

Does the Revision of ABET Student Outcomes Include the Competencies Required to Succeed in Start-Ups and Entrepreneurial Companies?

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Abstract

The Accreditation Board for Engineering and Technology (ABET) recently revised the student outcomes of Criterion 3. Researchers have already share their concerns about how this revision would decouple the acquisition of technical knowledge from the development of certain professional skills. From their perspective, this might affect engineering graduates' capacity to compete in an increasingly global labor market, which currently includes startups and entrepreneurial companies. To explore what competencies ABET's revision could have overlooked, we interviewed entrepreneurship stakeholders about the most important abilities engineers need. By entrepreneurship stakeholders, we mean entrepreneurship instructors, researchers on entrepreneurship education, and leaders from startup accelerators and business incubators in Chile, Colombia, the U.S., Spain and the U.K. Interviewees distinguished between competencies engineers demonstrate to master and others that they must reinforce. They also differentiated skill structures of startup founders and joiners. Recommendations were made for ABET's student outcomes consideration. Future work implies the application of a quantitative questionnaire to discuss national and international implications.

Introduction

Over the last two decades, ABET has become a major change agent in engineering education worldwide. In 1996, ABET's Board of Directors shifted its emphasis on outcomes rather than inputs by adopting the widely known accreditation criteria EC2000. Criterion 3 specified five technical and six professional skills that engineering graduates must face the challenge of international competitiveness.¹ Lattuca, Terenzini and Volkwein (2006) documented the impact of the engineering criteria EC2000 on engineering programs². Schools of Engineering worldwide have modified their curriculums to reinforce career preparation and engineering practice.^{1, 2}

In recent years, ABET members from the industry; academia and governmental agencies have revised Criterion 3³. Their objective is to keep ABET's criteria relevant to the changing needs of the world, besides ensuring that they are rich, measurable, and realistic⁴. However, the removal of some professional skills has already raised concerns. Researchers have argued that this change may not respond to the needs of an increasingly competitive global labor market⁵. Nowadays, there is significant interest in graduating engineers who possess entrepreneurship-related skills, such as the ability to address real world problems, identify new business opportunities, lead others, work in multidisciplinary teams, communicate effectively, react and adapt with flexibility in the face of uncertainty, and deal well with risk and failure⁶.

Today, engineering graduates must develop a broader range of skills than the technical competencies that were formerly required⁶. Due to globalization trends and the rapid pace of technological change, engineers have assumed an active role in the processes of commercializing new technologies and starting new technology-based ventures⁷. Startups and established companies are seeking out employees with the skills necessary to participate in entrepreneurial endeavors, firm renewal and revitalization⁶. However, it is currently unknown whether these skills coincide with those abilities in the ABET proposed revision. Furthermore, startups and established entrepreneurial spirited companies are not part of the ABET community, so they have

not necessarily participated in the proposed revision of the student outcomes criterion. Research is needed on ABET's revision of Criterion 3 to ensure that proposed student outcomes prepare future engineers to drive the generation of solutions to major technological problems locally and globally.

Today, universities are responsible for education delivery, research production and innovation. Entrepreneurial activity has become relevant as a key aspect of this 'knowledge triangle' among research, education and innovation⁸. The emerging role of engineers in innovation and technology-driven entrepreneurship raises the following research questions:

RQ1: What are the competencies that future engineers need to succeed in startups and entrepreneurial companies?

RQ2: What are the abilities that future engineers need that have been overlooked by ABET's revision?

Although current ABET's professional skills still emphasize the importance of entrepreneurship-related skills such as effective communication and teamwork, these questions arise from the exclusion of new stakeholders during the revision process. Additionally, recent academic criticisms open a debate of what makes a professional skill unmeasurable, considering that technical knowledge is usually measured with inadequate multiple-choice tests⁵.

This study explores the abilities engineering graduates might need to succeed in entrepreneurial endeavors. First, this article presents a theoretical framework about competencies in engineering education, followed by a description of the study objectives, the sample, the data gathering technique and the data analysis plan. We adopted a qualitative design to interview entrepreneurship stakeholders from Chile, Colombia, Spain, the U.S. and the U.K. The interviewees were entrepreneurship instructors, researchers on entrepreneurship education, and leaders from startup accelerators and business incubators. From their perspectives, we shared a definition of entrepreneurship, we explored the roles that engineers play in startups and entrepreneurial companies, and we identified critical competencies. Finally, we discuss the implications of these findings for ABET's consideration of the student outcomes revision, besides describing future work.

