

Supplemental Material

CBE—Life Sciences Education

Misheva *et al.*

Demographic Questions

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. 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

5. 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

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

7. Do you identify with your religion mainly on a cultural -but not spiritual- basis?
 - a. Yes
 - b. No
 - c. I'm not sure

Please indicate how much you agree or disagree with the following statements:

8. I attend religious services regularly.
9. I believe in God.
10. I consider myself a religious person.
11. I consider myself a spiritual person.

Options:

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

How much conflict do you perceive...

11. Between your personal religious beliefs and evolution?
12. Between the teachings of your religion and evolution?
13. Between your belief in God and evolution?
14. Between your religious culture and evolution?

Options:

- a. None
- b. A little
- c. A moderate amount
- d. A lot

15. Which college or university do you attend? _____

16. What is your current major?

- a. Biology
- b. Other STEM, please describe: _____
- c. Other non-STEM, please describe: _____

17. How many biology courses have you taken in college?

- a. 0
- b. 1 – 2
- c. 3 – 4
- d. 5+

18. Have you ever taken a college science course that was primarily on evolution?

- a. Yes
- b. No
- c. I'm not sure

Free-Response Interview Questions

The interviewer asked each student the following questions after the cognitive interview on either the GAENE or the I-SEA 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. What are your thoughts on human evolution?
2. Do you think that all of life on earth descended from one ancestral (original) species? If not, what types of species DO share a common ancestor? What types of species DON’T share a common ancestor?

Supplemental Table 1. Profiles of participants who completed cognitive interviews on the I-SEA and the GAENE.

I-SEA							
ID	Pseud.	Gender	Race/ Ethnicity	Religion	Evo. Ed.	Interview-based Acceptance	Composite Score
001	Deniz	F	Asian	Hindu	High	Full Acceptance	Macro: 4.5 Micro: 5.0 Human: 5.0
002	Darya	F	Hispanic	Agnostic	High	Full Acceptance	Macro: 4.2 Micro: 5.0 Human: 4.9
003	Ocean	F	Black	Christian - Protestant	High	Human: accept Non-human: higher taxa	Macro: 3.6 Micro: 5.0 Human: 4.9
004	Anup	M	Hispanic	Christian - LDS	High	Full Acceptance	Macro: 4.6 Micro: 5.0 Human: 4.5
005	Jafar	M	White	Agnostic	High	Full Acceptance	Macro: 4.9 Micro: 5.0 Human: 5.0
006	Moana	F	Hispanic	Atheist	Med	Full Acceptance	Macro: 4.5 Micro: 4.9 Human: 4.9
007	Poseidon	M	Asian	Muslim	High	Human: reject Non-human: reject	Macro: 1.6 Micro: 2.8 Human: 1.5

008	Marisol	F	White	Agnostic	High	Full Acceptance	Macro: 4.5 Micro: 4.6 Human: 4.5
009	Fishel	M	White	Muslim	Med	Full Acceptance	Macro: 4.8 Micro: 5.0 Human: 4.8
020	Anemone	F	Black	Christian- Other (Spiritual)	Low	Full Acceptance	Macro: 4.6 Micro: 4.6 Human: 4.8
021	Triton	M	Asian	Christian - Protestant	Med	Human: undecided Non-human: undecided	Macro: 3.3 Micro: 3.6 Human: 3.3
022	River	F	White	Other faith (Spirituality)	Med	Human: reject Non-human: only micro	Macro: 3.0 Micro: 3.3 Human: 2.5
023	Nemo	M	Prefer not to answer	Christian - Protestant	Low	Human: reject Non-human: only micro	Macro: 2.4 Micro: 4.6 Human: 3.1
026	Neptune	M	Hispanic, White	Agnostic	Low	Full Acceptance	Macro: 5.0 Micro: 5.0 Human: 4.5
027	Tethys	F	Hispanic	Christian - Catholic	Low	Full Acceptance	Macro: 3.9 Micro: 4.0 Human: 4.1
028	Marinus	M	NA	Hindu	Low	Full Acceptance	Macro: 4.1 Micro: 4.9 Human: 4.6
032	Azure	F	Black	Christian - Protestant	High	Human: undecided Non-human: higher taxa	Macro: 4.0 Micro: 4.9 Human: 3.6
035	Sapphira	F	Asian	Christian - Protestant	Low	Human: reject Non-human: higher taxa	Macro: 3.6 Micro: 4.1 Human: 1.8
036	Rio	NA	NA	NA	NA	Full Acceptance	Macro: 4.5 Micro: 4.6 Human: 4.1
037	Tiamat	F	White	Christian - Other (Nondenom.)	Med	Human: reject Non-human: micro & limited macro	Macro: 3.4 Micro: 4.0 Human: 2.3
038	Ariel	F	Asian	Christian - Protestant	Low	Human: reject. Non-human: higher taxa	Macro: 3.0 Micro: 4.9 Human: 3.0
039	Cyan	F	Hispanic, White	Christian - Catholic	Low	Human: undecided. Non-human: higher taxa.	Macro: 4.0 Micro: 4.8 Human: 4.0
GAENE 2.1							
ID	Pseud.	Gender	Race/ Ethnicity	Religion	Evo. Ed.	Interview-based Acceptance	Composite Score
010	Jocasta	F	White	Atheist	High	Full Acceptance	4.3

