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Scientism, creationism or category error? A cross-age survey of secondary school students' perceptions of the relationships between science and religion

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We report on a survey of 1717 students at two different points of their secondary school education. This survey is designed to discover their reasoning about scientific and religious accounts of the origins of the universe and life. The study was motivated by a concern, based on previous research, that factors such as the compartmentalised curriculum may limit students' progression in interdisciplinary reasoning and their capacities to appreciate why science and religion are not necessarily incompatible. To investigate these matters, we gathered data in seven secondary schools in England. The findings indicated that a significant proportion of students are working with a poor understanding of the limits of science and of the range of scholarly positions on the nature of religious explanation. The implications of the results for educational theory and practice are discussed.

Keywords: science and religion; worldviews; student perceptions; nature of science; conceptual integration; attitudes towards science; attitudes towards religion; epistemic insight

Introduction

There is a widespread perception among school students that science and religion take conflicting positions on how to explain the origins of the universe and of life (Reiss, 2008; Mansour & Wegerif, 2013; Francis & Fulljames, 2017; Konnemann *et al*., 2018). The question that motivates this study is to wonder about the extent to which school students have access to the idea that views, other than a conflict view, can be intellectually defended (see e.g. Brooke & Cantor, 1998, Polkinghorne, 2013; Peters, 2019).

While scholars who take diverse positions on how science and religion relate have access to the epistemic insight—that there can be different types of explanation—our hypothesis is that students are mostly confined to what we call *narrative* approaches in which science and religion are perceived to compete in a single explanatory category.

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The current study is set in England, where, as we will explain, the education system sets an expectation that students in secondary school will come to understand that a perception of conflict between science and religion is not a necessary position. Thus, while the question of how to relate scientific and religious explanations concerning the existence of the universe and life is contentious, it is uncontroversial to say that school students need a level of epistemic insight if they are to appreciate that and why a range of views of the relationship exist.

The methodology for this study is a large-scale survey which seeks to understand students' perceptions of how science and religion relate and also the reasoning underpinning their positions. In the sections that follow, we explain the rationale and methodology in more detail.

Conceptual framework

Scholarly perspectives on ways to relate science and religion

The position that scientific and religious explanations of the origins of life and the universe are not necessarily incompatible, is set out in current and historical reviews of science and religion. A science historian, John Brooke (1991) explains that scientists working in a Christian tradition in the seventeenth century presented their work as the search for order in a universe regulated by an intelligent Creator:

> *A created universe, unlike one that had always existed, was one in which the Creator had been free to exercise His will in devising the laws that nature should obey. A doctrine of creation could give coherence to scientific endeavour insofar as it implied a dependable order behind the flux of nature.*

Frances Bacon was one such early modern scientist and his position was that apparent conflicts were errors of human interpretation. He argued that God authored both the book of words (the Bible) and the book of His works (nature) and so these two books cannot be contradictory (Brooke, 1991).

In modern times, debates about the relationships between science and religion have been dominated by apparent conflicts between the creation story of the Abrahamic religions (Judaism, Christianity and Islam) and scientific theories about the origins of life and the universe. There are many scientists and theologians who argue that it is not necessary to see these as conflicting explanations (see e.g. Berry, 1996; Ward, 2008). The modern Catholic Church (Squires, 2014) and the Head of the Church of England (Bates, 2006) are among those who argue that the Christian doctrine of creation is not in competition with science to explain the processes that brought about life but belongs instead in a different explanatory category. The central ideas are that while science seeks to explain the mechanisms and processes that brought the universe and living things into existence, the Abrahamic creation story uses allegorical language to address questions about ultimate meaning—or in other words, teleological questions—about why anything exists at all (Bausor & Poole, 2002; Alexander, 2014). In contrast, Young Earth Creationism is one of a number of so-called episodic creationist theories, which draw on a literal reading of the Abrahamic creation story to argue that creation proceeded through a series of episodic supernatural events. While episodic creationist theories take different positions on the age of the earth

(Brooke, 1991), they have in common that they reject the possibility of 'macro' evolution—that is, evolution which leads to completely new forms of living things and assert instead that each species was created individually by God (Scott, 2005). Over time, it has become increasingly routine to label these stances as 'creationism'.

Another stance which describes scientific and religious explanations of origins as conflicting begins with a commitment to scientism—the belief that science provides the only valid route to knowledge and that nothing exists beyond the material universe (Stenmark, 2018). Although a few scientists and philosophers have claimed that scientism is an essential characteristic of a scientific worldview, this claim is rejected by the vast majority of philosophers of science and science educators who state that scientism is not a necessary presupposition of science (Cobern, 2000; Hutchinson, 2011).

We turn now to the 'god of the gaps' position which is said to be a 'self-defeating' approach of 'pointing to gaps in current scientific explanations, saying "That's God"' (Poole, 2008). Objections to this approach were raised by physicist and Christian Charles Coulson who said of God that

> *If He is in nature at all, He must be there right from the start, and all the way through it … When we come to the scientifically unknown, our correct policy is not to rejoice because we have found God: it is to become better scientists. (Coulson, 1955)*

The diagrams in Figure 1 are designed to visually represent a selection of stances on how science and religion relate. The stance of accepting both evolutionary science and theistic creation has a number of labels (Peters & Hewlett, 2010; Alexander, 2014). Our preferred label in the current diagram is 'Created natural mechanism'.

Children's views of science and religion

Studies of school students' views of how science and religion relate frequently focus on discovering how they conceptualise the natures of science and religion. Fulljames, Gibson and Francis (1991) reported on the basis of a large-scale survey in the United Kingdom that a majority of secondary schools students saw science and religion as opposed, and that this sense of opposition seemed to be underpinned by a perception

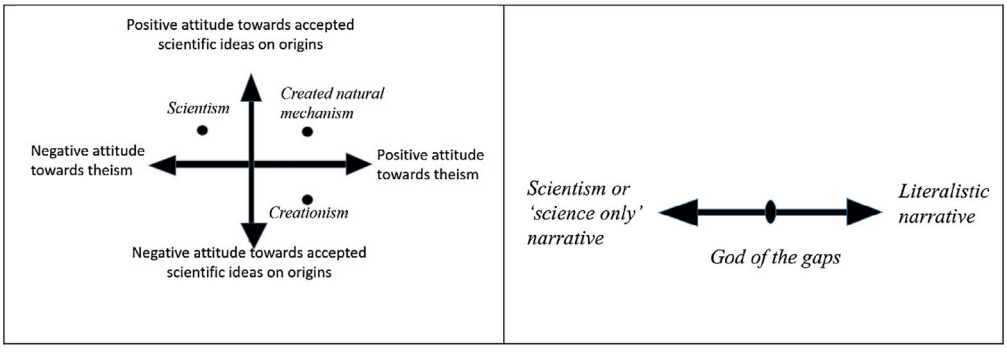

Figure 1. Stances on the relationships between scientific and religious accounts of origins [Colour figure can be viewed at wileyonlinelibrary.com]

that religion requires a commitment to creationism and a perception that science requires a commitment to scientism.