Theoretical framework

According to the Organization for Economic Co-operation and Development (OECD), a competence is the combination of knowledge, abilities and attitudes to bring complex demands into a particular context⁹. Competencies can be classified into two types:

- a) Specific competences: Related to technical skills necessary for the performance of an activity or work related to the qualification of the person. These are typically related to a specific discipline or field.
- b) Generic competences (also called transversal): Those that are not directly related to technical knowledge, but are required to apply technical skills in a variety of roles and contexts. These are common to multiple professions and transferable among activities.

Different international organizations have invested important efforts in the definition of key competences to guide quality assurance in higher education. One of these efforts was the

Tuning project launched by the Bologna strategy in 2000¹¹. A year later, this project was replicated in Latin America to promote the development of generic and discipline-specific competences for different programs, including engineering (generic competencies in Appendix 1)¹². Along these lines, the OECD carried out a feasibility study for the Assessment of Higher Education Learning Outcomes (AHELO) in 2013¹³. This initiative intended to test students from different countries to compare their attainment of learning outcomes in fields such as engineering and economics (see Appendix 2). Supporters of AHELO argued that its purpose was to provide feedback to higher education institutions. However, the initiative's approach raised concerns about the potential uses for ranking institutions and countries¹⁴.

Regarding the generic competencies, there are studies in which researchers ask employers which skills and abilities they consider most relevant. The study carried out by Humburg, Van der Velden and Verhagen (2013) on behalf of the European Commission showed that professional and interpersonal skills were the most important competencies from the perspective of employers¹⁵. By professional skills, the study refers to the knowledge and abilities required to solve problems, while interpersonal skills allude to the ability to work in a team, communicate and cooperate effectively with colleagues. In a third place, employers also demonstrated interest in skills towards entrepreneurship and innovation. Entrepreneurship was understood by the authors as the ability to recognize a commercial value of an idea and to generate a successful product. The innovative ability was defined as the ability to generate new ideas and analyze problems from different points of view¹⁵.

Concerning engineering competencies, the increased international mobility of engineers has motivated efforts to expand the definition of student outcomes across countries. By the mid-1990s, ABET anticipated this need by shifting the accreditation basis toward outcomes rather than inputs, affecting engineering programs' practices in the U.S. and in other countries, included Australia, Canada, Ireland, New Zealand, and the United Kingdom². These criteria, widely known as EC2000, specified 11 learning outcomes (see Appendix 3)¹⁶:

- a) Five technical skills: Related to the development of students' mathematical, scientific, and technical knowledge.
- b) Six professional skills: Those that emphasize communicating and working effectively on teams, besides the awareness of ethical and contextual considerations, contemporary knowledge, life-long learning, and the broad impact of engineering solutions.

In 2009, ABET's the Criteria Committee of the Engineering Accreditation Commission (EAC) started receiving requests from constituent groups for additional outcomes to be included in Criterion 3⁴. During that same year, the EAC convened a review process of Criterion 3, considering engineering programs, private enterprises, public companies, research laboratories, boards of professional engineering and professional societies. Major publications concerning desired attributes of engineers were also reviewed, and additional efforts were also made to gain additional input from a broad range of constituents⁴. Further discussions of the Criteria Committee between 2014 and 2015 resulted in following seven topic areas⁴:

1. engineering problem solving,
2. engineering design,
3. measurement, testing, and quality assurance,
4. communication skills,

5. professional responsibility,
6. professional growth, and
7. teamwork and project management.

Thus, the proposed revision to Criterion 3 listed seven student outcomes, withdrawing³:

- A knowledge of contemporary issues
- An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

The new criterion does not explicitly allude to teamwork in multidisciplinary settings, and it does not consider “21st-century skills” like critical thinking and creativity⁵. Additionally, it disregards outcomes for an entrepreneurial mindset defined by the Kern Entrepreneurship Education Network (KEEN), despite researchers suggestion to contrast these outcomes against ABET criteria (see Appendix 4)⁶. Specifically, ABET left out competencies related to creativity and value creation, such as the abilities to¹⁷:

- Demonstrate curiosity about our changing world
- Explore a contrarian view of accepted solutions
- Identify unexpected opportunities to create extraordinary value
- Persist through and learn from failure

In an attempt to develop a broad framework of skills engineer needs, we analyze ABET’s student outcomes along with the ones mentioned in the literature (see Appendix 5). Table 1 shows ABET current criterion 3 and competencies defined by other agents that are not included in ABET’s revised list. As in the ABET’s process of revising Criterion 3, we would have to invest additional efforts to gain additional input from a broad range of constituents⁴. More studies are needed to ask key stakeholders which skills and abilities they consider most relevant, particularly startups and entrepreneurial companies. Despite the active role of engineers in generating new venture, entrepreneurship stakeholders have not been actively involved in prior efforts to define skills required in engineering professional formation⁶.

