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A preliminary study on perceptions of critical thinking skills in undergraduate and graduate engineers

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Abstract

Nowadays, it is considered essential to have a society integrated by reflective, responsible citizens capable of making reasoned decisions on different issues related to science and technology [1]. In the case of engineering students, the development of these critical thinking skills is significant since any engineer must be able to persuade the interlocutor about a problem or its solution [2], as well as to overcome one of the main obstacles found in the literature, which is the difficulty in communication skills that engineers encounter when expressing formal reasoning [3]. This paper aims to compare the perceptions of critical thinking skills presented by a sample of students in the second year of the Industrial Technologies Engineering Degree at the University of Malaga (Spain) (N=26) with those of graduated engineers who are continuing their training in a Master's Degree (N=19). The survey proposed by Santiuste et al. [4] to assess the development of critical thinking skills was used as a data collection instrument. This survey consists of 30 items grouped into two dimensions (substantive, focused on the person's points of view, and dialogical, the confrontation between two or more people). Three categories (reading, expressing in writing, and listening and expressing orally) are established within each dimension. The results obtained through the Mann-Whitney U test revealed statistically significant differences in the reading category of the substantive dimension. However, differences were also detected in some items of the other two categories and all cases favouring graduate engineers. On the other hand, in no case were differences detected in the dialogical dimension. These results indicate that, after undergraduate training, engineers are autonomously able to develop critical thinking skills in the substantive dimension. However, more specific training is required for the dialogical dimension that should be promoted from the engineering degrees, which is necessary for their professional activity.

Keywords: *Critical thinking, Engineering students, Higher Education.*

1. Introduction

The literature on science and technology learning suggests that argumentation and reasoned decision-making skills help university students improve their scientific reasoning and promote their conceptual understanding [5-7] since they need to justify conclusions, which can be challenged by other ideas. Moreover, by contrasting ideas, students have the opportunity to evaluate their conceptions and learn new ones, thus favouring the construction and assimilation of new concepts [8].
These skills, among others, are part of a more complex concept called critical thinking [9]. Thus, Lipman [10] considers that reading comprehension, written expression, and listening and speaking are basic critical thinking skills that can be developed at any educational level. For Santiuste et al. [4], critical thinking has two dimensions: the substantive dimension, which includes all the acts performed by citizens to offer reasons and evidence to support their point of view, and the dialogic dimension, which includes those acts that focus on analysing and integrating points of view that are opposed or different from their own, where they must also develop reasoned arguments that allow them to respond to refutations and to clarify the different perspectives.
In the case of engineering students, their academic training has traditionally focused on the transmission of knowledge [11]. However, the current trend tends towards an integral education, understanding engineering as the intersection of the technical and social dimensions, in which critical thinking acquires a concrete and particular meaning and must be promoted [12].

Thus, promoting critical thinking skills in engineers would help improve their oral communication skills, detected as an obstacle in the literature [3]. Due to its importance, this paper aims to conduct a

preliminary study on the perceptions of critical thinking skills in Spanish undergraduate and graduate engineers.

2. Method

The participants in this study were 45 students from the University of Malaga (Spain) belonging to two different samples: 26 undergraduate engineers (UGE) in the second year of the Industrial Technologies Engineering Degree (20 men and 6 women), and 19 graduate engineers (GE) who are continuing their training in a Master's Degree (12 men and 7 women). The study was conducted during the academic year 2021/22.

The participants' perceptions of critical thinking skills were measured using the CPC2 survey by Santiuste et al. [4]. This survey addresses the dimensions of substantive (focusing on one's views) and dialogical (the confrontation between two or more people). Three categories related to the reading, expressing writing, and listening and expressing orally skills are established for each dimension. The survey comprises 30 items (table 1) presented on a Likert scale of 1 to 5 points (1, strongly disagree and 5, strongly agree).

Several statistical analyses were performed using SPSS 23.0 to compare the perceptions expressed between UGE and GE. The Mann-Whitney U test was used to study statistically significant differences between UGE and GE for each item, category and dimension. The means of the items comprising each category were calculated for each student to quantify each category. The quantification of each dimension was carried out similarly. The effect size of the Mann–Whitney U test was calculated using the equation $r = Z/\sqrt{N}$, where N is the number of students and Z is the value of the statistical test. As for the value of r calculated in absolute terms: 0.1 is considered a small effect, 0.3 a medium effect and 0.5 a large effect. We also analysed whether there were significant differences by gender in each group (UGE or GE).

