Changes in the perceptions of the nature of science and religious belief

Ester Aflalo
Hemdat Hadarom College of Education, Israel

Understanding the nature of science (NOS) is one of the challenging objectives in science education due, in part, to the complex relationship between religion and science. This study examines how NOS teaching affects the perception of the NOS amongst religious, as compared to secular, students. The participants included 205 religious and secular pre-service teachers; both categories, religious and secular, included Jewish and Muslim students. All students participated in a scientific content course, which integrated activities explicitly addressing the NOS. They completed a closed questionnaire that examined various aspects of NOS perceptions prior to, and following, the course and 22 also participated in semi-structured interviews. A paired *t*-test was performed and the interviews were recorded, transcribed, and analysed. The findings show that the course influenced some aspects of the NOS perceptions amongst all the participants, but did not change the perceived connection between religion and science among the religious participants. The interviews exposed the relationship between religion and science, and the educational implications of the findings are discussed.

Introduction

The nature of science (NOS) refers to the epistemology of science, or science as a way of knowing, and is concerned with the assumptions and values embedded in scientific knowledge. The research literature broadly refers to the importance of understanding the nature of science (NOS) and emphasises it as an essential component in scientific literacy (Osborne et al., 2003; Lederman & Lederman, 2014; McComas, 2014). It is claimed that NOS perceptions affect understanding of the scientific process, and have a major impact on argumentation and decision-making regarding socio-scientific issues (Lederman, 2007; Leung, Wong & Yung, 2015). In science education there is broad agreement that the NOS should be taught alongside scientific content, as is evidenced in diverse curricula and documents (Eurydice Network, 2011; National Research Council, 2012; National Research Council, 2013). Despite the declared importance of the NOS we are far from understanding it. Research shows that students' and teachers' perceptions of science are not congruent (Dogan & Abd-El-Khalick, 2008; Golabek & Amrane-Cooper, 2011).

Culture and religious belief have a significant effect on NOS perceptions. According to the Israel Central Bureau of Statistics (2014), Israel is becoming more religious and only about 40% of Israel's citizens define themselves as secular. Secular people are defined as those whose lifestyle does not embrace the observance of the instructions of any religion; the religious are those who observe the laws of their religion and see themselves as committed to such observance. In England most of the population claims some level of religiosity, and in the United States about 90% of the population defines itself as holding religious beliefs (Gauchat, 2008). Therefore, in the context of the prevalence of religious belief in various societies and the complex relationship between religious belief and

science, the ability to challenge NOS perceptions becomes particularly complicated. Previous research has found that perceptions of some NOS aspects are more confused and inconsistent amongst religious compared to secular pre-service teachers (Aflalo, 2013).

In addition to assumptions that the study of the NOS is important in shaping scientific literacy and in daily life, it is claimed that there is a positive connection between learning about the NOS and scientific content learning. Inclusion of some NOS aspects of science content leads to advancing the understanding of science and scientific knowledge (Brickhouse et al., 2000; Scharmann et al., 2005; Develaki, 2012; Peters, 2012). However, there are only a few empirical reports about the study of teaching the NOS along with science content (Hipkins, Barker & Bolstad, 2005). The objectives of the current study were to examine whether the teaching of the NOS in a science content course influenced the students' preconceptions and to compare the NOS perceptions of religious and secular students before and after the course.

NOS and teaching the NOS

Scientific knowledge, its quality, and its production are the underlying elements of the NOS. Many scientific educators agree on several basic aspects of scientific knowledge and inquiry: scientific knowledge is based on accessible empirical processes; it is subjective and theory-determined; it is not absolute and is constantly changing; it is influenced by human creativity and imagination; and it is influenced by the culture and the society in which the researcher functions (Schwartz & Lederman, 2002; Osborne et al., 2003; Lederman & Lederman, 2014; McComas, 2014).

These general aspects do not include all the attributes of science, and it is claimed they do not suffice, and present an overly narrow a picture of science (Allchin, 2012; Duschl & Grandy, 2013). The claims of the critics are that the diverse science disciplines entail different and unique attributes. Even if there are common attributes, they cannot be used to define all the scientific disciplines. However, Kampourakis (2015) believed that an important purpose of the general attributes is to challenge the students' preconceptions regarding science, and to define teaching about the NOS. According to him, in the context of teaching the NOS, the two approaches can be combined, first laying the basis for the general and common aspects of all scientific knowledge and only afterwards promoting unique attributes of specific scientific disciplines.

Empirical studies aver that many of these general and common aspects can be taught efficiently in school (Abd-El-Khalick, 2014; Lederman, 2007; Lederman & Lederman, 2014). However, studies show consistently that the NOS students' perceptions of what science is, how it is performed, and what it can attain in all age groups are often incorrect. Studies reviewed extensively by Simpson et al. (1994) found that many science students perceive scientific truth as absolute, and reject the possibility of speculation or of intuition regarding the scientific knowledge developed. Even students who studied science presented naïve and uninformed NOS perceptions (Aflalo, 2013). Teachers of sciences also present incoherent and uninformed views (Dogan & Abd-El-Khalick, 2008; Golabek

& Amrane-Cooper, 2011) which are reflected in their NOS teaching (Capps & Crawford, 2013).