Piaget's description of stages of development informed Goldman (1964, 1965) when he constructed his theory about the stages of religious cognitive development. Goldman gave an account of the developments he saw in students' religious thinking which in some ways, mirrors Piaget's stages of intellectual development. In particular, Goldman reported that students generally only developed the ability to draw allegorical meanings from Biblical narratives when they reached adolescence—at about 13 years old. This is similar to the age that Piaget gave for when students start mastering formal operations, and can begin to interact with abstract conceptual representations—such as those that are common in science.

Goldman argued that students' development in religious thinking could be accelerated if they were asked to think critically about ways to interpret texts in their religious studies lessons. Goldman identified a lack of epistemic skill and knowledge as reasons why school students tended to conflate creation and creationism. This conflation, he said is an underpinning cause for the misconception where it is held that science and religion are necessarily in conflict.

One of the recognised complexities when studying students' religious development is that children's thinking about Big Questions can change as they move from social context to social context (Abo-Zena & Midgette, 2019). Further, the role of parents is a significant factor, especially in the early years (Bunnell *et al*., 2018), though we are not discussing this factor, as the focus of this study is the role of formal education.

A study by Hansson and Redfors (2007) with 18-19-year-old students in Sweden found that a majority of students associated Physics with a commitment to scientism. Konnemann *et al*. (2016) report a survey of 1672 high school students drawn from an area with a strong Catholic tradition. In their discussion of their findings, the authors conclude that in a class of 25 students a teacher can typically expect to find five students with a scientistic attitude profile and four more with a borderline scientistic profile. In contrast, there might only be one student who has a creationist profile.

In our current study, we are not only interested in students' attitudes to creationism and scientism, but also in discerning the extent to which students are confined to stances that place science and religion in one explanatory category. We say more about this below.

Epistemological stances expressed in science education

A focus for our study is whether students have sufficient insight into the nature and limits of science to make sense of the argument that science and religion may be working in different explanatory categories when they seek to explain origins. The premise that this reasoning is intellectually challenging was investigated by Reich (1991) who concluded that children are unlikely to achieve this understanding unless they have effective teaching.

The survey we designed for this study draws on previous research which points to weaknesses in children's understanding of science that could foreseeably affect how they reason about science and religion. A recurrent theme in science education

for several decades has been concerned with the experiences students have in science lessons can suggest to them that science is a boundless set of facts (Osborne & Collins, 2001). Cobern (2000) drew attention to the frequent use of so-called recipe investigations in science lessons and argued that these lead children to suppose that scientists propose theories, these theories are experimentally tested, and then, are discounted or proven true. This prompted a wave of curriculum changes designed to portray science in more authentic and positive ways (Driver *et al.*, 1996; Tytler, 2007). One aspect of these reforms was to stipulate that students should be taught that science changes over time and another was to teach students that science has limits. In Australia, for example, the Curriculum and Standards Framework for the state of Victoria stipulated that students should be taught to 'recognise the limitations of science' (DEET, 2000). Similarly the 2007 science curriculum for England emphasised that 'there are some questions that science cannot currently answer, and some that science cannot address' (QCA, 2007). Both of these curricula have since been revised again and the most recently drafted science curriculum in England now states that students should learn to appreciate 'the power and limitations of science' (DfE, 2015). The Next Generation Science Standards (NGSS) in the U.S. put an emphasis on developing 'an understanding of the nature of science with particular reference to the practices that underpin working scientifically such as planning an enquiry' (Duschl & Bybee, 2014; Pruitt, 2014). Lombrozo *et al* (2008) recommend that students be taught that science does not have the power to resolve questions about the existence of God, gods and other supernatural entities. This point pertains to teaching that 'a scientific theory is a substantiated explanation of some aspect of the natural world' (Achieve Inc, 2013). While some teachers have taken on board the need to talk about changes to science over time, most have resisted calls about the power and limits of science and one reason for this is likely to be a lack of established methods of assessment (Lederman *et al.*, 2014). In a recent study, Erduran has identified the need for a teacher's professional development programme in order to nurture teachers' pedagogical skills in teaching argumentation in both science and religious education, drawing out implications for teaching and learning, including understanding the power and limitations of both science and religion in gaining truth (2020).

One further area of research, we review in this section is the possibility that the labelling of evolution as a theory may lead some children to suppose that it is not yet sufficiently certain to have the status of fact or law (Sinatra *et al.*, 2003). The potential for a misconstrued perception of what is meant by a scientific theory to influence students' attitudes to creationism has been a particular focus in the United States where levels of resistance to evolution by school students are persistently high (Reiss, 2010). Lombrozo and colleagues (2008) carried out a survey study with 96 undergraduate students and concluded that as predicted, acceptance of evolution correlated negatively with religiosity and positively with understanding of the nature of science. Interviews with students in the United Kingdom not only showed that the term theory is sometimes misunderstood in this context (Taber *et al.*, 2015), but also indicate that while some students say these theories are uncertain, some other students say that evolution and the Big Bang theory have been scientifically tested and are facts (Billingsley *et al.*, 2016).

Religions and religious education in England

Although there is an 'established' Church of England (i.e. an official state Church), England is a multi-cultural society. The most recent (2011) census found that in England 59% of respondents gave their religion as Christian; while 25% claimed to be of no religion and 7% of census respondents chose the option of not responding to this question (ONS, 2012). In addition, 5% of respondents identified themselves as Muslim, with another 5% identifying themselves as belonging to other religions including Hinduism, Buddhism, Sikhism and Judaism.

Most schools in England are not associated with a particular religion and are open to all children regardless of faith background. However, a significant minority (about a third) of state schools *do* have a 'religious character'. Religious education (RE) is provided in the vast majority of schools and this includes government-run (state) schools (Francis *et al.*, 2018). The subject is controlled in England through S.A.C.R.E.s (locally based Standing Advisory Councils for RE) or, in the cases of church schools, the relevant religious communities. Academies including Free Schools can in some cases develop their own RE syllabus while needing to meet certain requirements. A non-statutory National Curriculum Framework for RE was published in 2004 designed to meet the needs of a multi-cultural, liberal-democratic society (Schreiner, 2000; Jackson, 2004; Barnes, 2014). The vision was that teaching would be non-confessional (meaning that a commitment to any particular faith is not openly encouraged) and would help students to critically examine their own beliefs and other religious and non-religious positions. The curriculum successfully acknowledged pluralism, but was criticised by school inspectors for failing to convey to teachers a set of achievable aims for their subject (OFSTED, 2010). The 2004 Framework has since been replaced by a new National Framework (REC, 2013). Many of the aims of the previous version have been transferred to the current guidance, and for example, the new Framework includes the recommendation that students in lower secondary school (age 11–14) explore the relationship between science and religion. The objective in the current Framework states that: 'Students develop insight into an understanding of why some people argue that science and religion can be compatible and others argue that they cannot' (REC, 2013). As such, the curriculum documents in England state that students should develop their understanding of science, religion and of how science and religion relate. In particular, the science curriculum stipulates that children should be taught about the nature, power and limits of science. This could include exploring why questions might be more or less amenable to science. The RE classroom could then extend this discussion by looking more closely at the argument that religious accounts of origins are not necessarily addressing scientific questions.

