



# Acceptance of Biological Evolution by First-Year Life Sciences University Students

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## Abstract

Lack of acceptance of biological evolution, despite the overwhelming evidence that supports it, can be very problematic in higher education courses that have a strong biological basis. We investigated acceptance of biological evolution in 344 first-year Life Sciences undergraduate students across five programmes at the University of Roehampton, UK. In line with previous findings in British universities, we found that 9% of the students did not accept evolution by natural selection, with an increase to 16% for human evolution. Both religiosity and programme of study were significantly related to acceptance levels in our students ( $p < 0.001$ ). In particular, lower acceptance was associated with Muslim or Christian beliefs, and with Biomedical Sciences and Nutrition and Health programmes (compared with Anthropology, Zoology and Biological Sciences). We suggest embedding an evolutionary perspective in the teaching of biomedical and health programmes and creating space for explicit discussion of perceived conflicts with religious beliefs.

**Keywords** Evolution · Darwin · Religion · Biology · UK

## 1 Introduction

### 1.1 Acceptance of Biological Evolution

The theory of evolution by natural selection first proposed by Darwin (1859) has been refined and largely validated in the last 150 years by an overwhelming amount of evidence and forms the basis of modern understanding of biology. In the words of the famous evolutionary biologist Theodosius G. Dobzhansky, ‘nothing in biology makes sense except in the light of

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evolution' (Dobzhansky 1973). The modern theory of evolution provides an explanation for the diversity (and morphological changes) of organisms past and present. It provides a theoretical framework to understand and tackle modern challenges such as antibiotic resistance in medicine and pesticide resistance in farming. It is the basis for animal and plant conservation (Antonovics et al. 2007; Benton and Emerson 2007; Ffrench-Constant et al. 2000).

Despite its near-universal acceptance among scholars, however, acceptance of biological evolution is decidedly more varied among members of the general public. Miller et al. (2006) compared acceptance of the statement that 'humans have evolved from animals' across countries and found that, while the premise was not rejected by the majority in most surveyed countries, the majority of participants in Turkey and the USA did not endorse the concept.

The gulf between general population and scholars in accepting evolution has led to a number of controversies with regard to school teaching. Even though the National Academy of Sciences, USA (1998) suggested 'to use evolution as the organising theme in teaching biology' (Alles 2001, p. 20), repeated efforts have been made to include 'intelligent design', a scientifically discredited alternative to evolution, in school curricula (Miller et al. 2006; Journell 2013; Lynn et al. 2017).

In order to quantify attitudes towards evolution, several questionnaires have been developed. For example, the Measure of Acceptance of the Theory of Evolution (MATE) (Rutledge and Warden 1999), a 20-item five-point Likert scale instrument, has been extensively used within the education sector (Nadelson and Southerland 2012). Several studies have also aimed to identify the underlying reasons for rejecting biological evolution, to get a better picture of which groups within a population are more likely to do so. A number of these studies have pointed to the importance of religiosity for the rejection of evolution, among both students and teachers (e.g. Barone et al. 2014; Blackwell et al. 2003; Rissler et al. 2014), while others also cited economic background, gender or political campaigning (Akyol et al. 2012; Peker et al. 2009).

## 1.2 Acceptance of Evolution in Higher Education

Studies that have investigated higher education students' attitudes towards evolution have primarily been carried out in the USA. Sinatra and co-authors (2003) found a correlation between religiosity and rejection of evolution, though this was interestingly limited to the rejection of human evolution. No consensus exists on whether knowledge and understanding of evolutionary concepts are connected with acceptance of biological evolution, with studies on university students and graduates reporting either positive correlations (Nadelson and Sinatra 2008; Rutledge and Mitchell 2002) or no significant relationships (Bishop and Anderson 1990; Sinatra et al. 2003).

Though a relatively small phenomenon compared with other countries, recent studies have showed that rejection of evolution is also present in biology and medical students within British higher education (Downie and Barron 2000; Southcott and Downie 2012). Downie and Barron (2000) carried out a survey of student opinion on evolution based on a large sample of first-year undergraduate students attending the level 1 biology class at the University of Glasgow between 1987 and 1995. In 1998, data were collected from first-year biology and medical students, in order to compare acceptance of evolution in the two courses. The proportion of students that rejected the theory of evolution fluctuated between 4 and 11% depending on the year, and strong religious beliefs and literal interpretation of a religious account of creation were the prominent reasons for rejecting evolution. Interestingly, evolution

rejecters largely accepted the occurrence of evolution within a species (micro-evolution), but consistently rejected evolution as the mechanism for the generation of new species (macro-evolution). The study also found that a larger proportion of medical students rejected evolution in respect to biology students.

