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Progress Towards Educating the Engineer of 2020

Col. Jakob C. Bruhl, United States Military Academy

Lieutenant Colonel Jakob Bruhl is an Associate Professor and Civil Engineering Program Director in the Department of Civil and Mechanical Engineering at the United States Military Academy, West Point, NY. He received his B.S. from Rose-Hulman Institute of Technology, M.S. Degrees from the University of Missouri at Rolla and the University of Illinois at Urbana/Champaign, and Ph.D. from Purdue University. He is a registered Professional Engineer in Missouri. His research interests include resilient infrastructure, protective structures, and engineering education.

Dr. Brock E. Barry P.E., United States Military Academy

Dr. Brock E. Barry, P.E. is the Director of the Civil Engineering Division and Professor of Engineering Education in the Department of Civil and Mechanical Engineering at the United States Military Academy, West Point, New York. Dr. Barry holds a Bachelor of Science degree from Rochester Institute of Technology, a Master of Science degree from University of Colorado at Boulder, and a PhD from Purdue University. Prior to pursuing a career in academics, Dr. Barry spent 10-years as a senior geotechnical engineer and project manager on projects throughout the United States. He is a licensed professional engineer in multiple states. Dr. Barry's areas of research include assessment of professional ethics, teaching and learning in engineering education, nonverbal communication in the classroom, and learning through historical engineering accomplishments. He has authored and co-authored a significant number of journal articles and book chapters on these topics. Dr. Barry is the 2020 recipient of ASEE's National Outstanding Teaching Award.

Major David Carlson P.E., United States Military Academy

Major David Carlson is an instructor of Civil Engineering in the Department of Civil and Mechanical Engineering at the United States Military Academy, West Point, NY. He was commissioned as an Engineer Officer from the U.S. Military Academy in 2010 with a Bachelor of Science Degree in Civil Engineering. He earned a Master of Science Degree in Environmental Engineering from the Missouri University of Science and Technology in Rolla, Missouri in 2014. He also earned a Master of Science in Civil Engineering from Purdue University in West Lafayette, Indiana in 2019. CPT Carlson is a licensed Professional Engineer in the state of Missouri. He has served in a variety of Engineering and Combat units with varying leadership roles. His research interests include construction management and lean construction.

Progress Towards Educating the Engineer of 2020

The Engineer of 2020 was published in 2004 and predicted the roles that engineers would play in the year 2020. A companion text titled *Educating the Engineer of 2020: Adapting Engineering Education to the New Century* was published in 2005 and focused on changes necessary in engineering education to prepare engineers to practice in the year 2020. Both documents were heralded as inspirational, aspirational, and paradigm changing. But did change actually occur in the civil engineering curriculum?

The Engineer of 2020 report culminated in the presentation and description of a series of attributes. It is these attributes that the report suggested will "support the success and relevance of the engineering profession in 2020 and beyond." The report acknowledges that those future attributes are similar to what made an engineer successful at the time the report was published, but technology was expected to make those attributes more complex.

This study investigates how civil engineering programs in the United States have adapted their curriculum to align with the attributes suggested in the report during the time period of 2005 - 2020. This study used a survey of civil engineering program leadership to collect their assessment of the importance of each of the attributes and to collect information related to program changes.

This study will be of interest to all civil engineering educators with responsibility to ensure that their graduates are prepared to meet *The Engineer of 2020* attributes. This study will also be of interest to educators considering how the attributes described in 2004 remain relevant in 2020 and may spark conversation about how these attributes may need to be adjusted in the future. The study will be of particular interest to those responsible for recommending and implementing curricular changes in engineering programs.

Background

The report titled *The Engineer of 2020,* published in 2004, is a product of the National Academy of Engineering[1]. The committee responsible for writing the document included 18 people: 12 affiliated with academic institutions, 4 affiliated with technology-based companies (IBM, HP, Telcordia, and Reliant Energy), 1 affiliated with a national laboratory (Sandia), and 1 affiliated with National Public Radio.

The report's preface states that the intent of the document "centers on an effort to envision the future and to use that knowledge to attempt to predict the roles that engineers will play in the future." The charge presented to the committee by the National Academy of Engineering's Committee on Engineering Education reads as follows:

"1. Development of a vision for engineering and the work of the engineer in 2020.

2. Examine engineering education and ask, 'what it needs to do to prepare engineers for the future.'"

The committee hosted a workshop during the fall of 2002. A strategic planning consultant moderated the workshop and guided the 35 participants through four detailed scenarios. The

scenario-based discussion was used to "help participants think broadly about events and issues that could shape the future." After the workshop, members of the committee prepared the 101-page report (including appendices). The report starts with an executive summary followed by two chapters focused on trends in engineering as a means of considering what the future may hold. Specifically, chapter one summarizes the technological context of engineering practice and chapter two provides the societal, global, and professional contexts of engineering practice. The third chapter presents aspirations for the individual engineer in the year 2020.

The Engineer of 2020 report culminates with a fourth chapter which presents and describes a series of attributes. It is these attributes that the report suggests will "support the success and relevance of the engineering profession in 2020 and beyond." While the report acknowledges that those future attributes are similar to what makes an engineer successful at the time the report was published, technology has resulted in making those attributes more complex.

