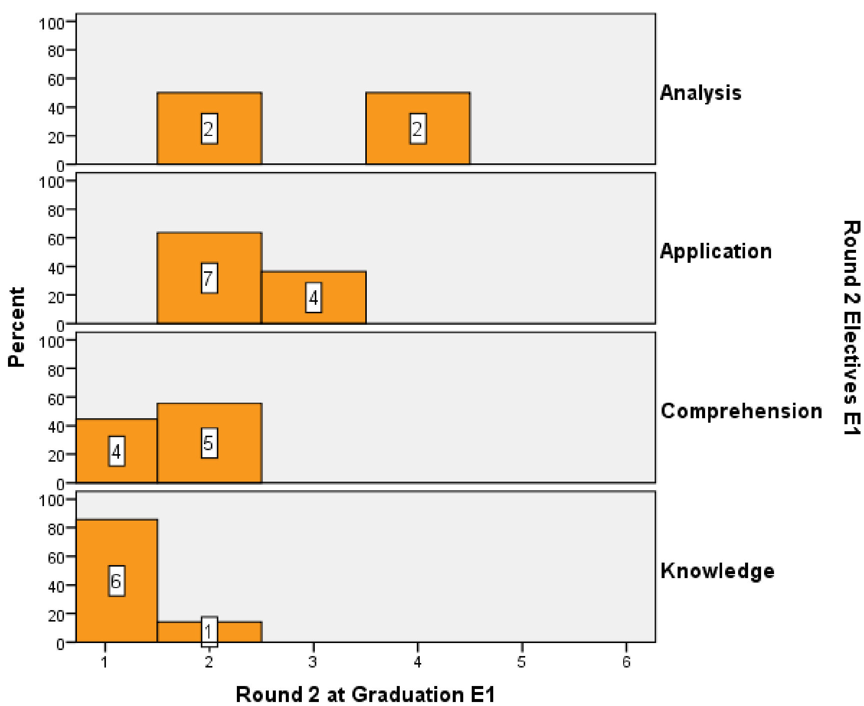


Figure A-92: Change in Expected Achievement Level, Question E1

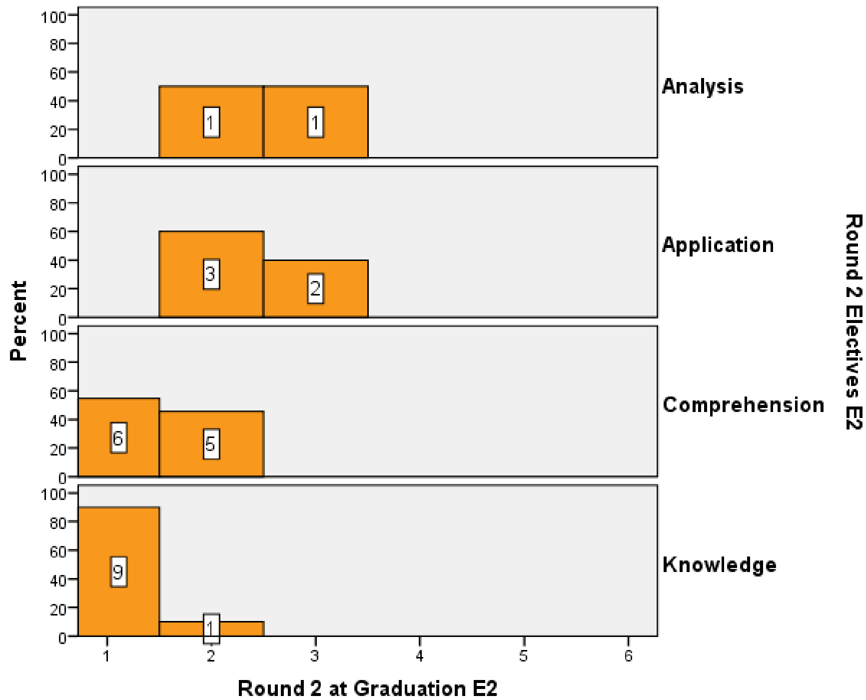


Figure A-93: Change in Expected Achievement Level, Question E2