Building on these results, Southcott and Downie (2012) carried out a similar survey of first- and fourth-year undergraduate biology students within the same university. The aim of the research was to evaluate if the proportion of evolution rejecters had changed over the years, and if there were a significant difference in such proportion between first- and fourth-year students. The survey was run for two consecutive years on first-year (2008–2010) and fourth-year (2009–2011) students. The results confirmed a significant proportion of first-year evolution rejecters (7%), similar to the one identified by Downie and Barron in 2000, and a strong link between rejection of evolution and religious beliefs. The study, however, also revealed that the proportion of rejecters decreased substantially in fourth-year students, possibly because they had been exposed to more detailed lectures on the theory of evolution compared with first-year students. When the theory of evolution was broken down to its components, rejecters appeared again to be more comfortable with the idea of micro-evolution than macro-evolution and were particularly sceptical of human evolution (Southcott and Downie 2012).

### 1.3 Aim and Importance of This Study

The proportion of evolution rejecters in university biology and medical courses, revealed by Downie and Barron's (2000) and Southcott and Downie's (2012) studies, is significant and potentially worrying.

Because of the pivotal role of evolution in modern biology, it is essential that lecturers are aware if some of their students enter their biology and medical courses with a preconceived rejection of evolution and develop strategies to address this problem. For this reason, we decided to test the level of acceptance of evolution in four consecutive cohorts of first-year students in the Department of Life Sciences of the University of Roehampton (UR), London. UR prides itself on its ability to attract students with diverse cultural, ethnic, religious and socioeconomic backgrounds, and it is important to understand how this diversity affects acceptance of evolution in incoming students. A high level of ethnic diversity in education has been associated with higher scores on academic self-confidence, social agency and critical thinking disposition (Nelson Laird 2005). An increased attitude towards critical thinking, in particular, would be beneficial in avoiding dogmatic positions of rejection of evolution based on pre-existing beliefs. On the other hand, given the fact that religious beliefs in particular appear to play a role in shaping preconceived ideas about biological evolution, it is difficult to predict the effect of a wide diversity of religious beliefs within the same cohort of students.

The aims of this study are:

- 1) To evaluate the level of acceptance of evolution and the proportion of rejecters of evolution within different cohorts of first-year undergraduate students in the Department of Life Sciences at the University of Roehampton;
- 2) To evaluate whether different programmes within the Department of Life Sciences are associated with different levels of acceptance of evolution, and in particular, if there is any difference between biomedical and health programmes on one side, and other biology programmes;

- 3) To evaluate whether demographic factors such as religious beliefs are associated with the level of acceptance of evolution;
- 4) To examine whether attitudes differed towards three aspects of evolution: micro-evolution, macro-evolution (non-human) and human evolution.

## 2 Materials and Methods

### 2.1 Instrument

In this study, we used the Inventory of Student Evolution Acceptance (I-SEA, Nadelson and Southerland 2012) to survey first-year undergraduate students' opinion on evolution.

The I-SEA questionnaire was developed on the basis of perceived ambiguities in the MATE questionnaire (Rutledge and Warden 1999) and aims to delineate attitudes towards three sub-areas of biological evolution, namely micro-evolution, macro-evolution and human evolution. As previous studies (e.g. Downie and Barron 2000) suggest that acceptance of the former is more widespread than of the latter two, we chose this instrument over the MATE. Each question scored an integer value from 1 to 5, where 1 = wholly rejecting and 5 = wholly accepting. Downie and Barron (2000) suggested that a value of 3.0 should be used as the cutoff for being regarded as sceptical. Questions 1–8 relate to macro-evolution, 9–16 to micro-evolution and 17–24 to human evolution.

The I-SEA contains a number of reversed statements, whereby a high score meant scepticism. The scores of these statements were then reversed so that in the final analyses all questions scored the same way (high scores for full acceptance of evolution).

In order to evaluate the potential impact of religious belief (e.g. Downie and Barron 2000), gender (Akyol et al. 2012), and country of origin (Miller et al. 2006) on the acceptance of evolution, we included a short demographic section in the questionnaire (see Online Resource 1).

### 2.2 The Student Sample

Questionnaires were distributed to first-year undergraduate students across different Life Science programmes at UR from the 2014/15 to the 2018/19 academic year. Voluntary participation was recorded via consent forms.

The effect of religion was examined by separating the students into four groups, based on their answers to the demographic section of the questionnaire: No Religion (which included students who identified as atheist, agnostic, or who declared that religion was not an important part of their life), Christianity, Islam and Other (all other religions).

### 2.3 Analysis of the Data

Data analyses were based on calculation of mean scores per individual, either over all questions or for a subset of their responses (micro-, macro- or human evolution).

