Supplemental Material

CBE—Life Sciences Education

Barnes *et al*.

MATE 2.0 Distribution Instructions and Example

The MATE 2.0 is open access and freely available for anyone to use as they wish. All validity evidence for this instrument was gathered from undergraduate college students at 4-year institutions in the United States. Those who wish to use the MATE 2.0 in a different population (such as secondary school students in a different country) are advised to gather additional validity evidence for the desired population.

The survey can be administered either on paper or online. During administration, instrument items should always be preceded by the following written prompt: "A species is a group of similar organisms. For example, dogs, cats, and humans are all different species. Given this definition of a species, please indicate whether you agree or disagree with the following statements, ***based on your personal opinion***." This prompt is needed because it provides a colloquial definition of "species" for survey-takers to use throughout the survey and specifies that they should answer based on their own views rather than on their impression of what others believe. We presented items in numerical order when gathering validity evidence (Table 2). A sample layout of an online format from Qualtrics is pictured on the following page.

The MATE 2.0 should be scored on a 5-point Likert scale. Most items are coded from strongly disagree (1) to strongly agree (5). Items 3 (The idea that new species evolve from earlier species is NOT supported by scientific evidence) and 5 (The idea that new species evolve from earlier species is NOT a scientifically valid theory) should be reverse-coded from strongly agree (1) to strongly disagree (5). An individual's total score can be calculated by adding together the point values of all their answers, yielding a minimum score of 9 and a maximum score of 45. However, for interpretability, we recommend using an average composite score, which is obtained by dividing the total score by 9 (the number of items). An average composite score can range from 1.0 to 5.0 and reflects the individual's average agreement with items on the survey. Finally, researchers can transform scores into person measures using Rasch analysis to overcome the limitations of using Likert based measures.

The main conceptual difference between the original MATE 1.0 and the MATE 2.0 is that the MATE 2.0 defines acceptance of evolution as "The agreement that it is scientifically valid that all species have evolved from prior species," while the MATE 1.0 does not provide a clear definition of evolution acceptance. Given this definition, the MATE 2.0 replaces the term "evolution" –which can be interpreted in a variety of ways– with the more specific phrase "the idea that new species evolve from earlier species." As such, an individual's score on the MATE 2.0 is intended to reflect their acceptance of macroevolution and human evolution.

A species is a group of similar organisms. For example, dogs, cats, and humans are all different species. Given this definition of a species, please indicate whether you agree or disagree with the following statements, *based on your personal opinion*:

	Strongly disagree	Somewhat disagree	Neutral	Somewhat agree	Strongly agree
All species that exist today have evolved from previous species.	○	○	○	○	○
Modern humans have evolved from earlier non-human species.	○	○	○	○	○
The idea that new species evolve from earlier species is NOT supported by scientific evidence.	○	○	○	○	○
Current scientific evidence suggests that new species can evolve from earlier species.	○	○	○	○	○
The idea that new species evolve from earlier species is NOT a scientifically valid theory.	○	○	○	○	○
The idea that new species evolve from earlier species is the result of scientific research.	○	○	○	○	○
The idea that species can evolve into new species explains the diversity of life on Earth.	○	○	○	○	○
The idea that new species evolve from earlier species is a scientifically valid theory.	○	○	○	○	○
All of life on earth evolved from previous species.	○	○	○	○	○

Demographic Questions used in Cognitive Interviews with Original MATE

1. What is your academic year?
    a. First-year
    b. Sophomore
    c. Junior
    d. Senior
    e. 5th year or higher

2. I most closely identify as:
    a. Female
    b. Male
    c. Nonbinary
    d. Decline to state
    e. Please describe your gender identity if the best option is not listed: _____

3. What is your ethnicity? Please select all that apply.
    a. American Indian, Native American, or Alaskan Native
    b. Asian or Asian American
    c. Black or African American
    d. Hispanic or Latino/Latina
    e. Native Hawaiian or Other Pacific Islander
    f. White or European American
    g. Decline to state
    h. Other, not listed: _____

4. I most closely identify as:
    a. Agnostic (does not have a definite belief about whether God exists or not)
    b. Atheist (believes that God does not exist)
    c. Buddhist
    d. Christian- Catholic
    e. Christian- The Church of Jesus Christ of Latter-Day Saints
    f. Christian- Protestant
    g. Christian- Other (please describe): _____
    h. Hindu
    i. Jewish
    j. Muslim
    k. Nothing in particular
    l. Other faith (please describe): _____
    m. Decline to state

5. Do you identify as an Evangelical Christian?
    a. Yes
    b. No
    c. I'm not sure

6. I attend religious services regularly:
    a. Strongly Disagree

b. Disagree
c. Neutral
d. Agree
e. Strongly Agree

7. I believe in God:
    a. Strongly Disagree
    b. Disagree
    c. Neutral
    d. Agree
    e. Strongly Agree

8. I consider myself a religious person:
    a. Strongly Disagree
    b. Disagree
    c. Neutral
    d. Agree
    e. Strongly Agree

9. I consider myself a spiritual person:
    a. Strongly Disagree
    b. Disagree
    c. Neutral
    d. Agree
    e. Strongly Agree

10. Are you a native English speaker?
    a. Yes
    b. No, but I'm very comfortable with understanding English
    c. No, I sometimes struggle to understand English, but only in the spoken form
    d. No, I sometimes struggle to understand English, but only in the written form
    e. No, I sometimes struggle to understand English, in both the written and spoken form
    f. Decline to state

11. What is your current college GPA? _____

12. What is your current major? _____

13. Which course were you recruited from for this study? _____

14. Have you ever learned about evolution in a college science course?
    a. Yes
    b. No
    c. I'm not sure

15. If yes, please list all of the college courses in which you have already learned about evolution.

Supplemental Table 1. Profiles of participants who completed cognitive interviews with the original MATE and the MATE 2.0.