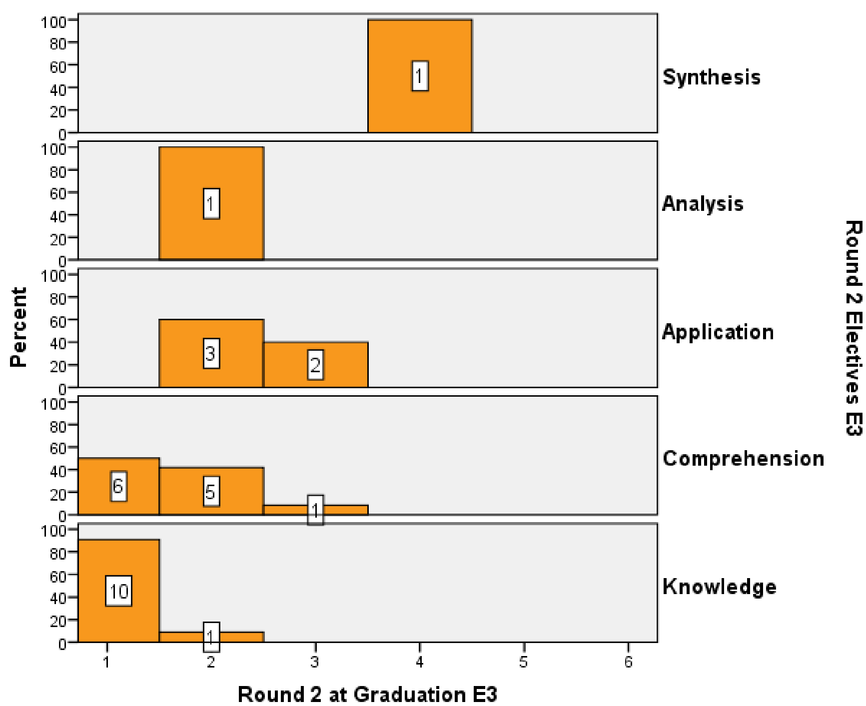


Figure A-94: Change in Expected Achievement Level, Question E3

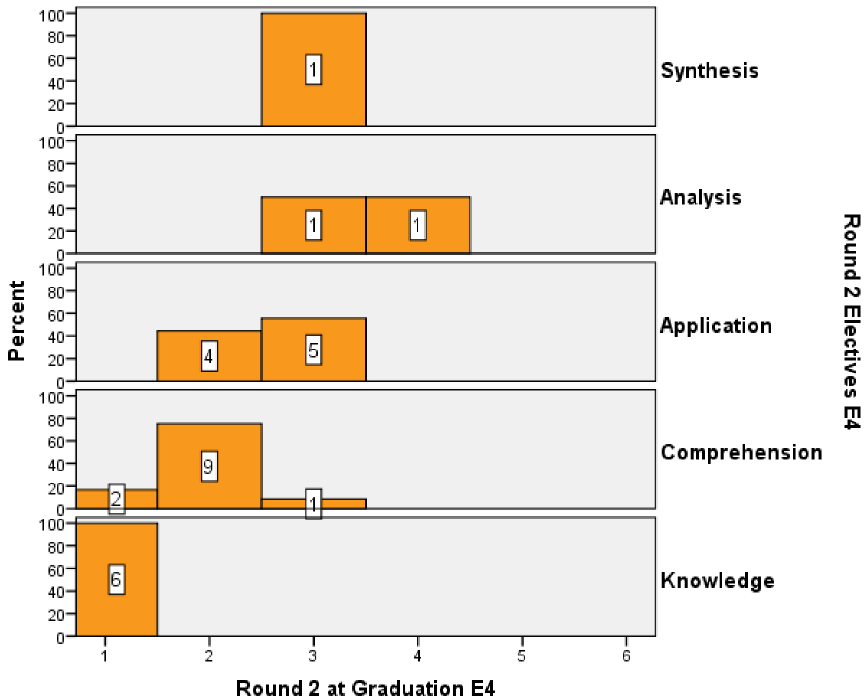


Figure A-95: Change in Expected Achievement Level, Question E4

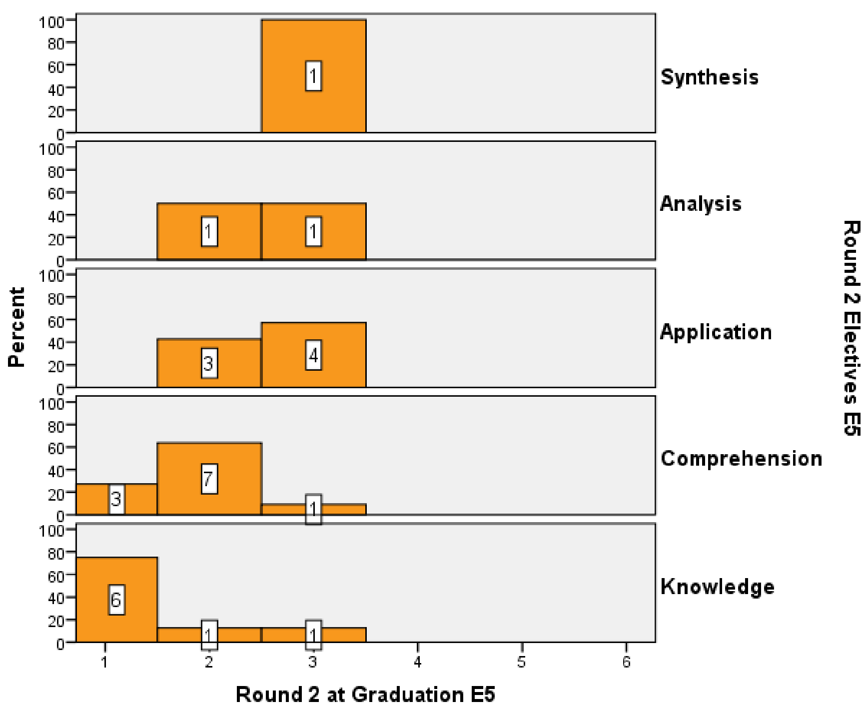


