Defining Acceptance of Evolution: A Delphi Study

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ABSTRACT

The American Association for the Advancement of Science (AAAS) cites evolution as a core concept of biology, yet studies have found that biology students often exhibit low acceptance of evolution. As such, much of evolution education research aims to identify the causes of evolution rejection and develop instructional strategies to increase acceptance. This research relies upon surveys that measure evolution acceptance. Survey validity is an essential component of research quality, and a thorough definition of the construct of interest is critical for survey development and validity assessment. Thus, the purpose of this study was to develop a detailed, consensus-based definition of what constitutes "full acceptance of evolution" within the context of undergraduate biology education. This study used the Delphi method, in which a panel of experts was iteratively surveyed to establish a definition of evolution acceptance. As expert panelists voted on a definition, we found that (a) all agreed that evolution acceptance can be compatible with religious belief, and (b) "full acceptance" requires knowledge of certain aspects of evolution, including the shared ancestry of all life and existence of extensive supporting evidence for evolution. This definition serves as a foundation for establishing a survey that more accurately assesses students' awareness and assent with key aspects of evolution.

INTRODUCTION

Why does evolution acceptance matter?

The National Association of Biology Teachers (NABT) recognizes the theory of evolution as "a necessary foundational framework for understanding our natural world" (NABT, 2019). However, studies in both secular and religious institutions have found that introductory biology students often exhibit low acceptance of evolution (Bowen et al., 2022; Ferguson & Jensen, 2021). It is important for students to accept evolution, as well as understand it, because even those who *understand* evolution are less likely to choose to apply the concept later if they do not *accept* the scientific validity of what they have learned (Berkman & Plutzer, 2011). This matters because evolution has applications for many fields including, agriculture, biomedical research, and public health (Graves et al., 2016; Plutzer et al., 2020). Furthermore, the issue of evolution acceptance among the general public is of great importance because, while evolution is included in the Next Generation Science Standards for K-12 education (National Research Council, 2013), recent legislation has sought to weaken evolution instruction and bring creationism into science classrooms (Mervis, 2024).

How and why is evolution acceptance measured?

Given the educational importance of evolution acceptance, much of evolution education research has aimed to (a) identify the causes of evolution rejection (Dunk et al., 2017; Wiles, 2014) and (b) develop instructional strategies that may increase evolution acceptance among students (Fiedler et al., 2019; Laidlaw et al., 2022; Nadelson & Hardy, 2015). While research questions and methods vary, nearly all such research relies upon surveys that measure evolution acceptance

as the means for collecting data on the primary variable of interest. At present, there exist several surveys that were designed to exclusively measure student acceptance of evolution (Barnes et al., 2022; Glaze et al., 2020; Nadelson & Southerland, 2012; Rutledge & Warden, 1999; Smith et al., 2016). All of these measurement tools are multi-item, Likert scale surveys that have been assessed for validity in their initial publications and in follow-up studies, and all have been found to have shortfalls, to varying degrees, when used to measure evolution acceptance among undergraduate students (Barnes et al., 2024; Romine et al., 2018; Sbeglia & Nehm, 2018, 2019).

The importance and current state of defining evolution acceptance for measurement

A survey's validity reflects the extent to which accurate inferences can be drawn from the results when the survey is used in particular contexts (AERA et al., 2014). Survey validity is an essential component of research quality because if a survey with low validity is used, then the inferences researchers draw from the survey results may not accurately reflect the construct they seek to examine. Within education research, there exist well-established standards for how to develop a survey in a manner that maximizes validity (AERA et al., 2014; Artino et al., 2014), critically starting with a thorough definition of the construct of interest, as this enables validity assessment according to alignment with the definition of what the survey is indented to measure.