011	Helen	F	White	Agnostic	Med	Full Acceptance	4.7
012	Adrastea	F	Black	Christian - Protestant	High	Human: undecided Non-human: undecided	3.9
013	Alecto	F	Asian	Christian - Catholic	High	Full Acceptance	4.5
014	Andromache	F	Hispanic	Christian - Other (Nondenom.)	Med	Full Acceptance	4.3
015	Clio	F	Hispanic	Atheist	High	Full Acceptance	4.6
016	Paris		N/A	N/A		Full Acceptance	4.2
017	Cora	F	Hispanic, White	Christian - Other (Progressive)	High	Full Acceptance	4.9
018	Daphne	F	Asian	Hindu	Low	Full Acceptance	4.9
019	Achilles	M	Native	Christian - Protestant	Med	Human: reject Non-human: higher taxa	3.5
024	Adonis	M	White	Christian - Protestant	Low	Human: undecided Non-human: accept	4.5
025	Penelope	F	Black	Christian - Protestant	Med	Human: undecided Non-human: accept	3.5
029	Agamemnon	M	White	Christian - Protestant	Low	Human: reject Non-human: only micro	3.8
030	Eudora	F	Black	Christian - Catholic	High	Human: undecided Non-human: higher taxa	4.6
031	Electra	F	White	Christian - Protestant	Low	Human: reject Non-human: higher taxa	4.2
033	Ajax	M	White	Christian - Catholic	Low	Human: reject Non-human: higher taxa	3.7
034	Ariadne	F	White	Other (Bahai)	High	Human: reject Non-human: higher taxa	3.5
GAENE 3.0 (new items only)							
ID	Pseud.	Gender	Race/ Ethnicity	Religion	Evo. Ed.	Interview-based Acceptance	Composite Score
040	Europa	F	White	Christian - Other (Nondenom.)	Med	Full Acceptance	4.4
041	Callisto	F	Black	Nothing in particular	High	Full Acceptance	4.1
042	Antigone	F	Asian, White	Agnostic	Med	Full Acceptance	3.2
043	Minos	M	Hispanic	Christian - Catholic	High	Human: accept Non-human: undecided	4.4
044	Dido	F	White	Christian - Catholic	Med	Full Acceptance	3.5
045	Circe	F	Hispanic, White	Christian - Other (Christian/Agnostic)	Med	Full Acceptance	4.5
046	Pandora	F	Asian, White	Agnostic	High	Full Acceptance	4.6

047	Theseus	M	Asian	Decline to state	Med	Full Acceptance	4.3
048	Clytemnestra	F	White	Agnostic	Low	Full Acceptance	4.3
049	Hecuba	F	White	Atheist	Med	Full Acceptance	4.6
050	Hector	M	Asian	Muslim	Med	Human: undecided Non-human: higher taxa	3.9
051	Odysseus	M	White	Agnostic	Low	Full Acceptance	4.6
052	Alcyone	F	Black	Other faith (Ifa)	Low	Full Acceptance	3.7
053	Orpheus	M	White	Agnostic	Low	Full Acceptance	4.4
054	Damocles	M	Asian	Muslim	Low	Human: reject Non-human: higher taxa	3.2
055	Hippolyta	F	White	Christian -Protestant	High	Human: undecided Non-human: higher taxa	3.5
056	Leda	F	White	Atheist	Med	Full Acceptance	4.5
057	Eurydice	F	Asian	Agnostic	Med	Full Acceptance	2.7
058	Cassandra	F	White	Christian- Other (Southern Baptist)	Low	Human: reject Non-human: limited macro	3.7
059	Hermione	F	Black	Christian - Other (Nondenom.)	Low	Full Acceptance	4.6
060	Phaedra	NA	NA	NA	NA	Human: reject Non-human: accept	4.7

Coding Rubric Used to Code I-SEA and GAENE Cognitive Interviews

This is the coding rubric used to analyze cognitive interviews on the I-SEA and the GAENE. It is the final rubric that was developed after all of the interviews were concluded. 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.