Promoting the students' understanding of the NOS has been presented as an educational goal since the 1980s (Bell & Lederman, 2003; Lederman, 2007). However, teachers have difficulty teaching the NOS effectively (Lederman & Lederman, 2014; McComas, 2014). The research literature describes diverse approaches to teaching the NOS, the two main approaches being the implicit and the explicit approach. The implicit approach focuses on the scientific research process, wherein the assumption is that the study of the NOS will be a by-product of experiencing research processes and scientific activity (Lotter, Singer & Godley, 2009; Fazio, Melville & Bartley, 2010). The explicit approach confronts the students through discussions and activities with various aspects of the NOS, and emphasises that the NOS should be considered directly and intentionally (Abd-El-Khalick, 2014; Schwartz & Lederman, 2002; Lederman, 2007).

Diverse studies have supported the claim that explicit teaching of the NOS is more efficient and critical for the development of understanding of the NOS (Scharmann et al., 2005; Liu & Lederman, 2007; Dogan & Abd-El-Khalick, 2008). Furthermore, it is claimed that including the NOS when teaching scientific content leads to better understanding of the scientific concepts (Peters, 2012). Develaki (2012), for example, proposed a method of integrating components of the NOS when teaching Newton's theory of gravity.

Despite the recognition that understanding the NOS is positively connected to studying science (Dang, Tasi & Chai, 2011; Peters, 2012), there are relatively few studies on integrating teaching of the NOS in science content learning. It is particularly hard to find studies that combine a course on scientific content with teaching the NOS while relating to sociological parameters such as religious belief.

Religious belief and the perception of science

The centrality of science in modern society alongside the high prevalence of religious belief in different societies (Gauchat, 2008) has made the connections between religion and science significant. The research literature presents diverse ways to describe the complex relationships between religion and science, the most quoted being Barbour's (1990) classification, which divides the relationships between science and religion into four approaches: conflict, independence, dialogue or integration.

The conflict approach between science and religion manifests the superiority of one side over the other when only one side is considered correct (Barbour, 1990). According to the approach that religion is superior to science, the conflict between the two stems from incorrect understanding of the world. The perception of science being superior to religion sees in science the source for receiving real knowledge about the world. Religion, according to this approach, is a mixture of dogmatic complaints concerning eternal validity which cannot be examined empirically.

The independent approach separates ideas and scientific approaches from ideas and religious approaches: science describes the reality and the search for its causes, while religion deals with the objective purpose of the world and the according demands of human behaviour; science deals with information and the practical world while religion deals with performing the commandments and amending qualities (Barbour, 1990). The world of the masses, to which religion is addressed, and the world of science are two different worlds that serve different goals and fill diverse roles (Yarchi, 1999).

The dialogue approach recognises the conflict between religion and science. According to this approach, despite the prevailing contradiction between the two, one cannot conclude from this that one side is mistaken; nor can one dismiss engagement with religion or science. This approach assumes that the use of scientific argument and scientific criticism are also valid in studying the world of sanctity (Barbour, 1990; Yarchi, 1999). Bickmore et al. (2009) claim that religion, like science, does not exist in a uniform style of thought. The dialogue approach recognises that religious sources are not unequivocal and are affected by human considerations. This approach does not fear subjecting tradition and authority to criticism and believes that one can educate to responsible criticism.

The integration approach assimilates science into religion and tries to bring religious belief closer to scientific theory. This approach perceives the study of nature as a means of proving God's existence and understanding his work. Mansour (2011), who explored the religious attitudes of science teachers, found that 46 out of the 75 teachers he examined saw the study of science as a means of boosting religious belief.

Barbour (1990) arranged these four approaches in a hierarchic manner, clarifying his preference for the dialogue and integration approaches. The current study was assisted by these approaches when analysing the connection between science and religion among the pre-service teachers, both religious and secular. The student's perceptions were examined before and after the course in relation to the following aspects of the NOS: (1) the tentativeness of scientific knowledge and the freedom to research; (2) religion and society regarding science; (3) the purpose of science; (4) the idealisation of science. The study deals with two key questions:

1. Did the course affect the student's perceptions of the NOS in terms of the aspects noted, and if so, what aspects changed and why?
2. Are there differences in the change in perceptions of science amongst religious students compared to secular students, and if so, from where do the differences stem?

Method

The research is based on comparative pre/post-test intervention. Intervention refers to integrating teaching of the NOS in a course of scientific content. The research was conducted using a mixed method approach combining closed questionnaires with semi-structured interviews.

Participants

The research participants included 205 pre-service teachers (of whom 38 were male and 167 were female) from two Academic Colleges of Education in Southern Israel. One college is associated with the religious sector, where mainly religious Jewish students are enrolled, and the other college is attended by both secular and religious students. The population numbered 81 Muslims and 124 Jewish students, 116 of whom defined themselves as secular (26 Muslim and 90 Jewish), and 89 students defined themselves as religious (55 Muslim and 34 Jewish). The students studied in eight separate courses. Four groups (117 students) took the course "Cell Biology" and four groups (88 students) took the course "Introduction to Life Sciences". The courses started with 241 students, but 36 students did not finish them or did not complete the questionnaires. The socio-economic status of most students was average, and all students studied sciences in high school at least till 9th grade.

The research process

The study was conducted over the course of four academic years (2010-2014), with all the pre-service students taking a course of scientific content that combined explicit NOS teaching. The students' perceptions of the NOS were examined at the courses' beginning and at its conclusion nine months later, using a closed questionnaire and semi-structured interviews.