In order to determine if the level of acceptance changed depending on programme or on religion, the means were compared by one-way ANOVA followed by a Tukey post hoc test. The relationship of programme and religion and gender with the responses was tested by generalised linear model using the *glm* function (R 2018). Model selection was based on

minimising Akaike's information criterion (AIC) (Akaike 1981; Johnson and Omland 2004). For the first 2 years, students of all programmes except Biomedical Sciences received five introductory lectures on evolutionary theory in one of their modules in the weeks before they filled in the questionnaire. During the following two years, however, Nutrition & Health students did not receive any lecture on evolution, creating an involuntary experiment on how effective our teaching of evolution is. We used a Kruskal-Wallis test to compare the scores for Nutrition & Health between the cohorts that attended evolution lectures and the cohorts that did not, to tests for significant differences in their acceptance of evolution.

To obtain an overview of the data, all complete responses were ordinated by principal components analysis (PCA), using the R code 'prcomp(..., scale = TRUE)' to ensure equality between variables (any lines with any missing data had to be excluded). This is a standard analytical tool for allowing the visualisation in two dimensions (e.g. a graph) of the important patterns within a high-dimensional data structure and can be likened to showing the reader a shadow cast by the data structure (Shaw 2003). In particular, lines of data that contain similar values will end up in close proximity on the PCA graph, making patterns visually accessible. Each line of data becomes a single point on the graph, and close proximity means similar values. The extent to which PCA condenses information is summarised by a percentage variance explained—the larger the variance explained, the more confident we can be that the PCA has picked out a trend across multiple variables.

All data are available upon request.

### 3 Results

The response rate of the questionnaire among Life Sciences students across 4 years was around 30% (101, 71, 94 and 78 of roughly 250 possible responses for each of the 4 years, respectively). Slightly less than half of our students classed themselves as agnostics, atheists or defined religion as unimportant in their life (49%, 44%, 43% and 44% in the 4 years, respectively, always excluding non-answers). Among major religions, the most represented religion was Christianity (19%, 33%, 34% and 32%, respectively), followed by Islam (20%, 17%, 13% and 17%). About seven in ten of our responders were females (75%, 72%, 69% and 65%) and the majority (71.5% overall) had been educated in the UK, with no dominant alternative country of secondary education. The I-SEA questionnaire on acceptance of evolution shows good internal consistency (Cronbach's  $\alpha = 0.94$ ).

The results of the I-SEA questionnaire are summarised in Table 1, showing that acceptance of evolution (scores > 3) was generally high, but a minority of students (about 9%) had a mean score below 3 points. When the general average scores were broken down to the three sub-

**Table 1** Descriptive statistics for the questionnaire scores for the whole dataset, including overall mean, median and proportion of individuals with a mean score below 3

	Mean	Median	% < 3
Evolution	3.88	4.01	9.01
Micro-evolution	4.02	4.12	6.69
Macro-evolution	3.87	3.99	9.3
Human evolution	3.85	3.88	16.28

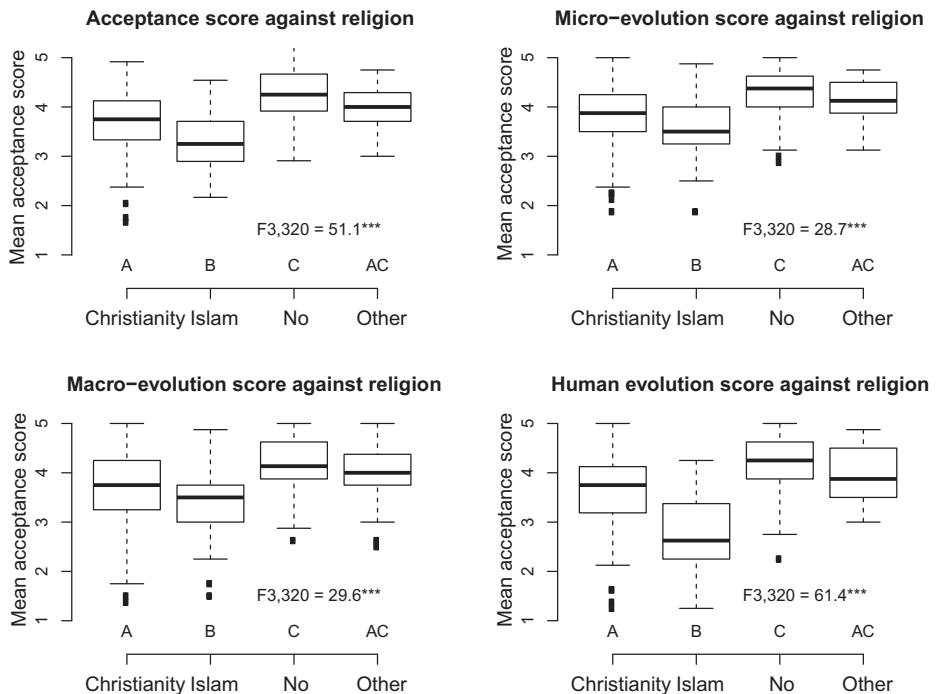
areas of evolution, it became apparent that micro-evolution statements elicited lower scepticism than macro-evolution and human evolution statements (Table 1).

