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Secondary school students’ perceptions of scientific and religious positions on miracles ¹

This paper reports on a study designed to discover how students characterise the scientific and religious positions on miracles and their access to a range of views on how science and religion relate. The study is part of a larger research initiative exploring the value of scholarly reasoning about the interactions between science and religion as a resource for educators, researchers and others seeking ways to advance young people’s epistemic insight. Teaching epistemic insight, ‘knowledge about knowledge’, includes considering the power and limitations of science in the context of different types of questions and how science relates to other ways of knowing. For many decades in schools in England and internationally the accepted practice has been to teach lessons about the nature of science within the confines of a subject (science) that focuses on teaching scientific content. This means that students’ opportunities for learning about science as a discipline in school can be limited to studying questions that are very amenable to science. The paper draws on the findings from a survey of 2,530 students and interviews with 61 students aged 14-19 to discuss the extent to which students seem to be accessing an appreciation of the power, relevance and limitations of science. The paper then examines some possible consequences of the findings and makes recommendations for science communication and secondary school education.

Keywords: Nature of science, epistemic insight, science and religion, miracles.

Introduction

This paper reports a study designed to discover how students in secondary schools perceive the relationships between science and religion on the topic of miracles. The study was conducted as part of the LASAR (the Learning about Science and Religion) project. Our research seeks to explore the role of education in students’ experiences of Big Questions. We characterise Big Questions as questions about human personhood and the nature of reality where both

¹ The project is supported by John Templeton Foundation grant number 15389. Supplementary Tables 1-3 are available online.

science and religion have something to say. Scholarly dialogues and debates about these big questions frequently discuss the nature, power and limitations of science. In our research we have previously argued that students are unlikely to achieve the 'epistemic insight' they need to understand these arguments and to appreciate why science and religion are not necessarily incompatible without their teachers' help.² We have also expressed a concern based on interviews we conducted in schools³ and research by other authors⁴ that students are unlikely to receive the teaching they need. This research reveals that the science classroom tends to operate in a silo in secondary schools and that students' opportunities for learning about science as a discipline in school can be limited to studying questions that are very amenable to science.

These findings prompted the analytical approach we are using in the current study as we notice that there are references to the power and limitations of science in scholarly discussions about how science and religion relate on miracles. We argue that these insights include appreciating that some claims are more amenable to science than others and that assertions about miracles may be difficult to investigate scientifically as miracles are said to be 'one-off events' that take place in very unusual circumstances. In the sections that follow we propose that helping students to gain the first of these insights is an appropriate and valuable objective for the science classroom. We also discuss whether and where there might be opportunities for helping students to gain the second insight. Before this, we address why it could be beneficial for schools to include teaching about the topic of miracles at all.

Miracles in popular culture

The word miracle is used in a range of contexts and these include references to moments of luck and serendipity which would not universally be thought of

2 Billingsley, B., Taber, K., Riga, F., & Newdick, H. 'Secondary school students' epistemic insight into the relationships between science and religion – a preliminary enquiry'. *Research in Science Education* (2013) 43(4), 1715-1732 .

3 Billingsley, B., Brock, R., Taber, K. S., & Riga, F. 'How students view the boundaries between their science and religious education concerning the origins of life and the universe', *Science Education* (2016), 459-482.

4 Paiva J.C, Morais, C. & Moreira, L. 'If neither from evolution nor from the Bible, where does tension between science and religion come from? Insights from a survey with high school students in a Roman Catholic society'. in Billingsley, B., Chappell K., Reiss M. (eds.) *Science and Religion in Education*. (2019). 277-290; Sheffield, R.S., Kurisunkal, J.J., & Koul, R. 'Learning to teach and teaching to learn stem through a makerspace approach', in *Science Education in India* (2019) pp. 181-207; Slomka, J.M. 'Analysing the nature of Ministry guidelines for developing interdisciplinary science courses (Grades 11–12) in Ontario (Canada), *Canadian Journal of Science, Mathematics and Technology Education*, (2019) 19(4), 367-386.

as miracles. Public conceptions of miracles may also be influenced by the use of the word to refer to cases of survival against the odds. Diem et al.⁵ reviewed ten episodes of 'Rescue 911', a TV show that dramatises real life medical emergencies, and report that the term 'miracle' was used to describe a patient's survival in 10 of 18 instances (56 %). The authors make the point that the outcome for patients in the stories selected is often a full recovery and that while medical teams are often shown expressing pessimism, family members speak of holding onto hope. The authors warn that these types of shows may suggest to the public that miracles are always beyond medical science to explain and may encourage those faced with similar difficult circumstances to disregard the advice of doctors and trust that such a miracle will also occur for them. Gaudia⁶ gives some examples of popular conceptions of miracles and warns that there are also some proponents of the possibility of miracles who have exploited public trust for their individual gains.

With these matters in mind, and indeed more broadly given a global curricular shift towards emphasising scientific literacy, there is mounting pressure on schools worldwide to do more to teach children about the types of questions science can investigate and the power and limitations of its methods.⁷

Teaching about science

The nature of science is complex, and to support students' developing understanding, curriculum designers need to set out a form of target knowledge for learners which manages to be both accessible for the intended age and level of students and yet 'intellectually honest'⁸ in the sense of being an authentic simplification of the ideas presented in scholarship. There is a consensus view in science education that a sound curricular model of the nature of science would need to represent scientific knowledge as generally robust and reliable, yet only taken as provisional (not absolute) knowledge of the world.⁹ For example, in his discussion of students' understanding of the nature of science, Sandoval¹⁰ gives four ideas about the nature of science which he argues are im-

5 Diem, S.J., Lantos, J.D. & Tulskey, J.A. 'Cardiopulmonary resuscitation on television - miracles and misinformation', *New England Journal of Medicine* (1996) 334, 1578-1582.

6 Gaudia, G. 'About intercessory prayer: the scientific study of miracles', *Medscape General Medicine* (2007) 9, 56.

7 Erduran, S. 'Argumentation in science and religion: match and/or mismatch when applied in teaching and learning?', *Journal of Education for Teaching* (2020) 46, 1-3.