The courses, "Introduction to Life Sciences" and "Biology of the Cell" were taught for two semesters. The lectures in each course were taught once a week for two hours, a total of 56 hours each for 28 lessons. Together with teaching the course content, activities and reflective discussions about NOS aspects were integrated. The NOS activities were taken from Somerville (1941) and Lederman and Abd-El-Khalick (1998). Teaching also included historic theories that led to prominent discoveries regarding the course subjects, as well as research exercises to intensify understanding of the scientific process. Some of the discussions of, and familiarisation with, the history of scientific discoveries were conducted online on the course web site (a detailed description of the course can be found in Aflalo, 2014).

Examination of the perception of the NOS

A questionnaire on the perception of the NOS was used, developed on the basis of Fleener's (1996) questionnaire that examined students' perceptions of mathematics and science. The questionnaire comprised 35 of the 46 statements in the original questionnaire. Eleven statements pertaining to attitudes towards mathematics only were deleted as well as those pertaining to the gender aspect. The questionnaire was translated into Hebrew and validated in my previous research (Aflalo, 2013). The students completed the questionnaire in the first lesson of the course and again in the final lesson of the course. They were asked to rank each statement on a Likert five-rank scale ranging from totally disagree (1) to totally agree (5).

Semi-structured interviews followed the course for 22 students selected from more than 50 who agreed to be interviewed. Twelve of them were religious, of whom six were Muslim and six were Jewish, and ten were secular, of whom seven were Jewish and three Muslim (most of the Muslims declared they were religious). Each interview lasted 30-40 minutes. The questionnaires they completed prior to, and following, the course were shown in the interview. Thereafter they were asked to explain why they altered, or did not alter, their opinion on four statements after the course. The first statement referred to the tentative aspect of scientific knowledge, the second referred to the freedom of inquiry, the third was connected generally to the relationships between society and science, and the fourth related directly to the connection between belief and science (the statements are numbered 1, 4, 15, and 13, and the content of the statements appear in the appendixes of the articles of Aflalo, 2013, 2014).

Data analysis

Of the 241 total students, 205 answered the questionnaires fully. The questionnaires were analysed using the Varimax factor analysis method with orthogonal rotation. Four categories were found:

a. Tentativeness and freedom of inquiry
b. Religion and social supremacy of science
c. The purpose of science
d. Idealisation of science

The above categories differ from Fleener's, probably because the statements regarding the perceptions of mathematics were removed. At the same time, the reliability test indicates a strong connection between the items for each category which is named according to the common denominator of the items it includes. Each of the categories relates to a particular aspect of the NOS. The first category refers to the change in scientific knowledge, the second to the social and cultural impacts, the third to the boundaries of science and its purpose, and the fourth to the idealisation of science.

The statements included in each category and the reliability coefficients (Cronbach's alpha) of the categories, prior to and following the course, are presented in Table 1 (all above 0.7). A paired *t*-test was performed to examine the differences in NOS perceptions before and after the course (Table 1) as well as in the comparison between the perceptions of the religious and the secular students (Table 2). The interviews with the students were recorded and transcribed. Notes were taken during and immediately upon the conclusion of each interview. Each transcript was processed according to the four interview questions, and then all the transcripts were summed up and the number of similar answers was calculated.

Results

Changes in the perceptions of the NOS amongst all the participants

Table 1 summarises the findings regarding the perception of the NOS of all the students before and after the course. Statistically significant changes occurred in three of the four NOS aspects that were examined. These findings support my findings regarding a smaller research population (Aflalo, 2014).

Before the course, students showed the greatest support for an idealised perception of science. Most of the students agreed, for example, with statements such as "Anything we need to know can be discovered through science." These agreements manifest naïve attitudes, and following the course there was a significant decline in the students' support of this category. There was also a significant change in the participants' perceptions regarding the tentativeness of scientific knowledge and the freedom to inquire. After the course, a significant statistical rise was found in support for this category. This change, together with the decline in support for the idealisation category of science, indicates a better understanding of these aspects of science as they are accepted in science education. It is important to note that prior to the course, support was relatively high for these two categories, as can be seen in Table 2. A high level of support for the tentative aspect (reflecting constructivist approaches) together with the idealisation of science (reflecting conservative approaches) indicates a lack of consistency and coherence in approach. Despite the changes following the course, there was still relatively high support for the idealisation aspect of science.

Table 1: Analysis of the questionnaire categories regarding the NOS perceptions before and after the course

Category	Statements	*M (SD)*		*α*		*t*	*Cohen's d*
		Pre	Post	Pre	Post		
Tentativeness and freedom of inquiry	14, 4, 1, 35, 30, 23 8 - reverse	3.37 (0.38)	4.01 (0.51)	.70	.72	4.10**	0.66
Supremacy of religion and society over science	15, 13, 11, 20, 21, 10 - reverse	2.73 (0.49)	2.22 (0.86)	.74	. 80	2.31*	0.43
The purpose of science	2, 18, 5, 3, 34, 27, 19	2.15 (0.71)	2.17 (0.66)	.71	.75	1.99	0.25
Idealisation of science	6,7, 22, 12, 9, 29, 25, 24, 33, 32, 31	3.66 (0.79)	3.01 (0.58)	.81	.70	3.28**	0.59

1. The questionnaire statements are presented in the appendixes of the articles by Aflalo (2013; 2014).
2. Statements numbered 16, 28, 17, 26 were found to be irrelevant.
3. *p (2-tailed) <0.05 **p (2-tailed) <0.01

Support for the superiority of religion and society over science was relatively low, and after the course most of the students supported this category even less. This change too was found to be statistically significant, although the size of the effect was moderate. In contrast to this, there was no change in the students' perceptions of the purpose of

science category. Support for statements such as "*When something is explained well, there is no reason to look for another explanation*" was admittedly moderate prior to the course, but did not decline thereafter. This stability reinforces the lack of consistency in the perceptions and the maintaining of mixed perceptions.