The nine attributes are discussed in the report but are not formally defined. Each attribute is generally described in the following list using excerpts from the discussion of each attribute in *The Engineer of 2020*. [1, pp. 54–56]

- **Strong analytical skills.** Employing "principles of science, mathematics, and domains of discovery and design to a particular challenge and for a practical purpose."
- **Practical ingenuity**. Using "skill in planning, combining, and adapting … [to] identify problems and find solutions."
- **Creativity.** Includes "invention, innovation, thinking outside the box, [and] art" because "the problems to be solved may require synthesis of a broader range of interdisciplinary knowledge and a greater focus on systemic constructs and outcomes."
- **Communication.** The "ability to listen effectively as well as to communicate through oral, visual, and written mechanisms" including "effective use of virtual communication tools."
- **Business and management.** The ability to "understand the strengths and limitations of science and technology" and to understand how "choices that affect physical, human, and political infrastructures and decisions that define priorities and objectives for a community, region, or nation are made."
- **Leadership.** "Understand[ing] the principles of leadership and be[ing] able to practice them … [and] accepting the challenge of bridging public policy and technology well beyond the roles accepted in the past."
- **High ethical standards** and a strong sense of **Professionalism.** "These [attributes] are supported by boldness and courage … balancing (for example) economic, social, environmental, and military factors … [while] recogniz[ing] the broader contexts that are intertwined in technology and its application in society."
- **Dynamism, Agility, Resilience,** and **Flexibility.** "Given the uncertain and changing character of the world … engineers will need" these attributes. "Not only will technology change quickly, the social-political-economic world in which engineers work will change continuously."

- **Lifelong learners.** "The ability to learn new things quickly and the ability to apply knowledge to new problems and new contexts."

This study used a survey of civil engineering program leadership from across the country to explore how civil engineering programs changed as a result of *The Engineer of 2020* report. Specifically, the research question investigated was:

How did civil engineer programs adapt their curriculum during the time period of 2005 - 2020 to align with the nine attributes identified in *The Engineer of 2020* report?

Literature

The Engineer of 2020 has influenced engineering education in the two decades since it was published. A recent search on Google Scholar resulted in 5340 titles in which the phrase "engineer of 2020" appears. Also according to a recent search on Google Scholar, *The Engineer of 2020* has been cited over 500 times and the companion *Educating the Engineer of 2020,* published in 2005,[2] has been cited more than 300 times. Clearly these publications have been widely read and discussed.

Within the literature, many papers which refer to the NAE publications report ideas and methods to prepare engineering students more broadly for the future. For example, Redish and Smith (2008) describe a framework for developing skills within engineering students beyond traditional engineering content.[3] This framework is based on cognitive science and educational research and highlights some counter-productive unintentional messages that traditional engineering courses may send. For example, they describe the costs of focusing on algorithms and results on developing student's ability to apply reasonable assumptions in the application of scientific principles which limits their design skills. While the authors provide practical implications for educators to consider, they concede that the engineering education community has made slow progress in changing current practice to meet these goals.

To determine where additional effort may be necessary in developing particular skills, it is important to know how well the current curriculum is achieving these goals. Mena, Zappe, and Litzinger (2012) reported results from a survey assessing Pennsylvania State University alumni opinion of how well they were prepared in a variety of skills and attributes based on a university goal of educating World-Class Engineers. These skills and attributes were closely aligned with those described in *The Engineer of 2020*. The survey also gaged alumni opinion of how important each was to their work as an engineer. Among the skills and attributes that were deemed very important and the alumni felt prepared for were: (1) applying engineering skills, (2) writing effectively, (3) making effective oral presentations, (4) applying professional ethics, and (5) developing innovative solutions. Skills that were deemed less important were related to global aspects of engineering work.[4]

Other papers focus on how to develop a specific attribute in students. For example Daly, Mosyjowski, and Seifert (2014) document practices employed in engineering courses to develop creativity within engineering students.[5] The study examined seven courses in which creativity was a stated learning objective. These included introductory and upper-level courses and five

were focused on design. These courses varied in the way in which creativity was taught, practiced, and assessed. The authors concluded that there were important categories of creative skills that were not addressed by any of the courses. Surovek, et. al. (2015) describes four example projects that were designed to aid in the development of creativity in engineering students along with suggested ways to assess creativity, all of which are rooted in creativity research.[6] Related to creativity, it appears that much more work is necessary. Sola, et. al. (2017) found that "freshman engineering students were significantly more creative than senior engineering students … [and] senior engineering students were found to be no better at critical thinking than their freshman counterparts."[7]

Another example of studying the development of a specific skill is provided by Paretti (2008) who provides suggestions of ways that instructors can assist the development of communication skills, specifically within capstone design courses. Practical suggestions are provided for instructors to consider in developing assignments and rubrics, and when engaging students concerning communication requirements.[8]

Other papers address how well *The Engineer of 2020* applies around the globe. For example, Lucena, et al. (2008) described the differences in defining engineering competencies between the United States, Europe, and Latin America.[9] They concluded that global engineering competencies cannot be developed for a variety of reasons including national identity, mobility of engineers between nations and within regions, and the role that private industry plays differs around the world.