### 3.1 Scores by Religion and by Programme

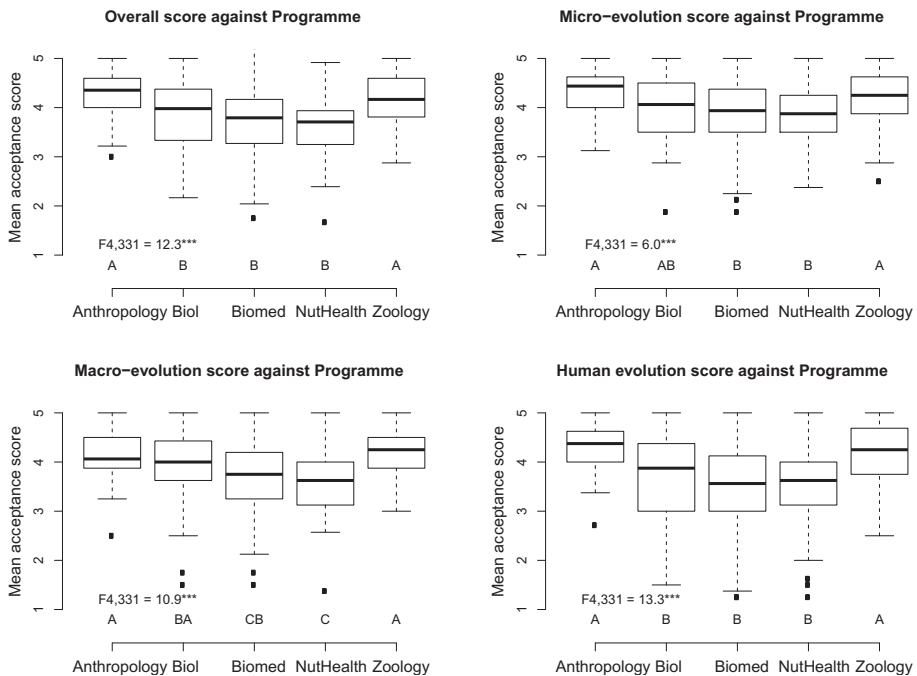
The best overall model (based on the lowest AIC score) to predict mean score per student was one that defined them by religion (Fig. 1) and programme (Fig. 2), but without an interaction term and excluding gender or calendar year. Comparing the overall scores between programmes shows a highly significant difference ( $F_{4,331} = 12.31$ ,  $p < 0.001$ ) and two subsets of students, with highest scores in Anthropology and Zoology, followed by lower scores in the other three programmes (Fig. 2). This pattern was repeated for the 3 subsets of the responses, with inter-programme differences (as measured by the  $F$  value) highest for questions about human evolution and lowest for questions about micro-evolution.

Comparing the overall scores between religions shows a more highly significant difference ( $F_{3,320} = 51.1$ ,  $p < 0.001$ ), with the students splitting approximately into three groups. The lowest scores were for Islam, followed by Christianity and 'Others', with highest scores for 'No Religion' (Fig. 1). This pattern was repeated for the 3 subsets of the responses, with inter-faith differences (as measured by the  $F$  value) highest for questions about human evolution and lowest for questions about micro-evolution.

We did not find any significant difference in the level of acceptance of evolution in Nutrition & Health students that attended formal lectures on evolutionary theory (first 2 years



**Fig. 1** Mean acceptance score by religion groupings (no = agnostic, atheist, or religion not an important part of their life; other = all other religions). Overall mean scores (top left) and mean scores for the three evolution subsets are shown in the graph. Religious groups bearing the same letter did not differ significantly in a post hoc Tukey test



**Fig. 2** Mean acceptance score by programme. Overall mean scores (top left) and mean scores for the three evolution subsets are shown in the graph. Programmes bearing the same letter did not differ significantly in a post hoc Tukey test

of the survey) in respect to the cohorts who did not (last 2 years) (chi-square 1df = 0.14,  $p = 0.7$ ).

When examining the individual statements, a number of statements were identified as differentiating the religious groups. Within macro-evolution questions, Q4 ('I think all complex organisms evolved from single celled organisms') had particularly low scores for Christians and Muslims (3.4 and 3.05, respectively) compared with the other groups (3.9 and 4.2 for other religion and no religion, respectively). Q8 ('I think that all organisms are related (or share a common ancestor') received particularly low scores from Muslims (3) in respect to Christians (3.6), believers of other religions (3.9) or no religion (4). Human evolution statements elicited particularly sceptical responses by Muslim participants, with six out of the eight statements averaging below 3: Q17 ('There is reliable evidence to support the theory that describes how humans were derived from ancestral primates'), Q18 ('Although humans may adapt, humans have not/do not evolve'—reversed), Q19 ('I think the physical structures of humans are too complex to have evolved'—reversed), Q20 ('I think that humans and apes share an ancient ancestor'), Q22 ('Humans do not evolve; they can only change their behaviour'—reversed) and Q23 ('The many characteristics that humans share with other primates (i.e., chimpanzees, gorillas) can best be explained by our sharing a common ancestor'). The human evolution statement that scored the lowest in Christians was Q23 (3.5). Students in the No Religion group scored 4 or higher in all of the human evolution statements. Overall, it appears that statements that explicitly mention common ancestry or human evolution are regarded with particular scepticism by Muslim and to a lower extent by Christian believers.



