IDENTIFICATION OF EVIDENCE BY ENGINEERING UNDERGRADUATES AND PRE-SERVICE SCIENCE TEACHERS IN AN ARGUMENTATION ACTIVITY

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Abstract: Scientific argumentation is considered as one of the general competencies that engineering students must achieve. This paper analyses the capacity to identify evidence in an argumentation activity on characteristics of materials, developed with 46 engineering undergraduates of the second year of the Degree in Industrial Technologies Engineering and 81 pre-service science teachers of the University of Malaga (Malaga, Spain). These pre-service science teachers studied a Master's Degree in Secondary Education and were classified for this study in two groups depending on whether or not their previous degree was related to the knowledge necessary to solve the activity. The activity proposes to argue the choice of a bicycle according to the material of manufacture (steel or aluminium), focusing this paper on the analysis of the evidence shown in their arguments. A number of evidence, their type, their quality in terms of the level of adequacy and precision, and the inclusion or not of personal ideas, were considered as dimensions. The results show that engineering undergraduates are capable of offering arguments with a greater number of evidence and of different types (economic, physical-chemical and mechanical) as opposed to pre-service science teachers. On the contrary, pre-service teachers offer arguments with a better quality of evidence than undergraduates. Pre-service science teachers from degrees unrelated to the activity used a great number of personal ideas when arguing. These results highlight the need to continue training both undergraduates and pre-service teachers so that they can argue in their profession in the best possible way.

Keywords: Initial Teacher Education (Pre-service), evidence-based approaches, decision making.

INTRODUCTION

The promotion of reasoning and argumentation skills constitutes an important role in the competencies that undergraduates must acquire (Mercier and Sperber, 2011). In the case of engineers, their development is especially important to prevent them from making mistakes in their projects, and that is why argumentation is considered as one of the general competencies that every student of the Degree in Industrial Technologies Engineering must achieve (Ministry of Education and Science, 2007). Argumentation is one of the relevant scientific practices in science education and consists of being able to evaluate statements based on evidence. It implies recognizing that scientific conclusions and statements must be justified, that is, supported by evidence (Jiménez-Aleixandre, 2010).

The argumentation can be raised in the teaching-learning process with respect to any problem, either exclusively scientific/technological or socio-scientific. In order to design and evaluate argumentation activities, it is important to have an adequate model to understand the argumentation. In this effort, the Toulmin model (2003) and the Jiménez-Aleixandre simplification (2010) stand out to facilitate the understanding of the essential elements of a good argument: evidence, justifications, and conclusions. This study aims to analyse the capacity to identify evidence in an argumentation activity proposed to engineering undergraduates and pre-service science teachers.

METHOD

A total of 127 students from the University of Malaga (Malaga, Spain) participated in this study during the academic year 2018/19, divided into three groups: undergraduates (UG) of the second year of the Degree in Industrial Technologies Engineering (N = 46, 37 men and 9 women); pre-service science teachers from similar degrees (SD) with the necessary knowledge to solve the activity (engineering and chemical sciences) (N = 37, 24 men and 13 women), and pre-service science teachers from other scientific degrees not related to the knowledge (NSD) (N = 44, 21 men and 23 women). SG and NSG were studying a Master's Degree in Secondary Education Teaching at the University of Malaga.

The participants answered an argumentation activity included in a broader questionnaire, as a previous step for the design of an argumentation training programme with students from the Industrial Engineering School of the University of Malaga. His statement was: "You are going to buy a bicycle and you have to choose the material for its frame. If the options are between a steel or aluminium frame, indicate which one you would choose and reasonably justify why you choose that frame with respect to the other".