Changes in NOS perceptions of secular relative to religious students

Previous studies showed that the support of religious students for the tentativeness of scientific knowledge and the freedom of inquiry is less than that of secular students. Similarly, religious students afforded religion and society greater weight than science compared to secular students (Aflalo, 2013). Following these findings, this study examined whether there are also differences in the perception of science among religious students after the course compared to secular students.

As can be seen in Table 2, there were no differences between religious and secular students regarding the purpose of science and the course did not influence this category at all. In contrast, the support of the religious students prior to the course on tentativeness and the freedom of inquiry was less than that of the secular students. However, after the course, the religious students supported this category more than the secular students, and thereby represented a more current perception of this aspect. Also, in relation to the idealisation of science, the religious students experienced a greater change in their perceptions. After the course there was a greater average decline in their support for this category (Table 2). These changes indicate that students have acquired a deeper understanding of that aspect of the NOS. But, as expected, and in contrast to the secular students, there was no statistically significant change in the perception of the religious students of the superiority of religion and society over science. The course had no influence on the religious students in terms of this aspect, and after the course they also expressed a clear preference for their beliefs and culture over science.

Table 2: NOS perceptions amongst religious and secular students prior to, and following the course

Category	Secular (n=116)				Religious (n=89)			
	M (SD) Pre	*M (SD)* Post	*t*	*Cohen's d*	*M (SD)* Pre	*M (SD)* Post	*t*	*Cohen's d*
Tentativeness and freedom of inquiry	3.48 (1.32)	3.97 (1.26)	3.57**	0.65	3.29 (0.70)	4.11 (0.91)	3.58***	0.71
Supremacy of religion and society over science	2.35 (0.92)	2.02 (0.88)	2.32**	0.48	3.15 (0.73)	2.81 (0.79)	1.89	0.36
The purpose of science	2.32 (0.51)	2.21 (0.66)	1.31	0.23	2.44 (0.61)	2.38 (0.49)	1.89	0.34
Idealisation of science	3.50 (0.87)	3.03 (0.81)	3.17**	0.66	3.58 (0.59)	3.00 (0.64)	3.45**	0.72

*p (2-tailed) <0.05; **p (2-tailed) <0.01;***p (2-tailed) <0.001

Analysis of the interviews: "Why did you change or not change your opinion about…"

This section summarises the analysis of the interviews that were conducted after the course. As noted, 22 students were interviewed: 12 religious students (six Muslim and six Jewish), and ten secular students (seven Jewish and three Muslim). Each interviewee tried to explain the reasons behind his/her changing or not changing his/her opinion, after the course, on the following statements.

It is likely that much of the scientific information we have today will be demonstrated to be inaccurate in the future

This statement refers to the category of change in scientific knowledge. About two-thirds of the interviewees reported greater support for this statement after the course. All the religious students (Muslim and Jewish) and most of the secular students said they changed their opinions somewhat regarding this statement since they understand the way in which scientific knowledge is obtained. For example:

> *Religious Jewish student:* "I agree more with the statement after everything we learned, such as the sequence of cell theory… I knew that scientific knowledge develops, but I now understand the extent to which the change depends on social factors… a large part of what was known in the past is unacceptable today, this will probably be the case in the future as well." (interviewee no. 8)

Scientists should be free to explore all phases of human life and the universe

This statement referred to the freedom of inquiry. Almost all the secular interviewees (8 out of 10) largely agreed with the statement prior to the course and their support also remained high afterward. They claimed, for example, that limiting scientists was liable to inhibit human development, and a more prominent claim was the damage to a person's freedom of choice. Only two secular (Jewish) students noted that they also deliberated, after the course, over to what extent they should agree with the statement. They thought that perhaps the freedom of inquiry should be somewhat limited. Amongst religious students, two (Jewish) students did not alter their opinion after the course and thought that restrictions should be set on the freedom of inquiry. Ten agreed with the statement slightly more after the course. The claims presented by the religious Muslims were no different from the explanations of the religious Jews. Their prominent claims were that religion encourages inquiry and accumulating knowledge about the world. Simultaneously, some of the interviews with religious students revealed deliberations and even contradictions. For example:

> *Religious Jewish student*: After the course I agreed more with the statement. Scientists must have the freedom to investigate the wonders of the Creator. But I also think that if there are areas that are liable to affect people, their inquiry should be limited.
> *The interviewer*: How do you think we can determine the areas that can affect people?
> *The student*: Don't know… I am referring to subjects that are known in advance to be harmful, such as the atom bomb… but actually atomic energy is also useful … in fact I am not sure one can determine…" (interviewee no. 12).

The scientist's activities must not violate the basic values of society
This statement refers to the superiority of society over science. In this statement, there were notable differences between the answers of the religious and the secular students. All six religious Muslim students and five of the six religious Jewish students interviewed agreed with the statement prior to and following the course. Only four of the secular students (all Jewish) out of ten agreed with the statement after the course as well. The support among the religious students for this statement after the course as well was explained by emphasising the importance of social values to human life. Social values were presented as superior and manifested the fear of questioning. For example:

> *Religious Muslim student*: No one, not even a scientist, has the right to infringe on social or religious values that will damage the structure of society… sometimes scientists do not consider ethics. Values need to be sanctified and protected as the Koran instructs us, and science should function according to these values (interviewee no. 17).

