DEBATE ON THE NATURE OF SCIENCE IN THE CONTEXT OF SCIENTIFIC COMPETENCE FOR CITIZENSHIP

Francisco-José González-García, Enrique España-Ramos, Ángel Blanco-López and Antonio-Joaquín Franco-Mariscal
Universidad de Málaga, Didáctica de las Ciencias Experimentales, Málaga, Spain

Abstract: In recent decades numerous publications have highlighted the need for citizens to acquire not just knowledge of science content but also knowledge about science. In a previous Delphi study of the key aspects of scientific competence for citizenship we identified a number of aspects related to the nature of science (NOS). Our aim here is to analyse four aspects which, in the Delphi study, yielded differences of opinion among the Spanish science professionals we surveyed. These aspects of the NOS concerned the environment and sustainability, an appreciation of science, problems in science and scientific method. A more detailed understanding of the content and importance of these aspects could help to identify which of them, if any, should underpin scientific competence for citizenship. To this end, we asked a group of experts to rate (on a 5-point Likert scale) the importance of four pairs of redefined NOS themes and to justify their rating with any pertinent observations. Descriptive statistics were calculated for each theme and statistical tests were applied to identify any significant differences between the ratings awarded and between professional groups. Significant differences in ratings were only observed on one pair of themes, and similarly, only one pair of themes yielded a significant difference in the ratings awarded by different professional groups. On the other three pairs of themes the experts did not ascribe greater importance to one or the other element. We nonetheless believe that this new analysis adds to our understanding of the epistemological beliefs of experts regarding these themes and goes some way to identifying the key elements of the NOS that should underpin scientific competence for citizenship.

Keywords: nature of science, scientific competence, citizenship

INTRODUCTION

Although the nature of science (NOS) is increasingly considered to be an important aspect of science education (OECD, 2013; NGSS Lead States, 2013) there is no consensus as to what it entails or how its key elements might be identified. Put simply, there are two main approaches to this issue: the 'domain-general' or 'consensus' view (Abd-El-Khalick, 2012) and the 'domain-specific' view (Hodson & Wong, 2014), to which we may add what is known as the 'family resemblance' approach (Erduran & Dagher, 2014).

In a previous Delphi study (Blanco, España, González and Franco, 2015) we examined the degree of consensus among a panel of Spanish experts regarding the key aspects of scientific competence for citizenship. During that study a number of discrepancies emerged regarding the content and importance of four aspects of the NOS. This raised the need for a new study so as to examine in greater depth the beliefs of experts regarding these aspects, the aim being to shed further light on those elements of the NOS which are most relevant for citizens to acquire.

METHOD

The first task was to identify those issues which produced differences of opinion, represented by the four aspects shown in the left-hand column of Table 1. Based on the content of the specific statements and observations made by the experts during the Delphi study we decided to redefine each of these aspects, thus generating a new series of eight themes (in four pairs) that expressed views which were significantly different from the original description or which included new ideas in their formulation (see second column

of Table 1). We then asked a number of experts to rate (on a 5-point Likert scale) the importance of each of these eight themes and to offer any observations they regarded as pertinent to their rating or to the themes themselves. The 22 participants belonged to the following professional groups: 4 scientists and engineers (SE), 4 researchers and/or private sector scientists (RP), 5 philosophers of science (PS), 6 science educators (SE) and 3 science communicators (SC). The mean, mode and standard deviation were then calculated for ratings of each theme, and we examined possible differences between 1) the ratings awarded to each pair of themes resulting from the four original aspects (by means of the Student's t test), and 2) the ratings awarded to each theme by different professional groups (using ANOVA and a post hoc Scheffé test). We also examined and compared the observations made by the various experts in order to support the overall conclusions.

RESULTS

In this section we present the results from the analysis of ratings for each of the eight themes (Table 1) and summarise the observations made by experts.

Table 1. Rating of the eight themes derived from the four controversial aspects of the NOS.

Controversial aspects of the NOS	Redefined NOS themes	No. of resp.	Mean rating	Mode	SD
Posing versus solving problems	Ability to solve problems	22	3.95	5	1.25
	Ability to pose problems (i.e. to identify or define problems of interest)	20	4.35	4	0.67
Environment and sustainability	Environmentally-friendly attitudes and behaviour	22	3.59	4	1.14
	Responsible attitudes and values, and actions that contribute to a sustainable future	22	4.09	4	0.87
Appreciation of science	Appreciation of scientific results	20	3.70	4	1.03
	Appreciation of scientific reasoning	21	3.86	4	0.85
Scientific method versus scientific practice	Knowledge and understanding of the scientific method	18	3.72	3	0.75
	Familiarity with the characteristic features of a scientific approach	19	3.95	4	0.78

Posing versus solving problems

Here we introduced a new theme labelled *Ability to pose problems*, since some of the experts in the Delphi study had commented that this was as -if not more- important than the ability to solve problems. Although the mean rating for posing problems was higher in the present study the difference was not significant. What should be noted, however, is that this pair of themes was the only one to produce significant differences in ratings according to professional group, specifically between PS and ST ($F=4.690$, $p=.010$): the mean rating for the importance of problem-solving ability was 2.5 points higher in the former group.