ABET has proven to be the most aggressive agent of change beyond the U.S². Although initiatives such as AHELO and the Tuning project have promoted specific engineering skills, the extent of its influence is unknown or unnoticed. For this reason, it is important to revisit ABET’s recent definition of engineering competencies, and anticipate its implications across countries. The omission of relevant competencies poses a difficult challenge to engineering graduates that want to leave their home country, start a new business or join an entrepreneurial endeavor. Therefore, more studies are required on global skills agendas within engineering education, including domestic and non-domestic perspectives from other regions, such as Europe and Latin America.

Methods

Objectives of the Study

The primary objective of this study is to explore the abilities future engineers need to succeed in entrepreneurial endeavors, concerning engineers’ active role in the creation of new ventures. The secondary objective of this study is to make explicit recommendations for revision to Criterion 3.

Study Participants and Sampling

To fulfill study objectives, we interviewed 20 entrepreneurship stakeholders from Chile, Colombia, Spain, the U.S., Spain and the U.K. By entrepreneurship stakeholders, we mean entrepreneurship instructors, researchers on entrepreneurship education, and leaders from startup accelerators, business incubators and other entrepreneurial initiatives. We used a convenience sampling method to access readily available actors of the entrepreneurial ecosystems of these countries. Table 1 shows the number of interviewees per country. Among interviewees, there were faculty members from selective institutions of higher education, bureaucrats, program managers, and former or current entrepreneurs. Voluntary participation was ensured by using informed consent forms according to the ethical committee's guidelines.^a

Table 1: Number of Interviewees per Country.

Country	Number of instructors and researchers on entrepreneurship education	Number of leaders from startup accelerators	Number of leaders from business incubators	Number of leaders from other entrepreneurship initiatives	Total number of interviewees per country
Chile	1	1	2	3	7
Colombia	1	1			2
U.S.	5				5
Spain	1			2	3
U.K	3				3

Data Gathering Techniques

We used semi-structured interviews to explore experts' perspectives on the roles of engineering in entrepreneurial endeavors, besides collecting information on abilities required to succeed in startups and entrepreneurial companies.^b The advantage of this data gathering technique is that it can be conducted in the interviewee's natural setting¹⁸. Chilean participants were interviewed face to face, while participants abroad were interviewed through a Skype conversation. The audios of the conversations were recorded under the consent of the interviewee. Research assistants transcribed these audios under a confidentiality agreement.

Data Analysis Plan

We established certain dimensions of analysis to code qualitative information collected in this study (see Table 2). Two reviewers codified semi-structured interviews transcripts in three rounds, and peer-checking assessed consistency. Concept maps were developed in the third round in order to reduce information and clarify themes, codes and categories. Data matrixes were used to contrast expert answers around a common theme. Although we cannot generalize findings due to the use of using convenience sampling, citations were used to support internal validity.

^a Link to informed consent form used in this study:

https://docs.google.com/document/d/1fJ2jH29piZJtM02_AHC_dWemaOWdcGDaOr8YnaOtpCQ/edit?usp=sharing

^b Link to the interview guideline use in this study:

<https://docs.google.com/document/d/1TKCASPqQiJaai5mqjI9qRIEQFIVrmNMXgZPK75i7R3Y/edit?usp=sharing>

Table 2: Category and Dimensions of Questions for Semi-structured Interviews

Category	Dimensions	Justification
Stakeholders' understanding of entrepreneurship	Stakeholders' definition of entrepreneurship	These sub-dimensions intended to obtain a formal definition of entrepreneurship.
	Relationship between entrepreneurship and technology	
Entrepreneurial engineering	Role of engineers in entrepreneurial endeavors	These sub-dimensions were used in order to explore stakeholders' perspectives on skills that engineers master, besides examining roles and disciplines that are more involved on entrepreneurship.
	Skills engineers master	
	Skills engineers need to reinforce	
	Engineering disciplines in entrepreneurship	
Revised engineering skills framework	Recommendations to explore skills engineers need to succeed in startups and entrepreneurial companies	These sub-dimensions were used in order to receive feedback for further work.

Results

Concerning the interviewees' definition of entrepreneurship, we identified two types of motivation factors: internal and external. The internal factors are attitudes and abilities that entrepreneurship instructors reinforce in their trainees:

'I think entrepreneurship is... what I teach my students is an act of rebellion that is basically saying that the existing solutions aren't good enough, and so we need to create something new' (Entrepreneurship Instructor and Current Entrepreneur, U.S.).

Regarding external factors, we identified methods and actions that are part of the process of starting and growing a new business:

'Folks that are starting usually have an idea and there is not even a prototype (...) Business accelerators help you with the project formulation. Then, they make you iterate, so that you deliver a prototype as valid as possible to attract customers. So then, when you already have the item, you go to market (...) ' (Bureaucrat, Chile)

Figure 1 shows a concept map that contrasts these two type of factors that define entrepreneurship. There were no country-specific differences within the two perspectives.