8 Bruner, J.S. *The Process of Education*, New York: Vintage Books (1960).

9 Lederman, N.G. 'Students' and teachers' conceptions of the nature of science: a review of the research. *Journal of Research in Science Teaching*, (2006) 29, 331-359; McComas, W.F. 'Understanding how science works: the nature of science as the foundation for science teaching and learning' *School Science Review* (2017) 98, 71-76.

10 Sandoval, W.A. 'Understanding students' practical epistemologies and their influence on

portant for students to appreciate but are rarely present in students' thinking. The author begins with 'probably the most important epistemological notion for students to understand' which he says is an appreciation 'that scientific knowledge is constructed by people, not simply discovered out in the world'.

Alongside an account of the characteristics of science, students also need to appreciate what if anything differentiates science from other forms of enquiry.¹¹ Osborne and Collins¹² explain that students typically view science as a large body of facts and as a mode of enquiry that places a particular emphasis on 'answers that were either right or wrong – an aspect that distinguished it from other subjects'. A body of existing work relates this view of science to the practice in science education of focusing students' attention only on those questions that science can resolve and has done so convincingly.¹³ While a belief that science produces unassailable truth is a misperception, the apparent factual nature of science is given by many students as a reason to like science and science education. Teachers are likely to have reservations about unsettling students from this view and are likely to be reluctant to constructively challenge their students or help them to understand the power and limitations of science.

With similar concerns in mind, Osborne et al.¹⁴ proposed a modified version of the tentativeness assertion, which is that some claims are more tentative than others. Arguably, to translate this into pedagogical practice, students need an experience of working scientifically that helps them to appreciate where and why science is reliable and to understand the limitations of its methods.¹⁵ As Sandoval¹⁶ notes, students should be given opportunities to design investigations and 'if students do not have to decide what kind of data to get, they are unlikely to engage in epistemological considerations of what kind of data would be appropriate'. In his explanation of the power and limitations of science Sadler¹⁷ explains that the methods of science centre on the idea that 'science relies on empirical evidence, and scientists employ creativity to obtain

learning through inquiry', *Science Education* (2005) 89, 634-656.

11 Bruner, J.S. *op. cit.*, (8)

12 Osborne J. & Collins S. 'Pupils' and parents' views of the school science curriculum', *School Science Review* (2000) 82, 23-31.

13 Fensham, P.J. 'The future curriculum for school science: what can be learnt from the past?' *Research in Science Education* (2016) 46,165-185.

14 Osborne J, Simon S. & Collins S. 'Attitudes towards science: a review of the literature and its implications', *International Journal of Science Education* (2003) 25, 1049-1079.

15 Paiva J.C, et al. *op. cit.*, (4).

16 Sandoval W.A. *op. cit.*, (10).

17 Sadler, T.D., Chambers, F.W. & Zeidler, D.L. 'Student conceptualizations of the nature of science in response to a socioscientific issue', *International Journal of Science Education* (2004) 26, 387-409.

and interpret this evidence'. In our study we are interested in the extent to which schools develop students' epistemic insight into the nature, power and limitations and limitations of science when they explore the topic of miracles. While we do not seek to promote discussion of miracles in science lessons, we do want to highlight here the value of including some questions in science lessons that do not and may never have scientific answers. This prompts the questions we explore in the next section. Is it reasonable to expect that insight gained in a science lesson about the power and limitations of science would be transferred to a discussion about miracles in another subject's lessons – and if not, why not, and what if anything would help that transfer to take place?

Pressures of compartmentalisation

In many schools each subject tends to work as a silo, with its own curriculum, text books, timetable slots, subject examinations, subject-specific teacher training and – in secondary schools – its own specialist teachers and classroom.¹⁸ This way of subject compartmentalisation, with its practical advantages, has some epistemic disadvantages. Big Questions usually have a multi-disciplinary nature and are arguably best addressed by subject teachers collaborating to create bridges across their different disciplines. However, the current teaching system in the UK and many other countries does not require or encourage educators to systematically approach Big Questions in a collaborative way.¹⁹ Further, students may hold back some of their concerns, questions and confusions in science lessons on the basis that they feel it's important to stay 'on topic' and away from anything that could be sensitive or risk 'causing offence'.²⁰

There is also a basis to say that subject teachers typically feel unprepared to discuss questions that span their own and another subject because their training and expertise tends to be limited to specialist curriculum and subject knowledge. These factors suggest that if schools are to help students to negotiate different accounts and positions on miracles without discussing religion in science lessons then it will be important to increase teacher collaboration and timetable some lessons that bridge the sciences and humanities. With this in mind, we move next to offer a conceptual framework concerning different scholarly positions on miracles. Our focus is on what scholars have said about the compatibility of science with religious accounts of miracles.

18 Ratcliffe, M. 'The place of socio-scientific issues in citizenship education', in Ross, A. (ed.) *Human Rights and Citizenship Education*, London: CiCe (2009), pp. 12-16.

19 Billingsley, B. 'Ways to prepare future teachers to teach science in multicultural classrooms', *Cultural Studies of Science Education*, (2016) 11(2), 283-291.

20 Billingsley, B., et al. *op. cit.*, (3).

Selected scholarly positions on miracles

Miracles, and the related issues of prayer and divine action, have long been central in discussions regarding the relationship between science and religion and have frequently proved controversial and divisive.²¹ Indeed it has been said that miracles constitute ‘one of the most contentious issues in the debates on science, religion and modernity’.²² One popular definition of a miracle, attributed to the philosopher David Hume²³ is that ‘a miracle is a violation of the laws of nature’. He adds that since, ‘a firm and unalterable experience has established these laws, the proof against a miracle, from the very nature of the fact, is as entire as any argument from experience as can be imagined’. Hume’s position then is that there is a body of evidence to support the existence of natural laws and this ‘proof’ is so well established that it must always outweigh any claim or testimony of a miracle.