				Original MATE			
ID	Pseudonym	Gender	Race/Ethnicity	Religion	Evolution Education	Interview-based Acceptance	Average Score on MATE items
1	Acacia	F	Asian	Atheist	High	Full Acceptance	4.6
2	Ash	M	Asian	Agnostic	High	Full Acceptance	4.6
3	Daisy	F	Hispanic or Latinx	Agnostic	High	Full Acceptance	4.4
4	Aspen	F	White	Agnostic	Medium	Full Acceptance	4.6
5	Azalea	F	Asian	Hindu	High	Full Acceptance	4.4
6	Bryony	F	White	Nothing in particular	High	Full Acceptance	4.4
7	Berry	M	White	Atheist	Medium	Full Acceptance	4.2
8	Clover	F	Hispanic or Latinx	Christian – Catholic	High	Full Acceptance	4.4
9	Coral	F	White	Christian – Catholic	Medium	Full Acceptance	3.9
10	Daffodil	F	Asian	Muslim	High	Full Acceptance	4.6
11	Dahlia	F	White	Agnostic	Medium	Full Acceptance	5.0
12	Amber	F	White	Agnostic	High	Full Acceptance	4.5
13	Eartha	F	White	Agnostic	Medium	Full Acceptance	4.6
14	Fern	F	White	Agnostic	Medium	Full Acceptance	4.6
15	Fleur	F	White	Christian – Greek Orthodox	High	Full Acceptance	4.8
16	Basil	M	Asian	Other – Jainist	High	Full Acceptance	4.6
17	Ginger	F	Hispanic or Latinx	Christian – Protestant	High	Human Exception	3.8
18	Hazel	F	White	Agnostic	High	Full Acceptance	5.0
19	Heather	F	White	Agnostic	Medium	Full Acceptance	4.9
20	Holly	F	White	Agnostic	Medium	Full Acceptance	4.7
21	Iris	F	Hispanic or Latinx; White	Christian – Protestant	High	Creation of Higher Taxa	4.4
22	Laverne	F	Hispanic or Latinx; White	Agnostic	Medium	Full Acceptance	4.6
23	Jasmine	F	White	Christian – undecided	High	Rejection	3.8
24	Lake	M	White	Atheist	High	Full Acceptance	4.9
25	Juniper	F	Asian	Atheist	Medium	Full Acceptance	4.3
26	Ivy	F	White	Atheist	Medium	Full Acceptance	4.8
27	Liana	F	White	Agnostic	Medium	Full Acceptance	4.8
28	Cedar	M	Asian	Nothing in particular	High	Undecided	4.1
29	Dale	M	Hispanic or Latinx	Christian – Catholic	High	Full Acceptance	4.4
30	Lilac	F	White	Christian – Catholic	Medium	Full Acceptance	4.3
31	Lily	F	White	Agnostic	High	Full Acceptance	4.8
32	Lavender	F	White	Agnostic	Medium	Full Acceptance	4.9
33	Linden	M	Hispanic or Latinx	Nothing in particular	High	Full Acceptance	4.6
34	Heath	M	Other: Middle Eastern	Decline to state	Medium	Full Acceptance	4.5