Concerning the role of technology within entrepreneurship, most interviewees agreed on the idea that an entrepreneurial endeavor does not necessarily imply the use of technology. However, the use of technology gives startups a competitive advantage to scale and to achieve higher impact. Technology also contribute positively to cash flow concerning product differentiation, speeding up business growth (see Figure 2).

'An entrepreneur is anyone who wants to launch a business of their own, okay? Then, there is the technology-based enterprise or the worth of a startup. Thus, understanding start up as a technology-based business in which technology allows the scalability and therefore the impact of that business' (Entrepreneurship Instructor and Current Entrepreneur, Spain).

Figure 1: Concept Map for Entrepreneurship

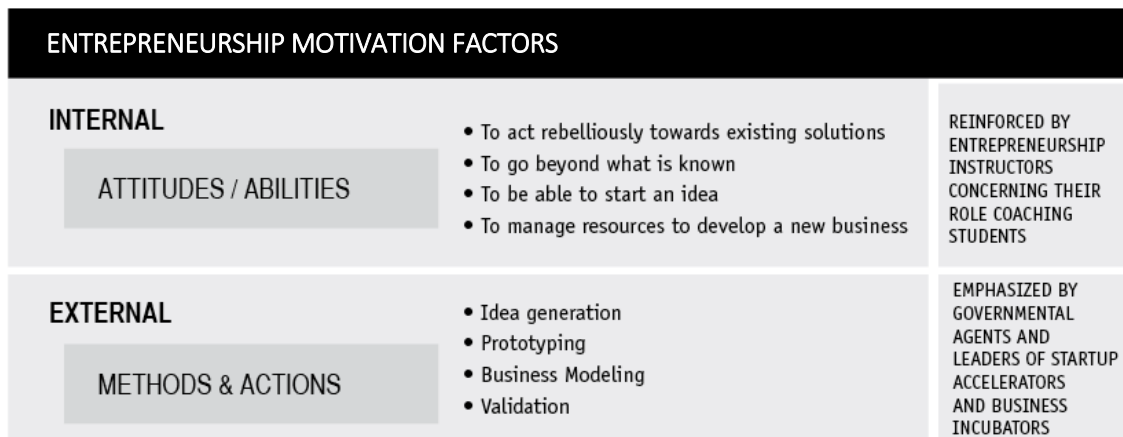
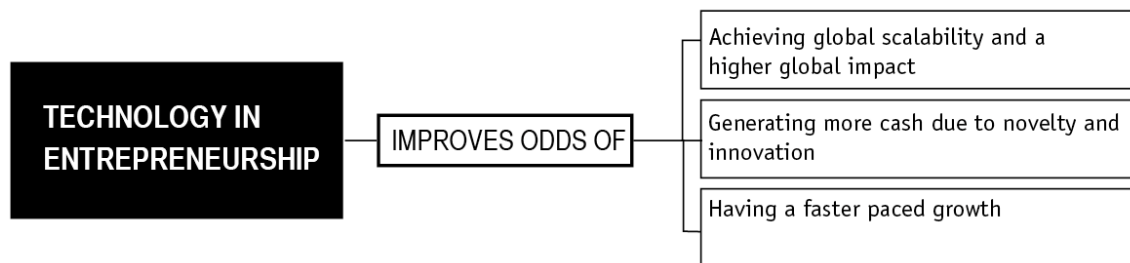


Figure 2: Concept Map Role of Technology in Entrepreneurship



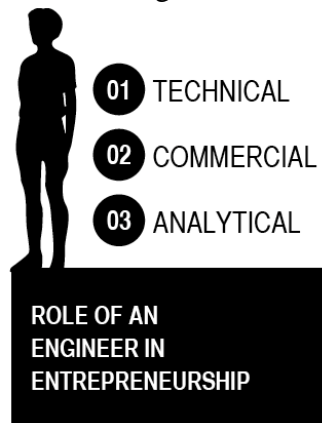
Regarding the roles engineers typically play in entrepreneurial endeavors, three descriptions emerged from the qualitative data: the technical role, the commercial role, and the analytical role (see Figure 3). According to interviewees' perspectives, the technical role is the one that works rigorously on product or service development, the commercial role is the one that has selling skills to get resources to develop ideas, and the analytical role is the one that structures projects and organizes processes. There were no differences among countries, but there were differences among interviewees concerning which role prevails:

'Well, in a startup, there are different kind of titles and roles (...) there are tasks and there are things that need to be done, and people need to step up into those functions, and sometimes someone who has an engineering degree will be selling. Right? Sometimes, they are doing business plans, sometimes they are building the team, they are hiring, and they are doing things that might not be consider engineering. Right?' (Entrepreneurship Instructor and Current Entrepreneur, U.S.).