Figure A-96: Change in Expected Achievement Level, Question E5

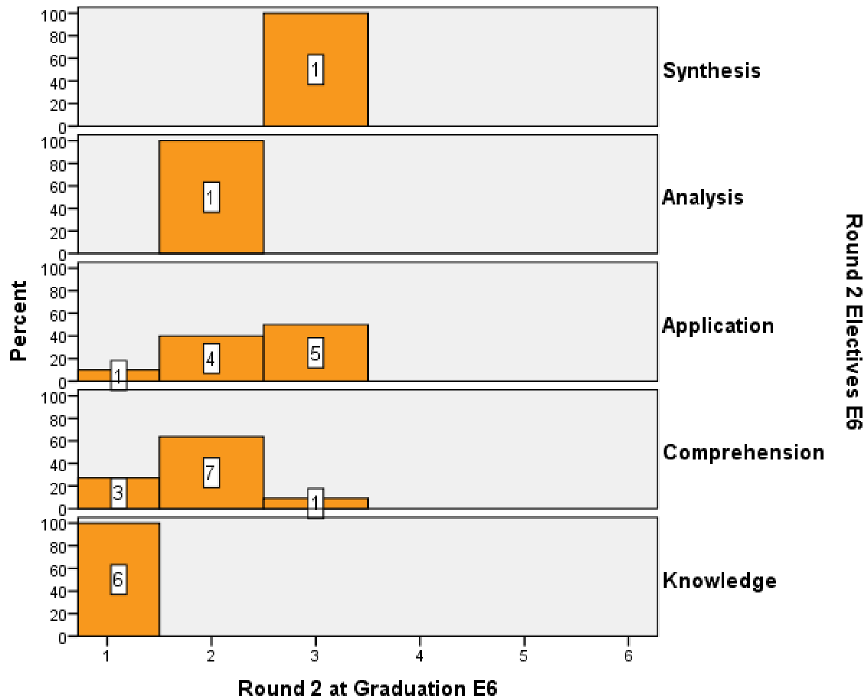


Figure A-97: Change in Expected Achievement Level, Question E6

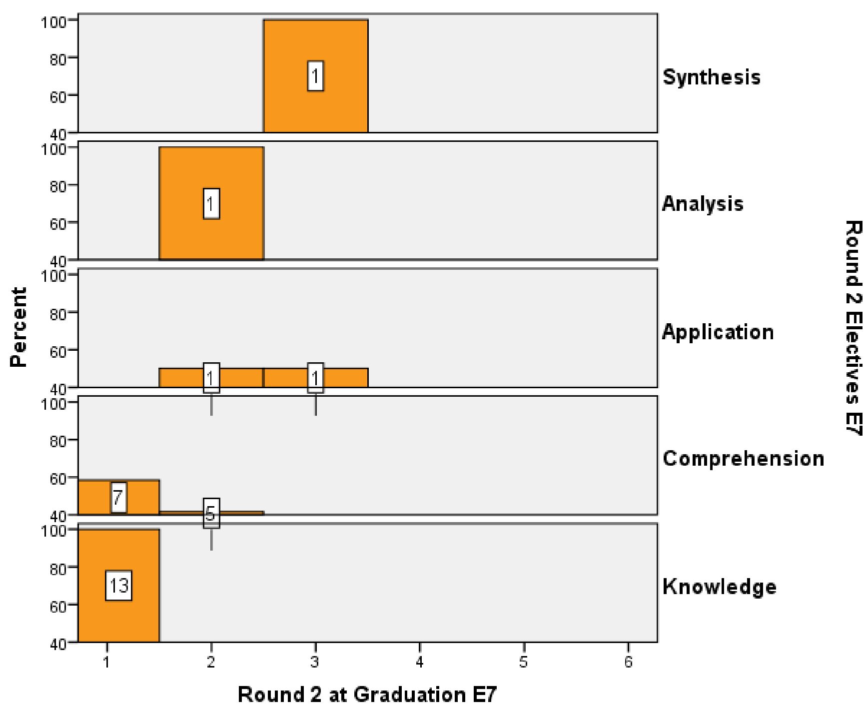