35	Reed	M	Native American	Agnostic	High	Full Acceptance	4.2
36	Magnolia	F	Asian	Hindu	Medium	Full Acceptance	4.5
37	Marigold	F	Black	Christian - Protestant	None	Undecided	3.6
38	Myrtle	F	Asian	Agnostic	Low	Creation of Higher Taxa	4.3
39	Haywood	M	Hispanic or Latinx	Agnostic	Low	Full Acceptance	5.0
40	Pansy	F	White	Nothing in particular	Low	Full Acceptance	4.9
41	Jasper	M	Asian	Agnostic	Low	Full Acceptance	4.9
42	Petunia	F	White	Other - spiritual	Low	Full Acceptance	4.8
43	Forrest	M	White	Agnostic	Low	Full Acceptance	3.7
44	Poppy	F	Asian	Buddhist	Low	Full Acceptance	4.7
45	Primrose	F	Hispanic or Latinx	Christian - nondenominational	Low	Creation of Higher Taxa	4.4
46	Rosemary	F	Black	Agnostic	Low	Human Exception	4.1
47	Sage	F	Asian; White	Atheist	Low	Full Acceptance	4.4
48	Briar	M	White	Christian – nondenominational	None	Full Acceptance	4.7
49	Moss	M	Asian	Nothing in particular	None	Full Acceptance	4.7
50	Savannah	F	White	Agnostic	None	Human Exception	3.9
51	Oliver	M	Asian; Pacific Islander	Christian – Catholic	None	Full Acceptance	4.4
52	Herb	M	White	Christian - Protestant	Low	Rejection	1.4
53	Violet	F	Black	Christian - Baptist	Low	Rejection	2.9
54	Willow	F	White	Jewish	None	Full Acceptance	4.1
55	Zinnia	F	Asian	Buddhist	None	Full Acceptance	4.4
56	Robin	M	Asian	Hindu	Low	Full Acceptance	4.4
57	Rowan	M	Hispanic or Latinx	Christian - Catholic	None	Rejection	3.6
58	Silvester	M	Asian	Other - Sikhism	Low	Full Acceptance	4.1
59	Dove	F	Hispanic or Latinx	Christian - nondenominational	Low	Rejection	4.0
60	Lark	F	White	Christian – Latter-Day Saints	Low	Undecided	4.8
61	Raven	F	Hispanic or Latinx	Christian - Protestant	Low	Creation of Higher Taxa	4.0
62	Wren	F	White	Christian - Lutheran	Low	Full Acceptance	4.5
MATE 2.0							
ID	Pseudonym	Gender	Race/Ethnicity	Religion	Evolution Education	Interview-based Acceptance	Average Score on MATE items
010	Bjork	F	White	Atheist	High	Full Acceptance	4.6
011	Hadas	F	White	Agnostic	Medium	Full Acceptance	4.6
012	Iva	F	Black	Christian - Protestant	High	Undecided	3.3
013	Sawda	F	Asian	Christian - Catholic	High	Full Acceptance	4.8
014	Kalina	F	Hispanic	Christian - nondenominational	Medium	Full Acceptance	4.8

015	Liepa	F	Hispanic	Atheist	High	Full Acceptance	4.9
016	Palmer	N/A	N/A	N/A	N/A	Full Acceptance	4.9
017	Melia	F	Hispanic or Latinx; White	Christian – Progressive Christian	High	Full Acceptance	4.9
018	Ornella	F	Asian	Hindu	Low	Full Acceptance	4.9
019	Alon	M	Native	Christian - Protestant	High	Creation of Higher Taxa	3.9
024	Aritz	M	White	Christian - Protestant	Low	Human Exception	4.4
025	Pomona	F	Black	Christian - Protestant	Medium	Undecided	3.8
040	Pihla	F	White	Christian - nondenominational	High	Rejection	2.4
041	Randa	F	Hispanic or Latinx	Christian - Latter-Day Saints	High	Creation of Higher Taxa	2.2
042	Jelena	F	Black	Christian – Church of Christ	Low	Creation of Higher Taxa	4.3
043	Boris	M	Prefer not to answer	Christian - Protestant	Low	Rejection	2.6
044	Taimi	F	White	Christian - nondenominational	Medium	Creation of Higher Taxa	3.1
045	Anargul	F	Asian	Muslim	Medium	Creation of Higher Taxa	3.6
046	Blodwen	F	White	Spiritual	Medium	Full Acceptance	4.8
047	Anthea	F	White	Agnostic	Low	Full Acceptance	4.3
048	Hanako	F	Black	Christian - Protestant	Low	Creation of Higher Taxa	4.8
049	Elon	M	White	Buddhist	Low	Full Acceptance	3.9
050	Tomer	M	Black	Nothing in particular	Low	Full Acceptance	4.7
051	Ione	F	White	Christian – Latter-Day Saints	Low	Creation of Higher Taxa	2.9
052	Laleh	F	Black	Christian – non-Orthodox	None	Creation of Higher Taxa	4.8
053	Vipin	M	Asian	Hindu	Low	Full Acceptance	4.7
054	Yasen	M	Black; Hispanic or Latinx	Christian - Catholic	Low	Full Acceptance	3.8
055	Leilani	F	Black; Hispanic or Latinx	Christian - Lutheran	None	Creation of Higher Taxa	2.8
056	Lys	F	Hispanic or Latinx	Christian - Catholic	None	Full Acceptance	4.7

Coding Rubric Used to Code Original MATE and MATE 2.0 Cognitive Interviews

This is the coding rubric used to analyze cognitive interviews with the original MATE and MATE 2.0. It is the final rubric that was developed after all of the MATE 1.0 interviews were concluded; it was used for the MATE 2.0 interviews as well. In it, each primary code from the pre-interview codebook is divided into several sub-codes. Note that some sub-codes are not discussed in the article because they arose in a relatively small number (<10%) of interviews. This codebook was developed using inductive methods, so each sub-code arose at least twice.

DEFINITION OF EVOLUTION

Species Specific: Student's answer depends on whether evolution is applied to humans.

Microevolution: Student defines "evolution" as evolutionary <u>processes</u>. Code is applicable if a student's answer is based only on microevolution, <u>or</u> if they say that their answer would depend on whether macroevolution is part of the evolution definition.

Socially Modern: Student interprets the word "modern" in an item as a reference to cultural or technological modernity, rather than anatomical modernity.

Extra Theories: Student includes concepts that are not actually part of evolutionary theory in their definition of evolution (e.g., origins of life, the Big Bang).

