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Arguments Expressed by University Students According to Their Scientific Background on the Banning of Single-Use Plastics

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Abstract

Society requires reflective and critical citizens who know how to get involved effectively in current problems, including scientific-technological aspects. To this end, education must train university students in the necessary competences to act responsibly in the face of these problems. In these competences, argumentation plays a central role and can be developed in the classroom, among others, by treating socio-scientific issues, as it allows them to reflect on the subject, argue and make decisions. This paper analyses the competence in argumentation about the socio-scientific issue of plastics of students with different scientific backgrounds: 35 students in the fourth year of the Degree in Mechanical Engineering and 43 students in the Master's Degree in Secondary Education Teaching of scientific specialities at the University of Málaga (Málaga, Spain). The activity proposes to argue about the appropriateness of the ban on single-use plastics after attending as listeners to a short debate by two students, one for and one against the issue. The evidence the students gave in their arguments varied, including physicochemical evidence, economic aspects, environmental and health risks, legislation and social awareness. The Mann-Whitney U test showed statistically significant differences between the Master's Degree in Teaching and engineering students in favour of the former, who were able to provide a higher total number of evidence (mean of 2.44 versus 1.83) ($Z=-2.762$, $p=0.006$) and also evidence relating to physicochemical ($Z=-2.066$, $p=0.039$) and social awareness ($Z=-2.972$, $p=0.003$) aspects. Significant differences in favour of engineering students were also detected in the justifications given to support the evidence ($Z=-2.230$, $p=0.026$) and economic evidence ($Z=-2.893$, $p=0.004$). These results highlight the need to continue training both university students and teachers in initial training so that they can argue in their profession in the best possible way.

Keywords: *Argumentation, Pre-service teachers, Engineering students, Socio-scientific issues, Plastics.*

1. Introduction

The development of critical thinking skills in pure science and engineering students is significant because their academic training is traditionally focused on the transmission of knowledge [1], and its development would contribute to improving their professional competences. Moreover, critical thinking acquires a specific meaning in university education, which should be promoted through a comprehensive training plan [2].

This training is, however, a difficult task since critical thinking is a complex construct made up of different skills. Among them are argumentation and decision-making [3]. Argumentation helps students to improve their scientific reasoning and promote their conceptual understanding [4] as they need to justify conclusions, which other ideas can challenge. Moreover, by contrasting ideas, students can evaluate their conceptions and learn new ones, thus favouring the construction and assimilation of new concepts [5].

Decision-making, on the other hand, involves identifying the different options available from the data provided, using appropriate evidence and scientific knowledge to support one option and reject others [6].

At a methodological level, developing these critical thinking skills can be encouraged by posing socio-scientific issues in the classroom, i.e. problems where science and technology play a relevant role and where society has an important involvement.

Within this theoretical framework, this paper studies the arguments provided by university students with different scientific backgrounds on the issue of banning single-use plastics. Environmental, economic and health aspects, among others, are present in this issue.

2. Methodology

2.1 Participants

The sample of this work comprises university students with different scientific backgrounds who were studying at the University of Málaga (Spain) during the academic year 2021-2022. On the one hand, 35 students from the fourth year of the Mechanical Engineering Degree, and on the other hand, 43 science graduates (Chemistry, Physics or Biology) from the Master's Degree in Secondary Education Teaching. All students participated in a training programme to improve their critical thinking skills [7], in which they received instruction in scientific argumentation.

2.2. Description of the activity

This study analyses the arguments used by students in response to a question posed through the socio-scientific issue of the ban on single-use plastics. Specifically, "The European Union has recently published a regulation to ban single-use plastics; do you support or oppose this ban? [8].
The activity was structured in the following phases:

- *Phase 1: Instruction on argumentation.* A two-hour training session was held to explain how different authors understand argumentation in the scientific-technological area, emphasising its importance in everyday life, science education, and its contribution to critical thinking. In addition, Toulmin's model of argumentation [9] and a simplified adaptation of it [10] were shown.
- *Phase 2: Attendance at a debate about the problem.* The participants listened to a 15-minute debate on the issue conducted in the classroom by three students. One played the presenter role and the other defended positions for or against the problem. The debate dealt with all the dimensions of the issue in a balanced way.
- *Phase 3: Making a decision on the problem.* After the debate, the students made a reasoned decision on the issue in response to the question posed.

2.3. Data analysis

This study analyses the decision-making after the debate and the arguments given to justify it. In the first case, the percentage of students in favour and against the ban on the use of plastics was calculated. In the second case, the arguments offered were analysed according to Toulmin's model [9], identifying the essential elements in each argument: evidence (considering number and type), justifications and conclusion. A rubric was used for this analysis (Table 1), established by consensus among the researchers.
In order to determine the possible existence of statistically significant differences between the evidence presented by the two student profiles, the Mann-Whitney U test was performed. The software used was the SPSS 25.0 statistical package.

3. Results and Discussion

The analysis of the choices showed that 75.6% of the students favoured a plastic ban. No differences were observed regarding the scientific background of the participants, as 77.1% of engineering students and 74.4% of science graduates chose this option.
Table 2 shows the analysis results of the arguments presented for the two participant profiles, regardless of the conclusion reached.