The responses of the participants were analysed according to the three elements of an argument (evidence, justification, and conclusions), focusing this paper on the identification of evidence. Three dimensions were considered in the analysis: 1) Evidence number, 2) type of evidence provided: economic, physical-chemical (density, interaction with the environment, etc.) and mechanical (tenacity, elasticity, production/repair properties, etc.), and 3) its quality in terms of the level of adequacy and precision to scientific-technological knowledge. The inclusion or not of personal ideas was also considered as another dimension. A rubric (table 1) was used for the analysis (table 1), which was established by consensus among the researchers (authors of the paper), adding the necessary levels to adequately address the range of responses offered by the participants. The Kruskal-Wallis test was used to study possible statistically significant differences between the different groups, using the Mann-Whitney U test to detect the group that produces the differences in each case and the possible differences between sexes.

Table 1. Rubric generated for the analysis of the evidence identified by students

Evidence number					
L0: No evidence	L1: One piece of evidence	L2: Two pieces of evidence	L3: Three pieces of evidence	L4: Four pieces of evidence	L5: Five pieces of evidence
Evidence type					
L0: No evidence	L1: Economic	L2: Physical-chemical	L3: Mechanical	L4: Two different types	L5: Three different types
Evidence quality					
L0: Inappropriate	L1: Some inappropriate	L2: Appropriate but imprecise	L3: All appropriate and some imprecise	L4: All appropriate and precise	
Personal ideas (qualities, use, appearance, preference, personal budget)					
No			Yes		

RESULTS

The percentages of responses in each group and dimension are shown in table 2. In none of the dimensions related to evidence were responses found at level 0 of the rubric.

Table 2. Percentage of responses of each group for the different dimensions identified.

	Evidence number					Evidence type					Evidence quality				Ideas	
	L1	L2	L3	L4	L5	L1	L2	L3	L4	L5	L1	L2	L3	L4	No	Yes
UG	39.1	30.4	23.9	4.3	2.2	4.3	39.1	8.7	32.6	15.2	17.4	8.7	28.3	45.7	67.4	32.6
SD	67.6	18.9	13.5	0.0	0.0	2.7	70.3	0.0	24.3	2.7	5.4	2.7	13.5	78.4	70.3	29.7
NSD	75.0	22.7	2.3	0.0	0.0	2.3	77.3	0.0	20.5	0.0	0.0	6.8	6.8	86.4	54.5	45.5

It can be seen that UG offers a higher number of pieces of evidence (mean value 2.00) compared to pre-service science teachers (mean SD: 1.46; mean NSD: 1.27). Likewise, UG was the group with the best results regarding the type of evidence, on the one hand since it was the only group that identified the three types of evidence (SD and NSD did not use mechanical evidence), and on the other hand, because they argued with a greater number of different types. However, the best results in the quality of evidence were offered by SD (mean value: 3.65) and NSD (mean: 3.80) versus UG (mean: 3.02). NSD was the group that used the most personal ideas when arguing. The Kruskal-Wallis test showed that there were significant differences in at least two groups for the number, type and quality of evidence, but not for personal ideas. The U Mann-Whitney test indicated statistically significant differences between UG and SD for the variables number of evidence (Z = -2.638; p-value = 0.008), type (Z = -2.399; p-value = 0.016) and quality (Z = -3.019; p-value = 0.003), but not for personal ideas (Z = -0.279; p-value =0.780). For UG and NSD the same significant differences were found (evidence number: Z = -3.866, p-value = 0.000; type: Z = -3.215, p-value = 0.001; quality: Z = -4.043, p-value = 0.000; personal ideas: Z = -1.234; p-value = 0.214). The U Mann-Whitney test indicated that there were no significant differences between the SD and NSD groups. No significant gender differences were found in the UG and SD groups, although there were within NSD, regarding evidence quality (Z = -2.720; p-value = 0.007) and personal ideas (Z = -2.125; p-value = 0.034), in both cases in favour of women.

CONCLUSIONS

The results show that knowledge may influence some aspects of the capacity to use evidence, in this study in terms of the quantity and types of evidence used, but not the evidence quality. The absence of such knowledge may be related to the use of personal ideas rather than evidence in the arguments offered.

On the other hand, the results obtained show the need to train both undergraduates and pre-service science teachers on scientific argumentation. In this second case, bearing in mind that they will be the future technology/science secondary teachers, who will, in turn, have to train their students in argumentation.

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