When the findings or theories of science conflict with religious belief, it is better to accept the religious belief
This statement refers directly to the issue of the relationship between religion and science. All 12 religious interviewees agreed with the statement before the course and after the course as well, similar to all ten secular interviewees who did *not* agree with it. In other words, the course did not affect their perception of science relative to religious belief at all. I analysed their answers, which revealed complexity and a lack of uniformity in Barbour's four approaches to classification (1990) that deal with the relationships between religion and science.

The conflict approach was particularly prominent and was presented by 11 students, of whom six religious students (Muslim and Jewish) agreed with the statement mainly because of the perception of religious certainty as absolute truth, which includes all aspects of life. The five secular students presented certainty regarding the superiority of science and felt religion could not afford any source of scientific knowledge.

The answers of eight students could be attributed to the independence approach. These students (three religious and five secular) distinguished belief from science. The main claims were that science and religion deal with different areas and are differentiated by methods. In fact, some of the secular and religious students' claims were similar but led to contrasting conclusions; the secular students did not agree with the statement but the religious students did. For example:

> *Secular Jewish student:* I found it difficult to relate to this statement because it actually determines that one can compare religion and science, when they cannot be compared. Science is based on empirical processes while religion is blind belief, so how can one possibly compare scientific knowledge with faith? (interviewee no. 21).

The two other approaches – the dialogue and the integration between religion and science – were presented in the answers of only three religious students (two Muslim and one Jew). Their answers combined the two approaches and were connected to the dialogue and the integration approach. These interviewees agreed with the statement and thought that science is a small part of the enormous religious world. Two mentioned an emotional

struggle. They believed there might be a conflict between science and belief, but it can be bridged. For example:

> *Religious Jewish student:* I noted that I agree with this sentence but it is not so simple. One cannot ignore scientific findings.
> *The interviewer:* So how does one deal with the conflict?
> *The student*: We can seek the answers in the Torah. These answers will empower faith… One cannot always interpret the depth of things in the Torah… It is not correct to refer literally to what is written in the Torah (interviewee no. 6)

Discussion

The first research question here was whether a scientific content course that integrates explicit NOS teaching influences the perceptions of the NOS of pre-service teachers. In a previous study, I showed that after teaching a scientific content course that integrates explicit NOS teaching, some of the students' perceptions changed significantly (Aflalo, 2014). The current study, which summarises findings from a larger population, presents a similar picture. It seems that the discussions held over the character of scientific knowledge, the diverse exercises, and the reflections challenged some students' perceptions.

Similar findings were also obtained in other studies that explored the curricular intervention on advancing the NOS perceptions (Akerson et al. 2008; McDonald, 2010). In fact, most studies that explored explicit NOS teaching showed improvement in some of the perceptions, as transpired in an extensive review (Deng et al. 2011). From the various studies, as well as from the current study, it is clear that the students have mixed perceptions regarding various categories of the NOS. The changes in some of the students' perceptions found in the current study, together with the stability of some others, indicate that the categories of the NOS are perceived as separate and independent. The perceptions, for example, of the changes and developments in scientific knowledge, that underwent significant change in this study, were separate from the perceptions of the purpose of scientific knowledge, which did not change. Furthermore, the lack of consistency in the perceptions, as presented in the section on the above results, supports the assumption that the perceptions of the NOS are multi-dimensional and do not necessarily develop in a coherent manner (Deng et al. 2011).

The second research question in this study dealt with a comparison between the NOS perceptions of secular students relative to religious students. This comparison pertains to the broad question of the relationship between religion and scientific education. Studies stress that religious belief affects the NOS perceptions and pedagogic practice of science teachers (Dagher & BouJaoude, 1997; Mansour, 2008, 2011). Surprisingly, the current study found greater changes in the religious students' perceptions regarding the idealisation of science and the tentativeness of scientific knowledge. The reason for this could lie in the religious students' perceptions before the course being more conservative relative to the secular students' perceptions. In any case, these findings indicate that perceptions regarding some of the NOS aspects are more dynamic and can be changed through explicit NOS teaching amongst all the students, religious and secular.

The main difference between religious and secular students was, as expected, in the category of the relationships between religion and society, and science. The religious students did not alter their positions, and even after the course supported cultural superiority over science. In other words, there was no change regarding subjects that are liable to be interpreted as a threat to religious belief or the cultural approach. A previous study showed that the more religious a person is, the more weight he or she affords culture and society vis-à-vis science (Aflalo, 2013).

The interviews conducted in the current study revealed the complexity regarding the students' positions in relation to this category. In the explanations given, diverse factors that affect the perceptions of the NOS were discernable: personal elements such as the degree of tolerance, the conceptual openness, and the degree of absolutism that were attributed to scientific knowledge; the ability to accept uncertainty; and the degree of conservatism in religious belief. In studies by Hanley et al. (2014) that examined the relationships between religion and science, such elements were found to have considerable weight in shaping students' perception of science. According to them, many students reject accepted scientific perceptions due to the conflict they see between religion and science. Similarly, Taber et al. (2011) showed that most students considered religious beliefs and scientific positions to be contradictory. Bickmore et al. (2009) averred that most students demonstrate little understanding of the NOS, amongst other things, because they hold religious attitudes that are opposed to scientific theories which affects their ability to learn these theories in a rational manner.