Michael Poole²⁴ objects to Hume’s definition of a religious miracle as a violation of natural law arguing that it suited Hume to see science and religion as mutually exclusive. Peter Harrison²⁵ makes a similar case and argues that for Newton, and in a more developed way for some of his followers such as the English theologian, William Whiston, the absence of a sense of conflict between science and miracles was rooted in a view of natural laws that differs fundamentally from that presented by Hume. In this alternative account, natural laws are an expression of the divine creator’s will and foresight, and so all miraculous events, including answers to petitionary prayer, are part of the natural order. The fact that some events appear anomalous is the product of our lack of understanding of the fullness of those laws²⁶

Physicist Paul Davies²⁷ argues that there are laws of nature which are universal, absolute and eternal, but he also identifies scientific laws as different to natural laws, saying that scientific laws reflect what we know to date and are likely to be modified in the light of new observations to portray new views of how reality works. Nancy Cartwright²⁸ in considering the boundaries of sci-

21 Brooke, J.H. *Science and Religion: Some Historical Perspectives*, Cambridge: Cambridge University Press (1991); Ward, K. *The big questions in science and religion*, West Conshohocken, PA: Templeton Foundation Press (2008).

22 Guessoum, N. ‘Understanding Qur’anic miracle stories in the modern age by Isra Yazicioglu’, *Journal of Islamic Studies* (2015) 26, 199-202.

23 Hume, D. *An Enquiry Concerning Human Understanding (1748)*. Oxford: Oxford University Press (1963).

24 Poole, M. *A User’s Guide to Science and Belief*, Oxford: Lion Books (2007).

25 Harrison P. ‘Newtonian science, miracles, and the laws of nature’, *Journal of the History of Ideas* (1995) 56, 531-553.

26 Harrison, P. *op. cit.*, (25)

27 Davies, P. *Mind of God: The Scientific Basis for a Rational World*, Simon and Schuster (1993).

28 Cartwright, N. *The Dappled World: A Study of the Boundaries of Science*, Cam-

ence, without specific reference to miracles, also presents a similar picture of what she terms a 'dappled world' in which scientific theories and laws describe only parts of a patchwork and that assumptions about universal applicability are often over presumptive. Priest and physicist, John Polkinghorne also says of miracles that these are not moments when God suspends natural laws and that God 'is no celestial conjurer, doing an occasional turn, but his actions must always be characterized by the deepest possible consistency and rationality.'²⁹

Materials scientist, Colin Humphreys discusses miracles of timing, giving the Israelites' safe crossing of the Red Sea as an example and saying that one possible explanation is that God interacted with his people to orchestrate events so that they arrived at just the right moment for a remarkable but naturally occurring event.³⁰

Ard Louis, a physicist and a Christian, argues that one of the presuppositions of science is that 'what we either predict or measure should be repeatable' so that 'if I claim to see an effect in an experiment, someone else in a different lab should be able to reliably measure the same effect'. Louis explains that his belief in the resurrection of Christ is compatible with his scientific attitude because on some very rare occasions, there are interventions by God which amount to 'special non-repeating actions' which are therefore, 'almost by definition, non-repeatable and a-scientific'.³¹

Scientist and Christian Arthur Peacocke took an even more cautious stand and argued that there is no theological need to believe that God would ever 'abrogate the scientifically observed relationships operating at the level of events in question'.³² In keeping with this position, Peacocke resisted assertions by other Christians that Jesus was born of a virgin and instead said the Bible only stipulates that Jesus was chosen by God and made incarnate. This approach of looking to maintain patterns that have been established, argued Peacocke, 'renders the concept of God's special providential action intelligible and believable within the context of the perspective of the sciences'. In this way Peacocke, like the other authors discussed in this section, argues for a position on religion which is consistent with the position he takes on science.

Another scientist, atheist and biologist, Richard Dawkins also proposes

bridge: Cambridge University Press (1999).

29 Polkinghorne J. *Science and Providence: God's Interaction with the World*, London: SPCK. (2005).

30 Humphreys, C. *The Miracles of Exodus: A Scientist's Discovery of the Extraordinary Natural Causes of the Biblical Stories*, San Francisco: Harper Collins (2003).

31 Louis, A. *Miracles and Science: The Long Shadow of David Hume*, (2010), available at: http://www.chavoux.com/Gericke/louis_scholarly_essay.pdf.

32 Peacocke, A. *Theology for a Scientific Age: Being and Becoming - Natural, Divine and Human*, Minneapolis: Fortress Press (1993).

a coherent position across science and religion but reduces further the status of religious testimony. Dawkins retains Hume's definition of miracles as violations of the normal running of the natural world. Then in contrast with the position espoused by Louis, Dawkins rejects the notion that miracles are outside the legitimate realm of scientific enquiry and instead describes stories about miracles as 'blatant intrusions into scientific territory'.³³ Dawkins refers to Gould³⁴ who proposed that science and religion are non-overlapping magisteria and that scientific questions and other religious questions are of different types so that each type of question can be considered independently. Dawkins emphasises that miracles are claims about the physical world – which is a domain addressed by science – and insists that theologians must choose between claiming that religion has its 'own magisterium, separate from science's' and in that case 'must renounce miracles'. Or alternatively, theologians 'can keep your Lourdes and your miracles [...] But then you must kiss goodbye to separate magisteria and your high-minded aspiration to converge with science'. The position that science has no limits is echoed by Professor Richard Atkins, who states that, 'there is no reason to expect that science cannot deal with any aspect of human experience'.³⁵

What is common among these scholars is that they each propose a coherent framework which bridges science and religion to argue for a particular position on the possibility of miracles. To defend their different conclusions, these scholars argue for different positions on the power and limitations of science and they also have different ways to characterise the criteria for a religious miracle.

In one position, there is an absolute natural order which is revealed only through science, which cannot be suspended or overruled and which is potentially fully accessible to human understanding. This position can be associated with scientism where scientism is a commitment to the view that science is the only valid way to construct knowledge and that nothing exists beyond the material universe.³⁶ Within this group, scholars are likely to say that miracles as supernatural events simply do not happen and are a delusion. It may also be said that claims about miracles do not correspond to suspensions of the natural order and that they instead have a natural explanation.

