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# Recalibrating the evolution versus creationism debate for student learning: towards students' evaluation of evidence in an argumentation task

Liam Guilfoyle  and Sibel Erduran 

Department of Education, University of Oxford, Oxford, UK

## ABSTRACT

There is substantial body of literature in science education focusing on students' understanding of the theory of evolution by natural selection. However, despite decades of research on the evolution versus creationism debate there is still widespread concern that particular misconceptions about evolution persist. The study aimed to recalibrate the evolution versus creationism debate by engaging students in an argumentation task where students can interpret evidence and reasons for why either position is justified or not, and on what basis. A card sort activity used to investigate the students' use of evidence and reasons. A sample of 77 students with an average age of 13 participated in the study in England in the context of a funded research project. The findings pointed to challenges and opportunities in teaching and learning of evolution through an argumentation task where alternative perspectives are drawn from both science and religious education. Furthermore, they illustrated how argumentation tasks can potentially provide a context for students to explore cross-subject topics. Research about the immersion of students in tasks that support their argumentation can generate understanding of students' reasoning, and ultimately such research may lead to the design of lesson resources to support students' engagement in science.

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## Introduction

There is substantial body of literature in science education focusing on students' understanding of the theory of evolution by natural selection given the centrality of the theory in biological sciences (e.g. Nehm & Reilly, 2007; Smith, 2010). There is widespread concern that particular misconceptions about evolution persist in students' thinking (Foster, 2012; Sbeglia & Nehm, 2020), for example essentialist thinking may contribute to such misconceptions (Coley & Tanner, 2015). Other research studies have focused on students' understanding in terms of the explanations that underpin the theory of evolution. For example, there has been research on the analysis of students creating

**CONTACT** Liam Guilfoyle  [Liam.Guilfoyle@education.ox.ac.uk](mailto:Liam.Guilfoyle@education.ox.ac.uk)  Department of Education, University of Oxford, 15 Norham Gardens, Oxford OX2 6PY, UK

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teleological and anthropomorphic explanations (Kampourakis & Zogza, 2009). Students' difficulties with relevant terminology (e.g. adaptation) in relation to their understanding of evolution has been reported (To et al., 2017). Some studies have proposed argumentation as a potential strategy in facilitating students' understanding of evolution (Tavares et al., 2010) as well as the role of argumentation skills in developing understanding about evolution (Basel et al., 2013).

The broader context of research on students' conceptions about evolution has included research on the evolution versus creationism debate (e.g. Brickhouse et al., 2000; Dagher & BouJaoude, 1997). Although there is abundance of research about this debate, there is scarcity of research on students' arguments about evolution versus creationism in a way that allows for interrogation of evidence and reasons from the particular reference point of the worldviews involved i.e. scientific and religious worldviews. In other words, although studies have investigated argumentation in the context of evolution (e.g. Zohar, 2007) including around the concepts related to evolution (Tavares et al., 2010), such research has often focused on teachers (e.g. Oliveria et al., 2011; Kwon & Cha, 2015) with an emphasis on arguments appealing to scientific evidence and reasons. In contrast, an alternative approach could involve students' engagement not only in scientific arguments but also religious arguments that appeal to evidence and reasons from religious worldviews, thus highlighting what would be deemed reasonable from a religious point of view.

While from a scientific point of view, one could argue that creationism is not supported by empirical evidence, other forms of evidence may play into the arguments of those who subscribe to creationism. In other words, the concept of 'evidence' can have a different sense in religious claims which may be based on experience rather than empirical investigation (Nieminen et al., 2020). The implication is that students will be better placed to tease out the nature and quality of warrants in supporting the use of evidence to justify claims in a nuanced manner relative to the source of the evidence, be it from a scientific or religious worldview. Focusing on argumentation contexts in general and students' use of evidence and reasons in particular can potentially help students understand why evolution is justified from a scientific point of view as well as why religious worldviews are justified from the reference of the particular traditions that frame these worldviews. In this article, we investigate secondary students' use of evidence and reasons to justify claims about evolution and creationism in an argumentation task administered in the context of a funded research project in England. The primary objective of this article is to report on an investigation on how secondary students engage in explicit arguments about evolution versus creationism whereby their participation is supported with evidence, and they are provided with opportunities to express their reasons for supporting particular positions with given evidence. Here, our reference to evidence is not exclusive of empirical scientific evidence but rather any information that can be used to provide justification. For example, in the context of religious education, historical data may be considered evidence in justifying particular religious claims (Chan et al., 2021).

Considering that evolution has been included as a topic in many international science curricula (Department of Education, 2013a, 2013b) and policy documents (e.g. National Academy of Sciences, 1998) for some time, and yet it remains a problematic aspect of science education, the research reported in this article aims to provide some insight

into how students' engagement in discussions about evolution can be enhanced. The empirical study reported in this article illustrates how students engage in argumentation about evolution when discussion activities are designed and structured in order to support their argumentation. Considering research in the learning of evolution has emphasised themes such as misconceptions (Nehm & Reilly, 2007) and essentialist thinking (Coley & Tanner, 2015) about evolution, this article contributes to a gap in the literature by bringing to the foreground the nature of students' argumentation about evolution.

## Literature review

This article provides an overview of the literature on the learning of evolution by natural selection as well as the role of argumentation in science and religious education. By bringing together these often-disparate areas of research, it provides a synthesis for enriching the debates about how students' understanding of evolution can be enhanced through an emphasis on argumentation. The underpinning assumption is that both bodies of literature will be enhanced particularly through the design, implementation and evaluation of an empirical study whose design has incorporated themes from both evolution and argumentation research. The review of literature thus begins with an overview of research on learning of evolution by natural selection and subsequently turns to the background on argumentation research in the context that is relevant to the evolution debate, namely the contrast of science and religious education.

