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Soft Skills Requirements for Engineering Entrepreneurship

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Abstract

Entrepreneurship is a vector that helps economic growth, social scaling, and job generation. However, the soft skills required for engineering entrepreneurship are unclear. This research aims to determine which of these skills are highly demanded

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as a reference to improve competitiveness among engineers and undergraduate programs. A survey was designed and applied to graduated mechanical engineers from the University of Pamplona. The instrument with excellent validity and reliability, according to Cronbach's Alpha, included 4 different dimensions evaluating 10 soft skills with 18 indicators. The statistical tools used were the Kolmogorov-Smirnov test, median, mode, Kruskal-Wallis ANOVA, and the Games-Howell post hoc test. All soft skills investigated are required to start an engineering venture at a high development level. Likewise, the surveyed engineers demonstrated a high level of development of these skills in such a way that the gap between those required to start an engineering entrepreneurial venture and those developed is minor. In addition, the most effective way to increase its development is training in administrative areas or personal development. Likewise, there is a small gap between the skills developed by the respondents and those required in a venture, and the way to overcome this gap is training in administrative areas or personal development. Engineers dedicated to teaching, or working in public institutions, have less developed three of the six entrepreneurship indicators. Finally, the gap between soft skills developed in undergraduate programs and those required in entrepreneurship is significant. Engineering programs must include experiential training in soft skills and entrepreneurship in their curriculum.

Keywords: entrepreneurship in engineering; soft skills in engineering; soft skills for entrepreneurship.

Habilidades blandas para el emprendimiento en Ingeniería

Resumen

El emprendimiento es un vector que ayuda al crecimiento económico de un país, una región, al escalamiento social y la generación de empleo. Sin embargo, no es claro cuáles son las habilidades blandas requeridas para iniciar un emprendimiento en ingeniería. Esta investigación tiene como propósito determinar cuáles son esas habilidades como referencia para mejorar la competitividad en los ingenieros como en los programas de pregrado. Para alcanzar este objetivo, se diseñó y aplicó una encuesta a ingenieros mecánicos egresados de la Universidad de Pamplona. El

instrumento con validez y confiabilidad excelente según Alfa de Cronbach, costaba de 4 dimensiones diferentes que valoraban 10 habilidades blandas con 18 indicadores. Las herramientas estadísticas usadas fueron la prueba bilateral de Kolmogórov-Smirnov, mediana, moda, Kruskal-Wallis ANOVA y post hoc de Games-Howell. Se encontró que todas las habilidades blandas investigadas son requeridas en un nivel alto de desarrollo para realizar un emprendimiento en ingeniería. Así mismo, que los ingenieros encuestados demuestran un nivel alto de desarrollo de estas habilidades, de tal forma que la brecha entre aquellas requeridas para realizar un emprendimiento en ingeniería y las desarrolladas, es pequeña, además, se evidencio que la forma más efectiva para incrementar su desarrollo es realizar entrenamientos en áreas administrativas o desarrollo personal. Se encontró también que los ingenieros dedicados a la docencia, o que trabajan en instituciones públicas, tienen menos desarrollado tres de los seis indicadores de emprendimiento. Finalmente se evidenció que la brecha entre las habilidades formadas en el pregrado y las requeridas en el emprendimiento son grandes, y los programas deben incluir en su currículo formaciones vivenciales de habilidades blandas y emprendimiento.

Palabras clave: emprendimiento en ingeniería; habilidades blandas en ingeniería; habilidades blandas para emprendimiento.

Soft skills para o empreendedorismo em Engenharia

Resumo

O empreendedorismo é um vetor que auxilia o crescimento econômico de um país, de uma região, de escala social e de geração de empregos. No entanto, não está claro quais são as habilidades sociais necessárias para iniciar um empreendimento de engenharia. O objetivo desta pesquisa é determinar quais são essas competências como referência para melhorar a competitividade dos engenheiros e dos cursos de graduação. Para atingir esse objetivo, uma pesquisa foi projetada e aplicada a engenheiros mecânicos formados pela Universidade de Pamplona. O instrumento com excelente validade e confiabilidade segundo o Alfa de Cronbach, teve 4 dimensões diferentes que avaliaram 10 soft skills com 18 indicadores. As