UNDERSTANDING NATURE OF SCIENCE

Tentative Nature: Student states that all scientific theories are falsifiable, which in itself is not a misconception. Rather, this code applies when a student emphasizes falsifiability to the point of avoiding answers of "strongly agree" and "strongly disagree." In their explanation, the student may mention either of the following:

- Current evidence supports evolution, but evidence against evolution could theoretically be found in the future.
- Current evidence supports evolution, but *more* supporting evidence will be found in the future.

Scientific Testing: Student states that some aspects of evolution cannot be tested. Their answer is based on a misconception about what counts as scientific testing. Code <u>does not</u> apply if the student says that they are generally unaware of how evolution can be tested. This trend takes four main forms:

- Evolution cannot be tested because we cannot go back in time to observe extinct species.
- Evolution cannot be tested because we as individuals cannot see one species evolve into another.
- Evolution cannot be tested because the only way to test a hypothesis is through a controlled experiment. Observations do not count as scientific testing.

- A scientific prediction is a prediction of what will happen *in the future* in the natural world. Predictions are not made about present-day processes or past events (i.e., evolutionary history).

NOS Unaware: Student is broadly unaware of some aspect of the nature of science (NOS) and acknowledges their lack of knowledge. Code takes two main forms:

- Student does not know how evolution can be tested.
- Student does not know what counts as scientific validity.

Speculation: Student states that science always involves some speculation. They equate "speculation" with generating new hypotheses.

Final Answer: Student states that evolution is not well supported until everything about evolution is discovered. In other words, a theory is not fully valid if scientists are still generating and testing new hypotheses.

Just A Theory: Student states that evolution is not fully supported by the evidence because it is "just a theory" that has not been declared a scientific fact. Unlike "Final Answer," this code applies only when the student clearly has a misconception about fact vs. theory in science.

Factual: Student is confused by the idea of factual vs. non-factual data. Their answer may be influenced by the idea that *factual* data must be 100% correct. Code is mainly applicable to Item 16 of MATE 1.0.

KNOWLEDGE ABOUT EVOLUTION

Unfamiliar Data: Student states that they do not know evolution-related data/evidence well enough to give a decisive answer. This code is similar to "NOS Unaware." Differences:

- DO NOT use this code if they do not know how evolution could be <u>tested</u>. "NOS Unaware" applies.
- DO NOT use this code if a student says that they have not made up their mind about evolution because they do not know whether there is evidence to support the theory. This is an accurate measure of uncertainty.

Earth Age: Student accepts the idea that the earth is old (i.e., millions or billions or years), but they are factually unaware of whether it is more than 4 billion years old.

Counts as Evolution: Student's answer is affected by the misconception that evolution necessarily involves a "progression" from less complex to more complex, meaning that that which does not superficially change does not evolve. Example: Early life was unicellular; this means that humans have evolved, but bacteria have not evolved. Code is mainly applicable to Item 9 of MATE 1.0.

KNOWLEDGE ABOUT SCIENTIST VIEWS

Rejecting Scientists: Student's answer is informed by the impression that some scientists do not fully accept evolution. This code applies if the student says that not all scientists accept evolution, or if they say that they don't know whether most scientists accept evolution (which implies that some may not). Code is applicable to Items 5 & 17 of MATE 1.0.

Accepting Scientists: Student's answer is informed by the impression that a majority of scientists do fully accept evolution. Code is applicable to Items 5 & 17 of MATE 1.0.

General Public: Student bases their answer on what the non-scientist public think about evolution, rather than on their own views. Example: The student says that the evidence for evolution is unconvincing/unclear because *other people* reject evolution; if there was no fault in the data, everyone would accept evolution. Student's answer may or may not reflect their personal view.

CHRISTIAN ASSUMPTION

Other Religion: Code is applicable only to Item 14 of MATE 1.0. Student says that they would answer this item differently if it said "my religion's account of creation" instead of "the Biblical account of creation" because they follow a religion other than Christianity.

Non-Christian Background: Code is applicable only to Item 14 of MATE 1.0. Student says that they are *unfamiliar* with the Biblical account of creation because they do not come from a Christian background. Code is applicable for both non-religious students and students who follow a religion other than Christianity. Code does not necessarily apply to every non-Christian religious student.

New Earth: Student says that they believe in a Young Earth but are not committed to the Earth being less than 20,000 years (i.e., it could be 25,000 years old). This influences their answer. Code is mainly applicable to Item 7 of MATE 1.0.

WORDING

Millions: Code is applicable to Items 1 and 3 of MATE 1.0. Student interprets "millions of years" to be a reference to how long individual species have existed on Earth.

- Example: Student interprets Item 3 as saying, "Homo sapiens as a single species have existed for millions of years."

Organisms: Code is applicable to Items 1, 9, 18, and 19 of MATE 1.0. Student displays confusion about the terms "organisms" or "living forms."

Who Scientist: Code is applicable to Items 5 and 17 of MATE 1.0. Student states that either a) they are uncertain about who counts as a scientist, or b) their answer would depend on how "scientist" is defined. Example: They might draw a distinction between biologists vs. scientists as a whole.

Much/Most: Code is applicable to Items 5 and 17 of MATE 1.0. Student states that they find the terms "much" or "most" to be vague, which makes it difficult for them to answer the item.

Data Clarity: Code is mainly applicable to Item 6 of MATE 1.0. Student interprets the item as asking, "Have you ever seen evolutionary data that is confusing?" They do *not* interpret it as, "Is evolution supported by data?"