Finally, some literature assesses how the needs of engineers have changed over time. Passow and Passow (2017) examined reports from engineering and education databases covering a more than 20 year period to establish a list of generic engineering competencies.[10] They compare the resulting list of 16 competencies, relative importance, and interrelationships to ABET student outcomes. The list compares quite closely to the attributes described in *The Engineer of 2020*.

Few papers have attempted to assess changes to engineering curriculum that were influenced by the ideas espoused in the NAE publications. One exception to this is a 2014 National Science Foundation report by a team led by Lattuca and Terenzini.[11] This report, based on surveys from more than 7500 participants from 31 different institutions assessed two ways that the influence of *The Engineer of 2020* may be evident: (1) the extent of educational experiences to prepare students and (2) the extent to which the attributes of *The Engineer of 2020* are promoted in courses, programs, and co-curricular activities. The survey participants included faculty, administrators, undergraduate students, and alumni and responses from these groups were compared to each other. Among their conclusions, the report explains that there is general agreement about the need for creativity, awareness of emerging technologies, systems thinking, consideration of a wide variety of factors in solving problems, ethics, global considerations, and interdisciplinary learning. There was disagreement about the role of sustainability, entrepreneurship, and leadership development. The report also found that there was limited emphasis on developing professional values (interdisciplinary, ethical decisions making, and the value of diversity) within engineering programs. Interestingly, it was reported that non-tenure track instructors tend to emphasize design thinking, problem-solving, and professional values to

a greater extent than tenured and tenure-track faculty. The report also summarizes potential barriers to realizing the vision published in *The Engineer of 2020*. These barriers include: (1) no formal preparation for faculty to teach leads to replicating what they have seen before, thereby reducing the likelihood of changes, (2) the role that research plays in faculty promotion may discourage innovation in teaching methods or course content, and (3) opportunities for students to work with their peers from other disciplines are uncommon.

In the two decades since *The Engineer of* 2020 was published, the literature includes examples of ways that skills and attributes can be effectively developed in engineering students. Other literature describes opinions about those skills and attributes from a variety of constituencies. What appears to be missing in the literature is details of how curricular changes within engineering programs relate to the vision described in *The Engineer of 2020*. Addressing that gap is the primary objective of this paper.

Methodology

A survey was developed to collect feedback related to changes made by programs during the time period of 2004 to 2020. The survey was prepared using MS Forms software and consisted of thirty-one open-ended response, Likert scale, and short response questions. Appendix A of this papers contains a complete copy of the survey. Requests for completing the survey were distributed by staff members at the American Society of Civil Engineers (ASCE) via a civil engineering department heads' listserv and division leadership of the Civil Engineering (CE) division of the American Society of Engineering Education (ASEE) to division membership. The email explained the intent of the study. The first requests were sent out to members of the ASEE CE Division on 15 December 2020 and civil engineering department heads on 18 December 2020. A follow-up email request was sent by ASCE staff on 11 January 2021; no follow-up email request was made by the ASEE CE Division. Survey responses were collected until 26 January 2021.

Results

A total of thirteen unique and useable surveys were completed by department representatives. Roughly 1/3 of the respondents self-identified as a Department Head, 1/3 as ABET Coordinator, and 1/3 as Faculty Member (note, respondents were permitted to select more than one classification). Eight (62%) of the respondents were affiliated with a public college or university and the remaining were affiliated with a private college or university. Twelve (92%) of the respondent programs offered a bachelors degree in civil engineering, seven (54%) offered a masters degree in civil engineering, and seven (54%) offered a doctor of philosophy. None of the respondent programs offered an associates degree. A variety of academic institution missions were represented in the survey respondents as Figure 1 illustrates (respondents were permitted to select more than one option).

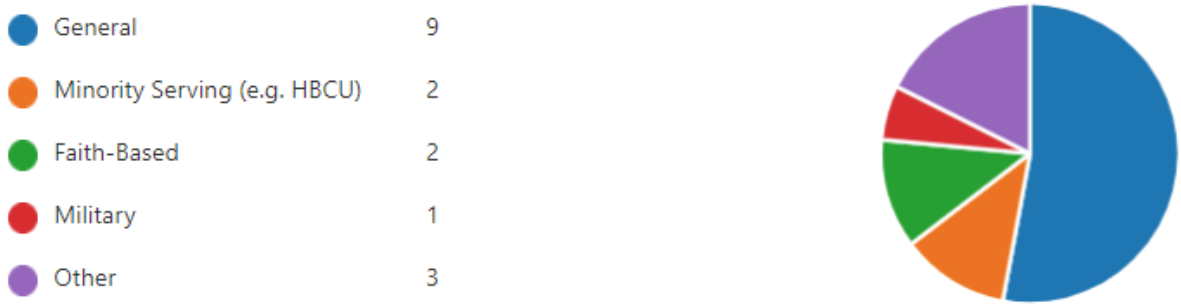

Figure 1 Mission of Institution for Survey Respondents

A wide range of academic institution sizes (less than 1,000 to more than 10,000), in terms of total undergraduate enrollment were represented in the survey respondents (see Figure 2). In addition, a wide range of program sizes (less than 25 to more than 100), in terms of the number of civil engineering bachelors degrees granted annually were represented (see Figure 3).