KNOWLEDGE ABOUT EVOLUTION

The student's answer is influenced by their factual understanding of evolutionary processes and/or evidence for evolution separate from their general acceptance of evolution. Code does not apply if misconceptions about evolution directly inform rejection of evolution.

Low certainty: The student recognizes that they have limited knowledge about certain evolutionary facts (ex: origins of life) or certain lines of evidence (ex: fossils) and thus does not want to take a strong stand on a particular statement.

Misconception: The student’s answer is based on a misconception about how evolutionary processes work (ex: if the environment is stable, species stop evolving), or other misunderstandings of biology.

Concept mix-up: The student confuses evolution for other natural processes, such as prenatal development or the central dogma. As a result, their answer reflects their views on the other biological process, and not necessarily their views on the evolutionary concept in question.

DEFINITION OF EVOLUTION

The item refers to evolution in general, but the student’s answer is based on their exclusion of certain concepts or species from their interpretation of the term “evolution.” (ex: student’s answer indicates high acceptance because they have removed ideas that they disagree with from their idea of evolution).

Micro: The student indicates that they’re only thinking about microevolution when answering an item that refers to evolution as a whole, or to macroevolution in particular.

Not Single Common Ancestor: Th students says they’re including at least some macroevolution (ex: speciation) in their definition of “evolution,” but they’re not including the shared ancestry of higher taxa.

Not Human: The student indicates that they’re applying the concept of evolution only to non-human species when answering an item that refers to evolution as a whole, or to human evolution in particular.

Other: The student has another non-standard interpretation of “evolution” that influences how they answer (ex: they interpret “evolution” and “theory of evolution” as referring to different concepts).

Artificial: The student conceptualizes artificial selection as a process that is related to, but separate from, evolution.

UNDERSTANDING NATURE OF SCIENCE

The student’s answer is influenced by their factual understanding of NOS separate from their overall acceptance of evolution. Code does not apply if misconceptions about NOS directly inform rejection of evolution.

Misconception: The student has a misconception about how science works, which influences their answer.

Example: The student claims to accept all aspects of evolution, but answers an item based on the idea that it’s “just a theory,” or says that when more evidence accumulates, evolution will be referred to as a fact and not as a theory.

Evidence Types: The student points out that the form of evidence referred to in the item is one relevant form of evidence, but that other forms of evidence are also necessary. This is an issue if the student says they accept the relevant evolutionary idea, but don’t strongly agree/disagree because the mentioned evidence isn’t the *only* evidence.

Fact vs. Theory: The student points out that “theory” & “fact” are different concepts in science, and evolution is a theory. (This mainly applies to GAENE #12)

Note: If a student says that evolution is “just” a theory and that it can become fact with more evidence, code response as “NOS: misconception.”

Plausible: The student’s answer is based on acknowledging that evolution is a scientifically plausible theory, even when they personally do not fully accept it.

WORDING

The student’s answer is influenced by confusion over the wording of an item. Code does not apply if the student doesn’t understand a scientific concept essential to the item (ex: unaware of how to establish “scientific validity”).

Definition: The student is confused about the meaning of a particular word or phrase, and struggles to answer because they don’t know what the item is referring to.

Strong Language: The student says that they are picking a more moderate answer than they would otherwise because the phrasing is too absolute or extreme (ex: because something is described as “dramatic”).

Confusing Phrasing: The student struggles to answer because they are confused by phrasing that contrasts terms with potentially similar meanings (ex: adapt vs. evolve vs. change), OR the whole item is phrased in such a way that it’s not clear what it means to “agree” or “disagree;” OR the student finds the item’s choice of concepts irrelevant, or otherwise unsuitable. In short, the concepts are unclear.

Complex: The wording is generally hard to decipher; it takes the students a few tries to make sense of the item as a whole. In short, the wording as a whole is unclear.

Partial: The student selected “agree” or “strongly agree” for GAENE #3 because they agree that some parts of evolution are true, and some are false.

PERSONAL CONTEXT

The item refers to actions that may be taken on the basis of acceptance or rejection of evolution, and the student’s answer is influenced by considering interpersonal dynamics in addition to their own views on evolution.

Not Insistent: The student says that they personally accept evolution but ensuring that other people accept and/or understand evolution is not a priority for them.