ferramentas estatísticas utilizadas foram o teste de Kolmogorov-Smirnov bilateral, mediana, moda, ANOVA de Kruskal-Wallis e post hoc de Games-Howell. Constatou-se que todas as soft skills investigadas são exigidas em alto nível de desenvolvimento para a realização de um empreendimento de engenharia. Da mesma forma, os engenheiros pesquisados demonstram um alto nível de desenvolvimento dessas habilidades, de modo que a lacuna entre as exigidas para a realização de um empreendimento de engenharia e as desenvolvidas é pequena, além disso, evidenciou-se que a forma mais eficaz de aumentar seu desenvolvimento é a realização de treinamentos nas áreas administrativas ou desenvolvimento pessoal. Constatou-se também que os engenheiros dedicados à docência, ou que atuam em instituições públicas, apresentam três dos seis indicadores de empreendedorismo menos desenvolvidos. Por fim, evidenciou-se que a lacuna entre as habilidades desenvolvidas na graduação e aquelas exigidas no empreendedorismo são grandes, e os programas devem incluir treinamento vivencial em soft skills e empreendedorismo em seu currículo.

Palavras-chave: empreendedorismo em engenharia; soft skills em engenharia; soft skills para empreendedorismo.

I. INTRODUCTION

The decrease in employment, the economic recession, the increase in the young labor force, the privatization of some public companies [1], and the economic crisis due to the COVID-19 pandemics [2] have forced the creation of economic alternatives supported by the high-quality human talent and the research abilities that lead to the creation of micro and small enterprises [3]. In response to these global situations, entrepreneurship based on innovation or technology [4] is one of the vectors helping resolve these drawbacks. Additionally, it provides economic development to a country or region, social scaling of diverse population sectors, and generates employment [5]. Entrepreneurship is defined as an incremental dynamic process of wealth production created by an individual or collective system within an organizational structure through the development of something new, from the conception of ideas to the creation of a business, which demands effort, time and resources and includes financial, psychological, and social risks [6]–[9]. The entrepreneurial capacity allows the creation of strategies ideal for expanding the productivity and the general development of any organization. It comprises four abilities: to innovate and be creative, identify and exploit new business opportunities, willingly take risks, and create and develop business networks [6]–[9]. However, despite the relevance of engineering entrepreneurship, the soft skills (SS) necessary to support an entrepreneurial venture and increase the entrepreneurial abilities have not been studied enough, and it is not clear which SS are necessary to boost entrepreneurship. Thus, this study aims at shedding light on this issue with the following research question: What is the gap between the SS required in engineering entrepreneurship and those developed by engineers?

II. METHODOLOGY

This quantitative research applied a survey [10], [11] which was designed after extensive bibliographical research and considered four dimensions: Demographics & business (D1), Undergraduate education (D2) (Table1), Current development of SS (D3) (Table 1), SS in entrepreneurship (D4) (Table 2). The validity of the survey was positive, according to the assessment carried out by three experts. Furthermore,

the reliability was determined through Cronbach's alpha coefficient by groups of maximum 20 indicatorsand the result was α = 0.95 which indicates an excellent internal consistency.

Of the 210 mechanical engineering graduates from Universidad de Pamplona that existed at the moment of the survey application, 81 participated in the study. The calculated error was 8%, and the reliability 95%. The collected data were non-normal and non-parametric according to the bilateral Kolmogorov-Smirnov test (p-value of <0.05), which is why the non-parametric statistic tools such as mean, mode, Spearman correlation coefficient, and Games-Howell post hoc test were used.

Table 1. SS measurement indicators for the D2 and D3 dimensions.

Categories	Soft Skills Indicators	Reference
Responsibility	Takes responsibility for solving situations (their own or others') that obstruct the achievement of their objectives.	[12]–[14]
Integrity	Makes professional decisions based on integrity and ethics.	[6], [8], [13], [12]
Humility	Admits not knowing something or being wrong, especially in situations of uncertainty or confrontation.	[12]
Critical thinking	Makes decisions based on facts, data and reliable information.	[6], [8], [15]–[17]
Communication	C1. Effectively deals with difficult or conflictive conversations; C2. Uses and identifies non-verbal language (body posture, arms, legs, eye contact, etc.) during conversation; C3. Effectively presents a subject to an audience with all levels of knowledge (Effectively: use of teaching media and excellent performance); C4. Writes management or technical reports with clarity.	[6], [8], [12], [15], [16], [18]–[21]
Negotiation	Conducts effective negotiations (situations with different interests and points of view).	[12], [22]
Actions coordination	A1. Undertakes adequate commitments with their work team. (Adequate: High achievement, low reprocessing), A2. Supervises the development of the tasks without generating rejection; A3. Makes claims effectively in case of non-compliance with the acquired obligations; A4. Acknowledges the achievements of the team members.	[12], [23]
Emotional competence	Addresses situations calmly, maintaining the emotional balance.	[12], [16], [24]–[28]
Leadership	Effectively leads small teams (8 people max.) oriented to meet specific goals.	[6], [8], [13], [15], [16], [18], [19], [21]
Entrepreneur-ship	B1. Analyzes the risk level of the possible ways of solving a problem; B2. Analyzes business ideas considering technical support, marketing, logistics, legal, organizational structure, and human capital required; B3. Solves different types of problems creatively.	[6]–[8], [13], [19], [21], [22], [29], [30]

Rating: 1:Very deficient, 2:Deficient, 3:Acceptable, 4:Good, 5:Excellent.