Figure 2 Total Undergraduate Enrollment Represented in Survey Respondents

Figure 3 Approximate Number of Civil Engineering Bachelors Degrees Granted Annually Represented in Survey Respondents

Survey respondents rank ordered the relevance of the nine attributes to the respondents' civil engineering program. The attribute "strong analytical skills" was by far the highest ranked with 11 of 13 respondents (85%) selecting it as their first or second choice and average ranking of 1.69/9.00. Conversely, the attributes of "dynamism, agility, resilience, and flexibility," "lifelong learning," as well as "business and management" were ranked on the low end of the relevance scale (7.00/9.00, 7.31/9.00, and 7.62/9.00 average rankings, respectively). The relevance of the

remaining attributes fell within the spectrum between first choice and last choice, but with a lesser degree of response strength (see Figure 4). It is interesting to note that the only attribute to be ranked by at least one respondent in each of the nine places (1 thru 9) was “Leadership.”

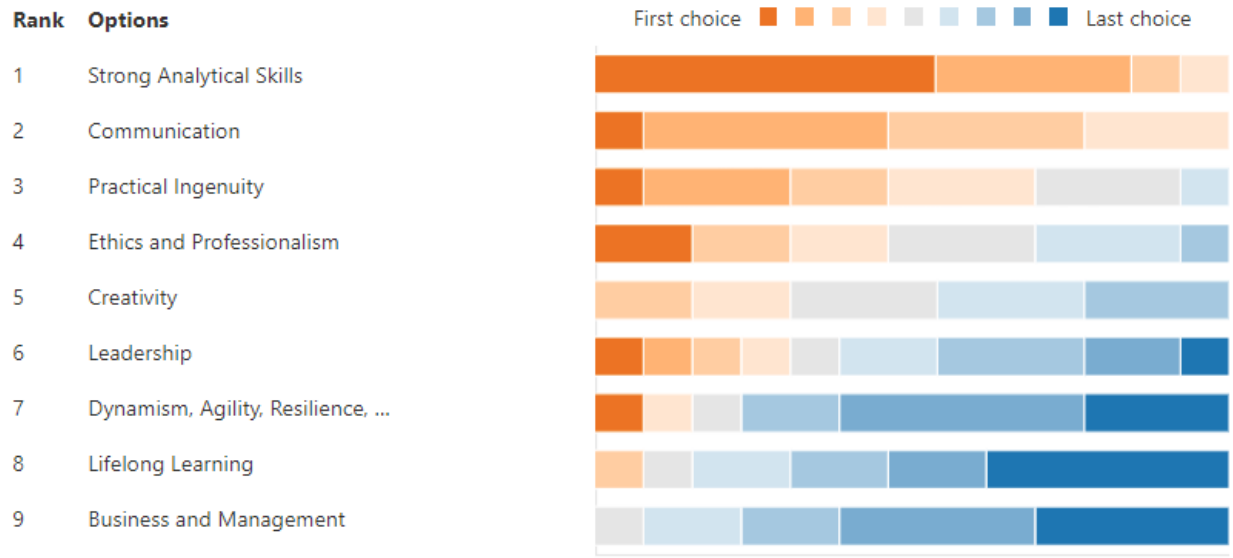

Figure 4 Ranking of Attributes Relevance to Program

Respondents were asked to elaborate on the rationale behind the selection of their top three attributes for their respective civil engineering program. Some respondents emphasized that their top three selected attributes were at “the core of engineering,” “required for the application of other attributes” or that other “attributes are less relevant if the engineer does not have the top 3.” Several respondents addressed how the top three relate to their program educational objectives. One respondent mentioned that the top three they selected were based on their perception of what employers value most. In their explanations, several respondents stated that all the attributes are important to some degree. By asking respondents to rank order the attributes, the intent was not to suggest that any of the attributes were not important but was intended to identify which attributes were most valued by respondents.

Each survey respondent was asked to consider how their programs have changed since the year 2005 as it relates to each of the nine attributes. Respondents were able to choose from “less emphasis,” “no change,” or “more emphasis.” Table 1 is a graphical summary of the responses and Figure 5 provides the percentage of responses for each attribute organized by specific categories. More emphasis is colored with green shaded boxes, no change is colored with yellow shaded boxes, and less emphasis is colored with red shaded boxes. Only two programs indicated “less emphasis” in any of the attributes and one program noted three attributes having less emphasis. Two programs suggested “no change” for all nine attributes. “Practical Ingenuity” and “Creativity” were the attributes with the most frequent “more emphasis” designation with 62% and 69% of the responses indicating this. The attributes least likely to see changes in the programs were “Dynamism, Agility, Resilience, and Flexibility”, “Lifelong Learning”, “Leadership”, “Communication”, and “Strong Analytical Skills.” From Figure 5, it is evident

that programs at large institutions (>10000 student population) were more likely to report "More Emphasis" for a larger proportion of the attributes while private institutions were less likely to report "More Emphasis."