Another position, proposed by some scholars including some scientists, is that the observable world is an indirect reflection of some deeper order that is

33 Dawkins, R. 'Snake oil and holy water', *Forbes Magazine* (1999) 10, 235-236.

34 Gould, S.J. 'Nonoverlapping magisteria', *Natural history* (1997) 106, 16-22.

35 Atkins, P.W. 'The limitless power of science', in Cornwell, J. (ed.) *Nature's imagination: The frontiers of scientific vision*, Oxford: Oxford University Press (1995), 122-132.

36 Stenmark, M. 'Scientism', in *Encyclopaedia of Sciences and Religions*, Springer (2013), 2103-2105; Peels, R. 'A conceptual map of scientism', *Scientism: Prospects and Problems* (2018), 28-56.

beyond our understanding and in that case what we perceive as suspensions of the natural order may reflect our incomplete understanding. This position would encompass theism and also other non-naturalistic positions. For someone with a theistic worldview, there is also a presupposition that nature is subjugated to God and the universe acts in whatever ways God ordains. In that case it may be said that God sustains, interrupts or sets aside laws as He sees fit. It may also be proposed that God sustains a consistent natural order and that miracles are not law-breaking but rather are very occasional events that take place in special conditions.

These different opinions about the power, relevance and limitations of science are all consistent with science and the diversity of views of scientists today. As such our position is that it is important for students to appreciate that scholars in general bring a high level of scepticism to claims of miracles and that where evidence exists, this should be scrutinised and considered; further if the evidence is not sufficient for scholars to form a consensus and particularly if the alleged anomaly is not amenable to scientific testing, the possibility of miracles is not necessarily incompatible with a scientific worldview.

Context

The data gathering aspect of the study was conducted in England, a country which has an 'established' Church of England (that is, an official state Church), but which is a multi-cultural society. The national curriculum in England has legal requirements for teaching science and Religious Education (RE).

RE is statutory for all registered pupils, including all pupils in reception classes and sixth form. However, parents have an option to remove their children from this subject if they wish to (students aged 18 or above can withdraw themselves). There is not a National Curriculum for RE; but, maintained schools have to follow the national curriculum requirements to teach a broad and balanced curriculum, which includes RE. Academies and free schools do not have to follow the national curriculum, but they are contractually required through the terms of their funding agreement to make provision for the teaching of RE. Schools either follow a non-statutory framework or the RE curriculum that is determined by the local Standing Advisory Council on Religious Education (SACRE). This advisory council is responsible for producing the locally agreed syllabus for RE. Agreed Syllabuses used in schools (maintained or academy), which are not designated with a religious character must 'reflect the fact that the religious traditions in Great Britain are in the main Christian, while taking account of the teaching and practices of the other principal religions represented in Great Britain'³⁷. Schools with a religious designation may prioritise one

37 <https://www.natre.org.uk/about-re/legal-requirements/>

religion in their RE curriculum, but all schools must recognise diverse religions and systems of belief in the UK both locally and nationally.³⁸

The amount of time allocated in the timetable for religious education can vary from school to school but even so, most students are likely to receive teaching about miracles at some point in their religious education: this could be as a topic or specific lesson, via a study of miracles in the doctrines or narratives of a religion, such as the stories of Jesus healing; or through a study of contemporary religious life in a Church tradition where miracles are believed to happen today. Some support for this claim can be seen in a specification published by the AQA exam board for GCSE RE (the public examination at the end of this period of study). This includes a topic on miracles and states that students are expected to know, 'what do we mean by miracles? – something impossible, something contrary to the laws of nature, something only God does' and also about 'Hume's argument regarding the impossibility of miracles'.³⁹ The wording of the advice prompts us to wonder whether students studying for this course are also taught about the criticisms of Hume's definition that are presented in many scholarly treatments of the topic.

Science is a statutory subject in England for students up to the age of 16 and lessons are guided by a National Curriculum. Students' reasoning about the relationships between science and miracles could conceivably be developed in relation to an objective in the science curriculum for students aged 14-16 which calls for students to 'appreciate the power and limitations of science'.⁴⁰ However, as we noted earlier – the range of questions studied in science lessons tends not to be that diverse.

To investigate students' reasoning about miracles, we drew on a large-scale survey and an interview study conducted with students in each of three age ranges in secondary schools in England. England is a multicultural country and the most recent (2011) census for which data is available found that in England 59% of respondents gave their religion as Christian; whilst 25 % claimed to be of no religion and 7% of census respondents chose the option of not responding to this question.⁴¹ In addition 5% of respondents identified themselves as

38 Department for Children and Families. (2010). Religious education in English schools: Non-statutory guidance. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/190260/DCSF-00114-2010.pdf (2010).

39 AQA. (2013) Religious Studies A: Full and Short Courses <https://www.aqa.org.uk/subjects/religious-studies/gcse/religious-studies-a-8062>

40 Department for Education (2014) Science programmes of study: key stage 4. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/381380/Science_KS4_PoS_7_November_2014.pdf

41 Office for National Statistics (2012) Religion in England and Wales 2011. London: Office for National Statistics. <https://www.ons.gov.uk/peoplepopulationandcommunity/culturalidentity/religion/articles/religioninenglandandwales2011/2012-12-11>

Muslim, with another 5% identifying themselves as belonging to other religions including Hinduism, Buddhism, Sikhism and Judaism.

The questionnaire for the survey and the schedule for the interview address a number of topics which are: the origins of the universe, the origins of life, prayer, and miracles, together with further questions about how topics bridging science and religion are managed in classrooms. The selection of these topics is partly because they are ones that are widely discussed in scholarship⁴² and also partly because they were topics that were frequently identified by tertiary level students in an interview study when they are asked whether they know of any apparent contradictions between science and religion.⁴³ These topics and the approach of asking students to comment on the scientific position, religious position, the relationship between these positions and their own positions were then developed for use with secondary school students via interviews, focus groups and pilot surveys in advance of a preliminary study exploring the positions of students in Year 9 (13 year olds).⁴⁴