'Well the role of engineer is always technical, that is, the engineer always plays a technical role within the ventures. When the engineer creates, he creates from the functionality. Depending on the knowledge he has, he creates or he to improves something in functional terms, yes?' (Leader of startup accelerator, Colombia).

'The engineers are machines that generate structures where business do not have them. In addition, they evaluate whether there are models required or not. They organize processes and not only physical processes, but also work flows, business models and that can be a super important contribution' (Bureaucrat, Chile).

Figure 3: Roles of an Engineer in Entrepreneurship



Among qualitative information, we identified competencies engineers demonstrate to master and skills they must reinforce; particularly in they want to succeed in entrepreneurial endeavors (see Table 3). The only difference among countries was that Spanish native speakers emphasize the importance of the ability to communicate effectively on a second language, while English native speaker overlooked this competency:

‘About the ability to communicate effectively, orally and writing in a second language. That is an interesting question for us, because we are very lazy because everyone speaks English. We have some optional modules available where you can do engineering in Spanish. Perhaps, we are not doing the effort, and again... I think is because our language is English, and we are lazy, or the world allows us to be lazy by talking to us in English’. (Entrepreneurship Instructor, U.K.).

Table 3: Interviewees’ Perspectives on Abilities Engineers Master and Skills to be Reinforced

Abilities Engineers Master	Skills to be Reinforced
<ul style="list-style-type: none"> • Ability to identify, formulate and solve problems. • Ability to apply scientific knowledge into practice in different contexts. • Ability to learn new knowledge and adapt to new situations. • Ability to understand and use new technological tools. • Ability to abstract, analyze and synthesize. • Ability to design a prototype to build a product, process or system. • Ability to search, process and analyze information from different sources. • Ability to work autonomously. • Ability to manage resources and projects. 	<ul style="list-style-type: none"> • Effective communication skills. • Effective communications skills in a second language. • Teamwork skills. • Teambuilding and leadership skills. • Business skills. • Empathy to understand client’s needs. • Respect for diversity, multiculturalism and multidiscipline. • Creativity and skills to generate new ideas. • Risk management skills. • Resilience and failure tolerance. • Ethical, social and environmental commitment.

Interviewees also distinguished between skill sets of entrepreneurship founders and joiners (see Table 4). These findings emerged from the qualitative data analysis, regardless they was not a category or dimension related to the differences between these two roles (see Table 2).

Table 4: Interviewees' Perspectives on Entrepreneurship Founders and Joiners Skills and Abilities

Founders	Joiners
<ul style="list-style-type: none"> • Ability to understand new technologies. • Ability to communicate effectively (visually, orally and written). • Ability to communicate effectively in a second language. • Teambuilding and leadership skills. • Business skills. • Critical thinking. • Decision-making skills. • Ability to manage resources and projects. 	<ul style="list-style-type: none"> • Ability to understand and use new technologies. • Ability to communicate effectively (visually, orally and written). • Teamwork skills • Ethical, social and environmental commitment. • Ability to design a prototype to build a product, process or system. • Empathy to understand client's needs • Ability to search, process and analyze information from different sources.

Interviewees identified disciplines where engineers are usually more involved. In Table 5, grey cells show the discipline or area that was mentioned by an interviewee of a specific country. There is no saturation of this information considering that there were different numbers of interviewees per country (see Table 1).

Table 5: Interviewees' Perspectives on Emerging Entrepreneurial Endeavors

Entrepreneurial Endeavors	Chile	Colombia	Spain	U.S.	U.K.
Fintech					
Biotech					
E-Commerce					
Transportation					
Mining					
Energy					
Food industry					
Water					
Information technologies					
Health and biomedicine					
Computer Sciences					
Artificial intelligence					
Design & innovation					
Construction					
Big data					
Sharing economies					
Environmental Sciences					
Sustainable agriculture					

Future work implies the design of a quantitative instrument to ask startup leaders and managers of entrepreneurial companies about the competencies engineers need to succeed in the current labor market. We shared this future task of our research project with the interviewees, who recommended the following actions:

- Revise the study objective
- Phrase properly the competencies that respondents should revise
- Consider breaking engineering competencies into different categories or clusters

- Avoid redundant competencies
- Avoid broad definitions of competencies

Finally, some interviewees mentioned the importance of educating engineers towards a purpose rather than based on specific competencies, skills or abilities:

‘It is necessary to educate more with a clear goal, with an objective to pursue, especially in the world of the engineering. To educate, at the same time that you build, it does not have to be physically, but could be conceptually. If you are educated around several integrating projects, which involve putting into competition very different subjects or fields, at least students would know from what to make a career (...) So I think we have to educate in that sense. It seems to me that it is less content and more committed to become familiar with the world to which you will be destined professionally as soon as possible.’
(Researcher on entrepreneurship education, U.S.)