### *Learning of evolution by natural selection*

The theory of evolution by natural selection is a core feature of biology and centres in many science curricula from around the world (Deniz & Borgerding, 2018). However it is notoriously difficult to teach for various reasons including potential conflict with worldviews and difficulties with understanding the key concepts involved. Common student misconceptions about evolution includes (a) all evolutionary change is adaptive, (b) evolutionary change is progressive, (c) evolutionary change is teleological (goal-directed), (d) evolutionary theory is a form of atheism, and (e) evolutionary process in general, and natural selection in particular are equated with event-like ontology rather than equilibration type ontology (Ferrari & Chi, 1998).

Numerous factors may contribute to students' difficulties with understanding evolution including the so-called 'cognitive construals' (Coley & Tanner, 2015) which are informal and intuitive ways of thinking about the world. Some examples of cognitive construals are anthropocentric, essentialist and teleological thinking. Anthropocentric thinking occurs when people distort how human beings are positioned in the world. People with this kind of thinking would have a tendency to reason about biological phenomena based on using analogies about human beings, assuming that human beings are separate from the natural world (Coley, 2007). Essentialist thinking relates to the idea that a property of a biological organism or system determines its identity, leading to the belief that members of a category are uniform relative to the shared properties (Shtulman & Schulz, 2008). Teleological thinking, on the other hand relates to explanations by reference to the consequences of phenomena, whereby causal reasoning

is employed with assumptions about purpose and function (Kelemen, 1999). Kelemen (1999) argues that over attribution of teleological thinking is an extension of younger children's intentional thinking. An assumption that students make is that every part or property of a living thing has a specific purpose (Poling & Evans, 2002). From an early age, students apply such reasoning to both animate and naturally occurring inanimate objects (Poling & Evans, 2002). Furthermore, Kelemen and Rosset (2009) indicate that teleological thinking continues to adulthood including professional scientists (Kelemen et al., 2013). Like essentialist thinking, although this way of reasoning may be appropriate during the early stages of psychological development, it becomes problematic when applied to reasoning about evolution (Emmons & Kelemen, 2015).

A key contributor to the debate on evolution and creationism in the context of England and internationally, Reiss (2018) further articulates the role of abstract reasoning in understanding evolution:

Evolution takes place over long periods of time and the geological notion of 'deep time' is one that is difficult for students. Then there is the problem that understanding the principal driver of evolution, natural selection, requires considerable powers of abstract reasoning. Added to this are difficulties in understanding the origins of phenotypic variation (including the non-directed nature of genetic mutations, independent assortment and the relationship between genotype and phenotype) and the ways in which change at the individual and population level interact. (p. 162)

Negative emotive response towards evolution may arouse in students because of potential tensions with their worldviews (Bertka et al., 2019). Students' perceived conflict of evolution with religious belief is an important issue for science education given such conflicts can potentially inhibit students from engaging with evolution (e.g. Berkman & Plutzer, 2012).

While much research on teaching and learning of evolution has focused on students' explanations (Kampourakis & Zogza, 2009), misconceptions (To et al., 2017) and worldviews (Bertka et al., 2019), some studies have proposed argumentation as a potential strategy in facilitating students' understanding of evolution (Tavares et al., 2010) as well as the role of argumentation skills in developing understanding about evolution (Basel et al., 2013). In comparing learning outcomes of the two different epistemic practices about evolution, argumentation can present the opportunity to consider alternative solutions to a problem. In a study focusing on an experimental design, Asterhan and Schwarz (2009) illustrated that argumentation can be a predictor of conceptual learning gains, whereas by contrast, consensually developed explanations were not. Furthermore, as a pedagogical strategy, argumentation centres in both science and religious education (Erduran et al., 2020) for which the evolution and creationism debate is equally relevant. Hence argumentation at the intersection of science education and religious education (RE) can potentially provide some insight into how students' understanding of evolution can be enhanced by drawing on cross-subject considerations in tasks that can potentially be used in lessons.

### ***Argumentation in science and religious education***

Shifting the focus of the evolution versus creationism debate towards students' skills in argumentation calls for the clarification of how argumentation is situated in both science

and RE. Argumentation is often defined as the justification of knowledge claims with reasons and evidence (Toulmin, 1958) and has emerged as a key area of research and development in science education in recent years (Lin et al., 2014). There are now well established practical resources that can be used to support teaching and learning of argumentation (e.g. Sampson & Schleigh, 2012).

Argumentation also centres in the RE research and syllabi, often with the purposes of expression and rationalisation of personal views as well as an empathetic understanding of the reasoning behind others' perspectives (Chan et al., 2021). In a Jewish education context, Gottlieb (2001) found students of both fifth and twelfth grades capable of religious argumentation, though the former paid little attention to the evidentiary basis for their beliefs. Several German-speaking researchers have investigated argumentation in RE, usually in connection with science and religion debates such as bioethics (Schmidt et al., 2017) as well as the creation and evolution debate (Basel et al., 2014). The findings of Basel et al. (2014) show that students found it more difficult to construct arguments from the religious than scientific perspective, while Schmidt et al. (2017) highlighted the importance of prior knowledge in argumentation in RE.

With respect to science education, there are at least three disciplinary bodies of research framing argumentation studies (Jiménez-Aleixandre & Erduran, 2007): (a) developmental psychology, highlighting argumentation as a form of formal language contributing to the development of cognitive capabilities; (b) language sciences, for instance the theory of communicative action; and (c) science studies, as in the interdisciplinary investigations on science drawing from history, philosophy and sociology of science and religion. By contrast, RE debates on foundational references in RE have ranged from theology to pluralistic RE (Cush, 1999), and they have included social sciences (Jackson, 1997) and philosophy (Hella & Wright, 2009). Collectively, the foundational disciplines help educators articulate how to frame argumentation for different purposes related to research in school settings.

The prominence of argumentation in both science education and RE research resonates with recent international curriculum policies in science and religious education in enhancing teaching and learning. In the context of science education, international curriculum standards such as the *Next Generation Science Standards* (NGSS Lead States, 2013) in the USA and scientific competences frameworks in the European Union (European Union 2006) have started to advocate the importance of students' evidence-based reasoning in science. Similarly, argumentation is often advocated as a learning outcome in the context of RE in curriculum policies from around the world. For example, although there is no single curriculum for RE in England, for example, there are legally determined local syllabi and curricula (Chan et al., 2021) that place a strong emphasis on argumentation. Creationism and evolution centre strongly in many RE syllabi (e.g. Leicestershire County Council, 2016).