Research methods

The quantitative study reported here is embedded in a long running project, the LASAR (Learning about Science and Religion) project, looking at students' developing capacities to reason about interdisciplinary questions relating to science and religion. The survey design was informed by a conceptual framework developed and

tested by Billingsley (2004) followed by exploratory interviews with students in Year 9 (13 year olds) (Billingsley *et al.*, 2013). We also conducted an exploratory study with open- and closed-ended questions used for item generation (n = 60) with student in Years 8 (12 year olds) and 11 (15 year olds) and a small-scale survey (n = 109) with students in Year 9 (Taber *et al.*, 2011). 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). Focus groups were organised in four schools by contacting secondary science school 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 were asked to complete a survey that included many of the questions in the current study. Students were told that participating in the survey is voluntary and they can skip any question they do not want to answer. The survey included a box to tick if students wanted to take part in focus group discussions to explore the themes in the survey further. The class teacher was provided with letters to go home and focus groups only took place for the students who provided their own and their parents' permission. In total, three focus group discussion took place with five students in each group. Participants were also told that their details would be anonymised and their responses would not affect their grades.

We report now on our main study with 1717 participants (Years 7, 9). Throughout these stages of development, we have focused our research around four 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 questionnaire for the survey consisted of 41 5-point (strongly agree—agree—partly agree/partly disagree—disagree—strongly disagree) Likert items (Cohen *et al.*, 2000). For each of the Likert items, students were offered two additional non-scale response options to avoid them feeling forced into a response, either if they did not understand the statement or if they were not sure how to respond. In addition, the order in which items were presented was arranged so that the themes explored were mixed-up through the instrument, with closely related items generally being separated to reduce the effect of students selecting a response option that was influenced unduly by their previous response. The introductory section of the questionnaire explained that students could skip any question they did not want to answer, and that students' real names would not be published.

This report focuses only on the sections of the questionnaire that sought students' reasoning about origins and their perceptions of their experiences in the two subject classrooms.

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 six statements, the percentage choosing this option was between 5 and 10%. For two statements, 'According to science, laws of nature determine everything that happens' and 'The scientific idea about how life began fits with the religious idea about how life began', 14.4% and 13.2% (respectively) of respondents said they did not understand the question.

Research questions

While scholars who take diverse positions on how science and religion relate have access to the notion of different categories of explanation, our hypothesis is that students are mostly confined to so-called narrative approaches in which science and religion occupy a single explanatory category. As such our research questions and the rationale behind them are:

What are students' attitudes towards different explanations of origins? And do these attitudes vary with age group?

To assess students' attitudes to scientific theories of origins we included the statements, 'I believe the scientific theory that the whole Universe began with the Big Bang' and 'I accept the scientific theory of evolution as the explanation for all the different kinds of life on Earth'. Students' belief in creation by God was assessed via the statement, 'I believe that God created the Universe'. Building on recommendations by previous studies to test for students' attitudes to creationist beliefs (Francis & Greer, 2001) we included in the questionnaire, 'I believe that God put life on earth by separately creating each type of living thing, such as horses, fish, people and so on'.

What are students' perceptions of the power and limits of science? And do these perceptions vary with age group?

The set of statements for this research question explores our hypothesis that for some students, scientism is an uncritical rather than a considered stance. To assess students' attitudes to scientism and drawing on previous studies such as by Astley and Francis (2010) the questionnaire included the statement, 'One day we may be able to explain the whole universe using science alone'. To look at whether students perceive that science is limited to studying the natural world we added a further statement: 'Religion is a set of beliefs that can be proved or disproved scientifically'. This statement would be rejected by the vast majority of scholars and science education specialists (see e.g. Lombrozo *et al.*, 2008) as science is generally understood to be limited to studying natural phenomena and mechanisms.

To what extent do students think that science and religion offer contradicting narratives about 'how' life and the universe came to be? And does their thinking vary with age group?

In relation to this research question, the survey included the two statements: 'The scientific idea about how the universe began fits with the religious idea about how the universe began' and 'The scientific idea about how life began fits with the religious idea about how life began'. The phrasing of these statements was developed with input by students in lower secondary school to ensure the wording was accessible to this age group. We chose the words 'fit together' to describe the relationship because the term 'compatible' was not understood by all the children in our focus groups. We also worded these statements positively in part to keep the phrasing straightforward

and in part because we balanced the number of positive and negative statements across the survey. The response options include agree, partly agree/partly disagree and disagree. Students taking part in focus groups who we judged to perceive science and religion to provide contradictory narratives chose the 'disagree' options while those who appreciated that religious narratives are open to different interpretations tended to choose 'partly agree/partly disagree'.

While these two statements explored the relationship between science and religion in the narrative 'how' category (how the universe began, how life began), a further statement explored students' perceptions of the relationship more generally and this was, 'You can believe both science and religion' (Figure 2).

Sample

The survey was completed by 1717 students from Years 7 (age 11) and 9 (age 13) in seven schools (1.6% did not identify their gender in the survey). The selection of schools was undertaken to produce inclusive samples, considering the range of secondary schools in the United Kingdom. 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). 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 paid envelopes. School names were replaced with pseudonyms during analysis.

School information

Table 1 sets out the composition of the sample by school. Students from each of the schools contributed to the samples in each of the two Year groups and it is notable that there was a similar pattern of contribution by school to the overall samples in Year 7 and Year 9. Table 2 shows the composition of the sample by Year group.

Religious background

Students were asked to select from a list to describe their upbringing. About 41.1% of participants chose Christian, 24.9% atheist, 5.2% Muslim, 0.8% Buddhist, 0.5% Hindu, 0.5% Jewish, 22.5% other and 4.7% did not respond to this question. In response to the question about gender, 48.2% of the survey participants chose male and 50.1% chose female with 1.6% choosing not to respond.

