

Evolution and Religion: Attitudes of Scottish Bioscience Students to the Teaching of Evolutionary Biology

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Abstract In a questionnaire-based survey, the proportion of Glasgow University first year biology students who rejected evolution in 2009–2011 was about 7%, similar to the previously reported average figure for 1987–1999. However, by final year, evolution rejection was absent in students who studied evolution beyond first year and 4% among those who did not. Evolution rejection was closely related to accepting a religion-based alternative, whereas acceptance was related to finding the evidence convincing. Although many religious students accepted evolution, 50% of Islamic students were rejecters, compared to 25% of Christians. A question testing acceptance of several scientific propositions showed no evidence that evolution rejecters were generally more skeptical of science than accepters. Rejecters were overall less secure than accepters in their identification of the correct definition for terms related to evolution and creationism, but, surprisingly, more than 10% of final year students chose a Lamarckian definition for Darwinian evolution. Accepters and rejecters responded equally poorly to a question on Darwin's history, but level 4 was much better. A breakdown of evolution into three components (human origins, macroevolution, and microevolution) found that some evolution rejecters accepted some components, with microevolution having the highest acceptance and human origins the lowest. These findings are discussed in terms of strategies for evolution education and the phenomenon of evolution rejection worldwide.

Keywords Evolution rejection · Biology students · Muslims · Christians · Evolution knowledge

Introduction

The theory of evolution has a curious status among the general public: some accept it as a cornerstone of modern science; others, often very vehemently, completely reject some or all of its basic propositions (Alters and Nelson 2002; Scott 1997). Few other established scientific theories are treated in this way: flat earthers are now rare, campaigners for the phlogiston theory of combustion even rarer. Climate change denial is common but there remains real debate among scientists in this field regarding predictions about the future, whereas rejection of evolution among scientists, especially bioscientists, is extremely rare (see, for example, the Inter Academy Panel statement on the teaching of evolution, endorsed by the science academies of 67 countries: www.interacademies.net).

Evolution rejection varies markedly between countries. Since 1985, a national survey in the U.S. has asked if the following statement is true or false or if the respondent is not sure: "human beings as we know them, developed from earlier species of animals." More recently, the same question has been put to adults in many European countries, Turkey, and Japan. Miller et al. (2006) reported that over the previous two decades, the percentage of U.S. adults accepting the statement had declined from 45% to 40%; evolution denial had increased from 7% to 21%. Evolution acceptance was high in Europe and Japan, around 80%. The only country to show evolution denial levels similar to the U.S. was Turkey, the only predominantly Muslim country in the survey. Branch and Scott (2009) have reviewed the political–religious battle over the teaching of creationism and its variant,

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intelligent design, in the U.S. public school system. Masood (2006) has commented on the links between American Christian fundamentalists and branches of Islam which are contributing to evolution rejection in Muslim countries, despite the original welcome to Darwin's ideas given by Islamic scholars.

The level of total evolution rejection in the UK general public, as reported by Miller et al. (2006), was relatively low at 7%, but what of UK bioscience students? Downie and Barron (2000) reported that over a 12-year period, 1987–1999, the proportion of University of Glasgow first year biology students rejecting evolution had ranged from 3.9% to 11.3% (mean, 7.3%; $n=9$ cohorts sampled, 420 students per cohort on average) with a slight but significant downwards trend in the more recent years. In two years sampled (1999 and 2002), evolution rejection among first year Glasgow medical students was consistently high at 10.2% and 10.8% (Downie 2004a, b) despite an expectation from medical school directors that it would be vanishingly low.

Downie and Barron (2000) reported results from first year students only, many of whom were studying biology for the first time (prior experience is not a prerequisite for the first year biology course), and some of whom were studying biology only for a single year as part of a degree program in other disciplines. It seemed worthwhile therefore to assess whether students changed their views on evolution over the course of a degree program in the biosciences. Here, we report on attitudes to evolution in a comparison between first and final year bioscience students, and update Downie and Barron's results a decade on.

Methods

Student Population and Courses

Our survey was carried out with the level 1 biology class at the University of Glasgow during sessions 2008–2009 and 2009–2010; and with the final year (level 4) class during sessions 2009–2010 and 2010–2011. Level 1 biology acts as a foundation course for all bioscience degree programs but is also studied by students who intend to progress to degrees in other disciplines such as chemistry and psychology. The course includes lectures on evolution, but the survey was carried out prior to these lectures, so that students' knowledge and understanding of evolution derived from their pre-university experience, including any informal learning. By level 4, bioscience students have chosen their degree program from a wide range of choices. Formal teaching at level 4 is in five-week optional courses, chosen by students to suit the theme of their degree program. Teaching on evolution is provided for all students in level 1 biology; a proportion of students (mostly those intending programs in genetics and

zoology) take level 2 options in evolutionary biology and animal diversity (which has a clear evolutionary basis); thereafter, evolution is not taught as a separate topic until final year where the option of evolution: pattern and process is taken mainly by zoology students. Overall, this means that for over half of Glasgow bioscience students their only formal instruction on evolution occurs at level 1. In analyzing the level 4 responses, we have divided them into two groups (a) those who study evolution to a high level (level 2 and/or level 4 courses); (b) those who only cover evolution at level 1, i.e., to a low level.