The conflict approach was prominent in interviews in this study as well: half the religious students, and the secular students, supported this approach. This approach makes it hard for all those holding it; it makes it hard for the religious students to adopt the accepted scientific approach, which as future teachers will also make teaching it hard; it also makes it hard for the secular students to contain their students' beliefs and prevent alienation from science. Coping with the conflict approach to religion is a complex science education challenge in a multi-cultural and multi-faith society. It is therefore important to contemplate how to meet this challenge and deal with the teachers' and students' concerns about the harming of religious belief. Advancing other approaches, such as independence, dialogue or the integrating of religion and science is likely to be an important key.

The independence approach between religion and science is also manifested in this study. The adoption of this approach opens the world of secular science to the religious persons, and enables them to accept the principles of science and its methods (Yarchi, 1999). Eight of the 22 interviewees in this study did not connect religion and science, and the religious students among them did not think that science was liable to harm their belief. Scheitle (2011) hypothesised, on the basis of many studies, that due to the inherent conflict between religion and science, those involved in science would display a lower level of religious belief. He found, however, that the religious belief of students studying natural sciences was no less than that of students studying other subjects. These students separated religion and science, or believed one can bridge or combine them.

Only three out of the 22 interviewees evidenced the integration or the dialogue approach in the current study. Hanley et al. (2014) researched Muslims and Christians, finding that most Muslim students saw a conflict between scientific knowledge and religious knowledge. Although Hanley examined perceptions of high school students while the current study explored pre-service teachers, this study also found the conflict approach to be dominant.

Summary and pedagogic implications

This study shows that explicit NOS teaching and its integration in science content courses should be given more serious consideration. Such teaching can challenge and deepen the perceptions of some aspects of the NOS. At the same time, we cannot relate to diverse aspects of the NOS as uniform. Some of the categories of the NOS are perceived as independent when culture and society have a crucial impact. Therefore, the development and the change in perceptions of different aspects of the NOS are distinguished. This understanding can alleviate coping with teaching the NOS, and choosing to cope with perceptions regarding the NOS that can be changed. Thus, for example, the religious students exhibited cognitive flexibility and openness to change in subjects that do not threaten their cultural perspective or religious belief. The main challenge in teaching sciences in this context is coping with the perception of religious certainty as absolute truth vis-à-vis the perception of science as the only and certain truth.

Sometimes, science teachers are not aware of, or ignore, the conflicts pertaining to the relationship between religion and science, which disturb their students. Ignoring students' beliefs is liable to cause opposition to and rejection of science (Hanley et al. 2014). Emotional opposition or objection will inhibit significant learning and the knowledge acquired will be instrumental only: knowledge that will enable the answering of questions and acquiring of procedures, but make it difficult to convert this to conceptual, qualitative knowledge. How, then, does one bring together understanding of the NOS and the love of learning science without harming social and religious values? What tools can be given to educators to cope with teaching sciences without undermining religious belief?

It is generally understood that changing students' religious perceptions or leading students to make a choice between scientific belief and religious belief is not one of the objectives of science education. Religious beliefs usually cannot be altered, even when scientific facts are presented. Any attempt to alter them is liable to lead to a strong negative reaction (Southerland, Sinatra & Mathews, 2001). Teachers, who maintain neutrality, and will not express a determined position, will manage to respect and contain the diverse perceptions in class and will encourage many more students to be involved in the subject (Hanley et.al. 2014). The integration of the personal story of famous religious scientists when teaching sciences can diminish the conflict between science and religion (Taber et al. 2011).

The main objective, therefore, should be to encourage dialogue that advances critical thought. This approach, which acknowledges the conflict between religion and science, assumes that the use of scientific argument and criticism is also valid when studying religious issues. Religion, like science, does not exist in a uniform pattern of thought. In

order to advance the dialogue approach, it is important for science teachers to be more proficient in their knowledge of the connections between science and religion. Teachers' ignorance is liable to distance students and to make attitudes more extreme. A better understanding of that relationship will reduce teachers' confusion and enable them to promote class discussions and to encourage thought and dialogue on the various approaches. The development of pedagogic methods for teaching according to the dialogue approach will facilitate the promotion by science teachers of clearer understanding about the NOS and about the science-religion interface.

As this and other studies suggest, certain aspects of NOS perceptions can be challenged and changed into concepts that are more accepted in science education. Although these are usually positively connected to the study of science (Deng et al. 2011), it cannot be claimed for certain that changes in NOS perceptions affect teaching or learning quality. At the same time, coping with the complexity of the NOS, the discussions, the arguments, and the reflections, as has occurred in this study, contributes to critical thought and casting doubt. Advancing these skills is also likely to advance students' openness to the dialogue or the integrative approach regarding the relationship between religion and science and to contribute to understanding science.

Acknowledgements

This study was undertaken with the assistance of the Research Authority at Kaye College of Education, Israel.