ATTITUDES TOWARDS DIFFERENT EXPLANATIONS OF ORIGINS
I believe the scientific theory that the whole Universe began with the Big Bang.
I accept the scientific theory of evolution as the explanation for all the different kinds of life on Earth.
I believe that God created the Universe
I believe that God put life on earth by separately creating each type of living thing, such as horses, fish, people and so on.
POWER AND LIMITS OF SCIENCE
One day we may be able to explain the whole universe using science alone
Religion is a set of beliefs that can be proved or disproved scientifically.
RELATIONSHIP
The scientific idea about how the universe began fits with the religious idea about how the universe began.
The scientific idea about how life began fits with the religious idea about how life began.
You can believe both science and religion.

Figure 2. Statements in the questionnaire analysed for this paper

Table 1. Composition of survey sample by school

School	School type/Gender/religious character	Region/Percentage of children eligible for free school meals	Number of respondents	Percentage of students from this school in whole sample		
				Year 7 (%)	Year 9 (%)	Percentage of students from this school in whole sample (%)
Dalesford	State funded/boys/none	North Yorkshire/2.1%	202	11.1%	12.5%	11.8
Julius	State funded/mixed/none	Somerset/not recorded	214	13.5	11.3	12.5
Eastgate	State funded/mixed/none	Durham/14.9%	277	16.4	15.8	16.1
Fieldwell	State funded/mixed/none	Wiltshire/10.5%	312	18.4	17.9	18.2
Girlake	State funded/mixed/none	Berkshire/4.9%	192	10.5	11.9	11.2
Hamlet	State funded/mixed/none	Cambridgeshire/6.7%	383	22.7	21.9	22.3
Immaculate	Independent/girls/Roman Catholic	Cambridgeshire/0%	137	7.3	8.7	8.0

Table 2. Composition of sample by year group

Year group	Number of respondents	Percentage of whole sample (%)
7	912	53.1
9	805	46.9
Total	1717	100.0

Analysis

SPSS was used for statistical analyses. We used the chi-square test to compare different year groups' responses, using the p value to assess the statistical significance of any differences we found between Year 7 and 9. We followed the convention that $p < .05$ is a statistically significant difference and $p < .001$ is highly statistically significant (Ellis, 2010). In all chi-square tests, there were no cells having an expected count less than five, so the requirement for chi-square test was met for all cases. For each statement, we also removed 'partly agree and partly disagree' and 'not sure' responses from the data, and then, ran a one sample chi-square test against the null hypothesis that the rate of responses to the strongly agree or agree options compared to disagree or strongly disagree options occur with equal probabilities. We did this to check whether the data are showing a clear tendency by students to choose agreement or disagreement—or whether the balance of difference we see in the data between these two groups (agree and disagree) could also be explained as by chance.

Findings

What are students' attitudes to scientific theories of origins? What are their attitudes to scientific theories for those who do and who do not believe in creation by God? And do these attitudes vary with age group?

Just over half the pupils (51.6%) strongly agreed or agreed with the statement that 'I believe the scientific theory that the whole Universe began with the Big Bang' while 14.8% disagreed or strongly disagreed with this statement (see Figure 3). We also found that 53.4% agreed or strongly agreed with the statement 'I accept the scientific theory of evolution as the explanation for all the different kinds of life on Earth', with just over 1 in 10 (11.4%) not accepting this view (6.0% disagree and 5.4% strongly disagree). About a third of students neither agreed nor disagreed or were unsure with each of these statements (Figure 4).

The proportion of students who show clear commitment (strongly agree + agree) to the statement 'I believe the scientific theory that the whole Universe began with the Big Bang' increases as we move to the older age group (see Figure 3). Further analysis showed that the change in the pattern of response between Year 7 and Year 9 for this statement is highly statistically significant ($\chi^2 = 19.321$, $p = .002$, df = 5), which may suggest that school students become more confident about scientific theories as they get older. Moreover, the null hypothesis that the rate of responses (both years) to the strongly agree or agree options compared to disagree or strongly

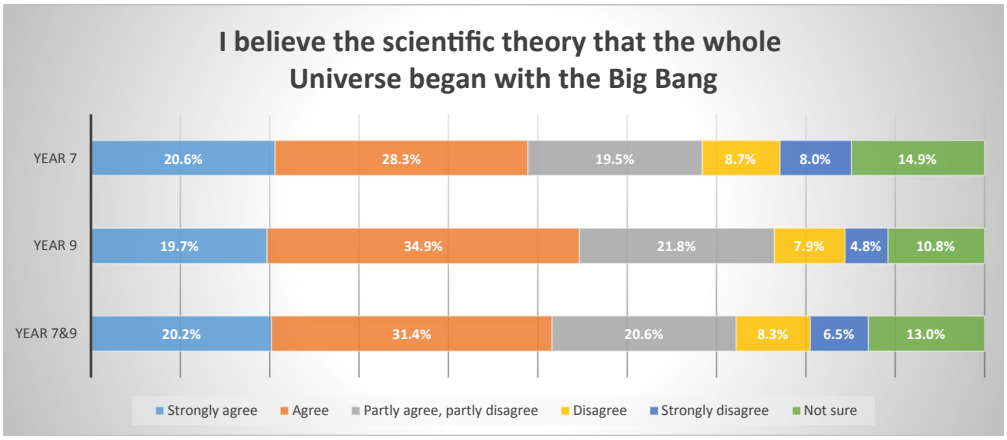

Figure 3. 'I believe the scientific theory that the whole Universe began with the Big Bang' [Colour figure can be viewed at wileyonlinelibrary.com]

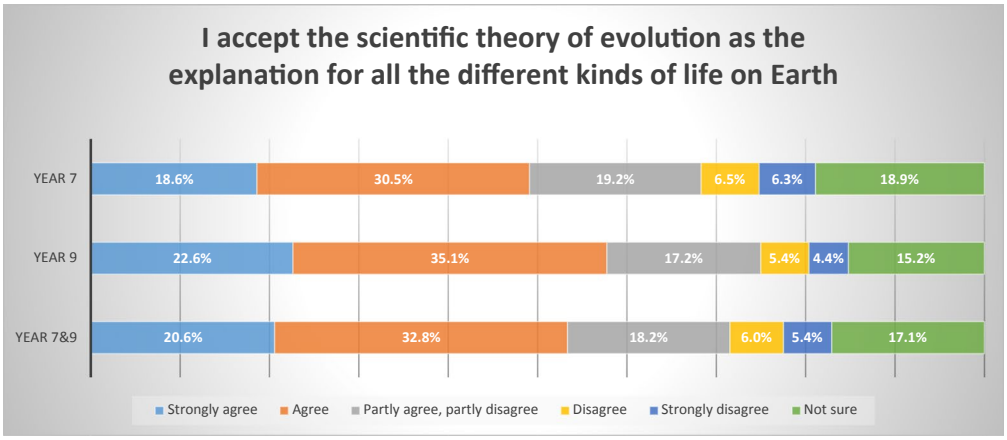

Figure 4. 'I accept the scientific theory of evolution as the explanation for all the different kinds of life on Earth' [Colour figure can be viewed at wileyonlinelibrary.com]

disagree options occurred with the same probability was rejected (one sample chi-square test, $p < .001$).