Differences between programmes were more down to lower average scores across all questions, but again Q4 and Q8 (for Nutrition & Health, 3.2 and 3.3 respectively) and Q17–19 as well as Q23 (for Biomedical Sciences and Nutrition & Health, all below 3.5) resulted in particularly low scores.

### 3.2 Overview of the Data by Principal Components Analysis

To obtain an overview of the data, a principal components analysis (PCA) was run on all complete questions (any lines with missing data were excluded). The PCA overview of our questionnaire data is summarised in Fig. 3. Only the first axis (45.3%) explains more variance than expected in a random model, using the broken stick distribution (Shaw 2003). We show axis 2 (6.3%) for convenience when graphing, but little interpretation should be put on this putative trend. This first principle axis loads all questions approximately equally and positively, meaning that the right hand (positive) side of the distribution consists of high scores on all questions (accepting evolution) while the negative end shows responses that are sceptical (Fig. 3). In the graph, individual responses are coded for religion, showing that the sceptical students (filled symbols) are entirely Muslim or Christian.

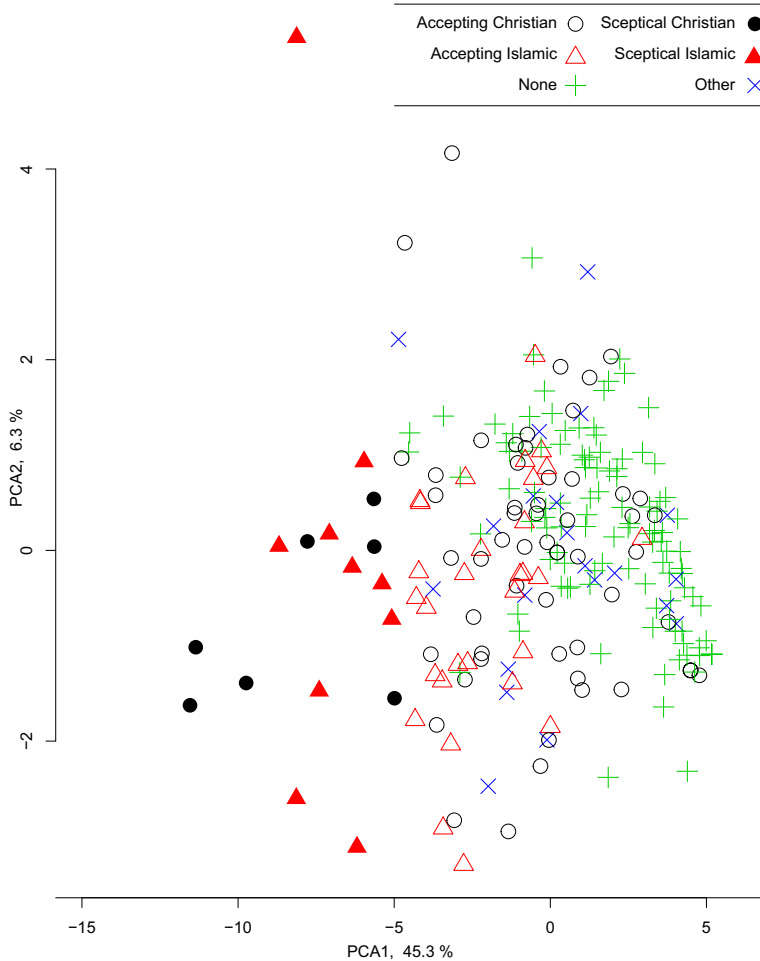
The first axis scores for each student can be used as a unit-free index of acceptance/scepticism and (unsurprisingly) were shown to behave almost identically to the average scores in Figs. 2 and 3 (examined by boxplots and ANOVA, not presented). We can also use the first axis loadings for each question to estimate its importance in structuring the data; hence, we can compare the loadings for the 8 questions about macro-evolution to those for the 8 questions on human evolution and to micro-evolution. The first axis loadings for each question (Fig. 4) are an estimate of that question's discriminatory power in predicting acceptance/scepticism, and they differ between the blocks of questions. The eight questions about human evolution had higher loadings than other questions, showing that they were especially important on the scepticism/acceptance axis. This difference is weakly significant by the Kruskal-Wallis test (chi-square 2df = 7.5,  $p = 0.023$ ) but not by ANOVA ( $F_{2,21} = 3.3$ ,  $p = 0.058$ ). The weakness of this result is down to one clear outlier, visible in the bottom right of Fig. 4, which is question 24 ('Physical variations in humans (i.e., eye color, skin color) were derived from the same processes that produce variations in other groups of organisms'). This question has among the lowest scores of all (0.15) despite being in the 'human evolution' subsection, probably due to its vagueness. If this outlier is excluded the inter-block differences increase dramatically (chi-square 2df = 10.95,  $p = 0.004$ ,  $F_{2,20} = 7.0$ ,  $p = .0005$ ).