3. Results and Discussion

Table 1 displays the statistical analysis results for each item of the survey, while table 2 shows the results by categories and dimensions.

Table 1. Mann-Whitney U test for each item of the survey [4] for UGE and GE.

UGE Media	GE Media	Z	p	In favour	Effect Size (r)
Substantive Dimension: Reading					
1. When I read something I disagree with, I look for reasons contrary to those stated in the text.					
3.654	3.579	-0.498	0.619	-	-
2. I can differentiate between facts and opinions in the texts I read.					
3.808	4.316	-2.331	0.020	GE	0.347
3. When I read a text, I clearly identify the relevant information.					
3.539	4.263	-3.252	0.001	GE	0.485
4. When I read a text, I clearly identify the irrelevant information.					
3.808	4.053	-1.003	0.316	-	-
5. When I read an argumentative text, I clearly identify the arguments that corroborate or refute a thesis.					
3.692	4.158	-2.322	0.020	GE	0.346
6. I can draw fundamental conclusions from the texts I read.					
3.769	4.263	-3.123	0.002	GE	0.466
7. When an author presents several possible solutions to a problem, I assess the usefulness of each of them.					
3.846	4.105	-1.209	0.227	-	-
8. When an author presents several possible solutions to a problem, I assess whether all of them are equally possible to implement.					
3.577	3.895	-1.460	0.144	-	-
9. When an author presents several possible solutions to a problem, I assess whether he has also presented all the conditions necessary to put them into practice.					
3.385	3.579	-0.739	0.460	-	-
10. When I read a text, I know whether the author is trying to give an opinion, present a problem and its solutions, explain facts, etc.					
3.885	4.000	-0.426	0.670	-	-

Table 1. Continuation

UGE Media	GE Media	Z	p	In favour	Effect Size (r)
Substantive Dimension: Reading					
11. I verify the internal logic of the texts I read.					
3.423	3.895	-2.418	0.016	GE	0.360
12. I ask myself if the texts I read say something that is valid today.					
3.577	3.684	-0.476	0.634	-	-
13. When I read something I disagree with, I consider that I may be wrong and that perhaps it is the author who is right.					
3.577	3.842	-0.916	0.360	-	-
14. When I read an opinion or thesis, I do not take sides until I have sufficient evidence or reasons to justify it.					
3.808	3.684	-0.732	0.464	-	-
15. When I read an opinion that agrees with my point of view, I side with it without considering other possible reasons to the contrary.					
3.154	2.895	-1.129	0.259	-	-
16. When I read the interpretation of a fact, I wonder if alternative interpretations exist.					
3.769	3.737	-0.112	0.911	-	-
Substantive Dimension: Expressing in writing					
17. When I write the conclusions of a paper, I clearly justify each one of them.					
3.808	3.526	-0.959	0.338	-	-
18. When I have to argue in writing about an issue, I give reasons both for and against it.					
3.962	3.474	-1.956	0.050	UGE	0.292
19. When I write about a subject, I clearly distinguish between facts and opinions.					
4.077	4.000	-0.026	0.979	-	-
20. When I look for information to write a paper, I judge whether the sources I use are reliable.					
4.000	4.053	-0.121	0.904	-	
21. When a problem has several possible solutions, I can write them down, specifying their advantages and disadvantages.					
3.308	4.000	-3.214	0.001	GE	0.479
22. When I write an idea that is not my own, I mention the sources from which it comes.					
3.962	4.474	-2.031	0.042	GE	0.303
Dialogical Dimension: Expressing in writing					
23. In my written works the main thesis on the subject, I present alternative opinions from other authors and sources.					
3.385	3.421	-0.073	0.942	-	-
24. When writing a paper, I present alternative interpretations of the same fact whenever possible.					
3.500	3.263	-1.285	0.199	-	-
Substantive Dimension: Listening and expressing orally					
25. I know how to clearly express my point of view in debates.					
3.462	3.632	-0.729	0.466	-	-
26. In debates, I know how to justify why I consider an opinion acceptable or well-founded.					
3.769	3.421	-1.183	0.237	-	-
27. When I orally present an idea that is not mine, I mention the source from which it comes.					
3.538	3.684	-0.362	0.717	-	-
28. When a problem has several solutions, I am able to present them orally, specifying their advantages and disadvantages.					
3.423	3.789	-1.962	0.050	GE	0.293
Dialogical Dimension: Listening and expressing orally					
29. In debates, I look for alternative ideas to those already expressed.					
3.885	3.632	-1.208	0.227	-	-
30. When I participate in a debate, I ask myself if alternative interpretations of the same fact.					
3.731	3.684	-0.138	0.891	-	-