The Questionnaires

The level 1 questionnaire was modeled on that used by Downie and Barron (2000) with some minor modifications and some additional questions. The level 4 questionnaire contained some questions identical to those in the level 1 version, to assess changes in response over the levels in higher education, but also some questions specific to level 4. Each questionnaire began with a brief introduction on the status of the theory of evolution in modern science. Both questionnaires were approved by our Faculty Research Ethics Committee before use. The full texts of both questionnaires are available from the authors on request.

Questionnaires were completed by level 1 biology students during a laboratory class (students in groups of 40–50) in the middle of semester 1. One of the researchers gave a brief introduction to the purpose of the research, making clear that completion of the questionnaire would provide valuable information, but that it was entirely voluntary and anonymous, and that we would only use the information provided if students gave permission by ticking an appropriate box on the form. An almost identical procedure was used at level 4, with the questionnaire presented during meetings of final year option classes in semester 1. At both levels, permission to survey students during class time was provided by course coordinators. This procedure led to very high completion rates: few students failed to complete our questionnaires. However, not all students answered all questions, leading to minor differences in sample sizes. In analyzing questionnaire responses, χ^2 was frequently used to test for the statistical significance of differences in response frequencies. Some questions asked students to respond to a statement using a five-point Likert scale from 1 = strongly agree to 5 = strongly disagree: in analyzing the data, we consolidated responses 1, 2 = agree and 4, 5 = disagree, with 3 = neutral.

Results

Where the same questions were answered by both levels 1 and 4 students, the data tables show both sets of responses.

Comparisons between level 1 and 4 responses are brought out in the commentaries on the level 4 data.

Level 1

Level 1: Accepters and Rejecters

Table 1 shows the proportions of students in level 1 cohorts who accepted or rejected evolution by their response to the question “Do you agree that the process of biological evolution lasting many millions of years has occurred in one form or another?” The proportion of evolution rejecters shows minor annual variations but no significant trend over the two decades surveyed. Table 2 shows the proportions of evolution accepters and rejecters grouped by their intended degree programs and pre-university biology experience. Evolution rejection was low among students intending to follow a degree program in a subject heavily underpinned by evolution (zoology) and higher in sports science, psychology, and pharmacology, where the evolution content of the course could be expected to be low, but this relationship did not follow in chemistry. Evolution rejection was significantly higher ($X^2=10.4$; 2 *df*; $0.01 > P > 0.001$) among students who had studied no biology prior to university compared to those who had studied biology to Scottish higher level or above.

Level 1: Reasons for Rejecting Evolution

Students who rejected the statement about evolution were offered three possible reasons for rejecting evolution plus “other reasons—please state” and asked to indicate which one most accurately described their position. The percentages of students choosing the different reasons are shown in Table 3. The differences between the two years are statistically significant ($X^2=12.5$; 3 *df*, $0.001 < P < 0.01$), mainly due to a shift in 2009–2010 toward the “insufficient knowledge” response. As expected, the most commonly chosen reason

Table 1 Proportions of students in levels 1 and 4 who rejected the proposition that a long period of biological evolution has occurred

Levels	Year	Total number sampled	Rejectors (%)
1	1987–2009 ^a (mean+range)	2,854	7.3 (3.9–11.3)
	2008–2009	388	7.6
	2009–2010	532	5.6
4	2009–2011 High	255	0
	2009–2011 Low	228	4.4

^aData from Downie and Barron (2000). Level 4 data presented separately for “high” and “low” evolution students: 2009–2010 and 2010–2011 combined

Table 2 Proportions of level 1 students (percentage) who accepted or rejected evolution arranged according to their intended degree programs and to their pre-university experience in biology: data combined from 2008 to 2009 and 2009 to 2010

	Accepters	Rejecters	% Rejecters in each group
Intended degree program	<i>n</i> =487	<i>n</i> =26	
Zoology/aquatic	15	4	1.4
Sports science	10	38	16.9
Pharmacology	5	12	11.1
Psychology	13	31	11.3
Chemistry	17	15	4.6
Human biology	14	–	0
Microbiology	7	–	0
Biology/ biotechnology	19	–	0
Pre-university biology	<i>n</i> =527	<i>n</i> =31	
High (Scottish higher or above)	68	45	3.8
Low (Scottish standard grade)	2	0	0
None	30	55	9.7

Sample sizes in intended degree program and pre-university biology differ because not all students provided the relevant information

for rejecting evolution was the one based on a religious alternative. Where “other reasons” were selected, students mainly claimed that there had not been enough time for evolution to generate observed biodiversity.