Table 2. SS measurement indicators for dimension D4.

Category	Entrepreneurship Indicators
Entrepreneurship (references Table 1)	E1. Analysis of the risk level in a project; E2. Quickly reaches out to others or support networks and trusts them. Systemic analysis of a project; E4. Ability to create new opportunities, products or processes; E5. Creative problem solving; E6. Resilience.

Rating: 1:Unimportant, 2:Minor importance, 3:Moderately important, 4:Important, 5:Very important.

III. RESULTS

The results of the Demographics & business dimension relevant to the development of SS are presented in Table 3.

Table 3. Demographics and business characteristics that influence the development of SS.

Indicator	**Indicator Levels and Percentage**							
Role or occupation	Area or dept. manager	Inspector or process engr.	Dev. or project engr.	Teacher	Consultant	Other		
	9.9	35.8	19.8	14.8	3.7	16		
Education	Associate's degree	Administrative area	Personal development	None				
	44.4	13.6	28.4	13.6				
Type of company	Public	Private	Mixed					
	16	80.2	3.7					
Economic activity	Mining Energy	Mfg. industry	Trans.	Constr.	Education	Govt.	Commerce	Other
	33.3	17.30	17.3	3.7	14.8	1.2	4.9	7.4

Table 4 presents the respondents' concept of Undergraduate education (D2), Current development of SS (D3), and SS in entrepreneurship (D4).

Table 4. Development of SS in undergraduate education, current development, and required for entrepreneurship.

Dimension		**Education***		**Current dev.****		**Entrepreneurship*****	
Soft skill		**Me**	**Mo**	**Me**	**Mo**	**Me**	**Mo**
Responsibility		4	4	4	5	4	5
Integrity		4	4	4	5	5	5
Humility		4	4	4	4	4	4
Communication	Difficult conversations (C1)	3	4	4	4	5	5
	Non-verbal language (C2)	3	2	4	4	4	4
	Presenting in front of different audiences (C4)	4	4	4	4	5	5
	Writing reports (C4)	3	3	4	4	5	5
Negotiation		3	2	4	4	5	5
	Commitment (A1)	3	3	4	5	5	5

Dimension / Soft skill		Education*		Current dev.**		Entrepreneurship***	
		Me	Mo	Me	Mo	Me	Mo
Action Coordination	Claims (A2)	3	3	4	5	5	5
	Supervision (A3)	3	4	4	4	5	5
	Acknowledgment (A4)	4	4	4	5	5	5
Emotional Competence		3	4	4	4	5	5
Leadership		3	4	4	4	5	5
Entrepreneurship	Risk (B1)	3	4	4	4	5	5
	Methodologies (B2)	3	3	4	5	5	5
	Creativity (B3)	3	3	4	4	5	5
Critical Thinking		4	4	4	5	5	5
Sales Performance		3	2	4	3	5	5

*Me: Mean, Mo: Mode. *Education, ** Current development, 2:Deficient, 3:Acceptable, 4:Good, 5:Excellent.*

****Entrepreneurship, 4: Important, 5: Very important.*

A. Skills Required for Engineering Entrepreneurship

This study determined that 15 of the 18 indicators researched (Table 1) are “Very important” (Me=5) (Table 4) in engineering entrepreneurship. However, the other three are “Important” (Me=4). An entrepreneurial engineer is a person with developed technical and soft skills, and the latter are required at the manager or CEO levels [31]. In contrast, this SS development level is not usually considered when engineers decide to be entrepreneurs, increasing the difficulty of the process.

B. Development of Entrepreneurial Skills in Engineers

The surveyed engineers have, on average, a soft skills development level of “Good” (Me=4) with a tendency in some skills to reach an “Excellent” level (Mo=5) (Table 4). This study only considered the Entrepreneurship (Table 2) and Demographics & business (Table 1) indicators with a p-value of <0.05 by using the Kruskal-Wallis ANOVA test (Table 5). Subsequently, these indicators were analyzed using the Spearman correlation coefficient (Table 5) and the Games-Howell post hoc test (Figure 1).

Table 5. Statistics for indicators D1 and D4 with a p-value of <0.05.