However, despite a wealth of research and policy advocacy on argumentation in both science education and RE, research is limited with respect to students' use of evidence and reasons in supporting claims about evolution versus creationism as an explicit goal. Basel et al. (2013) investigated problem-centred interviews on secondary students' beliefs about evolutionary processes of adaptation. The authors used two categorical systems: one addressing the complexity of students' arguments, the other focusing on students' use of argumentation schemes. The findings suggested that students produced

mainly single claims or claims with a single justification consisting of either data or warrants. With regard to argumentation schemes students drew their arguments mainly using causal schemes, analogies, or illustrative examples.

Focusing on argumentation contexts in general and students' use of evidence and reasons in particular can potentially help students understand why evolution is justified from a scientific point of view as well as why worldviews are justified from the reference of the particular traditions that frame them. In so doing, such shift in emphasis may help recalibrate the emphasis on the evolution versus creationism debate towards a favourable space so that students can engage in the topic of evolution in a nuanced manner.

## Methodology

### Research question

The empirical study was guided by the following research question: How do secondary students engage in the selection of evidence to justify claims about evolution and creationism in the context of an activity that supports argumentation?

### Context

In England, the National Curriculum for Science includes the topic of evolution between the ages of 11 and 16 years (Key Stages 3 and 4; Department for Education, 2013a, 2013b). Between the ages of 11 and 14 years, students learn about genes, inheritance and DNA. Related topics that are covered in the curriculum include variation between individuals within a species is either continuous or discontinuous; the role of variation in natural selection; organism-environment fit and extinction; and the need for biodiversity (Department for Education, 2013a). For example, a unit on evolution for students between the ages of 11 and 14 years introduces students to evolutionary theory by exploring the ideas proposed by Darwin and Lamarck. The unit on evolution also introduces biodiversity, and the conservation efforts to protect endangered species.

Evolution has historically been accepted in England in the public sphere. The impact of Charles Darwin as an English scientist is undeniable. However, there may be some shifting attitudes towards evolution in recent times. According to Miller et al. (2006) United Kingdom (comprised of England, Wales, Scotland and Northern Ireland) ranked 6th in terms of acceptance of evolution in a list of 34 countries. A subsequent survey indicated that only 37% of UK public believed in Darwin's theory of evolution was 'beyond reasonable doubt'. The majority of those surveyed either believed in creationism or intelligent design (Lawes, 2009). Hence, there is broader cultural precedence to investigate how the debate around evolution and creationism is situated in the context of schooling and how any potential tensions might be resolved in students' understanding.

### Sample

The study was conducted with 77 secondary students in the 11–14 year group at Key Stage 3 in England in the context of a 3-year funded research project (Guilfoyle,



Erduran & Park, 2021). The primary objective of the overall project was to promote the teaching and learning of argumentation in science and religious education. The purpose of the study with students was to investigate how students engage in argumentation. The study is intended to generate understanding of how students of this age group engage with evidence in justifying claims in the context of evolution versus creationism without any formal engagement in argumentation. We were not interested in how they were responding to any taught argumentation lessons and how they might have progressed. Rather, we were interested in finding out how students engage in this debate given some materials that provide scaffolding for their reasoning. Aspects of students' argumentation in relation to their intellectual humility in the same task context are reported elsewhere (Godfrey & Erduran, *in press*)

The mean age of students was 13years (SD 1.1years). The focus on argumentation can potentially provide a productive dialogue in the literature (e.g. Basel et al., 2014; Lawson & Worsnop, 1992; Thagard & Findlay, 2010) in relation to the teaching and learning of evolution and creationism. Teachers who were participating in the wider project, from 3 independent fee-paying schools and 6 state schools, were asked to select a range of students from their class to participate in the study rather than simply high performing or highly engaged students. This strategy was adopted to ensure a reasonable spread and balance of participants, rather than relying on randomised selection without contextual consideration. At the point of data collection, the teachers had not yet formally engaged the students in argumentation activities. Hence, the students' responses are examples of those who did not receive any explicit teaching of argumentation. Standard ethical and consent procedures were followed in line with the approval granted by the researcher's institution.

### **Data sources**

Data consist of student verbal statements as well as their responses in a card sort activity. The card sort activity was designed to promote students' argumentation in the context of evolution and creationism. Card sort activities have often been used as pedagogical strategies for teaching argumentation (González-Howard & McNeill 2019) but are used here as a research method to elicit students' warrants for linking claim to evidence. Warrants are often left unstated and thus can be challenging to identify in arguments (e.g. Kelly et al. 1998). The activity was designed to limit students' contributions to specifically the link (warrant) by providing fixed evidence and claims (see Figure 1). Such an approach was taken so as to reduce the cognitive load on students, focusing on only one element of argumentation rather than engaging in multiple elements simultaneously, and this specific element was the intended focus of our study. Furthermore, reducing the complexity of the task design in this way, rather than a more open task, provided an opportunity for engaging with a larger sample of students.

During the activity, which was completed individually with a researcher and audio recorded, students were presented with 'evidence cards' (numbered 1–9 in Figure 1) and 3 competing claims (Columns A–C). Students were asked to consider each card and place it under the claim that they felt the card supported (even if the student did not support that claim personally). They were further asked to explain why they thought the evidence might be used to support that claim. Students were instructed to



There are at least three different perspectives on how life came into being. Which pieces of text supports each perspective?