Table 1 Summary of Self-Evaluated Program Changes Since 2005

Respondent Number	Strong Analytical Skills	Practical Ingenuity	Creativity	Communication	Business and Management	Leadership	Ethics and Professionalism	Dynamism, Agility, Resiliance, and Flexibility	Lifelong Learning
1	No Change	No Change	No Change	No Change	No Change	No Change	No Change	No Change	No Change
2	No Change	No Change	No Change	No Change	No Change	No Change	No Change	No Change	No Change
3	No Change	More Emphasis	More Emphasis	More Emphasis	No Change	More Emphasis	No Change	More Emphasis	More Emphasis
4	No Change	More Emphasis	No Change	No Change	More Emphasis	No Change	No Change	No Change	No Change
5	More Emphasis	More Emphasis	More Emphasis	More Emphasis	More Emphasis	More Emphasis	More Emphasis	More Emphasis	No Change
6	No Change	More Emphasis	More Emphasis	No Change	More Emphasis	No Change	No Change	No Change	No Change
7	More Emphasis	No Change	More Emphasis	More Emphasis	More Emphasis	No Change	No Change	More Emphasis	No Change
8	More Emphasis	No Change	More Emphasis	Less Emphasis	More Emphasis	Less Emphasis	No Change	Less Emphasis	More Emphasis
9	More Emphasis	No Change	No Change	No Change	No Change	No Change	More Emphasis	More Emphasis	No Change
10	No Change	More Emphasis	More Emphasis	No Change	Less Emphasis	No Change	More Emphasis	No Change	More Emphasis
11	No Change	More Emphasis	More Emphasis	More Emphasis	More Emphasis	More Emphasis	More Emphasis	No Change	More Emphasis
12	No Change	More Emphasis	More Emphasis	More Emphasis	More Emphasis	More Emphasis	More Emphasis	No Change	No Change
13	More Emphasis	More Emphasis	More Emphasis	More Emphasis	No Change	More Emphasis	More Emphasis	No Change	More Emphasis

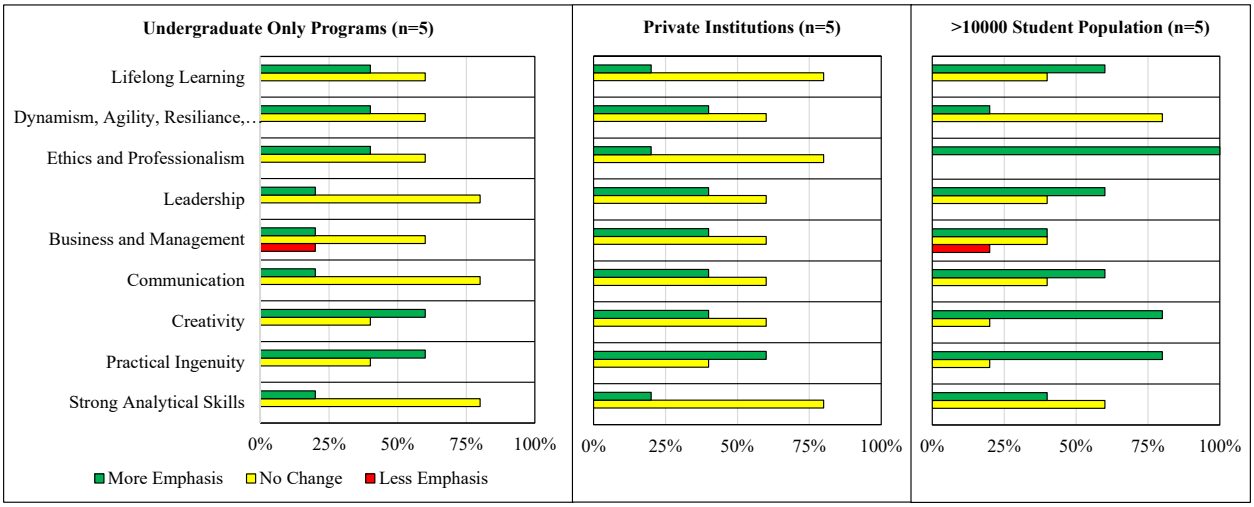

Figure 5 Percentage of Respondents Reporting Changes of Emphasis

The combination of attributes which respondents reported changes in emphasis varied across the respondents. It is informative to examine if there is a relationship between the likelihood of changes to one attribute based on changes to another as a way to identify if there are certain attributes of engineering that are complementary. For example, respondents were likely to report an emphasis on both creativity and practical ingenuity suggesting that these two attributes may complement one another.

All relationships are shown in Table 2. The numbers in the table represent the number of respondents who chose that combination of responses. For example, two respondents reported more emphasis on strong analytical skills and more emphasis on practical ingenuity. The darker the shade of purple in the table, the greater the number of respondents that chose that combination of choices which intersect at that cell. For example, because 7 respondents reported

more emphasis on creativity and more emphasis on practical ingenuity, that cell is a darker shade than for the case of those who reported more emphasis on strong analytical skills and more emphasis leadership. The purpose of Table 2 is not to indicate which individual attributes were necessarily rated as more emphasis but instead to assist in the identification of attributes which may be considered complementary by the respondents.