Species Definition: Code is applicable to Items 9 and 15 of MATE 1.0. Student interprets "organism" or "human" as referring to a single species. They give the reasoning that the "form" of a species does not radically change as long as it is still the same species. When the form of a species changes greatly, it becomes a new species.

Conserved Traits: Code is applicable to Item 9 of MATE 1.0. Student points out that certain biological features (e.g., ATP, ribosomes) have been highly conserved throughout evolutionary history. Their answer is affected by the idea that life exists in "essentially the same form" at the biomolecular level.

Sound: Code is applicable to Item 12 of MATE 1.0. Student displays confusion about the term "sound."

Current Evolution: Code is applicable to Item 12 of MATE 1.0. Student displays confusion about the term "current evolutionary theory." This may take the form of the student trying and struggling to draw a distinction between *current* vs. *old* evolutionary theory.

Characteristics of Life: Code is applicable to Item 13 of MATE 1.0. Student displays confusion about the term "characteristics of life."

Testable Predictions: Code is applicable to Item 13 of MATE 1.0. Student does not know the <u>literal meaning</u> of the term "testable predictions."

Respect: Code is applicable to Item 13 of MATE 1.0. Student displays confusion about the term "with respect to." Some misinterpret it as "acts kindly towards."

Historical: Code is applicable to Item 16 of MATE 1.0. Student displays confusion about the term "historical," and this impacts their answer.

Doubt: Code is applicable to Item 17 of MATE 1.0. Student interprets "doubt" to mean that there is debate within the scientific community about specific evolutionary hypotheses. They do not interpret "doubt" to mean questioning whether evolution occurs at all.

Brings Meaning: Code is applicable to Item 18 of MATE 1.0. Student displays confusion about the term "brings meaning." They may point out that there are two alternative definitions: "explains" or "provides philosophical value or purpose."

Opposite: Code is applicable to Item 19 of MATE 1.0. Student interprets this item as saying that all of life on earth descended from one common ancestor, which by definition

was alive at one point in time. This is the exact opposite of what the survey authors intended.

Exceptions: Code is applicable to Item 19 of MATE 1.0. Student displays confusion about the term "with few exceptions." They may ask something like, "What sort of exceptions?"

General Confusion: Student has no idea what the item as a whole is attempting to say and cannot pinpoint one word or phrase that is confusing. Code is applicable to all items.

Supplemental Table 2. Participants' most frequent uses of constructs other than personal acceptance/rejection of evolution when answering items on the MATE.

MATE Item	Theme 1: Code (Subcode)	N	Theme 2: Code (Subcode)	N
1. Organisms existing today are the result of evolutionary processes that have occurred over millions of years.				
2. The theory of evolution is incapable of being scientifically tested.	Understanding of NOS (Scientific Testing)	13/62		
3. Modern humans are the product of evolutionary processes that have occurred over millions of years.				
4. The theory of evolution is based on speculation and not valid scientific observation and testing.				
5. Most scientists accept evolutionary theory to be a scientifically valid theory.	Perception of Scientists' Views (Rejecting Scientists)	31/47*	Perception of Scientists' Views (Accepting Scientists)	6/15**
6. The available data are ambiguous (unclear) as to whether evolution actually occurs.	Knowledge About Evolution (Unfamiliar Data)	9/62		
7. The age of the earth is less than 20,000 years.				
8. There is a significant body of data that supports evolutionary theory.	Knowledge About Evolution (Unfamiliar Data)	9/62		
9. Organisms exist today in essentially the same form in which they always have.				
10. Evolution is not a scientifically valid theory.				
11. The age of the earth is at least 4 billion years.	Knowledge About Evolution (Age of Earth)	30/62		
12. Current evolutionary theory is the result of sound scientific research and methodology.				
13. Evolutionary theory generates testable predictions with respect to the characteristics of life.	Understanding of NOS (Scientific Testing)	22/62	Wording (Characteristics of Life)	21/62
14. The theory of evolution cannot be correct since it disagrees with the Biblical account of creation.	Christianity is Assumed	5/9***		
15. Humans exist today in essentially the same form in which they always have.	Wording (Species Definition)	9/62		
16. Evolutionary theory is supported by factual				

historical and laboratory data.				
17. Much of the scientific community doubts if evolution occurs.	Perception of Scientists' Views (Rejecting Scientists)	18/47*	Perception of Scientists' Views (Accepting Scientists)	9/15**
18. The theory of evolution brings meaning to the diverse characteristics and behaviors observed in living forms.	Wording (Brings Meaning)	18/62		
19. With few exceptions, organisms on earth came into existence at about the same time.	Wording (Opposite Interpretation)	11/62		
20. Evolution is a scientifically valid theory.				

*Out of 47 who fully accept evolution. **Out of 15 who do not fully accept evolution. ***Out of 9 who are affiliated with a non-Christian religion.

Own-Views Interview Questions:

The interviewer asked each student the following questions after the cognitive interview with the MATE was completed. This was a semi-structured interview in which the interviewer would ask follow-up questions based on the student's answers. The questions were prefaced using the following script:

"Now that we have completed the survey, I would like to ask you a few open-ended questions about your views on evolution. The purpose of these questions is for you to have a chance to describe your views in your own words. There are no right or wrong answers, and I encourage you to elaborate on your answers until you feel that you have fully conveyed your views about each of the questions. I might also ask some follow-up questions to make sure that I fully understand your answer."