There was no evolution. God created Humans. A	There was evolution. God had <u>some part</u> in this process. B	There was evolution. God had <u>no part</u> in this process. C	Does not support any of these three perspectives. D
1 "Humans are highly complex. Complex things must have a designer."	3 "The Hebrew for 'day', <i>yôm</i> , can also mean long periods of time. So, each of the 6 days of creation could have lasted millions of years."	6 "That humans descended from a common ancestor is supported by evidence in biology, genetics, and geology."	8 "Natural Selection means that those creatures with characteristics that give them an advantage are more likely to survive and so more likely to pass on their genes."
2 "Humans are different from animals in that they have a soul. Souls do not evolve but must have been given."	4 "Evolution is a tool that God used to develop human life." 5 "A scientific description of a process does not diminish God's active control of that process."	7 "The scientific timeline of creation is longer than the 6 days referred to in the Bible."	9 "The bible says that humans must subdue nature and rule over every living creature"

Figure 1. Card Sort Activity.

place the card in column D if they felt that the card could not be used to support any of the three claims. Only supportive prompts were used to elicit student reasoning such as 'Why did you place that there?' or 'Why do you think that card supports Claim A?' For some cards there may be more than one acceptable claim, depending on the warrant provided. Only if students hesitated between two columns, or specifically asked, were they instructed that it was acceptable to place a card between two columns. The student rationale for placing the card in both columns would be elicited. However, Figure 1 depicts the positions that are considered 'correct' for the purposes of this analysis. The cards were generated specifically for each perspective, as statements that a person holding that view would logically be able to use to support their perspective. That is, there is a clear underlying warrant to link the evidence statement to the primary claim of that perspective. While it is possible that some cards could, with some more complex warranting, support more than one perspective the 'correct' placement is that which we as researchers deemed most reasonable for the card (the perspective for which the card was generated). For the purposes of analysis, it was necessary to designate a singular correct response. But we have been alert to alternative reasonable placements in the analysis process, as will be evident in the results section (see evidence card 7).

The statements were constructed in a multidisciplinary team with science education and religious education expertise, drawing on pedagogical prompts which might regularly be used or heard in classrooms. Fifteen statements were initially generated, and these were refined to 9 through deliberative discussion. The final selection focused on cards which should require students to engage with the underlying meaning of the card to correctly place it. This meant removing rather obvious cards with statements such as 'Genesis 1:1 says 'In the beginning God created the heavens and the earth''. Instead, statements such as the following were used: 'Humans are highly complex. Complex things must have a designer.' This is a standard teleological argument a student might encounter but the key here is for the student to recognise that the card

is suggesting a designer and only someone taking the perspective that there is a God who is responsible for the creation of humans would use information suggestive of a designer. The analysis of students' choices first considers the extent of correct and incorrect placements to seek notable patterns and then explores possible explanations by examining how students rationalise the positioning (i.e. the link between the claim and evidence, or warrant).

## Methods

Students' choices of the evidence cards were categorised and counted, resulting in discrete data on correct and incorrect responses. Figure 2 illustrates how the data were organised. Each row represents one student and each of the columns represent the evidence cards 1–9. Within each intersecting cell the claim under which the student placed the evidence is given (A–D). When correct, the cell is green; when incorrect, the cell is blue. If a student did not place the card, the cell is blank and coloured blue. If the student placed the card between two claims, one of which was correct, it is counted as correct (cell is green). The right most column counts the number of correct answers for that given student. This column is formatted to show the lowest number of correct cards in the strongest shade of red. This allows, at a glance, to see which particular students were most and least successful in this activity.

There was a total of 77 card-sort activities conducted. Not all cards were placed in all card-sort activities. There are two reasons that not all cards would be placed: First, the student stated that they did not know and set the card aside. Second, the activity was halted due to time limitations, such as the end of a class period. Table 1 shows the number of attempted placements for each evidence card, ranging from 66–76 (or 86–99% of the students). However, only 48 students (62%) placed all 9 of the cards during the activity. In order to understand the pattern of placements in greater depth, we examine the rationales provided by all students for their placements. This involved organising the responses into each of the possible permutations (e.g. rationales for placing Card 1 with Claim A, Card 1 with Claim B, and so on for all 36 possible options).

Our purpose was not to provide an exhaustive account of all rationales, but to understand general patterns in student responses. Most combinations could be quickly summarised. That is, it was possible to establish a broad description of the sorts of reasons provided for each placement (Falk & Brodsky, 2014; Fincher & Tenenberg, 2005). We specifically focused on incorrect placements and organise our results and findings

		1	2	3	4	5	6	7	8	9	# Correct
Pupil-Interview-01	1	A	A	B	B	B	C	C	C	D	8
Pupil-Interview-02	2	A	A	C	B	B	C	B	B	B	5
Pupil-Interview-03	3	A	B	C	B	B	C	B	D	A	5
Pupil-Interview-04	4	A	D	C	B	D	B	B		B	2
Pupil-Interview-05	5	A	A	B	B	B	A	D	C	D	6

Figure 2. Organisation of card data.

**Table 1.** Number of attempted placements for each evidence card.

Evidence Card	1	2	3	4	5	6	7	8	9
Number Attempted	74	71	67	76	66	72	73	67	68
# Correct	60	55	41	60	50	56	39	14	20
% Correct of total	78%	71%	53%	78%	65%	73%	51%	18%	26%
% Correct of attempted	81%	77%	61%	79%	76%	78%	53%	21%	29%
% Incorrect or Not attempted	22%	29%	47%	22%	35%	27%	49%	82%	74%
% Incorrectly placed	20%	23%	40%	22%	24%	24%	48%	82%	72%

section in this way. This approach was deemed appropriate because while the sample and setting of the study may not allow for generalisability, focusing on key notable challenges that students experience will be transferable to other educational contexts and thus pedagogically useful (Joram et al., 2020; Lincoln & Guba, 1985).

**Results and findings**

The results and findings section are presented in two main parts. The first provides some quantitative cohort-level indicators of how students placed the evidence cards with respect to the claims. The second begins to unpack these quantitative findings by elucidating typical examples of the rationales provided by students for their placements. While rationales for both correct and incorrect placements are explored, the presentation is organised in descending order in terms of incorrect placements. Doing so provides a clearer image of the challenges experienced by students which have transferable implications for research and practice.