Level 1: Reasons for Accepting Evolution

As above, students who accepted evolution were offered three reasons for accepting evolution, plus “other—please state” and asked to indicate which one most applied to them. The percentage of students choosing each reason is shown

Table 3 Reasons for rejecting evolution: proportions (percentage) of level 1 students rejecting evolution who selected each of the possible reasons provided

Reasons for rejecting evolution	2008–2009 <i>n</i> =31	2009–2010 <i>n</i> =30
There is insufficient evidence to prove conclusively to my satisfaction that evolution has occurred	28	21
I have insufficient knowledge about evolution to show me that it has occurred	13	32
I believe there are alternative explanations for the diversity of life seen today (e.g., divine creation, intelligent design)	57	41
Other reasons (please state)	2	6

Table 4 Reasons for accepting evolution: proportions (percentage) of level 1 and 4 students accepting evolution who selected each of the possible reasons provided; level 1 students presented by year group;

Reasons for accepting evolution	Level 1		Level 4	
	2008–2009 <i>n</i> =357	2009–2010 <i>n</i> =502	High <i>n</i> =255	Low <i>n</i> =218
The evidence is convincing and well supported	75	72	93	76
No better explanation has been presented to me at this present time	16	21	6	17
I accept that my lecturers have a greater knowledge of the subject than me and so I accept what has been taught to me.	8	5	1	4
Other reasons (please state)	1	2	0	3

in Table 4, which presents the data for level 4 students alongside. The differences between the two level 1 years are statistically significant ($\chi^2=19.1$; 3 *df*; $P<0.001$) but the overall pattern of responses was the same. In both years, about three quarters of students who accepted evolution chose the “convincing evidence” option; very few chose to shelter behind their lecturers’ greater knowledge.

Level 1: Religious Beliefs

Both groups were asked to state their religion, if they had one, and otherwise to write “none” rather than leaving the response blank. The results are shown in Tables 5 and 6. For comparison, Tables 5 and 6 show some data from Downie and Barron (2000). The tables also show data for level 4 students. The proportion of level 1 students claiming to have a religion was clearly lower (43% and 44% in the two years) than in the report of Downie and Barron (2000) where it never fell below 54%. The link between stating a religious belief and evolution rejection was even stronger than that found by Downie and Barron (2000). As previously, the proportion of accepters stating a religion was very similar to the proportion in the whole class. Of those stating a religion, there has been a slight increase in the number of respondents whose religion is Islam (6% in 1991–1995; 10% in 2008–2010) and a slight decline in the number of Christians (91% in 1991–1995; 83% in 2008–2010) with numbers in other religions too small for analysis. The proportion of Islamic students who reject evolution shows a slight decrease (58% in 1991–1995 and 50% in 2008–2010), while the proportion of Christian rejecters shows an increase (16% in 1991–1995 and 25% in 2008–2010): data recalculated from Table 6.

Level 1: Comparison with Other Scientific Ideas

We wished to discover the extent to which students believed evolution to be a well-established theory compared to some other well-known scientific ideas. We started by pointing

level 4 students presented according to their depth of evolution teaching, years 2009–2010 and 2010–2011 combined

out that “many of what are considered scientific facts by the public are actually theories based on good but not certain evidence.” Students were then asked to rate how well established four such ideas are, using a five-point scale from 5=well established to 1=poorly established. Results are shown in Table 7. For ease of comparison, we have combined responses 1, 2 as “poorly established”; 3=neutral; 4, 5 combined as “well established.” We have also combined the results from years 2008–2009 and 2009–2010. Acceptor and rejecter responses have been compared using χ^2 and the results shown as *P* values. There was no significant difference in the responses of the two groups to two of the theories: the link between CO₂ emissions and climate change and the link between smoking and lung cancer. However, while students overwhelmingly accepted the link between smoking and cancer, only 57–58% were convinced about CO₂ and climate change. There were significant differences between rejecters and accepters in their responses relating to the other two theories: rejecters were much less convinced about Einstein’s famous energy/mass equation and even less sure about continental drift, whereas evolution accepters regarded these as well established.