## 4 Discussion

Downie and Barron (2000) and Southcott and Downie (2012) showed that the proportion of undergraduate students of biology and medical sciences that reject evolution can be significant (4–11%) in British universities, and that religious beliefs play an important role in shaping the students' approach to learning. Our results are in line with their findings, with about 9% of students who appear to be sceptical about evolution. Similarly to the cited studies, our results also show that our students are more comfortable with the idea of micro-evolution than with macro-evolution or human evolution.

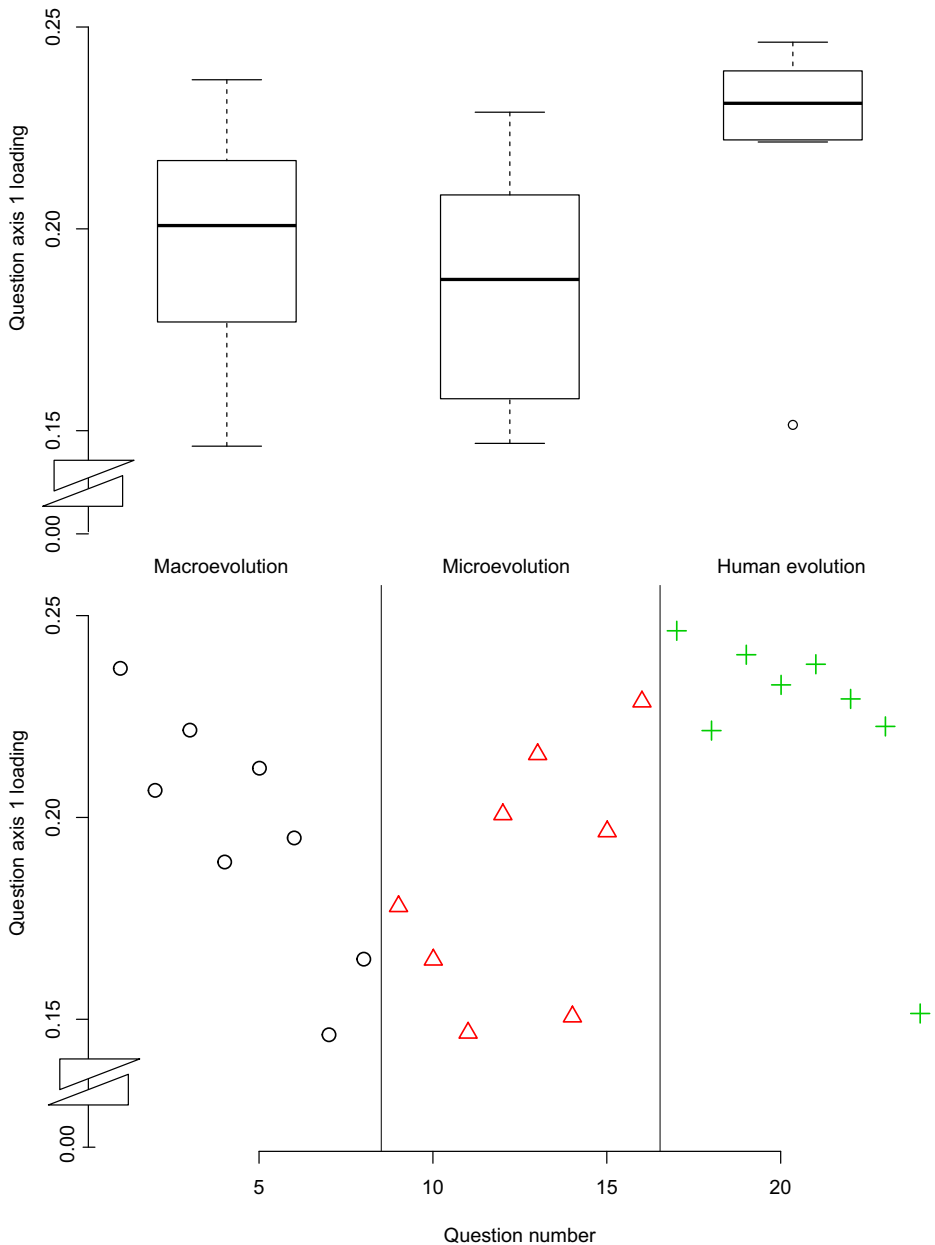
Four separate analyses concurred in the relative acceptance of these three facets of evolution. Firstly, the simple calculation of the percentage of students who were sceptical