The level of agreement for the statement 'I accept the scientific theory of evolution as the explanation for all the kinds of life on Earth' is shown in the Figure 4, and the change in the pattern is statistically significant when Year 7 and 9 are compared ($\chi^2 = 12.275$, $p = .031$, df = 5). Again, this comparison suggests that school students become more confident about scientific theories as they get older. Moreover, the null hypothesis that the rate of responses (both years) to the strongly agree or agree options compared to disagree or strongly disagree options occurred with the same probability was rejected (one sample chi-square test, $p < .001$).

In this cohort, a quarter of students (22.7%) strongly agreed or agreed with the statement 'I believe that God created the universe' while about two-fifth (40.9%)

disagreed or strongly disagreed. The proportion of students in the two year groups who believe that God created the universe decreases as we move to the older age group (see Figure 5). The change in the pattern of responses is highly statistically significant between Years 7 and 9 ($\chi^2 = 29.673$, $p < .001$, df = 5). Moreover, the null hypothesis that the rate of responses (both years) to the strongly agree or agree options compared to disagree or strongly disagree options occurred with the same probability was rejected (one sample chi-square test, $p < .001$).

Turning to students' attitudes to episodic creationist beliefs, we found that about a fifth (22.3%) of the total cohort and 58.6% of those who reported that they had a religious upbringing (n = 397) strongly agreed or agreed with the statement, 'I believe that God put life on earth by separately creating each type of living thing, such as horses, fish, people and so on'. The proportion of students with a religious upbringing who accept this stance (strongly agree + agree) is less for students in the older year group. Conversely the proportion of students with a religious upbringing who reject this stance (disagree + strongly disagree) is higher for students in Year 9 (see Figure 6). The change in the pattern of responses between Year 7 and Year 9 is statistically significant ($\chi^2 = 11.934$, $p = .036$, df = 5). Again, the null hypothesis that the rate of responses (both years) to the strongly agree or agree options compared to disagree or strongly disagree options occurred with the same probability was rejected (one sample chi-square test, $p < .001$).

What are students' perceptions of the power and limits of science? And do these perceptions vary with age group?

Two statements were designed to explore students' perceptions of the power and limits of science.

The statement, 'One day we may be able to explain the whole universe using science alone' probed students' attitudes to scientism. As Figure 7 indicates, 40.6% strongly agreed or agreed with this statement while just over a fifth (21.5%) disagreed or strongly disagreed. Further analysis showed that the change in the pattern

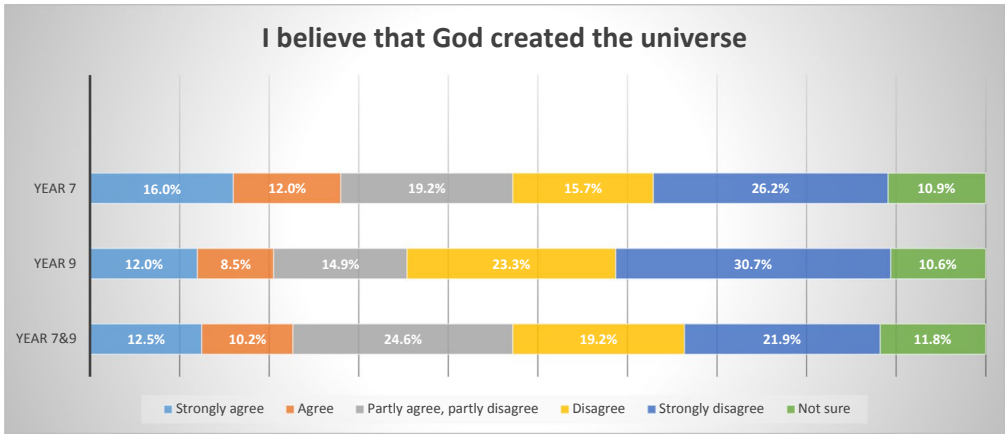

Figure 5. 'I believe that God created the Universe' [Colour figure can be viewed at wileyonlinelibrary.com]

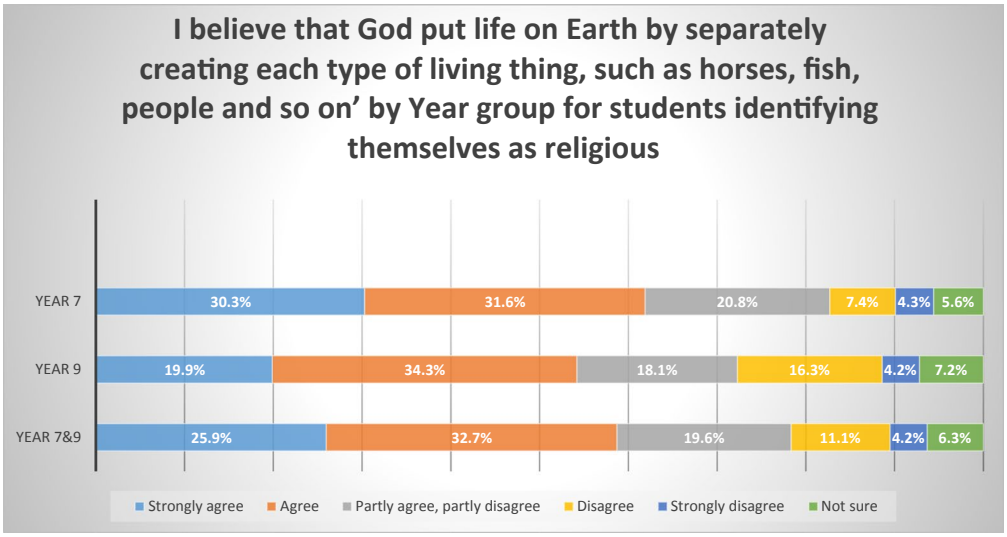

Figure 6. 'I believe that God put life on Earth by separately creating each type of living thing, such as horses, fish, people and so on' by Year group for students identifying themselves with a religious upbringing [Colour figure can be viewed at wileyonlinelibrary.com]