Table 2. Mann-Whitney U test for each category and dimension of the CPC2 survey

	Substantive Dimension				Dialogical Dimension			
	Reading	Expressing in Writing	Listening and Expressing Orally	Total Dimension	Reading	Expressing in Writing	Listening and Expressing Orally	Total Dimension
UGE Media	3.667	3.853	3.548	3.689	3.577	3.442	3.808	3.609
GE Media	3.982	3.921	3.632	3.845	3.539	3.342	3.658	3.513
Z	-2.367	-0.788	-0.348	-2.060	-0.248	-0.565	-0.668	-1.030
P	0.018	0.431	0.728	0.039	0.804	0.572	0.504	0.303
r	0.353	-	-	0.307	-	-	-	-

An overall view of the results shows that all the critical thinking skills proposed are well perceived by UGE and GE, with practically all the items presenting a mean higher than 3. Generally, it can be seen that the GE presented higher perceptions in the reading, and listening and expressing orally skills of the substantive dimension, while in the remaining cases, the UGE had higher perceptions.

To facilitate the discussion, Table 3 summarizes the items in which statistically significant differences were found and those in which they were not found, indicating in the first case in favour of which group of students the differences were in.

Table 3. Statistically significant differences by items between UGE and GE

	Substantive Dimension			Dialogical Dimension		
Differences in favour	Reading	Expressing in Writing	Listening and Expressing Orally	Reading	Expressing in Writing	Listening and Expressing Orally
UGE	-	18	-	-	-	-
GE	2,3,5,6,11	21,22	28	-	-	-
Without Differences	1,4,7,8,9,10, 12	17,19,20	25,27,27	13,14,15,16	23,24	29,30

As can be seen (Table 3), the Mann-Whitney U test detects statistically significant differences in 9 items between UGE and GE with a medium-large effect (Table 1). It is striking that all the differences are found in the substantive dimension and all, except item 18, favouring the GE. Within this dimension, the majority of items are in the reading category. These results reveal UGE's perception of their critical thinking skills as individuals (substantive dimension) is significantly lower than that of the GE, and it is in reading where the latter is more comfortable. It may be due to the security given to the surveyed by the scientific-technical knowledge that they have acquired during the degree, as well as training in the search for and analysis of information during that time. Thus, item 22 on citing sources when presenting the ideas of others is the item with the highest mean (4.474) for the GE. The training of students in this task throughout the courses and the development of their final thesis could be the reason.

The finding that none of the items of the dialogic dimension shows statistically significant differences may be due, according to the participants' perception, to the fact that during the development of the degree and in subsequent years, there has been no improvement in their skills related to the confrontation between points of view of two or more people. The low number of tasks performed in engineering degrees to develop critical thinking skills [12] may have influenced.

Finally, the statistical analysis by gender showed no significant differences in items, categories or dimensions.

4. Conclusions

This work has compared the perception of critical thinking skills of UGE and GE, focusing on the substantive and dialogical dimensions. The results obtained reveal two ideas. On the one hand, GE can progress autonomously in developing critical thinking skills in the substantive dimension. But, on the other hand, the different Engineering Degrees should encourage the use of activities that favour the development of skills related to both dimensions, especially in the dialogical dimension. Specifically, activities related to the critical reading of information, knowing how to express oneself adequately in writing, or knowing how to listen and express oneself orally, which, on most occasions, are understood as activities of linguistic degrees and are ignored in scientific careers.

As a future line of research, we intend to develop a training programme in scientific argumentation for engineers that includes this type of activities. Among them, we intend to encourage the development of argumentation through classroom debates.

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