***Overview of the accuracy in students’ use of evidence cards***

Figure 3 provides a full overview of the outcomes for the card sort activity for the entire cohort of 77 students. As the figure illustrates visually, the students were able to place the correct card to a greater extent for the reasons represented in cards 1–7 than the cards 8–9. Card 8 provides a description of natural selection and selective advantage. While related Claims B and C, it does not specific provide support for these claims. Card 9 is also irrelevant to the claims and needs to be placed in Column D.

Table 1 provides the quantitative measures of the placements of the cards. In particular, it illustrates the number of placements that were correct, the percentage of placements that were correct with respect to the total number of card-sorts conducted and percentage of placements with respect to only those students who made an attempt to place that evidence card. The inverse of these numbers are also provided for ease of examination (i.e. the percentage incorrect or not answered, and the percentage

**Table 2.** Number (percentage) of card placements to an incorrect claim.

Claim # (%)	Card								
	1	2	3	4	5	6	7	8	9
A			6 (9)	12 (16)	6 (9)	4 (6)	5 (7)	6 (9)	32 (47)
B	10 (14)	10 (14)				8 (11)	19 (26)	7 (10)	14 (21)
C	2 (3)	0 (0)	11 (16)	2 (3)	5 (8)			42 (63)	3 (4)
D	4 (5)	6 (8)	10 (15)	3 (4)	5 (8)	5 (7)	11 (15)		

Pupil	Evidence Cards									# Correct
	1	2	3	4	5	6	7	8	9	
1	A	A	B	B	B	C	C	C	D	8
2	A	A	C	B	B	C	B	B	B	5
3	A	B	C	B	B	C	B	D	A	5
4	A	D	C	B	D	B	B		B	2
5	A	A	B	B	B	A	D	C	D	6
6	B			B	B	C	B	C	A	3
7	A	A	B	B	B	C	C	D	A	8
9	A	A	B	B	B	C	A	C		6
10	A	A	B	B	B	C	B	C	D	7
12	A	A	D	B	B	C	C	C	A	6
14	A	A	C	B	B	C	C	D	D	8
15	A	A	C	B	C	B	D	A	B	3
17	A	A	B	B	B	C	B	C	D	7
18	A	B	B	B	A	D	B	C	A	3
20	A	A	B	B	B	C	C	C/D	D	9
21	A	A	B	B	B	C	C	C	D	8
22	A	A	B	B	C	C	A	B	A	5
25	A	A	B	B	B	C	C	D	B	8
26	A	A	B	B	B	C	C	C	D	8
27	B	B	B	B	B	C	D	C	D	5
28	A	D	B	B	B	C	C	D	D	8
29	B	B	D	B	B	C	D	C	D	4
30	A	A	B	B	B	C	B	C	A	6
31	A	A	B	B	B	C	C	C	B	7
32	A	A	B	B	B	D	C	C	D	7
33	A	A	D	B	D	C	C	B	A	5
34	A	A	D	B	B	A	D	C	A	4
35	A	A	D	B	B	C	D	C	D	8
38	A	A	B	B	B	D	C	C	A	6
39		A		B			A	C		2
40	A			B		C	B	A	B	3
41	B	D	B	B			D	B	C	2
42	D			B		A	C			2
44	A	A	B	B	B	C	C	A/B	B/C	7
46	A	A	B	B	B	C	C	C	A	7
48	A	A	B/C	B	B	C	C	C	A	7
49	A	A	A	B	B	C	C	C	A	6
50	A	A	B	B	B	C	C	C	A	7
51	A	A	B	B	B	C	D	C	A	6
52	A	A	A	B	B	B	C			5
53	A	A		B		A	C	A	B	4
54	A	A		B	B	C	D			5
55	A	A	C	B	B	C	B			5
56		A		B	A	C	C			4
58	A	A	B	B	B	C	C	C	A	7
59	A	A	B	B	A	C	C	C	A	6
60	A	A	B	B		C		C	B	5
62	A	A	D	B		C	C	C	D	6
63	D	A	C	B	A	B	C	C	B	3
64	A	A	A	B	B	C	C	C	D	7
65	A	A	D	B	C	C	C	C	A	5
66	A	A	C	B	B	C	C	D	A	7
68	A	A	A	B	A	C	B	C	B	4
69	A	A	B	B	B	C	C	D	D	9
71	A	A	B	B	B	C	B	D	A	7
72	A	A	B	B	B	C	D	C	A	6
73	A	A	B	B	B	C	B	C	B	6
74	B	A	B	B	B	C	C	C	A	6
75	A/B	D	B	B	D	C	C	D	D	7
76	A			A/B	B	B	D	B	C	3

**Figure 3.** Summary of card placement by all students.

incorrectly placed). The percentage correct and percentage incorrect do not always add to 100%, this is because where a student placed the card between two columns, it is being counted as both correct and incorrect. The discrepancy ranges from 1 to 3%. In order to examine the incorrect placements of evidence cards in greater detail, [Table 2](#) presents both the number and percentage of the times that each evidence card (1–9) was placed incorrectly under each claim (A–D).

Looking first to the final row of [Table 1](#), we can examine the number of times that a student incorrectly placed each evidence card as a percentage of all attempts to place a card. As indicated earlier, evidence card 8 and 9 are the clear outliers. In the vast majority of cases, students did not identify that these cards could not support any of the claims (A–C). This finding is important because it may highlight that students are not engaging with the key message of the evidence cards in order to assess the link between claim and evidence. For example, evidence card 9 states ‘The Bible says that humans must subdue nature and rule over every living creature’. This quote has no implication for either creation or evolution. Therefore, it cannot be used as evidence to support any of the perspectives (A–C). In order to unpack this finding further, we can use [Table 2](#) to examine which (incorrect) claims students thought were supported by each evidence card. This affords us the opportunity to examine the challenges experienced by students and why they might reason incorrectly, in addition to the reasons why some students were successful in their reasoning.

### ***Student rationales for card placements***

In this section, we illustrate in more depth the quality of the students’ use of the evidence cards starting with the highest frequency of incorrect placement and moving towards the least number of incorrect ones. We do this because while the student responses might not be representative of students generally, it is particularly useful in a transferable sense to identify the challenges which may be experienced by students while engaging in such reasoning task.

