Enhancing students understanding of the Nature of Science through philosophical dialogue

Nature of science (NoS) is a part of science education that is often overlooked. NoS is, however, also an important part of science and science education. Enhancing students' understanding of the NoS is a dream, possibility and necessity of public education.

Here philosophical dialogue can be a useful didactical tool. By engaging students in a discussion on challenging questions, asking them their opinion and arguments supporting that opinion, the students get a thorough understanding of the NoS.

In this work, material developed through design-based research with Flemish students in teacher training (19 y) is presented.

Keywords: pre-service teacher training, science education, philosophy

INTRODUCTION

The epistemological underpinnings of science (Lederman, 2006) are referred to as the Nature of Science (NoS). NoS is a part of science education that is often overlooked. NoS is, however, also an important part of science and science education. Enhancing students' understanding of the NoS is key in stimulating the scientific literacy of students (Miller, 1998). Additionally, it positively impacts naïve conceptions about science (Clough, 1997).

Teaching the NoS can be done both without (Abd-El-Khalick, Bell, & Lederman, 1998), and with context, e.g. historical and contemporary science examples (Höttecke, Henke, & Riess, 2012; Schwartz & Crawford, 2004). However, a supporting follow-up discussion is needed to elicit reflection by the students, a crucial step in understanding the NoS (Khishfe & Abd-El-Khalick, 2002). How this reflection process can be enhanced, is less studied. In this work we explore how the philosophical dialogue (Lipman, 2003; Schjelderup, 2009) can play a role in this process.

This paper aims to answer the following questions: What role can a philosophical dialogue play in teaching about the NoS? And, what is the impact of the presented methodology on pre-service teachers?

PHILOSOPHICAL DIALOGUE ABOUT NOS

In a philosophical dialogue a group of participants discusses a thought-provoking question. The focus of the discussion lies on exploring the coherence and relevance of the arguments. The teacher takes on the role of the facilitator who takes the Socratic stance, i.e. the teacher takes a role of not-knowing. This means that the teacher does not give answers and only questions participants. This in turn implies that the students autonomously develop their own lines of thought (Lipman, 1991, 2003). Initially these questions aim to explore the different NoS-conceptions that students have. Following this first exploratory stage of the dialogue, students are asked to clarify these conceptions and the goal is to understand the reasoning of the students for these conceptions. In later stages of the dialogue, the teachers' questions elicit hypothesis-formation and investigation of these NoS-related concepts.

In such a dialogue, the students are constantly asked for arguments supporting their opinions, hence eliciting reflection, and critical and creative thinking. By asking for examples supporting their arguments and opinions, students are invited to couple abstract epistemological knowledge about science with their own experiences. Interestingly, in addition to discussing the NoS, the dialogue itself mimics the argumentative processes going on among scientists. Hence, participation in the dialogue provides an analogy of the scientific process.

To evoke a philosophical dialogue about the NoS, students in the approach presented here started from classic NoS-learning materials (e.g. black box), or newly developed learning materials (through design based research, see further). This initial exercise leads to the thought-provoking initial question and fuels the discussion.

METHOD

The material was developed, and the research was conducted in several cycles, following design based research (DBR) methodology (Van den Akker, Gravemeijer, McKenney, & Nieveen, 2006). In early research cycles teachers were asked to comment on the applicability of the material, the involvement of the students and the influence of contextual factors (such as class-arrangement, timing,…). Students were asked to indicate their position with respect to the NoS, to rate the material and which adjustments they would do to enhance the material.

In the final cycle of the DBR the approach and developed material was tested on 181 students in pre-service teacher training, in six Belgian university colleges. To measure the students' conception of the NoS, students were asked to rate 20 statements using a 5-point Likert scale (α_{Cr}=0.75). These statements cover four aspects of the NoS:

1) Observation versus interpretation: there is an important difference between observation, based on senses or measuring equipment, and the interpretation of this observation. The interpretation is based on existing theoretical frameworks and is influenced by the scientist making the interpretation.
Students often skip the recording of the observation and jump straight to interpretation. They might also think that scientists always have the same explanation for a given phenomenon.

2) Influence of the scientist on science: a scientist is a human, with personal convictions, preferences… A scientist also works within a social and cultural context, which also has an influence on the scientist.
Students might think that scientists across the world will reach the same conclusions based on the same data, regardless of their cultural, religious … background.

3) Tentativeness: scientific laws, theories, and knowledge change through time.
Students might think that scientific laws are permanent, but that theories are subject to discussion.