References

Abd-El-Khalick, F. (2014). The evolving landscape related to assessment of nature of science. In N. G. Lederman & S. K. Abell (Eds.*), Handbook of research on science education* (volume II, pp. 621-650). New York, NY: Routledge. https://www.routledge.com/Handbook-of-Research-on-Science-Education-Volume-II/Lederman-Abell/p/book/9780415629553

Aflalo, E. (2013). Religious belief: The main impact on the perception of the nature of science on student teachers. *Cultural Studies of Science Education.* 8(3), 623-641. https://doi.org/10.1007/s11422-013-9504-9

Aflalo, E. (2014). Advancing the perceptions of the nature of science (NOS): Integrating teaching the NOS in a science content course. *Research in Science & Technological Education*, 32(3), 298-317. https://doi.org/10.1080/02635143.2014.944492

Akerson, V. L., Buzzelli, C. A. & Donnelly, L. A. (2008). Early childhood teachers' views of nature of science: The influence of intellectual levels, cultural values, and explicit reflective teaching. *Journal of Research in Science Teaching*, 45(6), 748-770. https://doi.org/10.1002/tea.20236

Allchin, D. (2012). Toward clarity on whole science and KNOWS. *Science Education,* 96(4), 693-700. https://doi.org/10.1002/sce.21017

Barbour, I. G. (1990). *Religion in an age of science*. London: SCM.

Bell, R. L. & Lederman, N. G. (2003). Understandings of the nature of science and decision making on science and technology based issues. *Science Education,* 87(3), 352-377. https://doi.org/10.1002/sce.10063

Bickmore, B. R., Thompson, K. R., Grandy, D. A. & Tomlin, T. (2009). Commentary: On teaching the nature of science and the science-religion interface. *Journal of Geoscience Education,* 57(3), 168-177. https://doi.org/10.5408/1.3544261

Brickhouse, N. W., Dagher, Z. R., Letts, W. J. & Shipman, H. L. (2000). Diversity of students' views about evidence, theory, and the interface between science and religion in an astronomy course. *Journal of Research in Science Teaching,* 37(4), 340-362. https://doi.org/10.1002/(SICI)1098-2736(200004)37:4<340::AID-TEA4>3.0.CO;2-D

Capps, D. K. & Crawford, B. A. (2013). Inquiry-based instruction and teaching about nature of science: Are they happening? *Journal of Science Teacher Education,* 24(3), 497-526. https://doi.org/10.1007/s10972-012-9314-z

Central Bureau of Statistics (2014). *Social survey 2014*. Israel: Central Bureau of Statistics.

Dagher, Z. R. & BouJaoude, S. (1997). Scientific views and religious beliefs of college students: The case of biological evolution. *Journal of Research in Science Teaching*, 34(5), 429-445. https://doi.org/10.1002/(SICI)1098-2736(199705)34:5<429::AID-TEA2>3.0.CO;2-S

Deng, F., Chen, D., Tsai, C. & Chai, C. S. (2011). Students' views of the nature of science: A critical review of research. *Science Education*, 95(6), 961-999. https://doi.org/10.1002/sce.20460

Develaki, M. (2012). Integrating scientific methods and knowledge into the teaching of Newton's theory of gravitation: An instructional sequence for teachers' and students' nature of science education. *Science & Education,* 21(6), 853-879. https://doi.org/10.1007/s11191-010-9243-1

Dogan, N. & Abd-El-Khalick, F. (2008). Turkish grade 10 students' and science teachers' conceptions of nature of science: A national study. *Journal of Research in Science Teaching,* 45(10), 1083-1112. https://doi.org/10.1002/tea.20243

Duschl, R. A. & Grandy, R. (2013). Two views about explicitly teaching Nature of Science. *Science & Education,* 22(9), 2109-2139. https://doi.org/10.1007/s11191-012-9539-4

Eurydice Network (2011). *Science education in Europe: National policies, practices and research*. Education, Audiovisual and Culture Executive Agency, Brussels. http://eacea.ec.europa.eu/education/eurydice/documents/thematic_reports/133EN.pdf

Fazio, X., Melville, W. & Bartley, A. (2010). The problematic nature of the practicum: A key determinant of pre-service teachers' emerging inquiry-based science practices. *Journal of Science Teacher Education,* 21(6), 665-681. https://doi.org/10.1007/s10972-010-9209-9

Fleener, M. J. (1996). Scientific world building on the edge of chaos: High school students' beliefs about mathematics and science. *School Science and Mathematics,* 96(6), 312-320. https://doi.org/10.1111/j.1949-8594.1996.tb15841.x

Golabek, C. & Amrane-Cooper, I. (2011). Trainee teachers' perceptions of the nature of science and implications for pre-service teacher training in England. *Research in Secondary Teacher Education,* 1(2), 9-13. http://roar.uel.ac.uk/1411/1/2046-1240_1-2_pp09-13.pdf

Gauchat, G. W. (2008). A test of three theories of anti-science attitudes. *Sociological Focus,* 41(4), 337-357. https://doi.org/10.1080/00380237.2008.10571338

Hanley, P., Bennett, J. & Ratcliffe, M. (2014). The inter-relationship of science and religion: A typology of engagement. *International Journal of Science Education,* 36(7), 1210-1229. https://doi.org/10.1080/09500693.2013.853897

Hipkins, R., Barker, M. & Bolstad, R. (2005). Teaching the 'nature of science': Modest adaptations or radical reconceptions? *International Journal of Science Education,* 27(2), 243-254. https://doi.org/10.1080/0950069042000276758

Kampourakis, K. (2015). The "general aspects" conceptualization as a pragmatic and effective means to introducing students to Nature of Science. *Journal of Research in Science Teaching,* 53(5), 667-682. https://doi.org/10.1002/tea.21305

Lederman, N. G. (2007). Nature of science: Past, present, and future. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of research on science education* (pp. 831-880). Mahwah, NJ: Lawrence Erlbaum Associates Inc.