**Fig. 3** Plot of principal components 1 and 2 for all questionnaire responses (excluding responses with missing data), capturing 52% of variation in responses. Different religious groups identified by different symbols (see legend; no = agnostic, atheist or religion not an important part of their life; other = all other religions). Sceptics (overall score < 3) are highlighted by full symbols

(based on a mean score < 3) came in the order human evolution (most sceptical responses) then macro-evolution, with lowest values for micro-evolution (Table 1). Secondly, the effect size of programme (as measured by the  $F$  value from the linear model) was greatest for human evolution followed by macro-evolution followed by micro-evolution (Fig. 2). Thirdly, the effect size of religion (as measured by the  $F$  value from the linear model) was greatest for human evolution followed by macro-evolution followed by micro-evolution (Fig. 1). Fourthly, the axis 1 loadings derived for each question from the PCA showed highest values for the human evolution questions, intermediate values for the macro-evolution and lowest values for micro-evolution (Fig. 4). This PCA also raised the curious observation that question 24 caused less confliction to sceptical students than the other questions on human evolution, perhaps because it did not require any evolutionary connection between humans and other life forms and refers to small amount of variation within species.



**Fig. 4** Principal component 1 loading (y axis) of individual questions (bottom) and questions grouped by evolution subsets (top). These loadings are an indicator of the power of each question to predict acceptance/scepticism

This different attitudes towards sub-types of evolution help explain some apparently conflicting answers; for example, Q21 ('I think that humans evolve') returned an average score of 3.9, while Q23 ('The many characteristics that humans share with other primates (i.e., chimpanzees, gorillas) can best be explained by our sharing a common ancestor') had an

average score below 3.6. These differences in score for similar statements, while initially contradictory, make sense when viewed in the light of a higher rejection of big evolutionary changes (common ancestry with apes) and simultaneous acceptance of small changes within a species (including humans, e.g. the eye colour example cited in the widely accepted Q24); in this sense, they reinforce and validate the differences we observed in average scores between macro-evolution and micro-evolution.

The results of this study also highlighted a higher proportion of evolution rejecters within biomedical and health programmes, in comparison with General Biology, Anthropology or Zoology programmes. We expected to find a low percentage of rejecters in a sample of students that had chosen a course of study pertaining largely to human (Anthropology) or animal (Zoology) evolution, but the difference between Anthropology and Biomedical Science was nonetheless considerable, both in terms of number of individuals being sceptical of biological evolution, as well as in terms of average scores. Interestingly, it has been suggested that biomedical literature avoids using the term 'evolution', even when talking about micro-evolutionary contexts (Antonovics et al. 2007). Religious beliefs were highly associated with levels of acceptance of evolution in our study, in line with a number of previous studies (Downie and Barron 2000; Miller et al. 2006; Rissler et al. 2014; Sinatra et al. 2003; Southcott and Downie 2012). However, the association seems to be limited to the two main monotheistic religions in our cohorts, Christianity and Islam, with Muslim students showing the lowest level of acceptance of evolution. Although numbers in other religions were too small for detailed analysis, students declaring a different religious affiliation did not show a lower level of acceptance of evolution than atheists or students for whom religion was not an important aspect of life. Due to the small sample size, it was not possible to separate further the diverse set of religions which were collated into the group 'Other', which is an unfortunate limitation of this study.

Southcott and Downie (2012) also found a higher proportion of Muslim students who rejected evolution; interestingly, their results revealed that the proportion of Christians rejecting evolution had increased over the years, while the proportion of Muslim rejecters had decreased with respect to Downie and Barron's (2000) data on Biology undergraduate students from the same university collected in the previous decades. We do not observe the same trend in our study, but we could only compare scores for four consecutive years.

The stronger association between rejection of evolution and Muslim and Christian religious beliefs, in comparison with other religious beliefs, has been linked to politicisation of the teaching of evolution in some countries such as the USA (Miller et al. 2006; Moore 2010; Paterson and Rossow 1999) and Turkey (Hameed 2008; Peker et al. 2009), where conservative politicians have expressed a rejection of evolution and a religious view of the creation of species as part of their political stance, and often associated it with other popular political ideas. Even in the absence of politicisation, the acceptance of a religious creation account is often perceived as the major obstacle for accepting evolution, particularly for human evolution (Journell 2013).

#### 4.1 Strategy Recommendations for Teaching in Higher Education

Given the fundamental importance of biological evolution to almost any biology-based teaching, the question remains as to how a priori scepticism about evolution should be addressed in the lecture theatre. To come to a recommendation, one has to be mindful of the fact that students reach university having been subjected to the teaching of evolution at school on various occasions.

