Evolution education is a complex landscape

Researchers in various contexts have long struggled with an apparent disconnect between an individual's level of understanding of biological evolution and their acceptance of it as an explanation for the history and diversity of life. Here, we discuss the main factors associated with acceptance of evolution and chart a path forward for evolution education research.

Some recent work on evolution acceptance has left us perplexed, prompting us to reflect on what we know about the current research on evolution acceptance and where further work is needed. Unlike most other subjects, individuals' level of acceptance of evolution does not always depend on their level of understanding[1]. A person who understands little about the evidence for evolution might accept it as a matter of scientific consensus, while another person might reject evolution on religious or other non-scientific grounds despite having a good understanding of the concept.

As a result, ever since evolution became a dominant paradigm in biology, evolution educators have faced a distinctive challenge: how to cope with the religious and other non-scientific factors that can impede student acceptance of evolution. For at least the past three decades, there has been an expanding interdisciplinary body of research regarding the acceptance of evolution among the public, and among students in particular. We (the authors) have all studied reasons for — and solutions to — the lack of acceptance of evolution among various groups[2]. Here, we use our collective knowledge and experience to summarize what is known about acceptance of evolution, describe a path for further exploration, and offer recommendations for how evolution acceptance research can inform curricular choices and instructional practices in life-science education.

Although the disconnect between understanding and acceptance of evolution is not limited to the United States, the majority of research into this phenomenon has been done there, and for good reason —compared to 32 European countries and Japan, only Turkey has lower public acceptance of evolution than the United States[3]. Researchers have examined numerous factors associated with acceptance of evolution[4,5] and found two main factors, beyond understanding of evolution, that have a major association with evolution acceptance: understanding the nature of science (the means, aims, processes, and practice of science)[6,7], and religiosity (salience of one's religious identity)[6–9].

Understanding of evolution is an important factor for acceptance. Earlier research in the field searched for a relationship between evolution acceptance and understanding but found contradictory results[1,10–13]. However, more recent studies employing multifactorial models have shown an independent significant association between evolution knowledge and acceptance when controlling for other variables[6–8,14], although the strength of this association varies between studies. Other recent work[15] suggests that in certain groups of UK school students, where there is a relatively low level of rejection of evolution, measures of knowledge may be more important than the factors of understanding the nature of science or of religiosity.

Those authors suggested that an instructional approach focused almost exclusively on evolution knowledge may increase acceptance of evolution for students without religious barriers[15]. We argue that such an approach may isolate and discourage students who have particular religious beliefs, by reinforcing the stereotype that it is impossible to identify as both religious and a scientist[16]. Although no single strategy is likely to be sufficient to reach all learners, one technique that holds promise, particularly for religious students, is the idea of making evolution education 'culturally competent'[17] by taking into account the unique backgrounds and experiences of learners and working towards curricula that are compatibilist, not combative, in nature. This derives from a constructivist view of education, which holds that learners come into learning opportunities with a wealth of attitudes and experiences that influence their reception and interpretation of the information presented. In the context of evolution education, it is clear (and confirmed by research) that certain religious and sociocultural experiences tend to make students less receptive to the presentation of evolution. Culturally competent pedagogy uses appropriate strategies to reduce conflicts and obstacles induced by such experiences[18–20]. This approach should lead to an increase in both understanding and acceptance of evolution—indeed, in one study, identification with evolution acceptors was found to be the only factor significantly related to change in evolution acceptance[21].

Along with teaching in a culturally competent manner, the demonstrated connection between understanding the nature of science and acceptance of evolution[5–7,22,23] suggests that including clear and explicit instruction about the nature of science may have direct benefits in increasing evolution acceptance[24,25]. Student understanding of the nature of science is a good pedagogical target for a number of reasons. Beyond increasing evolution acceptance, learning and understanding more about the scientific enterprise could help students become better informed citizens and more conscientious about the processes of science across all disciplines. In addition, nature of science is already a common part of most life sciences curricula, and, hence, education interventions can be designed to align with teachers' existing pedagogical content knowledge.

To continue to progress in our understanding of evolution acceptance and associated factors, one area that needs to be addressed is consistency in measurement. Currently, there is no universally used tool for measuring evolution acceptance. The three most common measures, however, are all multi-item Likert scale tools — demonstrably better[26,27] than single-item measures of the type commonly used in national surveys. Of the three measures of evolution acceptance, the Measure of Acceptance of the Theory of Evolution (MATE)[10,28] is the oldest and most widely used. The Inventory of Student Evolution Acceptance (I-SEA)[29] and Generalized Acceptance of EvolutioN Evalution (GAENE)[30] tools were more recently developed to address concerns with the MATE, and have gained some traction in the evolution education literature as robust measures. A recent study that employed more than one instrument found the correlation between measures may be quite strong[31]. However, ongoing work in measurement of evolution acceptance and associated factors is needed for furthering the field.

To avoid making overreaching recommendations across dissimilar contexts, we also need to explore in more detail the generalizability of results. Many existing studies have been performed in traditional university settings, which tend toward underrepresentation of certain groups of people, most notably, racial and ethnic minorities. Do these same patterns hold in underrepresented minority groups, which already face barriers in STEM education[32,33]? Does the

general public have the same reasons for rejecting evolution as the students in the majority of studies (early evidence shows they may[14])? Additionally, it is important to investigate whether the influence of various factors associated with evolution acceptance, such as nature of science understanding and religiosity, might change over time. Do these associations remain static in individuals, or does the relative impact of certain factors on an individual's acceptance of evolution change throughout their life and experiences[21,22]? And within and across populations, have these patterns been stable, or have changes occurred in the influence of these factors over the past 5, 10, or 30 years?

The ultimate goal of this area of research is to provide information and context to empower educators to increase their students' understanding of evolution. We also suggest that increasing acceptance of evolution should be a goal of instruction, insofar as possible and as long as it is not required of students. This is likely to necessitate some diversification of strategies, as different groups will respond differently to different strategies; although it is appropriate to seek out educational strategies that are the most beneficial and minimize harmful complications, we acknowledge that there is no one-size-fits-all approach to evolution education. To this end, we hope to see an increase in the number of studies that use longitudinal data sets and, where possible, use comparison groups and other controls to isolate the effect of different interventions. If science educators succeed in increasing evolution acceptance, the benefits will accrue not only to students but also to society as a whole, through better overall attitudes toward societal challenges that are tightly linked to evolution, such as antibiotic resistance, vaccine development, food security, and climate change.

The existing research we have discussed here is far from infallible and, as in any field, novel research can serve to drive the field forward. But we caution against sensationalist titles and conclusions that there is "no missing link"[14] between evolution knowledge and acceptance (a majority of evolution education researchers would never have argued there was), or that "teachers should teach the science and not focus on belief systems"[15] (an attitude which has been the driving force behind decades of curriculum changes that have failed to substantially move the bar on public acceptance of evolution[34]). Instead, we suggest that new research be understood through the lens of what we already know: acceptance of evolution is related not only to understanding of evolution, but also to understanding of the nature of science and to religious attitudes and identity. Strategies to increase evolution acceptance must necessarily include a consideration of all of these factors. To do less is to reject the preponderance of evidence arising from the science of teaching and learning — and to risk the scientific literacy of the rising generation.

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