Figure A-98: Change in Expected Achievement Level, Question E7

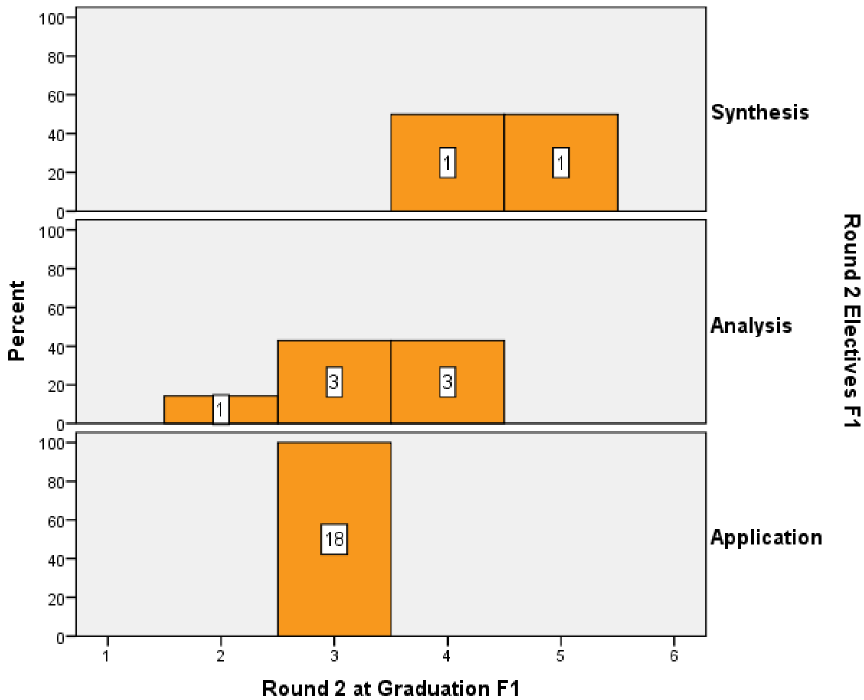


Figure A-99: Change in Expected Achievement Level, Question F1

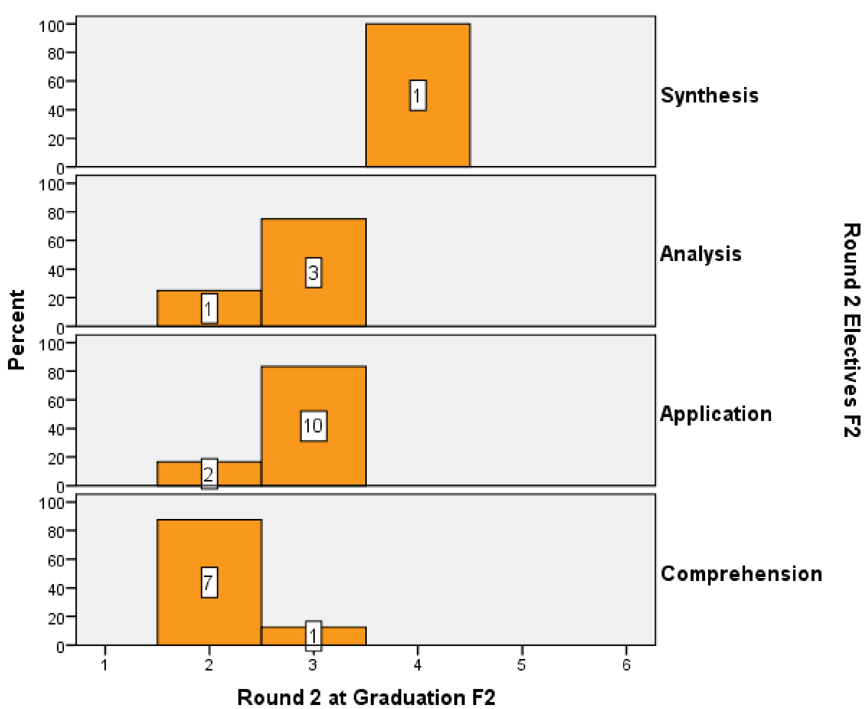