4) Creativity: In various stages of a scientific enterprise, creativity plays a role. Asking questions, composing research methodology, interpreting data, conceptualizing theories… all require creativity.
Students might think that scientists have to be objective at all time, or that scientists have to follow the steps of the scientific method (i.e. requiring no creative input).

RESULTS

By integrating the use of the philosophical dialogue with learning material focused on the nature of science in the context of the science class, a website (http://www.wetenschapsreflex.be/), posters and post-its, and a card game were developed. On the website the material can be found, as well as a user guide (all in Dutch, work on the translation is in progress).

For the latter three NoS-aspects that were measured in the test a significant shift ($p<0.001$) in the students' conception of the NoS was observed, see table 1. Students thus made a shift from a more naïve view to a view more in line with the current understanding of the NoS with regard to the influence of the scientist, the tentativeness of science and the role of creativity. Only a small change was observed in the students' view on the difference between observation and interpretation.

In addition to these quantitative results, several qualitative results were collected.

Both students and teachers appreciated, in general, the philosophical dialogue. Both, however, remarked that the role of the teacher, the role of the facilitator of the dialogue, is a very difficult one. The teacher has to manage the group, but above all maintain the Socratic stance (i.e. not show his/her own foreknowledge). One student remarked that, as a teacher,

> "*you cannot say that an idea of a student is good or bad. A teacher said that one student was correct, and I immediately saw the reaction of the other students. They took over the correct answer or suddenly had no opinion".* - Student Bachelor secondary education observing an in-service teacher facilitating a philosophical dialogue

Teachers might know the right answer, can assess the opinions and arguments of the students, and might hope the discussion will go a certain direction. However, in the philosophical dialogue and as a Socratic facilitator, they cannot share the answers, cannot show their appreciation for a certain opinion or argument of a student, and certainly should not direct the discussion. It is, therefore, a very different role than that of a classic teacher.

The group-size is another important factor. If the group is too large, the discussion can be chaotic, leading to less engaged students and a less in-depth discussion. If the group is too small, there are often not enough diverse opinions and ideas to fuel the discussion and thought process. A group of 16 is considered ideal.

DISCUSSION AND CONCLUSION

This study further strengthens the argument for introducing discussion and dialogue to teach the NoS in the science class. A philosophical dialogue may allow students to reflect on the NoS and, in collaboration with their fellow students and under guidance of the teacher, reach a more nuanced view. The role of the teacher is this process is very important. The Socratic stance, while difficult, is crucial to stimulate reflection and thought by the students. However, the reaction to answer a question of a student with a guiding question rather than with an answer is difficult to obtain and maintain throughout the dialogue.

Introducing dialogue to introducing and investigating the NoS in the classroom in not new (Höttecke et al., 2012). However, the philosophical dialogue can be a useful didactical tool to elicit reflection, and critical and creative thinking. It is different to other reflection and class-discussion techniques because the students autonomously, under guidance, discuss NoS concepts. In combination with the open questions inherent to philosophical dialogue, the discussion does not necessarily lead to a pre-determined answer that students can find in the course textbook. This is in line with Matthews (Matthews, 2012) view on the role of the NoS in the curriculum. By eliciting the right philosophical questions, e.g. by using the right starting exercises, students can develop their own ideas regarding the NoS.

Many of today's discussions regarding climate change ("the science isn't in yet"), or evolution ("science cannot prove evolution", "evolution is just a theory") can often be brought back to a arguments based on a poor understanding of the NoS. A public education where students leave with a rigorous, self-constructed, less naive view on the NoS is therefore certainly a dream, possibility and necessity.

Future research is thus certainly necessary. This work only considered pre-service teachers. Future research should, and will, look into the implementation, and impact, of the methodology in secondary education classes and pupils. Additionally, research in to the training of teachers into taking the Socratic stance seems valuable.

Table 1: Quantitative results

	influence of the scientist		Creativity		Interpretation vs Observation		tentativeness	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
N	167	159	170	159	169	158	167	159
Mean (max = 5)	3,43	3,58	3,37	3,62	3,23	3,30	4,04	4,16
Std. Deviation	0,56	0,53	0,67	0,69	0,38	0,42	0,49	0,52
T-test	t(153)=5,07		t(155)=5,28		t(153)=2,50		t(153)=4,18	
	p<0,001		p<0,001		P=0,013		p<0,001	

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