‘What happens in engineering curricula is that, given accreditation frameworks, we have made a lot of emphasis on how the engineering career is taught by following these lists. In the end, more than the value of defining a single list, we should study existing lists (of competencies) in order to analyze how engineering training has become oriented to solve problems, leaving out how you connect with somebody’s need, or you empathize with others. This is more the discussion that you want to generate rather than pointing to a perfect list.’ (Entrepreneurship consultant and instructor, Spain)

Discussion

Table 6 classifies ABET’s current student outcomes into the two categories defined by interviewees: abilities engineers master (left column), and skills that engineers need to reinforce (right column). Excepting for the ability to recognize the ongoing need for additional knowledge, the classification shows that engineering programs have failed to prepare students with the professional skills that remain in the revised version of Criterion 3. Regardless of ABET’s global influence¹, more efforts are needed to improve professional competency in engineering practice.

Table 6: Abilities Engineers Master and Skill Gaps concerning ABET’s revised Criterion 3

	Abilities Engineers Master	Skills Engineers Need
ABET’s revised Criterion 3	<ul style="list-style-type: none"> • An ability to identify, formulate and solve engineering problems by applying principles of engineering, science and mathematics. • An ability to apply both analysis and synthesis in the engineering design process resulting in design that meet desired needs. • An ability to develop and conduct appropriate experimentation, analyze and interpret data and use engineering judgment to draw conclusions. • An ability to recognize the ongoing need for additional knowledge and locate, evaluate, integrate and apply this knowledge appropriately. 	<ul style="list-style-type: none"> • An ability to communicate effectively with a range of audiences. • An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgements, which must consider the impact of engineering solutions in global, economic, environmental and societal contexts. • An ability to function effectively on teams that establish goals, plan tasks, meet deadlines, and analyze risk and uncertainty.

Concerning other skills and abilities mentioned by interviewees, ABET's revision might have overlooked the ability to use techniques, skills and modern engineering tools, particularly new technologies. Regarding the definition of the ability to function effectively on teams, the integration of risk analysis was a successful move, but the removal of multidisciplinary settings is weakness of the current framework. Additionally, there are entrepreneurship-related skills that have not been explored nor discussed:

- Teambuilding and leadership skills.
- Business skills.
- Empathy to understand client's needs.
- Respect for diversity and multiculturalism.
- Creativity and skills to generate new ideas.
- Resilience and failure tolerance.

Conclusions, Recommendations and Future Work

By means of this study, we have widened the discussion about skills and abilities needed for current engineering practice. We included new stakeholders from the entrepreneurship ecosystem of different countries. Although we cannot make scientific generalizations due to the use of convenience sampling, we can recommend engineering programs across countries to conduct more research on proposed student outcomes that engineering graduates might not have demonstrated mastery, such as teamwork, effective communication and professional ethics. From the analysis, we would also suggest ABET:

- To rewrite some of the student outcomes proposed in the revised Criterion 3 in order to include multidiscipline in teamwork, empathy in engineering design, leadership in teamwork and learning from failure on professional growth.
- To integrate the ability to understand and use new technologies.
- To promote engineering assessment research on entrepreneurship-related skills that are not included in Criterion 3, such as leadership, empathy, creativity, respect for diversity and resilience.

Although this study does not discuss the national and international implications of its findings, future work implies the design of a quantitative instrument to explore competencies engineer need in a larger scale. We plan to survey startup leaders and managers of entrepreneurial spirited companies. We are considering the same research sites concerning this prior effort and others that have adopted comparative approaches among the U.S., Latin America and Europe¹. Therefore, we expect to extend the impact of this study and contribute to the evaluation of national and international policies on entrepreneurship and engineering education.