Figure A-100: Change in Expected Achievement Level, Question F2

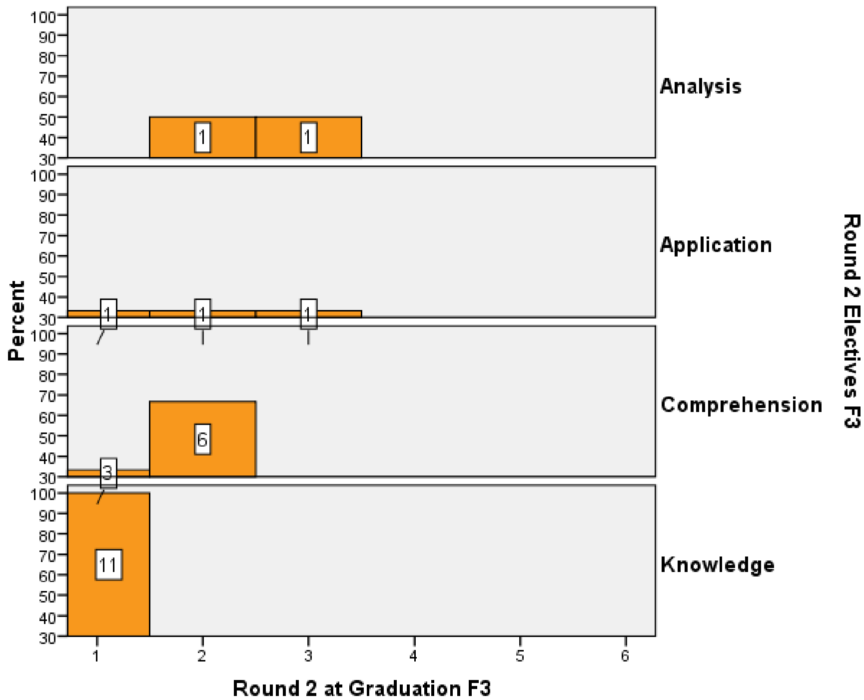


Figure A-101: Change in Expected Achievement Level, Question F3

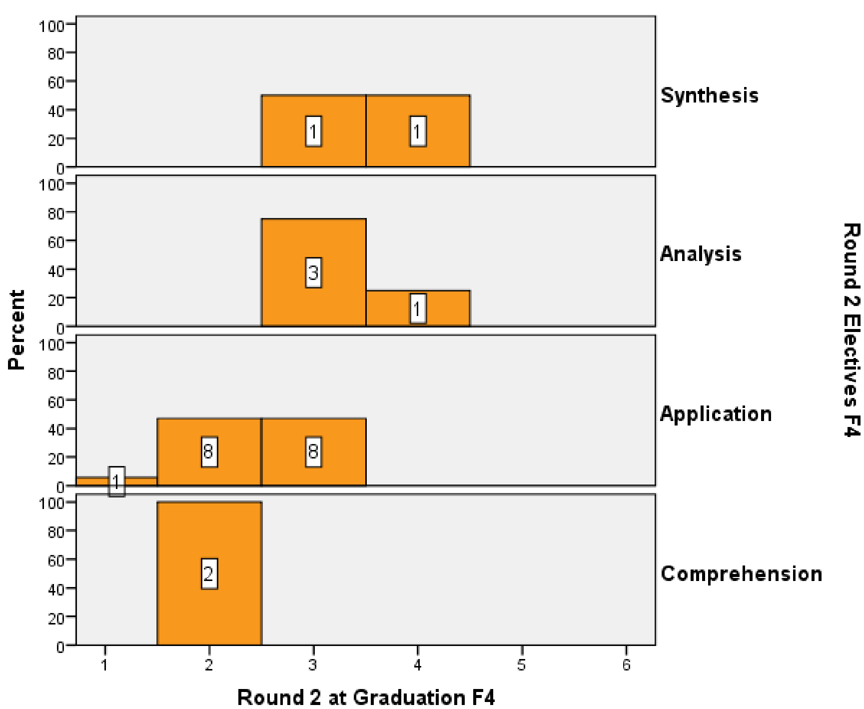


Figure A-102: Change in Expected Achievement Level, Question F4