We also conducted an exploratory study with open- and closed-ended questions used for item generation (n=60) with students in Years 8 (12 year olds) and 11 (15 year olds) and a small scale survey (n=109) with students in Year 9.⁴⁵ Further development took place following a series of focus groups and pilot tests for this particular study that focused on checking understanding, refining and validating different scales for the survey with individual age groups: Years 7 (age 11), 9 (age 13) and 11 (age 15). Focus groups were organised in four schools by contacting secondary school science teachers known to the project team and/or colleagues. The final selection of schools was made by drawing on a longer list to ensure a mix of rural and city, faith and non-faith. In each school one class was asked to complete a survey that included many of the questions

42 Francis, L.J., Astley, J. & McKenna, U. "Science disproves the biblical account of creation": exploring the predictors of perceived conflict between science and religion among 13-to 15-year-old students in the UK', *British Journal of Religious Education* (2018), 1-14; Hanley, P., Bennett, J. & Ratcliffe, M. 'The inter-relationship of science and religion: A typology of engagement', *International Journal of Science Education* (2014) 36(7), 1210-1229; McGrath, A.E. *Science & religion: a new introduction*, Hoboken, NJ: John Wiley & Sons (2020); Shane, J.W., Binns, I.C., Meadows, L., Hermann, R.S., & Benus, M.J. 'Beyond evolution: addressing broad interactions between science and religion in science teacher education', *Journal of Science Teacher Education* (2016) 27(2), 165-181.

43 Billingsley, B. *Ways of thinking about the apparent contradictions between science and religion*, PhD Thesis, University of Tasmania (2004).

44 Billingsley, B., Riga, F., Taber, K.S. & Newdick, H. 'Secondary school teachers' perspectives on teaching about topics that bridge science and religion', *Curriculum Journal* (2014) 25(3), 372-395.

45 Taber, K.S., Billingsley, B., Riga, F., & Newdick, H. '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* (2011) 22(2), 99-118.

in the current study. The final version of the current survey was piloted to ensure that it could be completed in the allocated time (30 minutes).

The introductory section of the questionnaire explained that students could skip any question they did not want to answer; that students' names would not be used in reports and that students' responses would not be used to inform school grades. At the beginning of the questionnaire students were asked to give their age, school and school year. At the end of the questionnaire students were asked to identify their gender and to select an option to indicate whether or not they saw themselves as having a religious faith and if so which tradition. Students were also asked to indicate their willingness to be interviewed. The largest portion of the questionnaire consisted of statements and students were asked to respond to each one by expressing their level of agreement or disagreement using the following scale: Strongly agree, agree, partly agree and partly disagree, disagree, strongly disagree. Two further categories were included: 'not sure' and, 'I do not understand the question'.

The statements in the survey which address miracles focus on the notion of miracles as alleged supernatural events. One item asks students for their own position stating that, 'I believe supernatural miracles happen'; a second proposes an opposing position for science stating that, 'The scientific view on miracles is that they can be explained in natural terms'. A third statement (in contrast) proposes that scientists would not necessarily be opposed to supernatural miracles, stating that 'A good scientist can believe that supernatural miracles happen'. In addition to choosing a level of agreement for each statement, students were also invited to add a comment. The three statements are designed to enable us to investigate the reasoning of a large cohort with the aim of comparing students' perceptions of the scientific view with their own view and their perceptions of scientists' positions.

In the interview schedule, the questions relating to miracles were more exploratory and were: 'What do you think a scientist would say about miracles in the Bible or in holy books?', 'What about a religious person - what would they say about miracles?' 'What does science say about a miracle?' 'What does religion say?' and 'What do you believe about miracles?'

To select participants for the interview study, we supplied class teachers with a list of students who had indicated willingness to be interviewed on their survey and who represented a range of faith positions including an atheistic stance. The final cohort of 61 participants comprised these students and included some who were substituted on the day. The interview was semi-structured, a method commonly used in education to explore aspects of learners' thinking in depth. Typically interviews lasted one hour, although this varied from individual to individual. Students were told that if they were uncomfortable with any question that it was acceptable to say they do not want to give an answer. While the experience of completing the survey is likely to have affected

students' thinking, this is not something we see as a disadvantage as it meant that students had an opportunity to gather their thoughts about the topics that were likely to be covered in the interview. The questions in the interviews echoed the themes addressed in the survey.

Ethical approval for the research to proceed was granted by the institutions associated with the authors and all ethical processes and considerations were complied with. For the interview study, students and their parents gave permission for participants to take part and for the interviews to be audio recorded and transcribed. Pseudonyms for schools and students were put into the transcripts and we created names such that the first letter links each student with the school he or she attended.

Sampling

The selection of schools was undertaken to produce inclusive samples, considering the range of secondary schools in England. We considered the regional location of schools, selective or open nature of intake, and the type of social context where the school was located. Possible project schools were identified with the aid of a database of schools in England with the exception of two schools where members of the project team had existing connections. Potential project schools were approached to see if they would be interested in being involved in the project, and if so, access was negotiated on the basis of the perceived needs to the project (primarily the ability to support the administration of the survey and facilitate student and teacher interviews). Data collection was before the COVID 19 pandemic and schools were approached by letter or email. Schools were given details of the project, and the nature of the survey, so that informed consent to completing the survey could be obtained. Surveys were printed and delivered by post to schools. Schools were asked to conduct the survey with whole year groups and to administer the survey during a supervised session. Surveys were either collected or returned in pre-paid envelopes. School names were replaced with pseudonyms during analysis and are shown in Supplementary Table S1.

Research questions

How do students characterise the scientific and religious positions on miracles and what access do they seem to have to a range of views on how science and religion relate?

Method

SPSS 24 was used for statistical analyses. We used the chi-square test to compare different year groups' responses using the p value to assess the sta-

tistical significance of any differences we found between Year 7 and 9. We followed the convention that $p < 0.05$ is a statistically significant difference and $p < 0.001$ is highly statistically significant.⁴⁶ In both cases of chi-square tests, there were no cells having an expected count less than five, so the requirement for chi-square tests was met for all cases. Following the picture drawn from the survey, we looked at the interview study for comments that helped us to explore further the reasoning behind students' positions. The interviewees were chosen from the survey participants who agreed to attend an interview about the relationship between science and religion. We do not offer the interview analysis as a systematic study of the transcripts but rather as an indication of some of the reasoning behind the decisions we see in the survey data. A full systematic analysis of the interview will be presented elsewhere.