Charac.		Statistics		Entrepreneurial Skill Indicators					
				E1 Risk	E2 Networks	E3 Systemic	E4 Opp.	E5 Creativity	E6 Resilience
Dem	Role Occup.	Kruskal-Wallis	χ^2	14.651		11.986		12.263	
			ρ	.012		.035		.031	

Charac.		Statistics		Entrepreneurial Skill Indicators					
				E1 Risk	E2 Networks	E3 Systemic	E4 Opp.	E5 Creativity	E6 Resilience
		Spearman Rho	Correlation	0.331*		0.279*			
			ρ (bilateral)	.003		.012			
		Games-Howell	F	4.065				3.150	
			ρ	.003				.012	
	Formal Educ.	Kruskal-Wallis	χ^2	8.410	10.878	10.505	14.176	12.899	10.133
			ρ	.038	.012	.015	.003	.005	.017
		Spearman Rho	Correlation	.282*		.342*	.403**	.400**	.326*
			ρ (bilateral)	.011		.002	.000	.000	.003
		Games-Howell	F	3.442	4.729	3.909	5.085	4.566	3.242
			ρ	.021	.004	.012	.003	.005	.027
Characteristics	Type of Comp.	Kruskal-Wallis	χ^2	7.485		6.796		6.183	8.095
			ρ	.024		.033		.045	.017
		Spearman Rho	Correlation	.272*		.241*			
			ρ (bilateral)	.014		.030			
		Games-Howell	F	4.593		4.146		3.566	4.866
			ρ	.013		.019		.033	.010

**Weak Spearman correlation; **Moderate Spearman correlation*

The role or occupation divided into six levels (Teacher, consultant/advisor, area/process engineer/inspector, development/project engineer, area/process manager, other) influences the development of the indicators E1, E3, and E5. E1 and E3 show a positive and moderate Spearman correlation, and the Games-Howell test evidence there is a significant difference in the development of the indicators E1 and E5 (Fig. 1A) in the group of engineers who are teachers and those who are consultants, the latter have a higher development. On the other hand, it is evident that the teachers' group has the lowest development of E1, E3, and E5 compared to all the other occupations. There is a more significant development level for the area or department managers compared to all the other occupations, except for consultancy.