Table 2 Likelihood of Combinations of Emphasis on Attributes

All Respondents (n = 13)	Practical Ingenuity			Creativity			Communication			Business and Management			Leadership			Ethics and Professionalism			Dynamism, Agility, Resiliance, and Flexibility			Lifelong Learning		
Strong Analytical Skills	2	3	0	4	1	0	3	1	1	3	2	0	2	2	1	3	2	0	3	1	1	2	3	0
	6	2	0	5	3	0	3	5	0	4	3	1	3	5	0	3	5	0	1	7	0	3	5	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Practical Ingenuity				7	1	0	5	3	0	5	2	1	5	3	0	5	3	0	2	6	0	4	4	0
				2	3	0	1	3	1	2	3	0	0	4	1	1	4	0	2	2	1	1	4	0
				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Creativity							6	2	1	6	2	1	5	3	1	5	4	0	3	5	1	5	4	0
							0	4	0	1	3	0	0	4	0	1	3	0	1	3	0	0	4	0
							0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Communication										4	2	0	5	1	0	4	2	0	3	3	0	3	3	0
										2	3	1	0	6	0	2	4	0	1	5	0	1	5	0
										1	0	0	0	0	1	0	1	0	0	0	1	1	0	0
Business and Management													3	3	1	3	4	0	2	4	1	2	5	0
													2	3	0	2	3	0	2	3	0	2	3	0
													0	1	0	1	0	0	0	1	0	1	0	0
Leadership																4	1	0	2	3	0	3	2	0
																2	5	0	2	5	0	1	6	0
																0	1	0	0	0	1	1	0	0
Ethics and Professionalism																			2	4	0	3	3	0
																			2	4	1	2	5	0
																			0	0	0	0	0	0
Dynamism, Agility, Resiliance, and Flexibility																						1	3	0
																						3	5	0
																						1	0	0

Likelihood of Combination: None, Little, Some, Very

Notably, when asked if any of the attributes were NOT relevant, nearly the entire population of recipients stated "no" (see Figure 6). The one respondent who stated "yes" identified "dynamism, agility, resilience, and flexibility" as the single non-relevant attribute, but went on to say "…I'm not sure that not relevant is correct, but I will say not currently considered is a reasonable statement."

Figure 6 Response to Inquire if Any Attributes Were NOT Relevant.

One of the driving forces behind the publication of *The Engineer of 2020* is technological change. Although no question specifically asked about the role that technology played in changes to curriculum, it was interesting to note that several respondents addressed this when asked to provide additional details on their selection for "more emphasis" on the attributes. For example, one respondent stated, "We have been exploring students digital skills in our classes and our

belief is that strong analytic skills are connected to digital competencies." Two others addressed the role that technology plays in communication: "This is an area for improvement. We need to do more to emphasize virtual communication tools." Responses about technology supported communication may be influenced by the recent pandemic which was in full swing when the survey was administered. On responded stated "We have always had a considerable emphasis on communication throughout our curriculum from the freshman through senior level. Over the years we have made changes and updates, but holistically I would say we are at a similar level. Possibly a slightly greater emphasis on virtual communication skills, but this would be influenced predominately by the recent pandemic and not an intentional inclusion."

Conclusions

The research questions considered in this study was "How did civil engineer programs adapt their curriculum during the time period of 2005 - 2020 to align with the nine attributes identified in *The Engineer of 2020* report?" At an aggregate level considerably more survey respondents indicated either no change or more emphasis, rather than less emphasis on the attributes identified in the report. It should be acknowledged that reference to more emphasis or less emphasis is not an indication of not enough or too much emphasis. A program could have had a strong emphasis in a particular key attribute area prior to 2005 and no change would mean that they continue to have a strong emphasis.

A single respondent did identify one key attribute (dynamism, agility, resilience, and flexibility) as being "not important", whereas all of the other respondents indicated that all of the attributes were in fact important. The one respondent who flagged a key attribute as not important provided an explanation that suggests that the attribute was simply perceived as not reasonable to achieve.

Large enrollment academic institutions were more likely to report more emphasis on lifelong learning, ethics and professionalism, leadership, communication, and creativity, than undergraduate only programs and private institutions. This current study was focused on program tendencies in reaction to *The Engineer of 2020* report and did not consider why some programs changed the emphasis placed on particular attributes. The observation about large enrollment academic institutions placing more emphasis on attributes other than strong analytical skills may come as a surprise based on the conclusions about barriers from Lattuca and Terenzini. One possible explanation for this difference is that large enrollment academic institutions were already more heavily investing resources in other aspects of the civil engineering curriculum prior to 2005. Another possible explanation could be an increase in non-tenure track instructors since 2008.[12] As Lattuca and Terenzini explain, non-tenure track instructors tend to emphasize design thinking, problem-solving, and professional values to a greater extent than tenured and tenure-track faculty. .