Results

General findings

The overall response rate to the survey was 65% (2,613 completed surveys were returned from a total of 4,014 posted out to participating schools).

Students were asked to select from a list to describe their upbringing. 39.7% of participants chose Christian, 25.8% atheist, 5.2% Muslim, 0.9% Buddhist, 0.8% Hindu, 0.6% Jewish, 22.6% other and 4.5% did not to respond to this question. In response to the question about gender, 47.0% of the survey participants chose male and 51% chose female with 2% choosing not to respond (see Supplementary Table S2). The missing data for any item was below 2% across the survey. For the majority of statements, the percentage of students choosing, 'I don't understand the question' was below 5%. For five statements, the percentage choosing this option was between 5 and 10%. For one statement, 'According to science, laws of nature determine everything that happens', 11% of respondents said they did not understand the question. We discuss this particular finding when we consider the limitations of the study later in this paper.

Students were asked to identify their religious or non-religious background. We found that 22% of students selected 'other' and within this some then identified a position that is a subcategory of a category in the list, including some who chose to tick 'other' and then wrote 'Catholic'. We reallocated the selections with this in mind, and the information are presented in Supplementary Table S3.

⁴⁶ Ellis, P.D. *The essential guide to effect sizes: statistical power, meta-analysis, and the interpretation of research results*, Cambridge: Cambridge University Press (2010).

Attitudes towards supernatural miracles

Students' attitudes towards supernatural miracles were ascertained through their response to the statement 'I believe supernatural miracles happen'. Overall, a little under a third of respondents (30.0%) believed in supernatural miracles, agreeing with the statement. A similar proportion, 29.7%, did not believe in supernatural miracles, disagreeing with the statement, leaving 27.3% of the cohort partly agreeing-partly disagreeing and 10.3% not sure. These results are shown in Table 1.

Table 1: Attitudes towards supernatural miracles

I believe supernatural miracles happen

		Strongly agree	Agree	Partly agree/ partly disagree	Disagree	Strongly disagree	Not sure	I do not understand the question
Gender	Male	7.9%	20.6%	26.5%	18.7%	17.6%	7.3%	1.4%
	Female	8.2%	23.1%	28.0%	15.9%	7.7%	13.1%	3.9%
Total		8.1%	21.9%	27.3%	17.3%	12.4%	10.4%	2.7%

Perceptions of the scientific position on miracles

Students were asked to respond to the statement 'The scientific view on miracles is that they can be explained in natural terms'. We found that 33.8% of respondent agreed with this statement.

We then looked at whether students who believe in supernatural miracles also tend to believe that science sees miracles as natural events. For the total cohort of students the findings indicate that 9.6% of students agreed that 'I believe supernatural miracles happen' and also agreed that 'The scientific view on miracles is that they can be explained in natural terms' which suggests that for these students, science may be perceived to have a different stance to their own.

Students were also asked to respond to the statement 'A good scientist can believe that supernatural miracles happen'. The findings suggest that 18.6% of the cohort disagree that a good scientist could believe in supernatural miracles. We were interested to see if there is a correlation between the profiles of scaled responses to this statement and the personal belief statement 'I believe supernatural miracles happens'. In order to do this, we selected respondents who answered each of the statements unambiguously with one of the five responses (strongly agree, agree, partly agree and partly disagree, disagree and strongly disagree) and then ran a Spearman's correlation test. The analysis

indicated that there is a positive correlation between the responses to the two statements with the strength of $r = 0.463$ and the result is statistically highly significant ($p < 0.001$).

We noted that a relatively high proportion of students indicated that they did not understand the statement 'According to science, laws of nature determine everything that happens'. We surmised that younger children may struggle to make sense of this statement and that the language we use in the statement may become more familiar as they move up in school. The data are consistent with this circumspection as we show below (Table 2). The proportions of students agreeing with the statement increased as we moved to older age groups, while the proportion disagreeing decreased as we moved to older age groups. We discuss later some reasons and consequences for this finding that students are increasingly supposing that the scientific view is that natural laws are deterministic.

The chi-square analysis shows that the association between age group and the perception of natural laws as deterministic is statistically highly significant ($\chi^2 = 109.796$, $p < 0.001$, $df = 12$). These results are shown in Table 2.

Table 2: According to science, laws of nature determine everything that happens

		Strongly agree	Agree	Partly agree/ partly disagree	Disagree	Strongly disagree	Not sure	I do not understand the question
Year Group	Year 7	5.2%	20.2%	21.7%	8.6%	3.5%	22.2%	18.7%
	Year 9	7.1%	25.3%	22.6%	10.7%	2.5%	21.8%	10.0%
	Year 11	8.3%	33.8%	21.7%	10.2%	3.0%	17.4%	5.6%
Total		6.8%	26.2%	22.0%	9.7%	3.0%	20.5%	11.8%

Discussion illustrated by selected interview findings

To extend the picture drawn from the survey, we studied the interview transcripts for comments that revealed more about the reasoning behind students' positions. As noted earlier in the analysis section, we do not offer this analysis as a systematic study of the transcripts but rather as an indication of some of the reasoning behind the decisions we see in the survey data.

The first question we explored was what students tended to say religion and science claim about miracles. Our review of the interview transcripts suggested that students typically understood religion to say that miracles were events that had a purpose and could be attributed to a deliberate act by God, and also

that they were events which necessarily had no scientific explanation. For Giselle (age 12) the criteria in religion included that 'the power was from God' and that 'God has some sort of, like, intention behind them to show somebody something, or to give a sign.' Danny (age 14) perceived that the religious definition of a miracle was an 'act of God'. The laws of science and/or of nature were referred to by a few students as part of their explanation. For example Declan (age 16) felt that in religion it is 'a spontaneous contravention of nature.' Henrietta (age 13) referred explicitly to 'the laws of physics' when she expressed the view that events presented as miracles might not really be miracles as 'we might not be able to explain something at the moment because we don't have enough like technology and stuff' and 'if we knew more about the universe and other places where the laws of physics that we know at the moment don't act then we could explain things on earth that we now can't explain.' Henrietta saw this as a basis to say that such an event was not really a miracle and further defined herself as an atheist. Denis (age 15) was another student who referred to laws. He was of the view that 'scientists would probably say miracles actually never happened' and echoed this position when he gave his own view that, 'I mean I would find it very hard to believe that a miracle could just actually happen. If we've sort of... if scientists have proven all of these ideas are physics and chemistry and then for something to come along and suspend those laws, I would find that quite hard to believe.'