**Evidence card 8** (‘Natural Selection means that those creatures with characteristics that give them an advantage are more likely to survive and so more likely to pass on their genes.’) was incorrectly placed in 82% of instances, and most frequently placed as supporting claim C, that there was evolution and God had no part in the process (61% of all placements). That the majority of students placed the card with claim C may be unsurprising given the relationship between the topic of the claim and the topic of the evidence. This might be indicative of strategies related to noticing key words and phrases that are relevant, rather than engaging with the substantive content of the sentences. For example:

Um, because natural selection is also connected to evolution. And again, it doesn’t mention anything about God (S26)

I put it in there because that sort of goes back to science thing (S59)

And it shows that evolution is a thing in it doesn’t mention God (S72)

Students who accurately placed this card generally recognised that while natural selection played a role in evolution, the statement was merely a definition. The definition, as phrased, would not add weight to the argument of any claim (A–C). For example: ‘I don’t think it really says which one it is, it is more just facts.’ (S70).

**Evidence card 9** ('The bible says that humans must subdue nature and rule over every living creature') was incorrectly placed 74% of instances. It is clear that the majority of students incorrectly thought it supported Claim A (47%), that there was no evolution and God created humans. Here we can examine a selection of the rationales provided by students for this decision.

That one is more about the Bible. It says 'the Bible says that humans must subdue nature', so it is more that the bible had nature ... God created nature, in the bible (S7)

I think it is saying that God has made it in that way. So, the Bible just tells us that humans ... yeah. I think (S11)

It doesn't really talk about evolution or anything. So, I think it doesn't square any of the statements (S33)

Because it talks about how the Bible says that humans should rule over other creatures, which would imply that we would be created before other creatures (S13)

These quotes indicate a range of reasoning strategies, from what appears to be reading comprehension strategies of matching similar words (the presence of 'Bible' or the absence of 'evolution'), to trying to infer beyond the content of the statement that creation must have occurred. While the latter would be an interesting and useful starting point to tease out reasoning, the former represents the use of strategies that would otherwise be useful in succeeding in school but may be shortcutting, or compensating for, the reasoning processes necessary for such a task.

**Evidence card 7** ('The scientific timeline of creation is longer than the 6 days referred to in the Bible.') was incorrectly placed in 49% of instances, and most frequently placed as supporting claim B (26% of all placements). While this was not the placement we deemed 'correct', per se, it is acceptable with the right rationalisation (such as in tandem with evidence card 3, that suggested the timeline of creation in the bible and the scientific timeline could be reconciled). We did see students using this thinking: 'So that there is time, but he created it, but maybe the six days referenced millions' (S2).

The more curious placements were the 22% of students who said the card supported Claim A or D. To engage with the substance of the card would be to recognise that the statements suggest a contradiction between the account of creation in the bible and the account of creation offered by science. Placing the card in A (that God created humans) or D (that it supports no claim) is indicative of a misunderstanding of the significance of the card's meaning. It is noted that students are adopting strategies that recognise the presence of the word Bible in order to match it with A:

It's in the Bible. And the six days of course of how God made the earth, Adam and Eve, I felt like it should just go in that bit, because that's the whole part of the story really? The whole point of what happened (S77)

Indeed, even those who placed the card in B (that God had some role in evolution), often simply do so because of the presence of both the word 'Bible' and 'scientific'

Because I think that it says it has a built both in it. (S36)

Hmmm ... I think number two because it mentions the Bible. And I think it does say about 6 days that made the world, like the different stages ... Um ... because like, the reason I put it in this because it's mentioned about scientific. (S40)

**Evidence card 3** ('The Hebrew for 'day', *yôm*, can also mean long periods of time. So, each of the 6 days of creation could have lasted millions of years.') was the next most frequently misplaced card (40% of all placements). The most frequent misplacement for this card was claim C (16% of all placements). 15% of placements were to Claim D and 9% to Claim A.

The key message of this card is that the scientific timelines and biblical timelines can be reconciled if one considers each day to be millions of years, which is one legitimate interpretation of the original text. If one understood this meaning, it would be very difficult to rationalise why someone arguing against the role of God in creation would call upon this point to support their view. Looking at the reasons that the students provided, placing the card as supporting Claim A it appeared that the presence of the phrase '6 days of creation' was suggesting God's creation alone ('It says, like more about the Bible, and like, the creation the story.' S36; 'Yeah, because it's more to do with Gods and not evolution' S49). Yet others appeared to articulate the reconciliatory position of the statement but placed it in Claim A anyway:

... but it could be used as kind of a metaphor for why ... for an explanation of how God have created something so quickly, when we know that our Earth is really old (S13)

It is not obvious how the card would be deemed irrelevant (D) but may be associated with a lack of understanding of the card. Most rationales merely reiterated that it did not support any claim (E.g. 'That doesn't really support any of them really' S12; 'That has nothing to do with it. Well, it could be I don't see it. So, I'm putting in the does not really support anything' S34).

**Evidence card 5** ('A scientific description of a process does not diminish God's active control of that process.') was placed incorrectly in 24% of instances, with an almost even split across the three alternative columns (A: 9%, C: 8%, D: 8%) (see [Table 2](#)). The essence of the message within the card is that God can still have a role even if we accept the scientific description of a process. It is difficult to see, then, how this card could be positioned as supporting that God had no role in creation (Claim C), or why someone arguing that there was no evolution would use such a statement to support their view (Claim A). Many students asked for clarification on the meaning of the word diminish. In such cases, the placement could have been as a result of a guess or a misunderstanding of the meaning of the card. This is evident in some responses, for example for Claim A: 'I think it is because it says about how, like, God being like, here it says, like, God controls stuff and something like that. So that is what I think.' (S23). This response might also be interpreted as an insertion of one's own position into the evaluation of the card. Similarly for Claim C, some misunderstanding was noted: 'The third one, because scientists did this. And God didn't do it' (S24). Yet, for others, there was a sense that one aspect of the statement outweighed the other for example, for Claim A: 'Because it is saying that it doesn't diminish his active control of the process' (S63), which ignores there being a scientific description. Some misunderstanding might not be surprising here as the language contained within this card is of a higher complexity than many of the other cards.