Table 5 Proportion (percentage) by year of the whole level 1 class, split into evolution accepters and rejecters, stating a religious belief (sample numbers as in Tables 2 and 3)

Year	Whole class	Acceptors	Rejectors
Level 1			
1987–1999 ^a	59	57	86
2008–2009	43	47	100
2009–2010	44	41	96
Level 4			
2009–2011	36	–	–

^a Mean data from Downie and Barron (2000). Whole class data also shown for level 4 for 2009–2010 and 2010–2011 combined

Table 6 Proportion (percentage) of the different religions, stated by level 1 evolution accepters and rejecters 1991–1995 (from Downie and Barron 2000), 2008–2009 and 2009–2010 combined; and by level 4 high and low evolution students: 2009–2010 and 2010–2011 combined

Religion	Level 1				Level 4	
	Accepters		Rejecters		High	Low
	1991–1995 (n=500)	2008–2010 (n=161)	1991–1995 (n=114)	2008–2010 (n=58)	(n=33)	(n=40)
Judaism	0.5	2	1	0	3	3
Islam	3	7	18	19	6	10
All Christianity	94	84	80	80	91	85
Buddhist, Sikh, Hindu	2.5	7	1	1	0	3

Level 1: Understanding of Terms

Since the survey of Downie and Barron (2000) surveys were conducted, the term “intelligent design” has been much promoted by opponents of evolution (see commentary by Sober 2007). We were interested to discover how well understood this term is compared with evolution and creationism. We therefore (level 1, 2009–2010 only) included a question where students were asked to match four terms with six definitions (i.e., there was some redundancy in the definitions list). The results are shown in Table 8 with data for level 4 students shown alongside those for level 1. Several features stand out. First, the accepters were generally more uniform in their responses and mostly correct, with >80% of respondents choosing the correct response. Rejecters were much more varied in their responses, only achieving a high level of correctness on intelligent design (hard to miss, since the word “intelligent” appears in the correct definition). It is also interesting how many of the rejecters had mistaken notions of what Darwinian evolution is: a higher proportion of them chose the Lamarckian definition (B) than any other, and several chose the mutationism option (F): only 30% of

rejecters got the correct definition. Even on the two kinds of creationism, the responses of rejecters were surprisingly insecure.

Level 1: Awareness of Darwin 200 Celebrations

Our surveys were carried out around the time of the celebratory events commemorating the 200th anniversary of Darwin’s birth (Darwin 200). We included a question to assess students’ awareness and knowledge of this event. Results are shown in Table 9 with data for level 4 students given alongside those for level 1. There is no significant difference between the responses of Level 1 accepters and rejecters ($\chi^2=2.13$; 3 *df*; $P>0.05$). Both sets of students performed poorly in identifying the correct statement (rejecters, 28%; accepters, 27%).

Level 1: Components of the Theory of Evolution

The theory of evolution includes several different propositions, and opponents of evolution do not necessarily reject them all. We investigated this aspect by asking students to rate their level of acceptance of three

Table 7 Level 1 students’ ratings regarding the extent to which four scientific ideas are established (evolution accepters and rejecters shown separately)

Idea	Accepters			Rejecters			P
	Poor	N	Well	Poor	N	Well	
Carbon dioxide emissions from human activity are the main cause of global climate change	26	16	58	25	18	57	NS
The equation $E=mc^2$	10	13	77	18	30	52	***
The continents once formed a single large landmass, now known as Pangaea	14	23	63	21	33	46	*
Smoking greatly increases the risk of developing lung cancer	5	11	84	3	8	89	NS

Data are shown as a percentage of those giving a ranking on a five-point scale from 1=poorly to 5=well established with 1, 2 combined as poor; 4, 5 combined as well; 3 neutral (N). Data from years 2008 to 2009 and 2009–2010 combined (n=1,018). Results of χ^2 comparisons shown as $P=NS$ (not significant); *0.01 < P < 0.05, *** P < 0.001

statements, using a five-point scale from 1=firmly reject to 5=firmly accept. Results are shown in Table 10. As expected, the responses of accepters and rejecters to these statements are highly significantly different (using χ^2 , $P < 0.001$ in each case), with at least 75% of accepters accepting each statement and at most 40% of rejecters accepting each statement. The curious feature of these results, however, is how many evolution rejecters actually accepted some or all of these statements with the statement on microevolution (evolutionary change within a species) receiving the highest acceptance and speciation (third statement) the lowest.

