PROMOTING CRITICAL THINKING SKILLS THROUGH DEBATES IN ENGINEERING EDUCATION. A CASE STUDY ON MANUFACTURING

José Manuel Hierrezuelo-Osorio, María José Cano-Iglesias, María del Mar López-Fernández, Antonio Joaquín Franco-Mariscal
University of Málaga, Málaga, Spain

Argumentation and decision-making are fundamental in the training of industrial engineers to effectively develop their critical thinking skills. Despite this, engineering education focuses on technical aspects that hardly promote the development of these skills in the classroom. To promote them, a specific training programme in critical thinking for industrial engineers was proposed, which, among other activities, included short debates on socio-scientific problems. This paper presents the impact of a debate on manual versus mass production on 30 students of the Degree in Industrial Technologies Engineering at the University of Malaga (Spain) acting as listeners. To assess this impact, we analyse the argued decisions made by the listeners about the problem before and after the activity, finding that the initial position of the majority was manual manufacturing based on social evidence, and the final position was mass production based on scientific-technical evidence such as economic aspects or the quality of the manufactured product. The arguments used by the debaters were scientifically vague but had an essential effect on changing decisions, especially the evidence used, which the listeners made their own.
Keywords: critical thinking, industrial engineers, debate, argumentation, decision making.

INTRODUCTION

Different authors advocate that engineering education requires an educational transformation that places greater emphasis on learning. Although engineering education is understood as a living, dynamic system, as a learning system that enables learning and teaching methodologies, its fundamental purpose is the integral development of the engineering student as a person and problem solver in his or her social context (Capote et al., 2016).

The aim is to propose strategies that enable the development of critical thinking in engineering students, which will improve the projects they usually carry out. These critical thinking skills must be promoted through comprehensive training (Carrillo and Nevado, 2017), which is a difficult task since critical thinking is a complex process of different skills. Argumentation and decision-making are among them (Blanco et al., 2017). Argumentation helps students to improve their scientific reasoning (Bogar, 2019) as they need to justify conclusions that 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 (Benegas, 2013). Decision-making involves identifying options available from the data provided, using appropriate evidence and scientific knowledge to support one option and reject others (Acar et al., 2010).

Recent literature shows that engineering students have poorly developed both skills and that active methodologies are required to promote them (Escudeiro et al., 2011). One active methodology is debate, as it allows students to organise rational and affective thinking through argumentation in the face of the presentation of different positions, ideologies and judgements, as well as to use persuasion and counter-argumentation (Carrillo and Nevado, 2017). When the debates are applied to engineering education, they allow different science and technology problems related to society to be addressed in a well-founded and evidence-based way. Therefore, they are suitable for achieving social transformation through engineering education. In order to promote and improve argumentation and decision-making skills in engineering education, within the framework of an R&D&I project, a training programme on critical thinking was developed for this student profile that included, among others, a debate activity. This paper presents the results of a debate on manual versus mass production.

METHOD

The sample for this study consisted of 30 students (7 women and 23 men) in the second year of the Degree in Industrial Technologies Engineering at the University of Malaga in the 2021/22 academic year. In order to find out the students´ argumentation and decision-making skills, several short debates were held in groups of three students on scientific-technological problems of a social nature, where one student defended a position in favour and another against the problem in front of a presenter. Before the debates, the students received instruction in argumentation, including, among others, Toulmin´s model (2003) and Jiménez-Aleixandre´s (2010) adaptation of the elements of an argument.

The indications given for the debates were: (a) presentation of the problem to be debated by the presenter using a digital presentation (3 minutes), (b) brief intervention of the students for and against the problem (2 minutes) and, (c) time for debate between the two positions (5 minutes). The remaining students were listeners and had to make a reasoned decision on the problem before and after each debate. This paper focuses on a debate about the appropriateness of manufacturing a product by hand or mass production. The problem was presented with this statement: *"You need a specific product, and you have two possibilities: (1) buy it from a small workshop that manufactures it manually or by hand, or (2) buy it from a large industry that mass-produces it. Are you in favour of manual or mass production?"* This debate took place when the students had already attended other debates, so they could start developing a proper argumentation technique based on the observation of other groups.

This work studies the debate´s impact on the students´ decisions before and after the debate and the arguments to support their position. For this purpose, we calculated the percentages of participants for each position at both times and quantified how many subjects maintained/changed their decision. We also provide examples of the majority arguments in each case, indicating the type of evidence on which they are based.

RESULTS AND ANALYSIS

Debate

The presenter´s exposition focused on the definition of manual and mass production, supported by examples (*"Craft production produces objects by transforming basic natural raw materials, through production processes involving machines and simple tools with a predominance of physical and mental labour"*).