Lederman, N. G. & Abd-El-Khalick, F. (1998). Avoiding de-natured science: Activities that promote understanding in the nature of science. In W. F. McComas (Ed), *The nature of science in science education: Rationales and strategies* (pp. 83-126). Dordrecht: Kluwer. http://www.springer.com/la/book/9780792350804

Lederman, N. G. & Lederman, J. S. (2014). Research on teaching and learning of nature of science. In N. G. Lederman & S. K. Abell (Eds), *Handbook of research on science education* (volume II; pp. 600-620). New York, NY: Routledge. https://www.routledge.com/Handbook-of-Research-on-Science-Education-Volume-II/Lederman-Abell/p/book/9780415629553

Leung, J. S. C., Wong, A. S. L. & Yung, B. H. W. (2015). Understandings of nature of science and multiple perspective evaluation of science news by non-science majors. *Science & Education,* 24(7-8), 887-912. https://doi.org/10.1007/s11191-014-9736-4

Liu, S.-Y. & Lederman, N. G. (2007). Exploring prospective teachers' worldviews and conceptions of nature of science. *International Journal of Science Education,* 29(10), 1281-1307. https://doi.org/10.1080/09500690601140019

Lotter, C., Singer, J. & Godley, J. (2009). The influence of repeated teaching and reflection on preservice teachers' views of inquiry and nature of science. *Journal of Science Teacher Education,* 20(6), 553-582. https://doi.org/10.1007/s10972-009-9144-9

Mansour, N. (2008). Religious beliefs: A hidden variable in the performance of science teachers in the classroom. *European Educational Research Journal*, 7(4), 557-576. https://doi.org/10.2304/eerj.2008.7.4.557

Mansour, N. (2011). Science teachers' views of science and religion vs. the Islamic perspective: Conflicting or compatible? *Science Education,* 95(2), 281-309. https://doi.org/10.1002/sce.20418

McComas, W. F. (2014). Nature of science in the science curriculum and in teacher education programs in the United States. In M. R. Matthews (Ed.), *International handbook of research in history, philosophy and science teaching* (pp. 1993-2023). Dordrecht, The Netherlands: Springer. https://doi.org/10.1007/978-94-007-7654-8_61

McDonald, C. V. (2010). The influence of explicit nature of science and argumentation instruction on preservice primary teachers' views of nature of science. *Journal of Research in Science Teaching,* 47(9), 1137-1164. https://doi.org/10.1002/tea.20377

National Research Council (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Washington, DC: The National Academies Press. https://doi.org/10.17226/13165

National Research Council (2013). *Next generation science standards: For states, by states*. Washington, DC: National Academies Press. https://doi.org/10.17226/18290

Osborne, J., Collins, S., Ratcliffe, M., Millar, R. & Duschl, R. (2003). What "ideas-about-science" should be taught in school science? A Delphi study of the expert community. *Journal of Research in Science Teaching,* 40(7), 692-720. https://doi.org/10.1002/tea.10105

Peters, E. E. (2012). Developing content knowledge in students through explicit teaching of the nature of science: Influences of goal setting and self-monitoring. *Science & Education,* 21(6), 881-898. https://doi.org/10.1007/s11191-009-9219-1

Scharmann, L. C., Smith, M. U., James, M. C. & Jensen, M. (2005). Explicit reflective nature of science instruction: Evolution, intelligent design, and umbrellaology. *Journal of Science Teacher Education,* 16(1), 27-41. https://doi.org/10.1007/s10972-005-6990-y

Scheitle, C. P. (2011). Religious and spiritual change in college: Assessing the effect of a science education. *Sociology of Education,* 84(2), 122-136. https://doi.org/10.1177/0038040711401811

Schwartz, R. S. & Lederman, N. G. (2002). It's the nature of the beast: The influence of knowledge and intentions on learning and teaching nature of science. *Journal of Research in Science Teaching,* 39(3), 205-236. https://doi.org/10.1002/tea.10021

Simpson, R. D., Koballa, T. R., Oliver, J. S. & Crawley, F. E. (1994). Research on the affective dimension of science learning. In D. L. Gabel (Ed), *Handbook of research on science teaching and learning,* pp. 211-233. New York: Macmillan.

Somerville, J. (1941). Umbrellaology, or, methodology in social science. *Philosophy of Science,* 8(4), 557-566. http://www.jstor.org/stable/184514

Southerland, S. A., Sinatra, G. M. & Matthews, M. R. (2001). Belief, knowledge, and science education. Educational Psychology Review 13(4), 325-351. https://doi.org/10.1023/A:1011913813847

Taber, K. S., Billingsley, B. & Riga, F. (2011). To what extent do pupils perceive science to be inconsistent with religious faith? An exploratory survey of 13-14 year-old English pupils. *Science Education International*, 22(2), 99-118. https://eric.ed.gov/?id=EJ941668

Yarchi, R. (1999). Educational stances of religiosity versus secularity and science in state-religious colleges of education that received academic authorization. *Mayim Midalav Academic Journal of Jewish and Educational Studies*, 181-201.

Dr Ester Aflalo is a senior lecturer in life sciences and the teaching of science, who heads the research and evaluation authority at the Hemdat Hadarom Academic College of Education in Israel. Her particular area of research is sciences education and technology in education.
Email: ester@hemdat.ac.il

Please cite as: Aflalo, E. (2018). Changes in the perceptions of the nature of science and religious belief. *Issues in Educational Research*, 28(2), 237-253. http://www.iier.org.au/iier28/aflalo.pdf