Level 4

Level 4: Accepters and Rejecters

Table 1 shows the proportions of students in the two level 4 groups (those who experienced post-level 1 evolution courses=high evolution; and those who experienced little if any post-level 1 evolution courses=low evolution) that claimed to accept or reject “biological evolution lasting many millions of years has occurred in one form or another.” The proportion of level 4 students overall who rejected evolution was only 2.1%, clearly less than

Table 8 Levels 1 and 4 students’ understanding of terms relating to evolution and creationism

Term	Definition	% choosing each definition			
		Level 1		Level 4	
		Acceptors	Rejectors	High	Low
Darwinian evolution	A	1	0	0	0
	B	11	48	13	14
	C	1	0	0	0
	D	2	4	0	1
	E ^a	82	30	81	82
	F	3	18	6	3
Old Earth creationism	A	4	4	1	0
	B	2	0	0	0
	C	10	50	19	4
	D ^a	80	38	79	88
	E	3	8	1	8
	F	1	0	0	0
Young Earth creationism	A	2	4	2	0
	B	4	8	0	3
	C ^a	81	46	81	79
	D	5	21	15	13
	E	4	21	2	4
	F	4	0	0	1
Intelligent design	A ^a	85	76	96	90
	B	2	8	1	1
	C	2	0	0	1
	D	1	0	0	4
	E	1	0	2	3
	F	9	16	1	1

Level 1 evolution acceptors ($n=502$) and rejectors ($n=30$) and level 4 high ($n=255$) and low ($n=228$) evolution groups shown separately as percentage

A Living systems are so complex that they must have been designed by some kind of intelligent agency; *B* during their lives organisms adapt to their environments and these useful adaptations are passed on to the next generation; *C* all living and extinct species were created at one time less than 10,000 years ago; *D* all living and extinct species were created over a long period of time, with species made extinct by catastrophic events replaced by new sets of created species; *E* all species are the result of a long period of gradual change, with favorable variations becoming more common in populations as a result of conferring a reproductive advantage; *F* an organism mutates and then changes to be fitter for its environment

^a Answers we consider to be correct. Key to definitions

Table 9 Levels 1 and 4 students’ awareness and knowledge of Darwin’s history

Statement	Level 1		Level 4	
	Acceptors (n=502)	Rejectors (n=30)	High (n=255)	Low (n=228)
Darwin was born 200 years ago ^a	27	28	64	43
Darwin wrote the <i>Origin of Species</i> 200 years ago	49	41	30	46
Darwin set off on his life-changing voyage on the <i>Beagle</i> 200 years ago	3	7	2	3
Darwin and Wallace first published their papers on natural selection 200 years ago	21	24	4	8

For level 1, evolution accepters and rejecters are shown separately; for Level 4, groups are shown according to depth of evolution teaching. All results as percentages of students picking the different responses

^aCorrect

level 1 students in the same time period. However, the proportion of level 4 students who had received only a low exposure to evolution teaching through their degree and who rejected evolution (4.4%) was not much less than level 1 students (7.6% in 2008–2009 and 5.6% in 2009–2010).

Level 4: Reasons for Accepting or Rejecting Evolution

As shown in Table 1 the numbers in level 4 rejecting evolution were small, although the proportion of rejecters in the low evolution group was in the same range as for level 1 over the years. We asked the rejecters to explain their position by responding to a set of responses. The results are shown in Table 11. We also asked the accepters the grounds for their position (Table 4). In addition, we asked the accepters whether any of them had been rejecters on entry to university: seven students responded positively and were asked a follow-up: “give your reason(s) for changing your opinion on biological evolution.” Results are shown in Table 12. All level 4 rejecters belonged to “low evolution” degree programs. It is clear that for

most of them, no amount of scientific evidence would overcome their beliefs, a more entrenched position even than that taken by level 1 rejecters. Table 12 shows that for those who had changed from rejection to acceptance during their university life, it was not scientific evidence that had made the difference, but the realization that evolution did not interfere with their religious beliefs. More encouraging from a science education perspective were the level 4 accepter results in Table 4. For level 4 students who had studied a “high evolution” program, the evidence for evolution was significantly more often chosen than at level 1 ($X^2=52.2$; 3 *df*; $P<0.001$); whereas for those in a “low evolution” program, the scientific evidence was no more often chosen than at level 1 ($X^2=3.2$; 3 *df*; $P>0.05$).

Level 4: Religious Beliefs

All students were asked to state their religion, if they had one, and otherwise to write “none” rather than leaving the response blank. In the whole class, only 36% claimed to have a religious belief, lower than any of our level 1

Table 10 Levels 1 and students’ level of acceptance of three evolutionary statements

Statement		Reject	N	Accept		Reject	N	Accept
<i>Homo sapiens</i> are descended from ancient species of apes: hence chimpanzees and <i>H. sapiens</i> share a single common ancestor	Level 1 acceptors	5	20	75	Level 1 rejectors	51	19	30
	Level 4 high	2	4	94	Level 4 low	5	16	79
					Level 4 rejectors	71	29	0
Species have been able to generate other species over long periods of time due to the process of natural selection (i.e., macro-evolution)	Level 1 acceptors	3	16	81	Level 1 rejectors	47	30	23
	Level 4 high	0	7	93	Level 4 low	3	6	91
					Level 4 rejectors	58	28	14
Natural selection acts at a within-species level allowing species to adapt to changes in their environment, e.g., antibiotic resistance in MRSA (i.e., micro-evolution)	Level 1 acceptors	2	16	82	Level 1 rejectors	34	26	40
	Level 4 high	0	7	93	Level 4 low	1	5	94
					Level 4 rejectors	0	29	71