As summarised in Journell (2013), it has been suggested that education in schools often does very little to effectively challenge beliefs about evolution (or more to the point, creation) that the student's family or circle of friends hold privately (Bishop and Anderson 1990; Hokayem and Boujaoude 2008; Journell 2013). Instead, the teacher is often seen as someone with an agenda, which leads to automatic rejection of the teacher's position rather than engagement with the material (Geddis 1991). Several approaches have been put forward to address the rejection of evolution.

Interestingly, an argument could be made for not addressing the issue at all. Blackwell et al. (2003) suggest that it could be easier to integrate evolution within the individual's belief system if human evolution is not addressed directly, given the particularly strong rejection of human evolution by some students because of an apparent conflict with pre-existing religious beliefs. More importantly, it has been suggested that attitudes towards biological evolution do not necessarily impact on the students' performance (Ingram and Nelson 2006).

A separate strategy aims to delineate religion and evolution, either by accepting that they are totally distinct entities with no bearings on each other or that they are not mutually exclusive. Both have been shown to be used in university teaching (Chuang 2003).

Another strategy involves reliance on more 'physical' evidence, such as a series of fossils, rather than evidence that is less concrete (and can be seen as more obscure) such as molecular data (Sinclair and Pendarvis 1998, as cited in Blackwell et al. 2003). However, with regard to higher education in Britain, Downie and Barron (2000) showed in their study that rejection of a scientific theory among first-year undergraduate students was driven not by lack of evidence, but by pre-existing beliefs which precluded an open-minded approach. Further, even among non-rejecters of evolution, there is no guarantee that these students actually understand the concept rather than accept their lecturers' positions as dogma (Barnett et al. 1983). A recent study by Mead et al. did find a lack in correlation between knowledge and acceptance in a recent large-scale study looking at the effect of genetics teaching on evolutionary understanding and acceptance in school-age children (Mead et al. 2017).

To address the issue of students having to accept the lecturer's position as dogma, open engagement of the issue of rejection using interactive teaching strategies like role play/debates has been proposed. Here, the teacher adopts a position of committed neutrality rather than pushing an agenda (Geddis 1991). Downie and Barron (2000) suggested an historical approach to the teaching of evolution, whereby the students go through the process of learning about evolution in a more gradual way, and which can include a discussion of historical conflicts with some religious beliefs. The results of Southcott and Downie's (2012) follow-up study support the applicability of this idea. When they looked at the reasons why some fourth-year students changed their opinion on evolution from rejection to acceptance over the course of their degree, the reason most commonly mentioned was the realisation that evolution was not in conflict with their religious beliefs, while nobody mentioned the weight of the scientific evidence.

Our findings confirm the important role of religion in the students' approach to learning about, and accepting, the theory of evolution and might suggest new ways of tackling the problem of mental barriers related to pre-existing beliefs which might limit the students' ability to assess scientific evidence in an objective way.

While avoiding the conflict between religion and evolution by limiting the teaching of evolutionary theory could be seen as an option, particularly in areas where 'evolution' is more or less synonymous with micro-evolution (e.g. in bio-medicine when talking about the

emergence of antibiotic resistance in bacteria), we do not believe this is the road to follow. Evolution underpins our understanding of biology as a whole, including medicine.

Another option would be to teach evolution without mentioning religion and the potential conflict that could arise for some faiths. This is a common approach and the one we have been employing at the University of Roehampton. While based on a small sample size (71 students of Nutrition and Health), it appears from our results that teaching evolution in itself does not decrease the number of sceptical students. In our Nutrition & Health programme, the proportion of sceptical students was very similar in the cohorts that received or not received lectures related to evolution. It has been argued convincingly that raising issues, by openly engaging controversial topics rather than ignoring them, is associated with a higher success rate (Wilson 2005). It is possible that discussing in class the possible conflict with some religious ideas and giving examples of how scientist combine faith and evolutionary theory might help engage the students' independent thinking. In line with Downie and Barron (2000) and Southcott and Downie (2012), we think that a number of students will come to realise that accommodating evolution and religion is not by definition impossible if dogmatic thinking (and presenting) is removed from the interaction.

We think that evolution, especially human evolution, should be discussed openly, focussing on the links and the differences between physical evolution and cultural changes. By juxtaposing some apparent paradoxes (e.g. the increase in brain complexity and size enabled the cultural progression of humans, but is also at the basis of many neurological disorders unique to humans), the topic could be easily woven into the discussion of most diseases even in programmes that do not include specific lectures on evolutionary theory. We propose to give students room for debating these paradoxes, as well as any conflict they perceive with their faith; open debates might hone their scientific argumentation skills, make them engage with the topic and ultimately make them come by themselves to the conclusion that 'nothing in biology makes sense except in the light of evolution' (Dobzhansky 1973).

## Compliance with Ethical Standards

**Conflict of Interest** The authors declare that they have no conflict of interest.

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