Environment and sustainability

The new theme referring to responsible attitudes and actions that contribute to a sustainable future was rated as significantly more important ($t = -2.217$; $p = .038$) than the other statement, which alluded to environmentally-friendly attitudes and behaviour. The comments made in relation to these issues revealed support for different models of development.

Appreciation of science

Some experts in the original Delphi study stated that an 'appreciation of scientific results' and an 'appreciation of scientific reasoning' should be treated separately, as they are not equally important. However, the present analysis revealed no significant differences in ratings. The comments on these issues revealed beliefs regarding the importance that scientific reasoning and procedures play in relation to citizens' ability to function adequately in everyday life.

Scientific method versus scientific practice

Two experts in the original Delphi study (both ST) criticised the often rigid interpretation of what constitutes scientific method. One of them suggested alternative terms, such as 'the scientific approach', and this was used in the wording of a new theme here. However, although the statement 'Familiarity with the characteristic features of a scientific approach' obtained a higher mean rating the difference with respect to the other theme in this pair was not significant.

DISCUSSION AND CONCLUSIONS

All four aspects of the NOS analysed here appear in several recent studies and proposals on this topic (Abd-El-Khalick, 2012; Erduran & Dagher, 2014; Hodson & Wong, 2014). Within the framework of the 'family resemblance' approach, the aspect we label 'environment and sustainability' would come under the 'social values' category of the social-institutional system, while the other three aspects would correspond to the following categories of the cognitive-epistemic system: 'processes of inquiry' (posing vs. solving problems and scientific method vs. scientific practice), 'methods and methodological rules' (appreciation of science, posing vs. solving problems and scientific method vs. scientific practice) and 'scientific knowledge' (appreciation of science). In three of the four pairs of NOS themes we considered, the experts did not ascribe greater importance to one or the other element. However, the newly defined themes did receive high ratings from the experts surveyed. With respect to the aspect we labelled 'scientific method versus scientific practice', it is worth noting that our experts did not rate the theme 'Familiarity with the characteristic features of a scientific approach' as being significantly more important, despite the fact that it is regarded as one of the most important issues in current discussions of the NOS.

Identifying key elements of the NOS is a complex and controversial issue, and in this respect we believe the present study makes a useful contribution, despite the limited number of statistically significant results in our analysis. By expanding and redefining four controversial aspects of the NOS we have been able to shed new light on the epistemological beliefs of the experts surveyed, as well as on the importance they ascribe to the themes considered. The study does, however, have certain limitations, notably the possible influence of the researchers themselves through the reformulation of themes based on comments made by a panel of experts in a previous study. Further and more specific studies of the NOS are now required in order to elucidate those elements which are most crucial for citizens to acquire as part of their science education.

ACKNOWLEDGEMENT

This work is part of the 'I+D Excelencia' Project EDU2013-41952-P funded by the Spanish Ministry of Economy and Finance through its 2013 research call.

REFERENCES

Abd-El-Khalick, F. (2012). Examining the Sources for our Understandings about Science: Enduring conflations and critical issues in research on nature of science in science education. *Int. J. Sci. Educ.*, *34*(3), 353–374.

Blanco, A., España, E., González, F.J., & Franco, A.J. (2015). Key aspects of scientific competence for citizenship: A Delphi study of the expert community in Spain. *Journal of Research in Science Teaching*, *52*(2), 164–198.

Erduran, S., & Dagher, Z. (2014).*Reconceptualizing the nature of science for science education*. Netherlands: Springer

Hodson, D. & Wong, S.L. (2014). From the Horse's Mouth: Why scientists' views are crucial to nature of science understanding. *International Journal of Science Education*, *36*(16), 2639–2665.

NGSS Lead States. (2013). *Next generation science standards: For states, by states. Achieve, Inc. on behalf of the twenty-six states and partners that collaborated on the NGSS*. Retrieved from www.nextgenscience.org/

OECD (2013). *PISA 2015 draft science framework*. Retrieved from http://www.oecd.org/pisa/pisaproducts/Draft%20PISA%202015%20Science%20Framwork%20.pdf