Comfort: The student says that their willingness to *discuss evolution with others* depends on whether the social context is welcoming or unwelcoming of their views, as a separate matter from the content of their personal views (ex: the students says they accept evolution, but are reluctant to argue with a hostile audience).

Whole Life: The student says that they find evolution to be broadly relevant to science & society, but it does not play a very large part in their personal life as a whole.

Betting: The student says that they’re very sure that evolution is true, but they’re disinclined to bet their life on anything.

No Change: For GAENE 3.0 (Item 6), the student says that understanding evolution hasn't changed their life because they never consciously rejected evolution, so accepting/understanding evolution did not constitute a change in their views.

SCIENTIFIC CONTEXT

Proximate: The student answers an item based on picturing evolution as a module in a biology course, and not as a major scientific theory (ex: the student says that they are able to learn about the proximate explanations for processes such as photosynthesis without knowing their evolutionary origins).

General Science: Student states that evolution is very important, but other major scientific theories (ex: general relativity) are equally important for science and/or society.

Inventory of Student Evolution Acceptance (I-SEA: Nadelson & Southerland, 2012)

Macroevolution

1. I think that new species evolved from ancestral species.
2. I think that the fossil evidence that scientists use to support evolutionary theory is weak and inconclusive.
3. There are a large number of fossils found all around the world that support the idea that organisms evolve into new species over time.
4. I think all complex organisms evolved from single celled organisms.
5. I think that new species evolve from a lot of small changes occurring over relatively long periods of time.
6. There is little or no observable evidence to support the theory that describes how one species of organism evolves from a different ancestral form.
7. The forms and diversity of organisms have changed dramatically over time.
8. I think that all organisms are related (or share a common ancestor).

Microevolution

9. I think that organisms, as they exist now, are perfectly adapted to their natural environments and so will not continue to change.
10. All groups of organisms will continue to change.
11. There are a large number of examples of organisms that have undergone evolutionary changes within the species (i.e., antibiotic resistance in bacteria, production of new strains of the flu virus).
12. Species were created to be perfectly suited to their environment, so they do not change.
13. I don't accept the idea that a species of organism will evolve new traits over time.

14. I think there is an abundance of observable evidence to support the theory describing how variations within a species can happen.
15. Species exist today in exactly the same shape and form in which they always have.
16. There is overwhelming evidence supporting the theory of evolution to explain how variations in a species develop over time.

Human Evolution

17. There is reliable evidence to support the theory that describes how humans were derived from ancestral primates.
18. Although humans may adapt, humans have not/do not evolve.
19. I think that the physical structures of humans are too complex to have evolved.
20. I think that humans and apes share an ancient ancestor.
21. I think that humans evolve.
22. Humans do not evolve; they can only change their behavior.
23. The many characteristics that humans share with other primates (i.e., chimpanzees, gorillas) can best be explained by our sharing a common ancestor.
24. Physical variations in humans (i.e., eye color, skin color) were derived from the same processes that produced variation in other groups of organisms.

Combined Generalized Acceptance of Evolution Evaluation (GAENE 2.1 & 3.0: Smith et al., 2016; Glaze et al. 2020)

This list reflects the GAENE item numbering used in this article. *Italicized* items are only found on the GAENE 3.0, while the **bolded** item is only found on the GAENE 2.1. All other items appear in both iterations of the measure.

1. Everyone should understand evolution.
2. It is important to let people know about how strong the evidence that supports evolution is.
3. **Some parts of evolution theory could be true.**
4. Evolutionary theory applies to all plants and animals, including humans.
5. People who plan to become biologists need to understand evolution.
6. I would be willing to argue in favor of evolutionary theory in a public forum such as a school club, church group, or meeting of public school parents.
7. Simple organisms such as bacteria change over time.
8. Nothing in biology makes sense without evolution.
9. Understanding evolution helps me understand the other parts of biology.
10. I would be willing to argue in favor of evolution in a small group of friends.

11. Evolution is a good explanation of how humans first emerged on the earth.
12. Evolution is a scientific fact.
13. Evolution is a good explanation of how new species arise.
14. *All evidence supports the claim that evolution is true.*
15. *All species can be traced back to a single ancestor.*
16. *Evolution is a fact.*
17. *Evolution is the most important theory devised by man.*
18. *I would bet my life on the claim that evolution is true.*
19. *Understanding evolution has changed my life.*
20. *Evolution explains how bacteria that are resistant to an antibiotic can arise in a population exposed to that antibiotic.*
21. *Evolution explains how careful breeding can produce members of a species that look different from their ancestors.*
22. *Small changes can occur in a species over time.*
23. *Most living things have some very basic similarities.*