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Appendix 1. Generic competences according to the Tuning Project

- Ability to communicate in a second language
- Capacity to learn and stay up-to-date with learning
- Ability to communicate both orally and through the written word in first language
- Ability to be critical and self-critical
- Ability to plan and manage time
- Ability to show awareness of equal opportunities and gender issues
- Capacity to generate new ideas (creativity)
- Ability to search for, process and analyse information from a variety of sources
- Commitment to safety
- Ability to identify, pose and resolve problems
- Ability to apply knowledge in practical situations
- Ability to make reasoned decisions
- Ability to undertake research at an appropriate level
- Ability to work in a team
- Knowledge and understanding of the subject area and understanding of the profession
- Ability to work in an international context
- Ability to act on the basis of ethical reasoning
- Ability to communicate with non-experts of one's field
- Ability for abstract thinking, analysis and synthesis
- Spirit of enterprise, ability to take initiative
- Interpersonal and interaction skills
- Ability to design and manage projects
- Ability to act with social responsibility and civic awareness
- Determination and perseverance in the tasks given and responsibilities taken
- Appreciation of and respect for diversity and multiculturality
- Ability to work autonomously
- Skills in the use of information and communications technologies
- Commitment to the conservation of the environment
- Ability to adapt to and act in new situations
- Ability to evaluate and maintain the quality of work produced
- Ability to motivate people and move toward common goals

Appendix 2. AHELO Generic and Discipline Specific Skills

Students taking the AHELO test will need to use **critical thinking, analytic reasoning, problem solving** and **written communication** to answer several open-ended questions about a hypothetical but realistic situation and gather the necessary evidence from different sources (letters, maps, memos, etc.).

In the case of engineering, the focus of the AHELO test is the capacity of students to extrapolate from what they have learned and apply their competencies in new contexts, particularly in:

- Engineering generic skills (effective communication and awareness of the wider civil engineering context).
- Basic and Engineering Sciences (knowledge and understanding of the scientific and mathematical principles underlying civil engineering – general sciences; materials and construction; structural engineering; geotechnical engineering; hydraulic engineering; and urban and rural planning).
- Engineering analysis (using analytical methods to identify, formulate and solve engineering problems).
- Engineering design (Understanding and application of design methodologies to meet specified requirements).
- Engineering practice (practical skills and knowledge required for solving problems, conducting investigations, and designing engineering devices and processes, besides addressing professional ethics, responsibilities and the impact of engineering solutions in a global, economic, societal and environmental context).

Source: OECD (2012). Assessment of Higher Education Learning Outcomes (AHELO).

Retrieved from: <https://www.oecd.org/edu/skills-beyond-school/AHELO%20Brochure.pdf>

Appendix 3. ABET Criterion 3. Student Outcomes

The program must have documented student outcomes that prepare graduates to attain the program educational objectives.

Student outcomes are outcomes (a) through (k) plus any additional outcomes that may be articulated by the program.

- (a) an ability to apply knowledge of mathematics, science, and engineering
- (b) an ability to design and conduct experiments, as well as to analyze and interpret data
- (c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
- (d) an ability to function on multidisciplinary teams
- (e) an ability to identify, formulate, and solve engineering problems
- (f) an understanding of professional and ethical responsibility
- (g) an ability to communicate effectively
- (h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
- (i) a recognition of the need for, and an ability to engage in life-long learning
- (j) a knowledge of contemporary issues
- (k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Appendix 4. KEEN Framework

- ENTREPRENEURIAL MINDSET
 - CURIOSITY
 - DEMONSTRATE constant curiosity about our changing world
 - EXPLORE a contrarian view of accepted solutions
 - CONNECTIONS
 - INTEGRATE information from many sources to gain insight
 - ASSESS and MANAGE risk
 - CREATING VALUE
 - IDENTIFY unexpected opportunities to create extraordinary value
 - PERSIST through and learn from failure
- Coupled with ENGINEERING THOUGHT AND ACTION:
 - APPLY creative thinking to ambiguous problems
 - APPLY systems thinking to complex problems
 - EVALUATE technical feasibility and economic drivers
 - EXAMINE societal and individual needs
- Expressed through COLLABORATION:
 - FORM and WORK in teams
 - UNDERSTAND the motivations and perspectives of others
- And COMMUNICATION:
 - CONVEY engineering solutions in economic terms
 - SUBSTANTIATE claims with data and facts
- And founded on CHARACTER:
 - IDENTIFY personal passions and a plan for professional development
 - FULFILL commitments in a timely manner
 - DISCERN and PURSUE ethical practices
 - CONTRIBUTE to society as an active citizen