It is worthy of note that the vast majority of students were successful in placing this card, and subsequent cards. In this case, 76% placed the card correctly. When examining the rationales for these placements, it was regular for students to recognise how this statement would be useful for supporting a reconciliatory position: ‘Because it says scientists ... like evolution theory can be true and also God can be true. So, it’s supports both ideas.’ (S72). Some rationales, however, were more elaborated:

I think that’ll be in two. Because there’s some evidence that ... person two might say there’s some evidence of evolution, and people do evolve. But we have to start somewhere. Even if we want to ... like bacteria. Where did the bacteria come from? And then I think the person in two would say that was God starting it and then he let evolution, like, take the rest. (S74)

**Evidence card 4** (‘Evolution is a tool that God used to develop human life.’) was placed incorrectly just 22% of the times, though the majority of these misplacements (16% of all instances) were with Claim A, that God created humans and that there was no evolution. It seems entirely contradictory to suggest that evolution is a tool that was used while also suggesting there was no evolution. By the evidence card suggesting evolution existed, it should rule itself out of being applicable to Claim A.

In some instances it was noted that students, again, used strategies that otherwise might be effective in schooling – by noticing the part of the sentence ‘God used to develop human life’ as similar to ‘God created humans’, they might have been able to match the cards based on the similarity of their construction without engaging in the substantive content or meaning of the card.

... because it talks about how God, how it was only God who developed human life and doesn’t say that ... It doesn’t say anything about evolution existing (S13)

Conversely, the 4% who suggested that this card supported Claim C (that there was evolution and God had no role in the process) could have focused on the presence of the word ‘evolution’ to find a match rather than seeing the key message that ‘God used’ it (i.e. had a role in evolution). For example: ‘It is just purely evolution is just adapting to your surroundings. And God has really got no part in it. It’s just you doing it.’ (S1).

For those who placed it correctly, there was a mixture of rationales provided, from those that focused on the presence of both ‘evolution’ and ‘God’ (‘That is saying both, because it is using evolution and God’ S9) as well as more comprehensive rationales that articulated the underlying message or the logic which necessitated it be placed in B:

That one is that evolution is a tool that God used to help develop human life. I’ll put it there because it’s kind of saying that evolution was used, but God did have a small part to actually play in that (S5)

Well, if God did create us, he’s also using evolution to help us develop. So, it can’t be there was no evolution, because it says God used evolution. But it can’t be God had no part because it says God used it (S31)

**Evidence card 6** (‘That humans descended from a common ancestor is supported by evidence in biology, genetics, and geology.’) was also placed incorrectly 24% of the times. These incorrect placements were more evenly spread across the other claims: (A: 6%, B: 11%, D: 7%). Similar to Evidence card 5, the language complexity of this card might be attributed to its incorrect placement more so than a particular pattern of reasoning. Placing the card in

column D may be indicative of a lack of understanding of the card's or claim's meaning, and this was the case for some. However, others provided a reasonable rationale that the statement was about descendants after the original creation (quote below), though interpreting the card in the way might better server Claim B than none at all.

Because it's not about how humans were created, but how they continued their race. It could support all of them, but at the same time, it's none of them because it's not about creation (S32)

Some students, however, rationalised their placement of the card as supporting Claim A (that there was no evolution and God created humans) on the basis that God was the common ancestor, ('because it's saying that humans descended from a common ancestor, which in this case would be God' S5), which shows some reasoning. Placing the card in B (that there was evolution, but God had some part to play in the process) also makes sense because Claim B is not trying to reject evolution. Some student rationalised it in this way. For example:

Because like ... God could have created the ancestor before. That means that God had some part in the process. But it was evolution because they descended, and he is part of it (S63)

**Evidence Card 2** ('Humans are different from animals in that they have a soul. Souls do not evolve but must have been given.') was placed incorrectly in 23% of instances; these were 14% in Claim B and 9% in Claim D. The key message of this card is that for something to have been 'given', there must have been a 'giver'. Such a statement would therefore lend itself to supporting the existence of God. In this way, it's positioning to support Claim B is not entirely unreasonable, but it is unlikely to be used by someone supporting B because it specifically highlights that humans are different from animals and not in a way that evolution can explain. Using similar phrase-matching strategies, 'do not evolve' should rule it out of Claim B and Claim C. This is likely why we do not see any placements in Claim C and it was a regular feature of rationales for students who placed it correctly in A:

Because it says souls do not evolve but they must be given? Because it's been given by God (S62)

Because it says that those souls have been given and souls do not evolve like there's no evolution in that (S66)

However, one student reasoned that soul-giving and biological evolution could be separate, and therefore could support Claim B:

I think soul ... Because God. And like they have to be given. And then evolution because I don't think that God would have made the person but could have given them the soul. In the way I think the human evolution and the soul was from God (S77).

Finally, **Evidence card 1** ('Humans are highly complex. Complex things must have a designer') was placed incorrectly in 22% of instances. In the majority of cases (14% of all instances) the card was placed with Claim B, 3% were placed with C and 4% with D. The key point of this card is that there is a designer (i.e. a God) and so it is a natural fit with Claim A, but not entirely unreasonable for Claim B. The reason it should not support Claim B is that the idea of 'design' would run counter to evolutionary processes. But if the student reasoned that God guiding the processes of evolution is tantamount to

'design', then the placement would be reasonable ('so in a way it could show that he designed it so took different evolutions or that he did in one go.' S75). However, more often the incorrect placements were rationalised with some evident confusion and some attempt to match words, for example in the case below where a student suggests that the word 'complex' is associated with scientists and 'designer' with God.