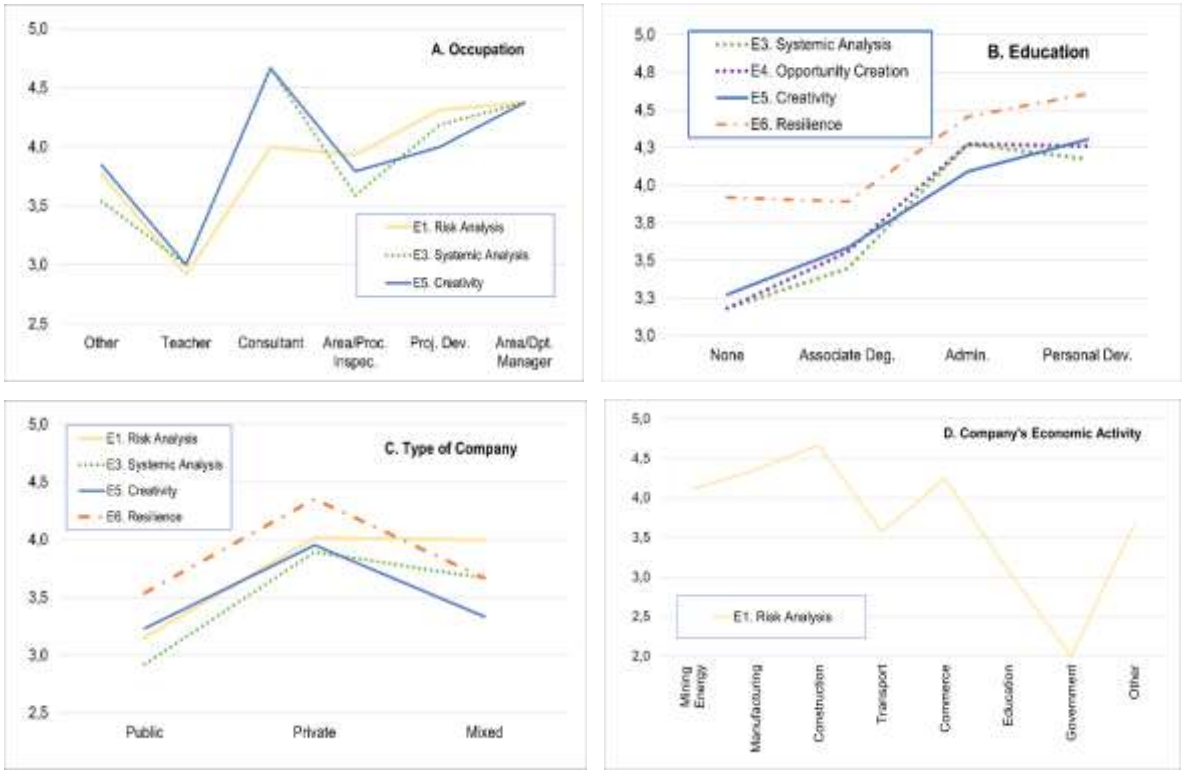

Fig. 1. Games-Howell in comparison to a) occupation vs. E1, E3, E5, b) education vs. E3, E4, E5, and E6, c) type of company vs. E1, E3, E5, and E6, d) economic activity vs. E1.

The formal education that is not part of a bachelor's degree was classified as: technical, administrative, or personal development or none. This demographic indicator demonstrated the highest relevance for developing the entrepreneurship indicators and, in general, for all soft skills. The value obtained for the indicators E3, E4, E5, and E6 (Fig. 1B) or, in other words, the development of those skills is lower in engineers with associate's degrees or without any formal education in comparison to those who had formal education in administration or personal development. Detailed analysis of the influence of this indicator on SS can be found in an article part of this research [32]. Furthermore, the type of company (public, private or mixed) influences the development of E1, E3, E5, and E6 (Fig. 1C). These indicators are less developed in engineers working in public companies than in private or mixed companies. Finally, the company's economic activity influences the development of E1 (Fig. 1D) weakly and positively, where engineers part of government and

education companies have this indicator less developed in comparison to the companies with other economic activities.

C. Undergraduate Education in Soft Skills

According to the program graduates, the training in soft skills during the undergraduate degree was “Acceptable” (Me=3). Humility, Critical thinking, Responsibility, Acknowledgment, Integrity and Presenting in front of different audiences were the most developed skills with a rating of “Good” (Me=4). The other 10 skills were rated as “Acceptable” (Me=3). Finally, Non-verbal language and Negotiation tended toward “Deficient” (Mo=2).

IV. Discussion and Conclusions

Regarding the research question, “What is the gap between the SS required in engineering entrepreneurship and those developed by engineers?”, it was evidenced that for engineering entrepreneurship, out of the 18 SS indicators, 15 are “Very important”; the other 3 were “Important”. Which demonstrates that all the soft skills analyzed are essential: Responsibility, Humility, Critical thinking, Communication (divided into Difficult conversations, Non-verbal language, Presenting in front of different audiences, Writing reports), Negotiation, Action coordination (divided into Commitment, Claims, Supervision, Acknowledgment), Emotional competence, Leadership, Entrepreneurship (divided into Risk analysis, Analysis of business ideas considering methodologies, Creativity). However, the surveyed engineers do not achieve the SS development level required for an entrepreneurial venture and even less during undergraduate education. The gap between the current development of SS in engineers and the requirements for engineering entrepreneurship is small since most engineers have an “Important” development level. Nonetheless, the gap extends to engineers who are teachers and engineers working in public companies in relation to the indicators of risk analysis (E1), systemic analysis (E3) and creative problem solving (E5), or for those who do not have formal education or whose education is on a level below a bachelor’s degree. The engineers who have not developed the SS level necessary

for an entrepreneurial venture will have to increase it during the project's development. This increases the expected investment return since they manage less efficiently the conflicts within the work teams, the suppliers or the customers, and have fewer tools and methodologies to lead, motivate and coordinate effective actions for their workers. To bridge this gap, engineers must undertake courses on administration and personal development [32].

On the other hand, the gap between the SS education in the undergraduate program and the SS required for entrepreneurship engineering is broad, as suggested in the bibliographic review. It is essential that the graduates have the possibility of developing their business ideas effectively, so they do not depend on the possible hiring from a company. Therefore, it is relevant and urgent for the engineering programs to include in their curriculum and the teachers' training the development of SS and entrepreneurship. This will support the development of the startups from their research results and enhance the graduates' competitiveness.

Finally, this research provides engineers and engineering students with a clearer perspective on the development level of soft skills required for engineering entrepreneurship and allows them to establish different education routes to increase their competitiveness and decrease the risk level when starting a business.

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AUTHORS' CONTRIBUTION

Yenny-Carolina Jaimes-Acero: Conceptualization, bibliographic analysis, methodology, data analysis, writing.

Adriana Granados-Comba: Writing-editing, methodology, statistic analysis of the data.

Rafael Bolívar-León: Conceptualization, methodological supervision and statistic analysis of the data.

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