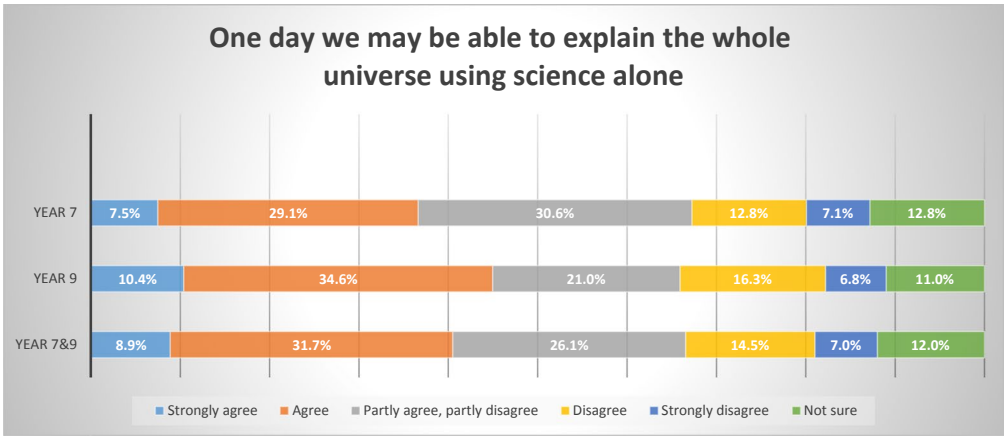

Figure 7. 'One day we may be able to explain the whole universe using science alone' [Colour figure can be viewed at wileyonlinelibrary.com]

of responses between Year 7 and Year 9 is highly statistically significant ($\chi^2 = 27.324$, $p < .001$, df = 5). The null hypothesis that the rate of responses (both years) to the strongly agree or agree options compared to disagree or strongly disagree options occurred with the same probability was rejected (one sample chi-square test, $p < .001$).

As Figure 8 indicates, just over a quarter (28.8%) of respondents strongly agreed or agreed that 'Religion is a set of beliefs that can be proved or disproved scientifically'. The levels of disagreement are higher when we look at the older age group. The percentage of the students who are not sure decreases when we look at older ages. The change in the pattern of response between Year 7 and Year 9 is highly statistically significant ($\chi^2 = 16.595$, $p = .005$, df = 5). Moreover, the null hypothesis that the rate

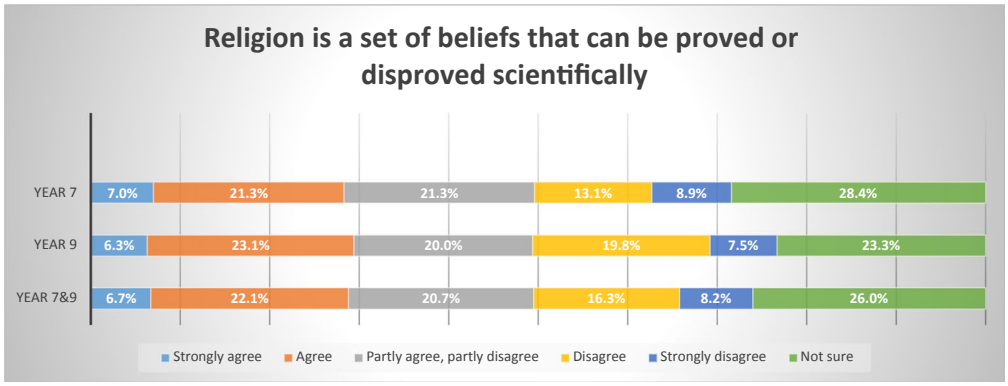

Figure 8. 'Religion is a set of beliefs that can be proved or disproved scientifically' [Colour figure can be viewed at wileyonlinelibrary.com]

of responses (both years) to the strongly agree or agree options compared to disagree or strongly disagree options occurred with the same probability was rejected (one sample chi-square test, $p = .024$).

To what extent do students think that science and religion offer contradicting narratives about how life and the universe came to be? And does this thinking vary with age group?

In this cohort, the most common response to the statement 'The scientific idea about how life began fits with the religious idea about how life began' was to clearly reject this idea (disagree or strongly disagree). Similarly, the most common response to the statement that 'The scientific idea about how the universe began fits with the religious view about how the Universe began' was also to strongly disagree or disagree.

For the older year group there are higher levels of disagreement with these statements (see Figures 9 and 10). For both statements, the null hypothesis that the rate of responses (both years) to the strongly agree or agree options compared to disagree or strongly disagree options occurred with the same probability was rejected (one sample chi-square test, $p < .001$).

These findings suggest that older students are more likely to reject the notion that science and religion offer compatible positions on how to explain the origins of the universe.

Given the high proportions who feel that science and religion offer conflicting accounts of the history of life and the universe, it is interesting to see that just over half the cohort of pupils (54.5%) agreed or strongly agreed that 'You can believe both science and religion' (Figure 11). The null hypothesis that the rate of responses (both years) to the strongly agree or agree options compared to disagree or strongly disagree options occurred with the same probability was rejected (one sample chi-square test, $p < .001$).

Discussion

The proportion of students expressing agreement with the two statements presenting scientific positions on origins is high (51.6% and 53.4%, respectively).

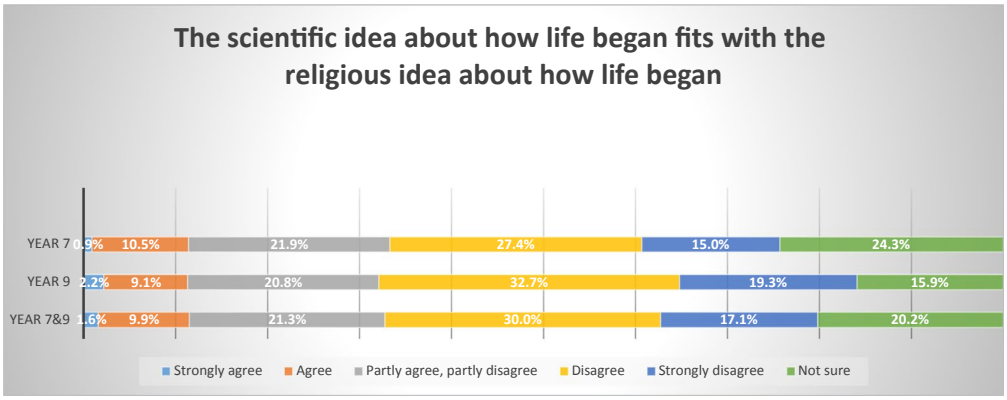

Figure 9. 'The scientific idea about how life began fits with the religious idea about how life began' [Colour figure can be viewed at wileyonlinelibrary.com]