Each debater then defended his or her position, illustrated by these arguments:

- Student in favour of manual production: "*For some companies, the initial investment cost can be perceived as high, but in manual production, this problem does not exist, as there is no need for highly specialised machinery or excessively high costs, but just enough materials to obtain the desired product"*.
- Student in favour of mass production: *"This production rate can be increased further, with the development of new technologies and better assembly lines, which are constantly being developed to be as efficient as possible. It leads to automation of production, which is easily implementable in series production*."

The debaters then established a dialogue by refuting the opponent's arguments. At this stage, the students lacked training, insisting on earlier arguments. The predominant evidence was economic (investment cost) or design (exclusivity) for manual manufacturing and economic (cost of unit parts) or quality and production volume-related evidence for mass production.

Initial decision

Before the debate, 73.3% of the students (22/30) were in favour of small workshop manual manufacturing, with most arguments presenting social evidence related to helping small businesses (*"Because this way we help small businesses to survive"*, Student 17). However, they forgot important aspects that, as engineers, they should not omit, such as the part's use, the complexity of the desired geometry, dimensional tolerance, etc.

The remaining 26.7% (8/30) were against and supported their arguments on economic evidence or geometric accuracy, as illustrated by this example: *"I would buy it from bigger companies because they are usually cheaper and more accessible"* (Student 18). In all cases, the conclusions were justified in ambiguous terms and with little scientific-technological character.

Final decision

After the debate, the percentage of students favouring mass production increased sharply (73.3%). Of the students who initially stated this position, 20.0% maintained it, and the remaining 53.3% changed their decision from manual to mass production. In these cases, there were differences in the arguments: *"Mass production gives a greater benefit to both the customer and the employer since high-quality products are produced, with fewer faults and at a very affordable price. Moreover, although some jobs are lost, other indirect jobs are generated, such as maintenance, etc."* (Student 17, after discussion). As can be seen, this student initially favoured small business support, and after the debate, took on board the evidence presented, such as economics, quality of parts and elimination of failures or jobs.

The percentage6 of students in favour of manual fabrication decreased to 26.7%. Of these, 20% maintained their position, and only 6.7% came from students who were initially against it. In the arguments, while understanding the advantages of mass production, these students still prioritised the social test of supporting the small manufacturer (*"You should always support the local market, although there are many advantages to buying in mass production"*, Student 9). Therefore, as seen in the examples, listeners began to appropriate the evidence presented by the debaters to make a decision.

CONCLUSIONS

This work shows activity on debates as a strategy to teach industrial engineers argumentation and decision-making skills in socio-scientific problems. The results indicate that students need to improve these critical thinking skills. In the case of argumentation, more classroom activities should be promoted to enable them to develop higher quality arguments based on scientific evidence and in a more precise way, as well as to encompass all aspects that are part of the problem. A detailed analysis can help this in the classroom with the quality of the arguments used in the debate by identifying the evidence, justifications and conclusion used. Regarding decision-making, it should be noted that the changes in position between the initial and final decision were due to the debate's impact on the students, hence the importance of having good arguments to make the most appropriate decision.

ACKNOWLEDGEMENTS

This work is part of the R+D+i Project "Citizens with critical thinking: A challenge for teachers in science education", reference PID2019-105765GA-I00, funded by MCIN/AEI/10.13039/501100011033. The study was conducted in accordance with the protocol was approved by the Ethics Committee on Experimentation of the University of Malaga (Spain) (CEUMA) with reference 31-2022-H.

REFERENCES

Acar, O., Turkmen, L., y Roychoudhury, A. (2010). Student difficulties in socio-scientific argumentation and decision making research findings: Crossing the borders of two research lines. *Int. J. Sci. Educ.*, *32*(9), 1191–1206.

Benegas, J. (2013). *El aprendizaje activo de la Física Básica Universitaria*. Santiago de Compostela: Andavira.

Blanco, A., España, E., y Franco-Mariscal, A.J. (2017). Estrategias didácticas para el desarrollo del pensamiento crítico en el aula de ciencias. *Ápice, Revista de Educación Científica*, *1*(1), 107-115.

Bogar, Y. (2019). Synthesis study on argumentation in science education. *Int. Educ. Studies*, *12*(9), 1-14.

Capote, G., Rizo, C., Bravo, C.G. (2016). La formación de ingenieros en la actualidad. Una explicación necesaria. *Universidad y Sociedad*, 8(1), 21-28.

Carrillo, S., y 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.

Escudeiro, N., Barata, A., y Lobo, C. (2011). Enhancing students teamwork and communication skills in international settings. *Proceedings of 2011 International Conference on Information Technology Based Higher Education and Training (ITHET 2011)* (pp. 57-64). Turkey: Institute of Electrical and Electronics Engineers.

Jiménez-Aleixandre, M. P. (2010). *10 Ideas Clave. Competencias en argumentación y uso de pruebas*. Barcelona: Graó.

Toulmin, S. (2003). *The uses of argument*. 3rd. edition. Cambridge: University Press.