Table 1. Rubric for the analysis of the elements of the arguments used

Conclusion				
0: No conclusion provided	1: Hesitation in reaching a conclusion		2: An adequate and accurate conclusion is provided	
Evidence				
Number of evidence				
0 (No evidence)	1	2	3	4
Type of evidence				
Economic	0 (No evidence)	1	2	
Physicochemical	0 (No evidence)	1	2	
Environmental risk	0 (No evidence)	1	2	
Health risk	0 (No evidence)	1	2	
Legislative	0 (No evidence)	1	2	
Social awareness	0 (No evidence)	1	2	
Justification				
0: No justification provided	1: A justification that does not link evidence to conclusion is provided		2: A justification linking evidence to conclusion is provided	

Table 2. Mean of the essential elements of an argument according to the student profile

	Average Engineering students	Average Science graduates
Conclusion	2.00	2.00
Justification	1.60	1.33
Evidence		
Economic	0.29	0.05
Physicochemical	0.34	0.60
Environmental risk	0.66	0.65
Health risk	0.17	0.30
Legislative	0.11	0.16
Social awareness	0.26	0.67
Total number of evidence	1.83	2.44

All students drew a conclusion in the level 2 of the rubric (table 2). However, not all students justified it adequately, but listed a series of evidence only, this being more pronounced in science graduates.
They based their conclusions on were qualitatively similar type of evidence, with minor differences being found depending on the student profile. Thus, the difference in the social awareness evidence, physicochemical evidence and health risks, which science graduates used more, was striking, while engineering students notably used economic evidence.
Table 3 shows the results of the Mann-Whitney U test, where statistically significant differences between science graduates and engineering students can be seen in favour of the former, who were able to provide a higher total number of evidence (mean of 2.44 vs 1.83) ($Z=-2.762$, $p=0.006$) and also of physicochemical evidence ($Z=-2.066$, $p=0.039$), and social awareness ($Z=-2.972$, $p=0.003$) evidence. Significant differences in favour of engineering students were also detected in the justifications given to support evidence ($Z=-2.230$, $p=0.026$) and economic evidence ($Z=-2.893$, $p=0.004$).

Table 3. Mann Whitney U-test for the argument elements

	Mann Whitney U-test		
	Z	P	Significance
Conclusion	.000	1.000	NS
Justification	-2.230	.026	In favour of engineering students
Evidence			
Economic	-2.893	.004	In favour of engineering students
Physicochemical	-2.066	.039	In favour of science graduates
Environmental risk	-.194	.846	NS
Health risk	-1.331	.183	NS
Legislative	-.608	.543	NS
Social awareness	-2.972	.003	In favour of science graduates
Total number of evidence	-2.762	.006	In favour of science graduates

4. Conclusions

The results show university students' difficulty in arguing and making decisions about relevant issues in a society where science and technology play an important role.
An important aspect to consider is using evidence on social awareness based on students' personal ideas, mostly focused on opinions. These ideas seem to be quite usual in environmental issues.Indeed, statistically significant differences were found in this type of evidence in favour of science graduates. Therefore, this type of evidence should be avoided and replaced by other evidence of higher argumentative quality.
These results highlight the need for further training of science and engineering undergraduates to argue in their profession and in their daily life in the best possible way. Finally, based on this preliminary study and with the idea of improving the quality of the scientific-technological argumentation of students, the design of mobile applications for learning scientific argumentation on climate, environmental and resource efficient actions is intended as a future line of work.

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References

[1] Caro, S., & Reyes, J. (2003). Prácticas docentes que promueven el aprendizaje activo en ingeniería civil. *Revista de Ingeniería*, *18*, 48-55.
[2] Carrillo, S., & Nevado, K. (2017). El debate académico como estrategia didáctica para la formación de competencias argumentativas y la aproximación al diálogo científico. *Rastros Rostros*, *34*(19), 18-30.
[3] López-Fernández, M.M., González, F., & Franco-Mariscal, A.J. (2022). How Can Socio-scientific Issues Help Develop Critical Thinking in Chemistry Education? A Reflection on the Problem of Plastics. *Journal of Chemical Education*, 99(10), 3435-3442.
[4] Bogar, Y. (2019). Synthesis study on argumentation in science education. *International Educ. Studies*, *12*(9), 1-14.
[5] Benegas, J. (2013). *El aprendizaje activo de la Física Básica Universitaria*. Andavira.
[6] Acar, O., Turkmen, L., & Roychoudhury, A. (2010). Student difficulties in socio-scientific argumentation and decision making research findings: Crossing the borders of two research lines. *International Journal of Science Education*, *32*(9), 1191–1206.

[7] Cano, M.J., Franco-Mariscal, A.J., & Blanco, A. (2021). Secuencia de actividades de argumentación para estudiantes de ingenierías industriales. In D. Cebrián, A.J. Franco-Mariscal, T. Lupión, M.C. Acebal & A. Blanco (Coords.), *Enseñanza de las ciencias y problemas relevantes de la ciudadanía. Transferencia al aula* (pp. 153-172). Graó.
[8] European Union, The European Parliament and the Council of the European Union (2019). Directive (EU) 2019/904 of the European Parliament and the Council, of 5 June 2019 on the reduction of the impact of certain plastic products on the environment. European Union.
[9] Toulmin, S. E (1958). The uses of argument (2003, 3rd ed.). Cambridge University Press.
[10] Jiménez-Aleixandre, M.P. (2010). *10 ideas clave. Competencias en argumentación y uso de pruebas* (Vol. 12). Graó.