With this said, most of the students interviewed did not use philosophical terms like natural law, scientific law or physical law to set up the idea of a natural order but rather the notion that objects can be relied upon to behave in particular ways seemed to be part of their everyday understanding of what science says about how reality works. Jill (age 14) explained that 'religion thinks that God made that miracle or that happen, but science says that there has to be something physical that made that happen. For Glenn (age 11) if science could explain a miracle, it would no longer be a miracle and he added that he was unsure about what to believe 'because I kind of believe the miracles could have happened, but then I also believe that there might be a scientific explanation for them. So I'm not actually entirely sure.' Iris (age 11) similarly felt that a 'real' miracle was one where there was no scientific explanation, saying that 'Some miracles are coincidences or have scientific explanations but others are real miracles'. Damien (age 14) said 'science says that miracles are like a coincidence' and Edward (age 12) felt that science would see it as a 'fluke' and Giselle felt that science would say it's 'a bit of a fluke' 'or it could have been a trick'.

We note the significant proportion of students who perceive that science has a position on how to explain miracles. Thus for more than a third of respondents, the scientific view on miracles was that they could be explained naturally. We also note that 9.6% of the cohort participating in the survey (assuming that they appreciated the significance of 'supernatural' in the phrase 'supernatural miracles') appeared to perceive science to take a position that differed from

their own on the possibility of supernatural miracles. These students agreed that 'I believe supernatural miracles happen' and also agreed that 'The scientific view on miracles is that they can be explained in natural terms'.

The interviews also suggested that a proportion of students' perceptions of science appears to be similar to scientism – which is to say that everything that happens can be explained naturally and the universe can ultimately be known through science alone. Two examples as such are Finn (age 13) and Fraser (age 11) who both felt that a scientist would – as they did – reject the possibility of miracles on the basis that they were 'not realistic'. Fraser said of miracles that science said 'they're impossible [and] none of them could actually happen.' Fraser recalled that in the Bible it is said that Jesus turned water to wine and said, 'I can only explain that as he had like a purple powder or something and he put it in the wine when he put his hand in it ... and it made it into a different colour and made it taste like wine, but it actually wasn't, it was still water.' Interestingly Irma (age 13) felt that although science provided truth, that was not what always what mattered most when deciding what to believe. She added that in her view 'Even if it's not true you can still believe it'. Irma explained that for her, religion was 'based on stories and myths' and also that 'myths dig deeper than scientific truths.'

We note that the survey findings suggest that 18.6% of the cohort disagreed that a good scientist could believe in supernatural miracles. We also note that a significant proportion of students who themselves did not believe in supernatural miracles also disagreed that a good scientist could believe in them (35.2%). On the other hand, a majority of students who believed in supernatural miracles also agreed that a good scientist can believe this too (62.4%). These findings suggest that the potential for a student to feel that their belief in supernatural miracles should sway them against further study of science might be reduced by a tendency to suppose that scientists with a religious faith have ways to accommodate the apparent dichotomy.

In our previous analysis of these students' reasoning about origins, we noticed their tendency to associate science with fact, proof and evidence while religion was associated with choice and entitlement.⁴⁷ The current analysis of the data indicates a similar dichotomy between students' perceptions of a scientist as someone who would require evidence and proof, and contrastingly perceptions of a religious person who would accept what is written in a holy book without feeling a need to question it. For example Fifi (age 15) felt that a scientist would reject the possibility of miracles on the basis that, 'there's not actual evidence' and further that a scientist would be dismissive of religious

47 Billingsley, B., Brock, R., Taber, K.S. & Riga, F. 'How students view the boundaries between their Science and Religious Education Concerning the Origins of Life and the Universe', *Science Education* (2016), 459-482.

testimony on the basis that it is just something 'written down'. Denis also contrasted the attitudes held by scientific and religious people saying that 'as a theologian [...] you can study the Biblical text but you can't prove anything I would say'. Isobel (age 13) who described herself as religious similarly felt that 'a good scientist' would need 'evidence or proof' to believe in a miracle and that 'in science today, we always rely on evidence to back up answers'. Isobel expressed the view that religion was 'an option' and more open to question than science because 'all of science has been proven [and it's] a lot more difficult to question than just something that someone has written down thousands of years ago.'

This raises the question – can someone be religious and also have a scientific attitude when reading and evaluating what is written in a religious holy book. Many students including those who had a religious faith seemed to see this as a paradox. Horace (age 13) said that a religious person would think a miracle is 'just God but a scientific person would want proof and I don't think it would work'. Isobel said she knew that there were scientists with a religious faith explaining that 'I'm often like in church and thinking, praying,' and that 'I know scientists that pray.' At the same time she perceived believing in miracles to be something difficult for a scientist saying, 'I think you do have to rely more on evidence for science' and that a scientist would 'probably find it very difficult to explain [miracles]'

Finn (age 13) who was secure in his own position that miracles do not happen perceived the decision about what to believe to be clear-cut with no middle ground. Finn said that religious people believed that miracles 'happen all the time' and that it's just what people believe in. Like if they're religious they'll go for the religious one, if they're scientific they'll go for the science one.' Gwendoline (age 14) who explained that 'I am not religious' felt that miracles were 'luck'. Her position was that 'obviously scientists can be scientists and Christians, so they are entitled to both'.