Appendix 5. Literature Review on Engineering Skill Needs

Engineering skills needs	Sources
An ability to identify, formulate and solve problems.	Sancho, Gomez & Arruata, 2008; ETSI, 2012; Retana, 2012; Martinez, 2011; UPCT, 2010; Cerato y Gallino, 2013; Zaharim, Yusoff, Mohamed, Zaidi, Muhamad & Mustapha, 2010; Teijerio, Rungo & Freire, 2013; Abdulwahed, Balid, Hasna y Pokharel, 2013; Vaz & Quinn, 2015; Hart Research Associates, 2015; Humburg, Van der Velden & Verhagen, 2013; Hyotynen, Kokko, Teini, 2015.
An ability to function effectively in a team.	Sancho, Gomez & Arruata, 2008; ETSI, 2012; CIDAC, 2014; Martinez, 2011; Cerato y Gallino, 2013; Palma, De los Ríos & Guerrero, 2012; Rahmat, Ahmad, Idris y Faridatul, 2012; Zaharim, Yusoff, Mohamed, Zaidi, Muhamad y Mustapha, 2010; Teijerio, Rungo y Freire, 2013; Abdulwahed, Balid, Hasna y Pokharel, 2013; Vaz y Quinn, 2015; Hart Research Associates, 2015; American Society for Engineering education, 2013; Humburg, Van der Velden y Verhagen, 2013.
An ability to communicate effectively.	Sancho, Gomez y Arruata, 2008; ETSI, 2012; CIDAC, 2014; Martinez, 2011; UPCT, 2010; Cerato y Gallino, 2013; Ramirez, s/f; Rahmat, Ahmad, Idris y Faridatul, 2012; Zaharim, Yusoff, Mohamed, Zaidi, Muhamad y Mustapha, 2010; Teijerio, Rungo y Freire, 2013; Abdulwahed, Balid, Hasna y Pokharel, 2013; Vaz y Quinn, 2015; Hart Research Associates, 2015; American Society for Engineering education, 2013; Humburg, Van der Velden y Verhagen, 2013; Hyotynen, Kokko, Teini, 2015.
An ability to innovate.	Sancho, Gomez y Arruata, 2008; Villa y Poblete, 2007; CIDAC, 2014; Martinez, 2011; UPCT, 2010; Abdulwahed, Balid, Hasna y Pokharel, 2013; Hart Research Associates, 2015; Humburg, Van der Velden y Verhagen, 2013.
An ability for decision-making.	Sancho, Gomez y Arruata, 2008; Martinez, 2011; UPCT, 2010; Ramirez, s/f; Zaharim, Yusoff, Mohamed, Zaidi, Muhamad y Mustapha, 2010; Teijerio, Rungo y Freire, 2013; Hart Research Associates, 2015; American Society for Engineering education, 2013.
Ethical commitment	Sancho, Gomez y Arruata, 2008; ETSI, 2012; Cerato y Gallino, 2013; Zaharim, Yusoff, Mohamed, Zaidi, Muhamad y Mustapha, 2010; Teijerio, Rungo y Freire, 2013; Abdulwahed, Balid, Hasna y Pokharel, 2013; Hart Research Associates, 2015; American Society for Engineering education, 2013.
Social commitment	Sancho, Gomez y Arruata, 2008; ETSI, 2012; Martinez, 2011; UPCT, 2010; Cerato y Gallino, 2013; Núñez, 2012; Palma, De los Ríos y Guerrero, 2012; Ramirez, s/f; Teijerio, Rungo y Freire, 2013; Abdulwahed, Balid, Hasna y Pokharel, 2013.
Commitment to quality	Sancho, Gomez y Arruata, 2008; Villa y Poblete, 2007; ETSI, 2012; Martinez, 2011; Cerato y Gallino, 2013; Núñez, 2012; Teijerio, Rungo y Freire, 2013; Abdulwahed, Balid, Hasna y Pokharel, 2013;
An ability to abstract, analyze and synthesize.	Sancho, Gomez y Arruata, 2008; Martinez, 2011; UPCT, 2010; Cerato y Gallino, 2013; Ramirez, s/f; Teijerio, Rungo y Freire, 2013; American Society for Engineering education, 2013.
An ability to apply scientific knowledge.	Sancho, Gomez & Arruata, 2008; ETSI, 2012; CIDAC, 2014; Martinez, 2011; Cerato & Gallino, 2013; Ramirez, s/f; Rahmat, Ahmad, Idris y Faridatul,

Engineering skills needs	Sources
	2012; Zaharim, Yusoff, Mohamed, Zaidi, Muhamad & Mustapha, 2010; Abdulwahed, Balid, Hasna & Pokharel, 2013.
Critical thinking	Sancho, Gomez y Arruata, 2008; Cerato & Gallino, 2013; Ramirez, s/f; Abdulwahed, Balid, Hasna y Pokharel, 2013; Hart Research Associates, 2015.
An ability to organize and plan strategically.	Sancho, Gomez & Arruata, 2008; Martinez, 2011; Teijerio, Runo & Freire, 2013.
An ability to adapt to new situations.	Martinez, 2011; Cerato & Gallino, 2013; Palma, De los Ríos & Guerrero, 2012; Rahmat, Ahmad, Idris & Faridatul, 2012.
Goal orientation	Villa & Poblete, 2007.
An ability to design.	ETSI, 2012; Núñez, 2012.