1. Do you think that a species can change over time due to evolutionary processes, such as natural selection?
2. Do you think that new species of organisms evolve from earlier species?
3. Do you think that human populations can change over time due to evolutionary processes, such as natural selection?
4. Do you think that humans have descended from other animals?
5. Do you think that all of life on Earth comes from one single ancestor? If not, how many different types of "original" ancestors do you think life on Earth had?
6. On a scale of 1-100, how much would you say that you accept evolution? Why did you pick that number?

Coding Rubric - Own-Views Interview

This is the coding rubric for the own-views interview questions which were presented after the cognitive interview with the original MATE. This portion of the interview was coded holistically; one of the five codes listed below was assigned based on a student's full set of answers in response to all of the interview questions. Note that the "Rejection" code allows for acceptance of microevolution, since not a single student rejected evolutionary change within species.

Full Acceptance

Student expresses the following views throughout the own-views interview:

- Humans share a common ancestry with other animals, such as primates.
- New species arise through the process of speciation.
- All species descended from single-celled ancestors.

Coding tips:

- Use this code if the student quickly answers "yes" to all of the interview questions, and this appears to be consistent with the explanations that they gave during the think-aloud.
- If the student is unsure or doubtful about whether all of life descended from one common ancestor, their views can still count as full acceptance ONLY IF they:
    - Agree that all of life evolved from unicellular ancestors, but doubt whether the unicellular ancestors of plants & animals likewise share a single common ancestor. This appears to be a factual misconception for many students.
    - Limit their explanation to purely natural causes and <u>never</u> say that God created the ancestors of higher taxonomic groups as separate from one another.

Human Exception

Student expresses the following views throughout the own-views interview:

- New species arise through the process of speciation.
- All <u>non-human</u> species descended from single-celled ancestors.
- Humans do not share a common ancestry with other animals.

Coding tips:

- Do use this code if the student accepts human microevolution as the cause of phenotypic diversity *within* the human species, but rejects human macroevolution (primate ancestry).
- The student does <u>not</u> have to say that God created humans in order for this code to apply.
- Do use the code if the student asserts that humans did not evolve from animal ancestors, yet they are not sure about where we came from.

Creation of Higher Taxa

Student expresses the following views throughout the own-views interview:

- God created a relatively small number of "original ancestors" that do not share a common ancestry with each other.
- Evolutionary processes have caused the "original ancestors" to diversify into the species we see today.
- Examples of independent evolutionary trees that students might mention:
    - Primates, carnivores, etc.
    - Mammals, reptiles, fish, insects, etc.
- Humans do not share a common ancestry with other animals. The student may say that humans were created in their present form OR they may say that God created hominins separately from primates, and the hominins underwent their own internal evolution (i.e., Neandertals existed as a separate population/subspecies).

Rejection

Student expresses the following views throughout the own-views interview:
- God created a relatively large number of initial species that resembles the diversity of life that we see today.
- God created humans in more-or-less their present form.

Coding tips:
- Do use this code if the student believes that all present-day species were part of the initial creation, but microevolutionary change has occurred *within* these species.
- Do use this code if the student believes that a small amount of speciation has occurred since the initial creation, but the process has only produced animals that are "essentially" of the same "type." This is consistent with the creationist account presented by organizations such as Answers in Genesis. Examples:
    - Grey wolves and coyotes descended from a canine ancestor.
    - Horses and donkeys descended from an equine ancestor.

Undecided

- Do use this code if the student says that they have not made up their mind about one or more major aspects of evolution that are *necessary for choosing between the other codes.* Examples:
    - Undecided about whether humans share a common ancestry with other animals, or if hominins were created separately
    - Undecided about whether life evolved by natural processes alone, or if God created several major taxa separately
- Do use this code if the student says that they are oscillating between accepting the scientifically accurate version of evolution vs. believing a creationist account that is not consistent with the scientific evidence (e.g., creation of higher taxa or rejection).

- Do not use if the student is factually uncertain about whether plants and animals share a common ancestry without bringing God into the explanation.

Supplemental Table 3: Unweighted and Weighted mean squares item fit statistics (equal to outfit and infit MNSQ respectively) for the unidimensional partial credit Rasch model for MATE 2.0. Values of 0.7-1.3 are considered to indicate good fit. Values outside of this range are underlined.

Item	Outfit	Infit
mate_1	0.97	0.97
mate_2	1.15	1.13
mate_3	0.83	0.90
mate_4	0.84	0.86
mate_5	1.43	1.37
mate_6	0.82	0.89
mate_7	1.12	1.10
mate_8	1.39	1.33
mate_9	0.94	0.94
mate_10	0.79	0.81
mate_11	0.99	0.99

Supplemental Table 4: Unweighted and Weighted mean squares item fit statistics (equal to outfit and infit MNSQ respectively) for the unidimensional partial credit Rasch model for MATE 2.0 without Items 5 and 8. Values of 0.7-1.3 are considered to indicate good fit.