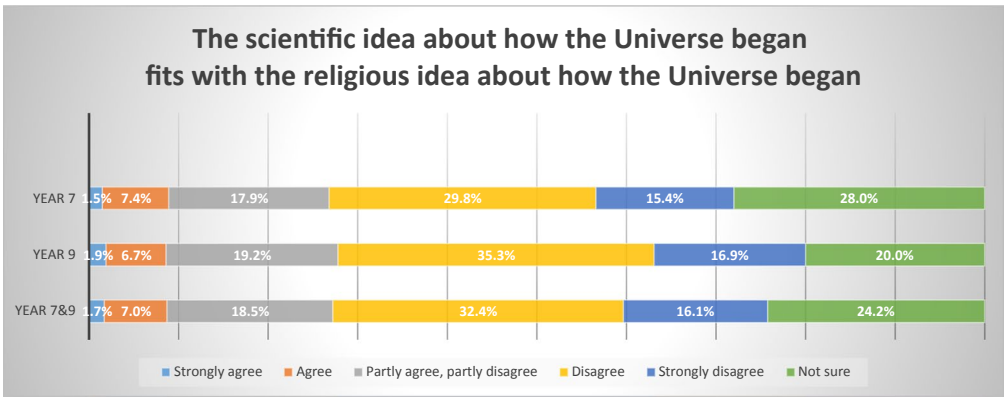

Figure 10. 'The scientific idea about how the Universe began fits with the religious idea about how the Universe began' [Colour figure can be viewed at wileyonlinelibrary.com]

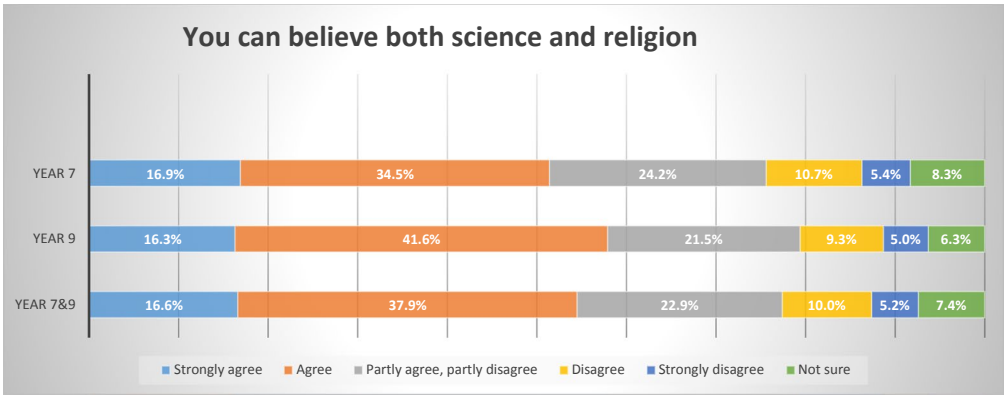

Figure 11. 'You can believe both science and religion' [Colour figure can be viewed at wileyonlinelibrary.com]

However, when we explored students about their general confidence in science by asking their level of agreement with the statement 'science is a reliable source of information', the level of agreement was much higher (69.0%). This can be explained in a number of ways. Previous studies have suggested that the labelling of scientific accounts of origins as 'theories' leads some students to conclude that they are uncertain (Taber *et al.*, 2015). Some students may be reluctant to endorse an explanation that they perceive to be in conflict with their faith and the findings seem to be consistent with this interpretation. We found that 34.2% of those who accept creation by God also strongly agree or agree with the statement, 'I accept the scientific theory of evolution as the explanation for all the different kinds of life on Earth', whereas 72.8% of those who do not accept creation by God strongly agree or agree with this statement. It is also conceivable that within this group some of those who reject evolution as 'the explanation' for all the different kinds of life on Earth have interpreted the statement as asserting a scientistic position which excludes other parallel explanations.

The statement, 'I believe that God put life on earth by separately creating each type of living thing, such as horses, fish, people and so on' presented one aspect of a creationist stance. This statement was supported (strongly agree or agree) by 58.7% of students who identified themselves as having a religious upbringing. We wanted to understand why a large proportion of the participating students seem to support creationism. Some explanations for these responses can be drawn from our interview studies (Billingsley et al., 2013, 2016). The interviews indicate that when students critique the Biblical creation story they tend to focus on whether or not the universe and everything in it was created in six literal days and their knowledge of apparent contradictions with science may be limited to this aspect. Some students, including some who say they believe in a six-day creation, also (mistakenly) say that the Pope says that the universe was created in six literal days. It seems feasible that a substantial proportion of students with a religious upbringing who agree that 'I believe that God created all the living things on Earth but not as the Bible describes' are doing so because they reject a six-day creation rather than on the basis of a deeper analysis in the light of evolutionary theory. These findings are in line with the students' delayed development in religious thinking that Goldman (1965) and Fowler (1981) have pointed out. Goldman argues that biblical texts should only be studied once students are sufficiently advanced—including via targeted teaching—to understand that texts can contain deeper stages of meaning. Our data suggests that this level of insight is widely missing in young people. As Goldman argues, asking students to work with difficult texts before they have this level of epistemic insight 'only creates confusion and difficulties' (1965, p. 33).

In the light of previous research, this study included statements to probe students' attitudes to scientism. We noted that over two-fifths of students (40.6%) strongly agreed or agreed with the scientistic claim that 'One day we may be able to explain the whole universe using science alone' while just over a fifth rejected it. This reasoning, that science has the potential to fully explain the universe, could reflect an informed philosophical commitment to scientism but it could also be consistent with an uncritical assumption that science can resolve every kind of question.

The survey included another statement that was designed to look at whether or not students perceived religious claims to be in a different category to scientific claims and knowledge. About a third (28.8%) of respondents strongly agreed or agreed that 'Religion is a set of beliefs that can be proved or disproved scientifically'.

Stenmark (2018) defines scientism as a tendency to say that, in the future, science will provide a full explanation of how nature behaves using simple 'scientific' language. Kidd (2018) takes scientism as a stance, suggesting that it involves attitudes and beliefs and that a scientistic person is likely to be closed to the possibility of there being forms and sources of knowledge, evidence, enquiry or reason that are not scientific in character. Elsewhere, we have coined another term, 'uncritical scientism', which has a family resemblance to scientism. Some authors associate scientism with a lack of criticality (see e.g. Miller, 2015). Our label 'uncritical scientism' makes this aspect explicit as the notion that scientism can be accepted uncritically is central to our use of the construct in education. There are several factors that can foster uncritical scientism among young learners that we have discussed in our previous studies (Billingsley & Nassaji, 2019); among them are entrenched compartmentalisation, teaching science via fragmented topics in secondary school, lens of simplification (simplified accounts of scientific explanations in textbooks) and exaggerated news media headlines. By upper secondary, school students are increasingly likely to have seen media headlines and stories that present scientific advances in ways that suggest that scientists are on the brink of having a sufficient model and explanation for how reality behaves. Some examples are, 'GCSE results "influenced by children's genes, not teaching"' (Paton, 2013) 'New blood test targets depression' (Roberts, 2016) and 'Scientists prove chocolate better than being in love' (Freeman, 2002). The way that science courses and examinations are currently structured means that students are unlikely to spend lesson time critiquing these kinds of headlines.