Examination of Table 2 suggests there are attributes that may be viewed as complementary: Practical Ingenuity, Creativity, Communication, Business and Management, Leadership, and Ethics and Professionalism. Respondents who were likely to report more emphasis in one of these areas were likely to report more emphasis in at least one other from this list. The connection between practical ingenuity and creativity may be explained by their value in the

design process. Connections between business and management, leadership, and ethics and professionalism may be related to emphasis on other design considerations listed in ABET student outcome (2) and the requirement of ABET student outcome (5) to function effectively on a team.[13]

In reality, *The Engineer of 2020* may have had little direct influence on programmatic changes. Most programs do not make changes in response to visionary statements. Rather, they are more likely to make changes in response to accreditation criteria. ABET adopted Engineering Criteria 2000 (EC2000) officially in 1997.[14] The primary change in accreditation that EC2000 instituted was a shift away from evaluation of what material was taught, how and by whom towards an evaluation of what students learned. Criterion 3 of EC2000 included a list of 11 specific outcomes that students were expected to embody upon graduation from accredited engineering programs. While the list of outcomes has undergone modification since its original release it is notable that many of the original Criterion 3 outcomes align closely with several of *The Engineer of 2020* attributes:

Table 3 ABET EC2000 Criterion 3 Outcomes Related to *The Engineer of 2020* Attributes

ABET EC2000 Criterion 3 Outcome (in effect prior to the 2019-2020 accreditation cycle)	The Engineer of 2020 Attribute
(a) an ability to apply knowledge of mathematics, science, and engineering	strong analytical skills
(b) an ability to design and conduct experiments, as well as to analyze and interpret data	practical ingenuity
(c) an ability to design a system, component, or process to meet desired needs	practical ingenuity; creativity
(d) an ability to function on multi-disciplinary teams	
(e) an ability to identify, formulate, and solve engineering problems	
(f) an understanding of professional and ethical responsibility	high ethical standards and professionalism
(g) an ability to communicate effectively	communication
(h) the broad education necessary to understand the impact of engineering solutions in a global and societal context	business and management
(i) a recognition of the need for, and an ability to engage in life-long learning	lifelong learners
(j) a knowledge of contemporary issues	
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	dynamism, agility, resilience, and flexibility

The *Engineer of 2020* greatly influenced the creation of ASCE Body of Knowledge, 2nd Edition [15]. That document and the subsequent editions of the CEBOK, in turn, influence the ABET EAC Civil Engineering Program Criteria. Thus, it is appropriate to suggest that the curricular changes that the survey respondents indicated are, in part, the result of *The Engineer of 2020*,

and the ASCE CEBOK, and the ABET Civil Engineering Program Criteria. The research question specifically asked what changes were made to align with *The Engineer of 2020* attributes, but it did not specifically suggest that those changes were made as a reaction to only the report's publication. Additional study would be required to differentiate between the influence of those three documents.

While the survey data collected represents a diverse cross-section of civil engineering programs in terms of institution size, program size, degrees granted, and institution mission, the authors recognize that the overall sample size is small. The strength of the resulting conclusions must be considered in light of the sample size.

An assumption made in the collection of survey data was that the respondents had sufficient knowledge of their program during the defined timeframe. While implied that the individual would have been present throughout that time period, it is possible that a respondent would simply have sufficient program knowledge without having been part of the program throughout that time period.

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Appendix A – Survey

Changes to Civil Engineering Curricula Since 2005

This survey is designed to gather insights to how civil engineering curricula have changed since 2005. Particularly, it seeks to relate these changes to key attributes identified in The Engineer of 2020, published by the National Academy of Engineering in 2004. Page number references to this publication are provided within this survey. The publication is available for free download: https://www.nae.edu/25876/The-Engineer-of-2020-Visions-of-Engineering-in-the-New-Century. We are not suggesting that changes to curricula were solely the result of The Engineer of 2020, but are seeking to evaluate the extent to which those changes align with the attributes identified in the document. We acknowledge that many of these attributes are similar to those described in ASCE's Civil Engineering Body of Knowledge.

* Required

Addressing "Key Attributes"

For the following questions, please describe the extent to which the curriculum in your program changed since 2005 to to address "key attributes that will support the success and relevance of the engineering profession" (p53)) For each attribute, a brief summary from The Engineer of 2020 is provided along with the page number if the respondent desires additional detail about what was meant by the original authors.

1. Strong Analytical Skills (employing "principles of science, mathematics, and domains of discover and discovery and design to a particular challenge and for a practical purpose" (p54)) *

- ◯ Less Emphasis
- ◯ No Change
- ◯ More Emphasis

2. Please provide details about your response to the emphasis on Strong Analytic Skills. For example, if you selected "More Emphasis" please provide two or three ways in which your program has placed more emphasis on this attribute.

Enter your answer

3. Practical Ingenuity (Using "skill in planning combining, and adapting ... [to] identify problems and find solutions" (p54-55)) *

- Less Emphasis
- No Change
- More Emphasis

4. Please provide details about your response to the emphasis on Practical Ingenuity. For example, if you selected "More Emphasis" please provide two or three ways in which your program has placed more emphasis on this attribute.