Level 1 evolution acceptors (n=859) shown separately from rejectors (n=61). Level 4 high acceptors (n=255) shown separately from low (n=228) and from rejectors (n=7). Results from 2008 to 2009 and 2009 to 2010 combined. Data are shown as a percentage of those giving a ranking of 1, 2=reject; 3=neutral; 4, 5=accept

Table 11 Reasons for rejecting evolution: proportions (percentage) of level 4 students in low ($n=7$) evolution programs who chose particular reasons: data for 2009–2010 and 2010–2011 combined

Reasons for rejecting evolution	Low
The increase of evidence and teaching of evolution during my university career is still not enough to convince me	29
The evidence that has been produced in support of biological evolution is not trustworthy	0
Despite the increase of teaching and evidence relating to biological evolution this would never be enough to overcome my beliefs	71
Other reasons (please state)	0

No student in a high evolution program rejected evolution

samples. In the high evolution group 32% ($n=58$) claimed to have a religious belief and 41% ($n=92$) in the low group. A breakdown of religions is given in Table 6 alongside the data for level 1 students. The number of level 4 evolution rejecters was too small for statistical analysis of their religions. From Table 6, there is some indication that Islamic students were more likely to choose a low evolution program, but the differences are small.

Level 4: Understanding of Terms and Awareness of Darwin 200 Celebrations

As noted earlier for level 1 students, we were interested to assess the level of understanding of terms relating to evolution and creationism. We asked the same question as of level 1 students. The responses for level 4 students are shown in Table 8 alongside those for level 1. Results for level 4 students were very similar to those for level 1 accepters, and show little difference between high and low evolution groups. For science educators, it is discouraging to note the persistent acceptance of the Lamarckian mechanism of evolution into level 4 in just over a tenth of the students. Level 4 student responses to the question on Darwin's history are shown in Table 9. It is encouraging to see that more level 4 students than level 1 students got this right, especially those who had studied evolution in more depth.

Level 4: Components of the Theory of Evolution

As for level 1 students, we assessed the degree of acceptance of three evolutionary statements, using a five-point scale from 1=firmly reject to 5=firmly accept. We asked this question of both evolution accepters and rejecters. For level 4 accept, we again analyzed the data separately for "high" and "low" students: results are shown in Table 10

alongside those for level 1 and for level 4 rejecters. For the statement on human evolution, the acceptance level of high evolution students was significantly greater ($X^2=98$; 2 *df*; $P<0.001$) than low evolution students and also clearly greater than level 1 accepters. Level 4 rejecters had the lowest level of acceptance of this statement. For the statement on speciation, the acceptance level of high evolution students was higher than for level 1 accepters, but not significantly different from level 4 low students ($X^2=0.5$; 2 *df*; $P>0.05$). Level 4 rejecters were similar in their response to level 1 rejecters. For the statement on microevolution, the acceptance level of high evolution students was again higher than level 1 accepters, but not significantly different from level 4 low students ($X^2=1.32$; 2 *df*; $P>0.05$). Level 4 rejecters generally accepted this statement, contrary to the result for level 1 rejecters, but the sample size was small.

Discussion

The problem of evolution rejection among the general public, high school, and even college students in the U.S. has been well documented (Scott 2010; Branch and Scott 2008). In the UK, this issue has received much less attention. Williams (2008) has reported worrying developments in UK schools, but in higher education there is little evidence other than our earlier paper (Downie and Barron 2000). Here, we have updated the earlier study on first year bioscience students but also surveyed final year students, both those who have continued to study evolution and those who have not. Several aspects of the results are worth discussing.

Evolution Rejection Levels and the Influence of Education

The report of Downie and Barron (2000) on Glasgow level 1 biology students found a nine-year mean of 7.3% evolution

Table 12 Reasons for switching from evolution rejection to acceptance: proportion (%) of level 4 students ($n=7$) who agreed/disagreed to particular reasons: data for 2009–2010 and 2010–2011 combined

Reasons for switching to acceptance	Agree	<i>N</i>	Disagree
I have become convinced by the increase of evidence that has been presented to me	0	29	71
A change in my social or personal life has caused a change in any religious beliefs I may have	14	28	58
I have accepted that biological evolution does not interfere with any religious belief that I may hold	71	29	0