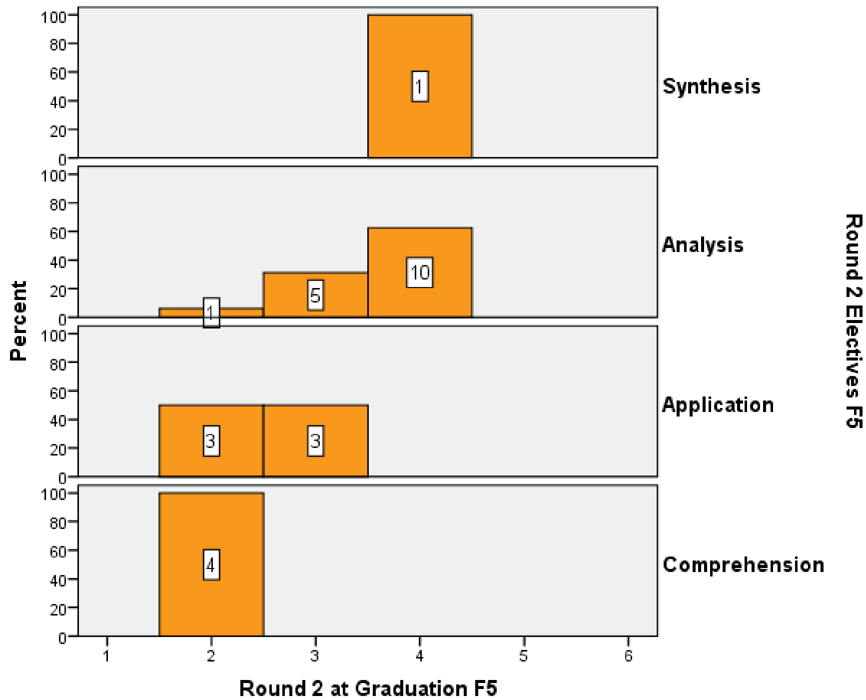


Figure A-103: Change in Expected Achievement Level, Question F5

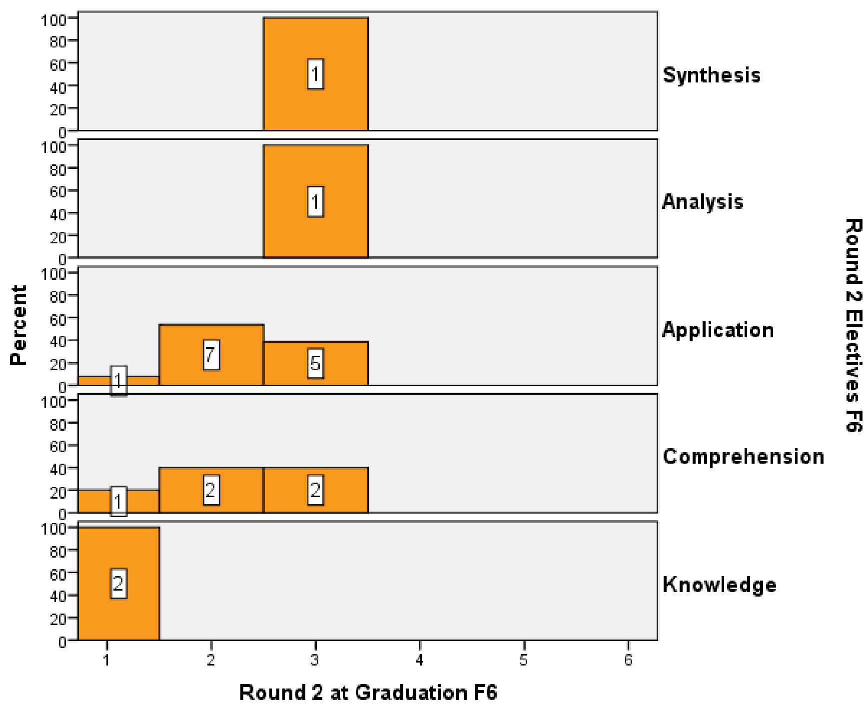


Figure A-104: Change in Expected Achievement Level, Question F6