Earlier measures of evolution acceptance were not based on explicit definitions of what it means to "accept evolution" (Nadelson & Southerland, 2012; Rutledge & Warden, 1999). The developers of a later survey sought to correct this oversight by defining evolution acceptance as "the mental act or policy of deeming, positing, or postulating that the current theory of evolution is the best current available scientific explanation of the origin of new species from preexisting species" (Smith et al., 2016). When other researchers revised the Rutledge & Warden survey, they similarly defined acceptance of evolution as "the agreement that it is scientifically valid that all species have evolved from prior species" (Barnes et al., 2022). While this shift toward the incorporation of a construct definition into survey development has been an important step forward in measuring evolution acceptance, both the definitions themselves and the processes of creating them still exhibit key shortcomings. First, though both definitions emphasize the importance of accepting speciation, they offer little additional detail on either (a) what other evolutionary concepts one must accept to be said to "accept evolution," and (b) what potentially similar or related constructs lie *outside* of each definition of acceptance. Second, both definitions were developed by small (< 5), independent teams of researchers without broader consultation of the evolution education research community (Barnes et al., 2024). As such, evolution education researchers have recently called for the development of a consensus definition of evolution acceptance that is shared across the evolution education research community (Barnes et al., 2024; Beniermann et al., 2022).

Therefore, the purpose of this study was to develop a detailed, consensus-based definition of what constitutes "full acceptance of evolution" within the context of undergraduate biology education. Our goal is to strengthen the quality of evolution education research by providing a consensus definition of evolution acceptance that can be used to develop survey tools with greater validity.

METHODS

The Delphi Method

This study uses the Delphi method, which is a technique for utilizing expert opinions to establish a consensus perspective on a topic. It is best suited for situations in which definitions, standards,

or guidelines are needed, yet have an inherently subjective component. In a Delphi study, researchers iteratively survey a panel of experts until the desired level of agreement has been reached. Panelists complete their surveys individually without direct communication with the other panelists; this enables each panelist to reevaluate their own position across survey rounds while limiting the potential for outspoken individuals to directly sway others to their own opinion, as might occur in a live meeting (Green, 2014). The Delphi method has previously been used in education research to define complex concepts (Ruppert & Duncan, 2017) and establish core principles (Grunspan et al., 2018).

Expert Panel Recruitment

To establish a panel of experts, we contacted individuals who have published on the topic of measuring student acceptance of evolution in the context of higher education since 2010. To generate a list of publications relevant to development of measures (as opposed to only using them for data collection), we first identified multi-item measures of evolution acceptance and then included publications that either further evaluate these surveys or provide commentary on measuring student evolution acceptance. Once a list of relevant publications was developed, all authors were added to the list of prospective panelists. The list was updated to remove middle authors with no other history of publication in biology education research and individuals who lack up-to-date, publicly available contact information. We contacted a total of 33 experts, 26 of whom participated in one or more rounds of the Delphi.

Survey Process and Data Analysis

This study consisted of three rounds of surveys, which were sent out in Apr 2022 – Jan 2023. The first round used four open-ended questions to elicit panelists' ideas about what concepts *should* be incorporated into a definition of "full acceptance of evolution," as well as what concepts are *extraneous* to evolution acceptance and thus should not be measured by an evolution acceptance survey. We analyzed the Round 1 data using inductive coding (Cho & Lee, 2014). One researcher developed the codebook and coded all responses, while another researcher used the codebook to code 10% of responses, yielding an 85% agreement rate. These codes were used to develop the second round of the survey.

The purpose of Round 2 was to determine the extent to which panelists agree with the answers offered by their peers in the first round via closed-ended versions of questions from Round 1. Each question offered a checklist of choices generated from the free-response codes; panelists were asked to select all of the choices they wished to include in their new response. Each panelist had the opportunity to see and include -or exclude- other answers that they did not include in their initial open response. We calculated the frequency with which each answer choice was selected by panelists and used this information to develop the Round 3 of the survey.

The purpose of Round 3 was to provide panelists with a set of several alternative definitions of evolution acceptance so that they may vote and comment on their preferred definition. Round 3 consisted of three sub-parts. Part 1 offered several options for how to phrase the core definition of evolution acceptance. These options were generated by combining the evolutionary concepts most frequently selected for inclusion in previous rounds, and differed from one another in the total amount of evolutionary knowledge a student is expected to have in order to fully accept evolution. Participants were asked to rank the options in order of preference. Part 2 offered several statements that provide researchers with clarifications about what an evolution acceptance survey should or should not measure. Participants were asked to check off the statements they want to add to the core definition. Part 3 asked participants to take a stance

on several topics that appeared to be particularly contentious in the previous rounds. These concepts could be grouped into three topics: (1) how views on the origins of the human mind fit into evolution acceptance, (2) whether supernatural intervention in evolution is compatible with full acceptance, and (3) whether positive and/or negative emotions about evolution are an intrinsic feature of acceptance. Participants were asked to select one answer option for each topic. Each part of the Round 3 survey provided a free-response option and/or a comment box.