Item	Outfit	Infit
mate_1	1.02	1.04
mate_2	1.30	1.28
mate_3	0.92	1.00
mate_4	0.86	0.89
mate_6	0.94	1.00
mate_7	1.16	1.16
mate_9	0.98	0.98
mate_10	0.78	0.83
mate_11	1.04	1.06

Supplemental Figure 1: Wright map of MATE 2.0 data. The data points on the right represent item difficulties and the histogram on the left shows the distribution of person abilities. Higher points and higher respondents indicate more difficult items, i.e. high evolution acceptance. Colors indicate various points on the Likert scale: green = "disagree," orange = "neutral," blue =

"agree," pink = "strongly agree." Comparison of the histogram with the item difficulties shows that Rasch item difficulties are below most person abilities, indicating that most students in our sample were accepting of evolution.
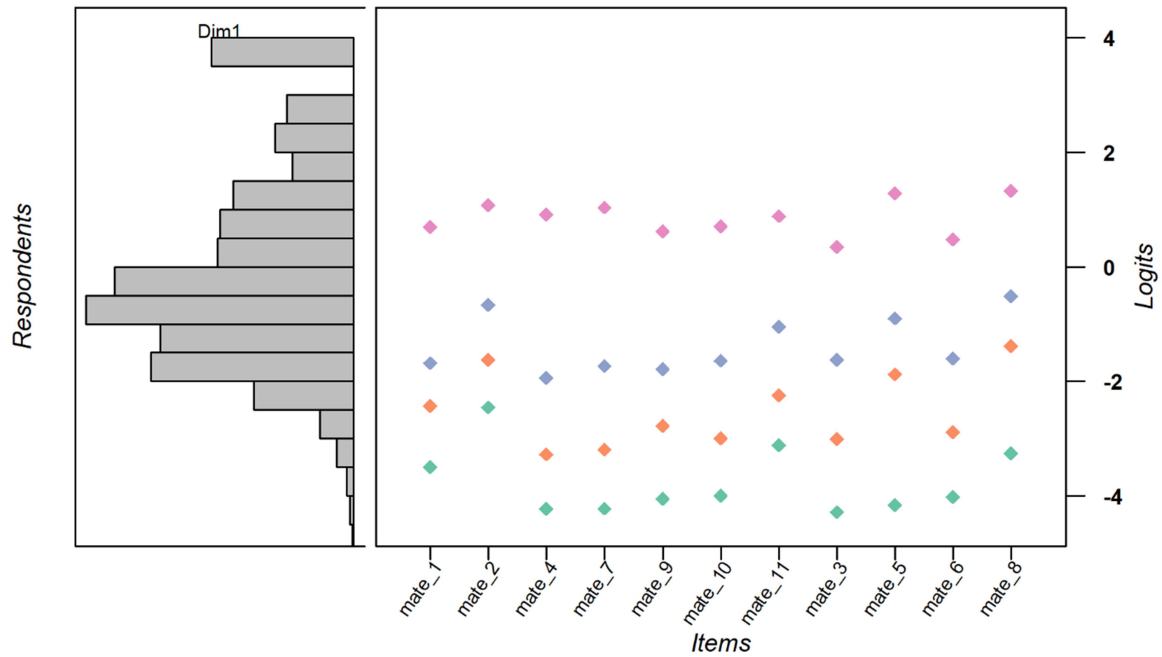
Supplemental Figure 2: Wright map of MATE 2.0 data without Items 5 and 8. The data points on the right represent item difficulties and the histogram on the left shows the distribution of person abilities. Higher points and higher respondents indicate more difficult items, i.e. high evolution acceptance. Colors indicate various points on the Likert scale: green = "disagree," orange = "neutral," blue = "agree," pink = "strongly agree." Comparison of the histogram with the item difficulties shows that Rasch item difficulties are below most person abilities, indicating that most students in our sample were accepting of evolution.
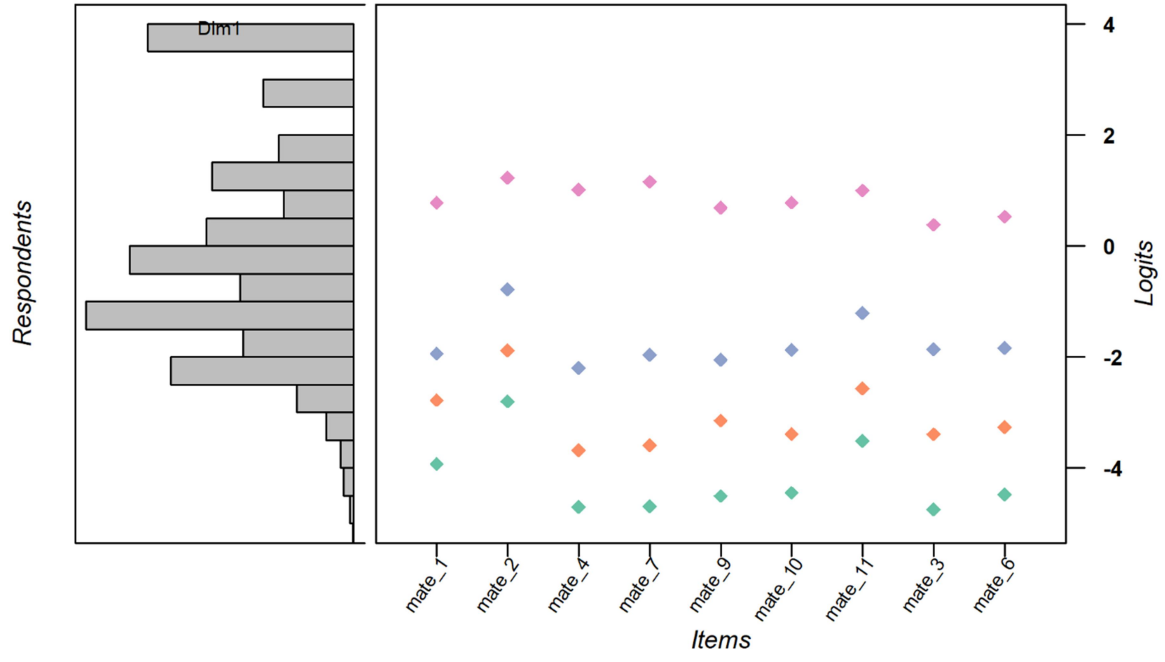
Supplemental Table 5: A direct comparison of items on the MATE 2.0 vs. the original MATE, together with the reasons for each revision choice.