The finding that just over half the cohort of pupils (54.5%) strongly agreed or agreed that 'You can believe both science and religion' despite the high proportions who feel that science and religion offer conflicting accounts of the history of life and the universe might seem puzzling to some people. In our focus groups, we noticed that perceiving science and religion as conflicting was often not perceived as a reason to reject one or the other, a finding that has been reported previously such as by Costa (1995). Some children said they believed different things in different places and one expressed the view that his parents frequently disagreed […] but he maintained a good relationship with both.

Conclusion and recommendations

A number of previous studies have proposed typologies designed to characterise students' approaches to reasoning about how science and religion relate. For example Hanley *et al*. (2014) characterise students in terms of four engagement types (resistors, reconciled, explorers and confused) while Konnemann *et al*. (2016) draw on their study of German students to say that scientistic attitude profiles are far more prevalent in this group than, for example, creationist attitudes. In our conceptual framework, we proposed that while scientism and creationism can be considered

positions, some of the reasoning associated with each stance can also be indicative of reasoning which uncritically conflates scientific and teleological categories of explanation. Our recommendation in the light of this data is that it is useful to characterise students as potential apprentice scholars and to notice that while students' reasoning is affected by many factors, in a strictly compartmentalised curriculum system such as in England, children may have few opportunities to compare the questions, methods and norms of thought that characterise different disciplines. The issue is all the more complex because students frequently struggle to recall what they have learnt in one curriculum subject when they engage with another (Andersen & Krogh, 2010). As such, we are particularly concerned that students have few opportunities to develop their epistemic insight in school and posit that, among other factors, this is affecting their capacities to reason about the relationships between science and religion (Billingsley *et al.*, 2018).

Further, it is interesting that notable shifts of thinking take place between the cohorts in Years 7 and 9. The sizes of the shifts are not trivial with an increase of 7-9% for the proportions in Year 9 compared with Year 7 who strongly agree or agree that 'One day we may be able to explain the whole universe using science alone' and 'Religious ideas about how the universe began have been proved wrong by science'. There are many possible explanations for why we see these differences in the data from Year 9 and Year 7. One possibility would be if the proportions of children from different schools in our Year 7 and Year 9 samples are different. School is a factor that has a significant impact on students' stances—and hence, we would expect a different outcome if the proportion from different schools were not the same.

However, as indicated by Table 2, there was a similar pattern of contribution by school to the overall samples in Year 7 and Year 9, which suggests that school differences is not a factor in shifts of thinking between Year 7 and Year 9. Another possible explanation is that this is a period during which students are re-evaluating how they understand and value the disciplines. Year 7 also marks the beginning for most students in England of a transition from primary school, where students typically have all their lessons with one class teacher, to secondary school where students typically have different teachers for each subject. This study indicates that the first years of secondary school could be a particularly important period for students to have more opportunities to develop their reasoning about how science relates to other disciplines alongside teaching that focuses on within-discipline objectives.

We would like to see schools introduce a range of strategies that help students to appreciate the distinctive natures of the disciplines in their curriculum subjects. This suggestion is not something beyond the curriculum goals. For instance, science curricula in England (DfE, 2015) and internationally (Hansson & Redfors, 2007b; ACAPA, 2011) suggest that formal education has a role to play in ensuring that students have opportunities to critically examine the nature of science. These strategies can include pedagogical, organisational and curriculum measures—such as and in particular, guidance for subject teachers on tools and pedagogies that they can use for this purpose, timetable changes to enable meetings for staff to consult each other about their planned approaches to common topics, links in the curriculum

documents to other curriculum subjects to guide teachers to useful shared epistemological questions and areas of content overlap.

This raises the question of where teaching about interdisciplinary relationships should take place and whether it is appropriate to raise these matters in science lessons or only in other curriculum subjects (Ratcliffe *et al.*, 2005). In response to these considerations, we recommend that curriculum teachers in the sciences and humanities explore ways to teach some lessons collaboratively in a multidisciplinary space such as a school library. This recommendation is also a response to Konnemann, *et al.* (2016), p. 28) who rightly in our view notice that one of the reasons why science teachers tend to 'sidestep the issue of the "limits of science" is the fear that by addressing the topic, students might think that scientific knowledge is less reliable than it really is'. Our response is that by engaging with how to formulate a scientific question while working with cross disciplinary themes, it seems reasonable to propose that students can contextualise but not diminish their confidence in the validity of science. In studies building on the findings reported here we are developing cross-curricular workshops for students designed to investigate this proposition. Workshops explore questions such as, 'Why did the Titanic sink' through scientific and in this case, historical perspectives (Billingsley, Simpson, & Abedin, 2020; Billingsley, Chappell, & Reiss, 2019). By selecting a range of topics and interacting disciplines, the aim is to appeal to a broad range of interests. Aside from the anticipated benefits to students' developing understanding of how disciplines interact, there is also the anticipated gain that allocating time to explore questions that bridge science with students' everyday lives and interests has been shown to have a positive effect on students' enthusiasm for studying science (Hagay & Baram-Tsabari, 2015).

Moving to wider issues, a particularly challenging philosophical and pedagogical question raised by this study is whether or not any question can or should be identified to students as non-scientific. While writing about the need for students to 'recognise the limits of science and the power of other ways of thinking that are also functional in the world', DeBoer (2000) asserts that 'There are emotional and spiritual aspects to our existence that fall outside the realm of science, and the line between these and the nature of scientific thought needs to be drawn so that students can more fully comprehend what science is and what it is not'. It seems reasonable to say that if this line exists, it is not a line that will be drawn easily and would depend on how science is characterised (Hodson, 2014). Further, the current paper is situated in a period of science education in which students are all too frequently developing a narrow and positivistic perception of science (McComas *et al.*, 2002). Thus, for example, Lederman, *et al.* (2014) encourage teachers to counter the stereotype of science as a set of facts and to establish instead that 'scientific knowledge is never absolute or certain'. Similarly, these authors emphasise that 'even though scientific knowledge is, at least partially, based on and/or derived from observations of the natural world (i.e. empirical), it nevertheless involves human imagination and creativity' (p. 288). Within these broader discussions and to help to address the issues raised by this study, a successful characterisation of science would arguably emphasise that science can inform our thinking about a wide range of questions and some questions are more amenable to science than others.

Disclosure statement

There is no competing interest.

Data availability statement

There is no data set associated with this paper.

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Geolocation information

The geographical locations where the data are collected is the United Kingdom.

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[Corrections made on 14 July 2021, after publication: The second author's name has been corrected to Keith S. Taber in this version.]