RESULTS AND DISCUSSION

Full acceptance of evolution requires knowledge of certain aspects of evolution

While the expert panel did not reach a unanimous consensus for the "best" definition of what constitutes "full acceptance of evolution", certain trends did arise. Importantly, in the closed-ended second round of the survey, 100% of panelists agreed that students do not need to reject the ideas that "God(s) or a higher power exists" or that "humans have a soul that is separate from the cognitive processes physically produced by the brain" in order to fully accept evolution; all agreed that acceptance of evolution can be compatible with religious belief.

When asked to rank three alternative core definitions of evolution acceptance, the largest proportion (50%) of panelists selected Option A as their top preference (Table 1).

Table 1. Three alternative definitions of student acceptance of evolution as ranked by expert panelists as their top preference (1st), middle preference (2nd) and lowest preference (3rd).

Core Definition	Relative Complexity	Preference Rank
Option A: The student accepts that (1) the theory of evolution is a well-established theory that is supported by a large amount of scientific evidence, (2) all life on earth shares a common ancestry, (3) evolutionary processes produce changes within individual species and cause new species to arise, (4) life on earth has been evolving for many millions of years, which has made it possible for simple, single-celled life forms to give rise to the wide variety of complex species we see today, and (5) humans evolved from earlier non-human species through the same evolutionary processes that have shaped all other species.	Highest complexity	1st: 50% 2nd: 12.5% 3rd: 37.5%
Option B: The student accepts that (1) all life on earth shares a common ancestry, (2) the diversity of life we see today was produced through the process of new species evolving from other, earlier species, and (3) humans evolved from non-human animals through the same evolutionary processes that have shaped all other species. The student does not reject any major, well-established aspects of the theory of evolution.	Medium complexity	1st: 37.5% 2nd: 37.5% 3rd: 25%
Option C: The student accepts that (1) all species are related to other species, and any two species do not have to look alike to be related, (2) the diversity of life we see today was produced through the process of new species evolving from other, earlier species, and (3) humans evolved from non-human animals. The student does not reject the shared ancestry of all life on earth or the existence of abundant supporting evidence, even if they are unaware of these and other major, well-established aspects of the theory of evolution.	Lowest complexity	1st: 12.5% 2nd: 50% 3rd: 37.5%

Option A is the most scientifically detailed of the three definitions; it is the only definition that does not specify that a student can fully accept evolution if they simply do not reject any major aspects of the theory. Of the 16 panelists participating in the final round of the study, five ranked

Option A as their highest preference and the least scientifically detailed Option C as their lowest preference, while a further three ranked Option A as their top choice with Option B (medium detail) as their bottom choice. The most-detailed Option A is also fully consistent with the InterAcademy Partnership (IAP) Statement on the Teaching of Evolution; which was signed by the Academies of Science of 65 countries (IAP, 2006).

Option B was the second-most popular top choice of definition; it was selected by a total of 6/16 panelists. Unlike Option A, Option B in itself does not expect students to be familiar with the evidence for evolution, the timescale of evolution, or the unicellular origins of multicellular life; it specifies that absence of rejection is the same as acceptance for concepts not explicitly listed in the definition. Four of the six panelists who preferred Option B, however, also voted in favor of adding the following statement to the core definition: "Both the theory that describes how evolution occurs and the shared ancestry of life on earth are supported by extensive evidence; this is why most scientists think that the basic principles of evolution are accurate, even as scientific knowledge about evolution continues to grow." Most panelists do agree that to fully accept evolution, a student must know that evolution is supported by extensive evidence.

Only two panelists selected the least scientifically detailed Option C, indicating that the great majority agreed that specific knowledge is an important part of acceptance.

CONCLUSION

While some experts chose simpler, less encompassing definitions, only the most comprehensive definition of full acceptance of evolution was satisfactory to at least 50% of the expert panel. This definition also more than meets the threshold at which all other panelists were satisfied. Thus, this Delphi study has provided a working definition of evolution acceptance that aligns with international scientific consensus on the "facts" of evolution (IAP, 2006) and that is expansive enough to indicate full acceptance of evolution by the standards of all participating experts. This definition serves as a foundation for establishing a survey that more accurately assesses students' knowledge and assent regarding these key aspects of evolution acceptance.

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