I would put it in this one, but I can't think which one to put it in. Because it says humans are highly complex. But that's like, scientists, and then it says complex things must have a designer, so it would be like God makes the design. (S61)

The illustrative examples on the reasons provided by the students begin to indicate how students are engaging with the argumentation task on evolution and creationism. Considering the sample size of 77 students, it is beyond the scope of this article to report on all types of responses provided. In future studies, we intend to report on the overall categorisation of the student responses based on the types of reasons provided, for example by using Walton's categories of presumptive reasoning (Walton, 2006). Such an analysis will extend the scope of this article by providing a systematic illustration of the nature of the reasons provided by students as they engaged in the card sort activity. As such, it will address a different research question than the one addressed here. In this article, we were interested in exploring how secondary students engage in the selection of evidence to justify claims about evolution and creationism when they are immersed in an activity that support their argumentation. Future studies can focus on the analysis of the reasons that students provide for their reasons for selecting the evidence to generate a classification in a more systematic manner.

## Conclusions and discussion

The empirical study reported in the article contributes to understanding of both challenges and opportunities in teaching and learning of evolution by engaging in an argumentation task where perspectives are drawn from both science and RE. The challenges include the students' difficulties in identifying when evidence was irrelevant to any of the competing claims provided. For the two cards which ought to be identified as not supporting any claim, cards 8 and 9, they were placed correctly by only 18% and 26% of the students respectively. Examining the rationales provided for the incorrect placements, students primarily relied on two key strategies in making their decision: (a) identifying the presence of a keyword that they associated with one of the claims (such as 'Bible' in card 9) and, somewhat conversely (b) recognising the absence of a concept (such as there being no reference to a God in card 8). It is noteworthy students appeared to experience this challenge with evidence from both science and RE, suggesting the difficulty is not necessarily unique to one subject/content area.

Students demonstrated high levels of success in terms of placing some of the other evidence cards. Five of the nine cards had between 65 and 78% of students correctly placing them. In many instances, students were able to identify the underlying warrant by engaging with the meaning of the statement in the context of the claim. For example, in the case of card 1 ('Humans are highly complex. Complex things must have a designer'), students would often state that would be used to support the idea of God creating humans because the 'designer' being referred to would be suggestive of a God. However, the

strategies with keyword identification and recognising the absence of concepts appeared to be utilised at times for these cards too. (e.g. Card 6 correctly placed because ‘it doesn’t talk about God’ or ‘it is more to do with science’). This raises questions about how students engage in tasks, such as card sort activities, which are frequently used for developing argumentation skills. It suggests that some students might use short-cut strategies, which are perhaps generally useful in schooling, to guess rather than engaging in reasoning with the content of the evidence cards.

This observation highlights both a limitation as well as a finding of this study and it has implications for research and practice. It is a limitation of the study insofar as it can be argued students’ use short-cut strategies means that their reasoning is not being accessed by the research task. However, this is how students are engaging with a reasoning task when it is presented to them. The observation is akin to what Jimenez-Aleixandre and colleagues (2000) highlighted as ‘doing the lesson’ versus ‘doing science’ when students engage in procedural school activities as opposed to deep thinking about the subject being taught. The observation has important implications for the use of these strategies for argumentation in classroom practice, such as the need to explicitly elicit, examine, and develop the warrants that students generate for their decisions, and to differentiate routine and procedural lesson tasks from learning goals.

The study extends the literature on both the teaching and learning of evolution (e.g. Dagher & BouJaoude, 1997; Deniz & Borgerding, 2018; Mansour, 2015) and argumentation (Jimenez-Aleixandre et al., 2000; Osborne, 2010) in science education potentially contributing to research on socio-scientific issues (Sadler, 2005). This article extends the discussion on evolution versus creationism in science education by recalibrating the debate towards students’ engagement in argumentation where evidence and reasons are brought to the foreground. The research instrument used in this study has potential beyond research purposes and could be used pedagogically within classroom contexts. The activity helps to isolate and elicit the reason (warrant) within the argument, even in arguments which students themselves do not agree with.

As previous research has indicated how students find it difficult to generate evidence in debates (Bravo-Torija & Jiménez-Aleixandre, 2018), providing students with evidence cards in this task has been one way to negate this difficulty to a certain extent while also focusing attention to the reasoning that links claims and evidence. Although the data illustrate students’ difficulties with engaging with evidence and reasons, it is of note that the students had received no formal lessons on argumentation. The results are thus likely to be similar to other students’ engagement in such tasks if their teachers are not familiar with argumentation themselves and don’t teach argumentation-based lessons.

This article has numerous implications for teaching practice particularly in relation to the incorporation of argumentation in science lessons. First, the design of the task used with the students can be used as a framework where competing claims can be presented to students with alternative pieces of evidence. In the task, there were 3 alternative claims and several pieces of evidence that would go with either claim. There may be different number of claims and different science topics, for example two competing claims about sun rotating around the earth or the earth rotating around the sun, a historically significant case in science. In our study, the task was presented to students on an individual basis to gain in-depth understanding of their engagement with arguments.

However, in the context of an actual science lesson, it is possible for the task to be used by groups of students where 4–5 students are encouraged to debate about the different claims, for instance through role play. Ultimately, the understanding about students' engagement with the task can inform what teachers can expect to emerge in their lessons when teaching similar activities.

Research on science teachers' professional development in argumentation has demonstrated that learning to teach higher order thinking skills such as argumentation requires long-term and sustained engagement in a teacher learning community (Zemba-Saul & Vaishampayan, 2019; Zohar, 2007). In this sense, generating exemplars of activities that teachers can use to engage their students in argumentation is a positive step forward in supporting teachers. The study illustrates an account of how argumentation tasks can potentially provide a context for students to explore cross-subject topics such as evolution thereby enhancing coherence in the curricular goals in schools. Research about the immersion of students in tasks that support their argumentation can generate understanding of the issues that arise in students' reasoning, and ultimately such research can potentially lead to the design of lesson resources that can be used by teachers. Ultimately, this article contributes to evolution education by incorporating a renewed orientation towards argumentation extending the literature beyond an emphasis on biological knowledge and teleological thinking.

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## ORCID

Liam Guilfoyle  <http://orcid.org/0000-0002-3736-0339>

Sibel Erduran  <http://orcid.org/0000-0001-5226-0136>

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