MATE 1.0	Reason for Change	MATE 2.0
1. Organisms existing today are the result of evolutionary processes that have occurred over millions of years.	Rephrased to specify macroevolution for consistent interpretation (Finding 1).	1. All species that exist today have evolved from previous species.
2. The theory of evolution is incapable of being scientifically tested.	Deleted because misconceptions about scientific testing affected answers (20% of students).	Deleted
3. Modern humans are the product of evolutionary processes that have occurred over millions of years.	Rephrased to specify macroevolution for consistent interpretation (Finding 1).	2. Modern humans have evolved from earlier non-human species.
4. The theory of evolution is based on speculation and not valid scientific observation and testing.	Rephrased to a) specify macroevolution for consistent interpretation (Finding 1) and b) reduce emphasis on understanding of NOS (Finding 2).	3. The idea that new species evolve from earlier species is NOT supported by scientific evidence.
5. Most scientists accept evolutionary theory to be a scientifically valid theory.	Deleted because answers based on impression that scientists' views do not align with students' own views (60% of students)	Deleted
6. The available data are ambiguous (unclear) as to whether evolution actually occurs.	Deleted because negative wording & focus on ambiguity made Item 6 more challenging to revise than Item 8.	Deleted
7. The age of the earth is less than 20,000 years.	Deleted to remove all testing on age of the Earth and remove all references to Christianity-specific beliefs.	Deleted
8. There is a significant body of data that supports evolutionary theory.	Rephrased to a) emphasize existence of evidence rather than its significance, and b) specify macroevolution for consistent interpretation (Finding 1).	4. Current scientific evidence suggests that new species can evolve from earlier species.
9. Organisms exist today in essentially the same form in which they always have.	Deleted from draft 1 of MATE 2.0 due to inconsistent interpretation of "essentially/largely the same form" (33%) & results of Rasch analysis.	10. Organisms exist today in largely the same form in which they always have. [DELETED]
10. Evolution is not a scientifically valid theory.	Rephrased to specify macroevolution for consistent interpretation (Finding 1).	5. The idea that new species evolve from earlier species is NOT a scientifically valid theory.
11. The age of the earth is at least 4 billion years.	Deleted because many do not know exact age of the Earth (48% of students).	Deleted

12. Current evolutionary theory is the result of sound scientific research and methodology.	Rephrased to a) specify macroevolution for consistent interpretation (Finding 1) and b) reduce emphasis on understanding of NOS (Finding 2).	6. The idea that new species evolve from earlier species is the result of scientific research.
13. Evolutionary theory generates testable predictions with respect to the characteristics of life.	Deleted because unclear wording (34%) & misconceptions about scientific testing (35%) affected answers.	Deleted
14. The theory of evolution cannot be correct since it disagrees with the Biblical account of creation.	Deleted because "Biblical" affected answers for students with non-Christian religion (55%).	Deleted
15. Humans exist today in essentially the same form in which they always have.	Deleted from draft 1 of MATE 2.0 due to inconsistent interpretation of "humans" (50%) & results of Rasch analysis.	11. Humans exist today in largely the same form in which they always have. [DELETED]
16. Evolutionary theory is supported by factual historical and laboratory data.	Rephrased to a) specify macroevolution for consistent interpretation (Finding 1) and b) reduce emphasis on understanding of NOS (Finding 2) and (3) incorporate explanation of diversity of life.	7. The idea that species can evolve into new species explains the diversity of life on Earth.
17. Much of the scientific community doubts if evolution occurs.	Answers were based on impression that scientists' views do not align with students' own views (44% of students)	Deleted
18. The theory of evolution brings meaning to the diverse characteristics and behaviors observed in living forms.	Deleted because unclear wording affected answers (29% of students).	Deleted
19. With few exceptions, organisms on earth came into existence at about the same time.	Deleted because unclear wording affected answers (18% of students).	Deleted
20. Evolution is a scientifically valid theory.	Rephrased to a) specify macroevolution for consistent interpretation (Finding 1).	8. The idea that new species evolve from earlier species is a scientifically valid theory.
[n/a]	Added to include an item about the shared ancestry of all life.	9. All of life on earth evolved from previous species.