Responses on a five-point scale: 1, 2 combined as disagree; 3=neutral; 4, 5 agree

rejecters but with a significant downwards trend in the more recent years. Our new data, collected a decade later, indicate no continuation of that trend: a persistent minority of evolution rejecters remains. From an evolution education viewpoint, the encouraging feature of our findings is that evolution rejection is associated with low previous exposure to biology (enrollment in level 1 biology does not require school or college biology as a prerequisite) and with students who do not intend further study in aspects of biology where evolution is a core theme. Comparison with our level 4 students requires some caution: we did not follow the same cohort of students through to level 4 and then reassess them. However, given our large sample sizes and the fairly stable proportion of level 1 rejecters, the levels 1–4 trend should be meaningful. Overall, there was a substantial reduction in evolution rejection between levels 1 and 4. This was not simply a matter of general maturation since evolution rejection remained fairly high in level 4 students whose courses included little or no evolution, but dropped to zero in students whose courses included post-level 1 evolution content.

Reasons for Accepting or Rejecting Evolution

Evolution accepters mostly chose the option “the evidence is convincing and well supported” as their reason for acceptance, with the proportion increasing from over 70% to over 90% in level 4 students who had studied evolution beyond level 1. Rather a small proportion selected the option “my lecturers have a greater knowledge of the subject, so I accept what has been taught to me,” and an intermediate proportion opted for “no better explanation.” Although Downie and Barron (2000) phrased this question somewhat differently, there has been a shift in this new survey toward “convincing evidence” and away from “no better explanation.”

For level 1 evolution rejecters, the commonest option was the religion-based alternative explanation, but substantial numbers chose “insufficient evidence” (presumably the same evidence that evolution-accepters predominantly found “convincing and well supported”) and significant numbers cited insufficient personal knowledge, especially in 2009–2010. Downie and Barron (2000) again presented this question somewhat differently and found the commonest option the acceptance of a “religious creation account that excludes evolution.” By level 4, our evolution rejection sample size was very small, but the importance of a belief precluding evolution remained the main factor. Our sample size for switching from rejection to acceptance was also small ($n=7$), but it is fascinating that these students were less affected by scientific evidence than by a realization that evolution and their religious beliefs were not in conflict.

As Downie and Barron (2000) noted, a worrying feature of these results is that these are science students who are

allowing a religious belief to influence their view on a scientific theory. Scientists need to be able to assess evidence objectively, and science education needs to help prospective scientists to understand how science works as a process and to develop their own scientific skills and practices. Blancke et al. (2011) have emphasized that the creationist challenge to evolution has highlighted a deficiency in science education when it neglects to make clear the nature of science as a continuing process. As Williams (2009) has noted, it is not easy to influence beliefs which young people have developed from an early age, even by the presentation of strong evidence. Williams also notes that science education rarely deals well with science as a process, but this is precisely what is needed when preconceptions and mistaken beliefs need to be confronted. Part of the process of science is the historical development of ideas: as Williams notes, this is usually inadequately dealt with in science classes. Few of our level 1 students were able to identify correctly the key dates concerning Darwin and *The origin of species*.

Where our students stated a religion, Christianity and Islam were predominant, with the proportion of Christians declining and Muslims increasing since Downie and Barron (2000). The proportion of Christians rejecting evolution has increased since 2010 while the proportion of Muslims rejecting has decreased. There has been considerable coverage of the influence of faith-based education on evolution rejection in the UK (Williams 2008), but without a detailed analysis of the school backgrounds of our students, it is not possible to ascribe the causes of the trends we have found. Downie and Barron (2000) noted the high proportion of Muslim rejecters but also that many Muslims were accepters. Burton (2010) has emphasized that in this, as in many other features, Islam is no more a monolithic faith than is Christianity. She particularly contrasted Iran, where evolution is comprehensively taught, with Saudi Arabia where science textbooks devote much space to discrediting evolution. In apartheid South Africa, evolution was excluded from the school curriculum under the influence of the fundamentalist Christian Afrikaans Reformed Church: only since 2008 has evolution entered the curriculum (Abrie 2010).

The proportion of level 1 biology students claiming to hold a religious belief is lower (43% in 2008–2009 and 44% in 2009–2010) than the 59% reported by Downie and Barron (2000). It is worth emphasizing that, although evolution rejection was strongly associated with holding a religious belief, the majority of believers accepted evolution.