Enter your answer

5. Creativity ("invention, innovation, thinking outside the box, art" because "the problems to be solved may require synthesis of a broader range of interdisciplinary knowledge and a greater focus on systemic constructs and outcomes." (p55)) *

- Less Emphasis
- No Change
- More Emphasis

6. Please provide details about your response to the emphasis on Creativity. For example, if you selected "More Emphasis" please provide two or three ways in which your program has placed more emphasis on this attribute.

Enter your answer

7. Communication ("an ability to listen effectively as well as to communicate through oral, visual, and written mechanisms" including "effective use of virtual communication tools." (p55)) *

- Less Emphasis
- No Change
- More Emphasis

8. Please provide details about your response to the emphasis on Communication. For example, if you selected "More Emphasis" please provide two or three ways in which your program has placed more emphasis on this attribute.

Enter your answer

9. Business and Management ("understand the strengths and limitations of science and technology." Also, understand how "choices that affect physical, human, and political infrastructures and decisions that define priorities and objectives for a community, region, or nation are made." (p55-56)) *

- Less Emphasis
- No Change
- More Emphasis

10. Please provide details about your response to the emphasis on Business and Management. For example, if you selected "More Emphasis" please provide two or three ways in which your program has placed more emphasis on this attribute.

Enter your answer

11. Leadership ("understand the principles of leadership and be able to practice them ... accepting the challenge of bridging public policy and technology well beyond the roles accepted in the past." (p56)) *

- Less Emphasis
- No Change
- More Emphasis

12. Please provide details about your response to the emphasis on Leadership. For example, if you selected "More Emphasis" please provide two or three ways in which your program has placed more emphasis on this attribute.

Enter your answer

13. Ethics and Professionalism ("These are supported by boldness and courage. ... balancing (for example) economic, social, environmental, and military factors ... recogniz[ing] the broader contexts that are intertwined in technology and its application in society." (p56)) *

- Less Emphasis
- No Change
- More Emphasis

14. Please provide details about your response to the emphasis on Ethics and Professionalism. For example, if you selected "More Emphasis" please provide two or three ways in which your program has placed more emphasis on this attribute.

Enter your answer

15. Dynamism, Agility, Resilience, and Flexibility ("Given the uncertain and changing character of the world ... engineers will need" these characteristics. "Not only will technology change quickly, the social-political-economic world in which engineers work will change continuously." (p56)) *

- Less Emphasis
- No Change
- More Emphasis

16. Please provide details about your response to the emphasis on Dynamism, Agility, Resilience, and Flexibility. For example, if you selected "More Emphasis" please provide two or three ways in which your program has placed more emphasis on this attribute.

Enter your answer

17. Lifelong Learning ("the ability to learn new things quickly and the ability to apply knowledge to new problems and new contexts." (p56)) *

- Less Emphasis
- No Change
- More Emphasis

18. Please provide details about your response to the emphasis on Lifelong Learning. For example, if you selected "More Emphasis" please provide two or three ways in which your program has placed more emphasis on this attribute.

Enter your answer

19. Please rank the "Key Attributes" from most to least relevant in your civil engineering program. Note that the attributes are listed below in the order in which they were presented in The Engineer of 2020, which does not imply an assumed hierarchy. *

- Strong Analytical Skills
- Practical Ingenuity
- Creativity
- Communication
- Ethics and Professionalism
- Business and Management
- Leadership
- Dynamism, Agility, Resilience, and Flexibility
- Lifelong Learning

20. Briefly explain your rationale for choosing the TOP THREE most relevant key attributes for your civil engineering program, as identified in Question 19. *

Enter your answer

21. Are there any of these key attributes that you believe are NOT relevant for your civil engineering program? *

- Yes
- No

22. Please list key attribute(s) listed in Question 19 which is/are NOT relevant and briefly explain why. *

Enter your answer

23. The attributes described above have seen a larger degree of change in your undergraduate program than your graduate programs *

- True
- False
- Undergraduate only institution

24. Are you interested in participating in a follow-up interview on this topic? *

- Yes
- No

25. Thank you. Please provide your contact information.

Enter your answer

26. Which best describes the type of institution at which you are employed?

- ○ Public College or University
- ○ Private College or University

27. Select all civil engineering degree programs offered at the institution at which you are employed

- ☐ Associates Degree
- ☐ Bachelors Degree
- ☐ Masters Degree
- ☐ Doctor of Philosophy

28. How many total undergraduates are enrolled at your institution in a typical year?

- ○ <1000
- ○ 1000-3000
- ○ 3000-10000
- ○ >10000

29. Approximately how many civil engineering bachelors degrees does your program grant each year

- ○ 0-25
- ○ 25-50
- ○ 50-75
- ○ 75-100
- ○ >100

30. What is the mission of your institution? (Check all that apply)

- ☐ General
- ☐ Minority Serving (e.g. HBCU)
- ☐ Faith-Based
- ☐ Military
- ☐ Other

31. Select all that describe your personal role at your institution

- ☐ Faculty Member
- ☐ Department Head
- ☐ ABET Coordinator
- ☐ Other