Joy (age 14) explained that 'I'm a Christian, I'm quite religious' and expressed the view that, 'I don't think that if you were religious it would be easy to be a good scientist ... they may feel that they're being turned against their religion if they became a scientist ... every day you're trying to prove your religion wrong. So I don't think that would really work out.' There were also students who perceived science and religion to conflict on many of the topics addressed in the interview but who did not perceive this to be a barrier to pursuing a career in science. Jayne (age 13) was unsure what she believed herself about miracles, explaining that 'my mum's sort of spiritually religious so I believe some of that, but more of science 'cos I think it makes more sense.' She echoed many other students by saying that scientists would reject or explain away claims of miracles saying that 'if it was something like healing they'd say that it was lucky, but something like water into wine I think they'd probably say that was, maybe wrong or very unlikely.' Although Jayne felt that 'scientists wouldn't be

religious' she also felt that 'a religious person' could still become a scientist if they had not 'thought about that aspect of science or something.'

Limitations and opportunities for further research

There are some limitations with the design and implementation of this study. Firstly, the purposes of the instruments used in this study are relatively narrow – in that they are designed to probe students' positions on apparent contradictions between science and religion. This means that throughout the study we are pressing students to formulate their thinking in relation to the structure we present – for example, asking them for a view of the scientific position, the religious position and their own position. This pattern of questioning is repeated throughout the questionnaire and is then probed further in the interviews. In some ways, the instruments are guiding students to explore their own thinking using the structure we offer and we know from our earlier studies that, for some students, this research will have been the first time they reflect on these questions. In other words, the research may not reveal an authentic picture of how students spontaneously reason about science and religion but rather reveals how students reason about the apparent contradictions that we draw to their attention.

Secondly, one of the challenges with this study (in contrast with our previous work looking at students' reasoning about origins) is that the language and metaphysical deliberation in scholarship associated with scientific and religious discourse about miracles is more complex and less familiar to students than the language and terminology associated with scientific and religious ideas about origins. This became apparent during the preliminary work and focus groups we conducted to prepare the statements for the questionnaire. We wanted nonetheless to include miracles in the study and to probe for some of the positions described in scholarship. One of the statements in the survey is designed to indicate the extent to which students see the scientific position as deterministic and is 'According to science, laws of nature determine everything that happens'. We have chosen not to include this statement in the current analysis not least because 11.8% of respondents said they did not understand the question. At the same time, the findings from this study suggest that students, including the younger students (aged 11), have an intuitive sense that everyday objects seem to adhere to expected patterns of behaviour and that there is the potential for science and religion to have different positions on how these apparent patterns should be understood. This leads us to say that there is a case for looking again at students' perceptions of the scientific position on reality and we intend to explore this further in future research. We surmise that as students move into the later years they become more familiar with terminology like 'laws of nature' and 'scientific laws' and we wonder what students understand these terms to mean and the extent to which students

perceive scientific laws as necessarily prescriptive and the scientific position on reality as necessarily deterministic.

Conclusion and recommendations

The data reviewed for this study suggest that in many cases, students' reasoning about what science and religion say about miracles leans them towards a perception of conflict. Students widely consider that having a scientific attitude means taking evidence seriously whereas having a religious attitude seems to include believing that evidence is inconsequential; many perceive that for an event to fit the criteria for a miracle in religion, it necessarily cannot be explained by science; meanwhile the position they present as the scientific view on miracles is that they can always be explained as part of the natural order. Students' reasoning included the idea that the decision about what to believe about miracles is straightforward for those who characterise themselves either as scientific or as religious. Several students also expressed the view that if someone is both religious and scientific then the choice is more difficult and they did not know how (if at all) scientists resolved the dichotomy.

The analysis also suggested that students' access to some of the arguments that scholars espouse can be affected by subject compartmentalisation and the types of questions they perceive it to be appropriate to raise in a science lesson. Several students expressed the view that it would not be appropriate to put questions that have a religious aspect to a science teacher, for instance, Joy (age 15) explained that 'I don't think it's the kind of thing you'd ask your science teacher, just because it's not ... Things with science and religion, I just don't see them linking with science lessons.'

Drawing these findings together we conclude that school students would benefit from teaching to help them to access and appreciate more nuanced and sophisticated ways of addressing cross-disciplinary topics. The study supports the case that although subject compartmentalisation has important practical and pedagogical benefits, the education system needs to be aware of some the challenges this compartmentalisation creates for school students' capacities to gain insight into how science relates to Big Questions and other domains of knowledge. We surmise that teaching with some cross-disciplinary elements may be a step towards overcoming the disconnection that many people say they feel from science - as noted by O'Connor and Joffe⁴⁸. As such, it seems pertinent to ask how this objective can be achieved.

One option is for science teachers and RE teachers to co-design an RE lesson about miracles. This would provide students with opportunities to discuss

48 O'Connor, C. & Joffe H. 'Social representations of brain research exploring public (dis) engagement with contemporary neuroscience', *Science Communication* (2014) 36, 617-645.

methodological and epistemological questions about whether it is possible to investigate a question scientifically when the evidence presented is testimonial and when the conditions cannot be recreated. A session about miracles is also an opportunity to highlight the diversity of the scientific community by talking about scientists who adopt different metaphysical positions. This could include learning about scientists who adopt a naturalistic and scientific attitude towards accounts of miracles, those who describe religious accounts of apparent miracles as metaphors and also those who believe that the natural order is created and sustained by a supernatural deity who, in some accounts, very occasionally intervenes directly with material aspects of the universe. The notion that in religion evidence and science do not matter could be countered by emphasising the methods of investigation that scholars apply when scrutinising testimonies of miracles.

Another option would be a series of lunchtime discussions about the philosophy and history of science. This could give students new insights into the interests and beliefs of scientists whose names are familiar to them such as Galileo, Newton and Bacon. The historian of science, John Hedley Brooke notes that debate about the relationship between science and religion is underpinned by the assertion that there is an objective reality and that science and religion are both truth-seeking disciplines which ask questions about that reality.⁴⁹ Brooke explains that this was Galileo's argument when he asserted that science and religion are mostly concerned with different types of truth and it was also a point made by Bacon when he argued that nature and the Bible share one author and so cannot truly be in conflict. Throughout the history of the debate, scholars have sought ways to capture the natures of science and religion and they have also asked metaphysical questions about demarcation issues and the ultimate nature of reality.

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⁴⁹ Brooke, J.H. *op. cit.*, (21).