Science Skepticism and Beliefs

In considering the reasons for evolution rejection by some students, Downie and Barron (2000) tested the proposition

that evolution rejecters are generally skeptical of the claims of science. They found some evidence for this idea: rejecters were more skeptical than accepters of the impact of CFCs and acid rain and the link between smoking and lung cancer. However, the big difference between the groups was on evolution and an evolution-related phenomenon, plate tectonics. This time, the set of propositions we assessed contained both similar and different theories. The smoking–cancer link had high acceptance from both accepters and rejecters with little difference from 2000. As before, the plate tectonics proposition was significantly more accepted by evolution accepters than rejecters. Curiously, Einstein’s energy equation showed the biggest difference between the two groups, due to the low proportion of rejecters who believed this equation to be well established (perhaps reflecting a limited exposure to physics). The climate change proposition showed no difference between the groups, but interestingly, both groups gave this a low level of acceptance, possibly reflecting the high media exposure of climate change skeptics. In the U.S., there is linkage between evolution and climate change rejection (Young 2012), but no evidence of this was found among our students. Overall, there was little evidence from this study that evolution rejection was linked to a generalized skepticism about the claims of science.

Are Evolution Rejecters Simply Poorly Informed?

A possible explanation for evolution rejection in our level 1 students is that they have not had the opportunity to, or taken the trouble to learn much about evolution, i.e., they are poorly informed. We noted earlier that many of the rejecters had not studied biology prior to our level 1 course. Tables 8 and 9 provide support for this explanation. Over 80% of level 1 accepters and all level 4 students identified the correct definition for Darwinian evolution whereas only 30% of level 1 rejecters got this right. Even on the two kinds of creationism, level 1 rejecters were insecure. The question relating to the Darwin 200 celebrations did not require understanding or acceptance of the theory, and there was no difference between level 1 accepters and rejecters (both did poorly). It was encouraging to see an improvement in factual knowledge of Darwin in the level 4 cohort, especially those who had studied evolution in more detail.

Williams (2009) has argued that the low level of acceptance of evolution and ignorance of what the theory actually comprises is largely the result of weak coverage at school which starts too late and which is poorly delivered. He recommends that evolution should at least be introduced as part of primary school science, but Blancke et al. (2011) caution that the process of child cognitive development suggests that evolution is a concept better tackled once children are over ten years old.

Acceptance of the Different Propositions of Evolutionary Theory

Evolution is a multi-proposition theory (Futuyma 1998), and some evolution rejecters accept some aspects. In particular, microevolution within species is so self-evident that many creationists accept it while rejecting other aspects (for example, see Yahya 2006). Downie (2004a) reported that all but one of a group of 24 first-year medical students who rejected evolution accepted that natural selection operates within species. Speciation and the descent of human beings from a common ancestor with chimpanzees are generally known to be much more problematic. To what extent were these differences reflected in our surveys? The only group showing a low acceptance level for microevolution was the Level 1 rejecters. Both low- and high-level 4 students showed higher levels of acceptance than level 1 accepters. We regard these results as showing that the better-informed students are, the more likely they are to accept microevolution. For macroevolution and human origins, the influence of enhanced knowledge is again evident in the comparison between level 1 accepters and level 4 high students, with level 4 low students also showing higher levels of acceptance. As expected, these two propositions are more problematic for evolution rejecters, but it is surprising to find that a proportion of level 1 rejecters actually accept all three propositions: it is unclear from this what they think they are rejecting, and this question remains to be explored.

The Importance of Language: Acceptance or Belief

In our surveys, and in those by Downie and Barron (2000), the question we asked was worded as “Do you accept that...”, rather than “Do you believe that...” In our view, “belief” is inappropriate for questions about science. Williams (2009) and Moore (2009) both agree on this point but note that general public surveys of attitudes to evolution often do use the word “believe.” It is unclear how many people in a general public survey, or even a science student survey, would appreciate this distinction. “Acceptance” ought to imply knowing and understanding the evidence, but how many of us can take this position on more than a few scientific theories? Mostly, we accept what authoritative scientists, experts in a field, tell us. In this respect, those students who told us that their reason for accepting evolution was the greater knowledge of their lecturers were possibly the most honest. Such a response may be more akin to a belief than the process of objectively weighing up scientific evidence. The low acceptance levels of global climate change by our students may reflect something similar: students are unlikely to have considered the evidence themselves; their attitudes therefore reflect the confusion generated by media exposure of a minority of vocal rejecters.

Conclusion

Kitchner (2008) has discussed the dangers for society of what he terms “hybrid epistemologies” where people choose which collections of scientific evidence to accept or reject not on the basis of the evidence itself but on the basis of their religious beliefs. This is clearly especially problematic for young people intending to become scientists. Much evidence indicates that this issue is more serious in the United States and in predominantly Muslim countries than it is in Europe, but educational practice should devise coping practices wherever it occurs. In the specific case of evolution education, evolution as a theory needs to be more effectively taught as the cornerstone of modern biology, not as an optional adjunct. In our view, it is good practice to make clear the alternatives that have been considered by the scientific community (this is not the same as “teaching the controversy”) so that students can see what process science has gone through to arrive at its current conclusions (Pennock 2002; Pigliucci 2007).

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