Why Teach Biology If It Is Rejected? How to Teach Evolution So That It Can Be Accepted

Clinton Laidlaw [1] and Jamie Jensen[2]

[1](Corresponding Author), Brigham Young University, Biology 4101 LSB, Provo, UT, USA 84602-0002, 303-709-4528, clintlaidlaw@gmail.com

[2]Brigham Young University, Biology 4059 LSB, Provo, UT, USA 84602-0002, (801) 422-6896, jamie.jensen@byu.edu

Abstract

There exists a disconnect between instruction about biological evolution and acceptance of evolution by students. This disconnect prevents students from applying the theory to their lives or to their understanding of the field of biology. We examine the literature for common barriers to the acceptance of evolution, correlates with acceptance of evolution, and potential means by which education might result in increased levels of acceptance among students. We find that by changing the way that teachers themselves are taught, and by altering the methods teachers use to teach, it is likely that student acceptance of evolution can increase from instruction.

Keywords: Evolution, Education, Instruction, Acceptance, Teaching

Introduction

Biological evolution is the central organizing theory of the field of biology [Dobzhansky, 1973; American Association for the Advancement of Science (AAAS), 1993, 2011; Bybee, 1997; Kagan, 1992; National Association of Biology Teachers (NABT), 2010; National Research Council (NRC), 1996]. Without evolutionary theory, biology is reduced to an assemblage of tangential and loosely connected facts. Despite possessing a unifying theory, biology as a subject is still frequently viewed by students as being a disparate and nonsensical field requiring extensive levels of memorization of seemingly unrelated topics (Nomme, 2014). Given this perceived disconnect between topics, every aspect of biology becomes more difficult or even impossible to understand and is therefore avoided by many students (Nomme, 2014).

A major factor contributing to the dissociation of concepts in biology is the fact that the unifying element (evolutionary theory) is so widely rejected. Nearly a third of American adults firmly reject evolution (Miller et al., 2006), and less than a quarter accept evolution of humans (Lovely & Kondrick, 2008). Among educators, evolution is occasionally rejected and frequently ignored or marginalized as to evade what is perceived as avoidable conflict with both students and parents (Lerner, 2000; Farber, 2003; Olivera et al,. 2011; Verhey, 2005; Goldston & Kyzer, 2009). This widespread rejection within the general populous comes despite near complete consensus among scientists (Pew Research Center, 2015; Alters & Alters, 2001). If the central organizing theory of the entire field of biology is rejected, then there is some question as to the utility of attempting its instruction at all. If what is taught isn't internalized, then it becomes nothing more than trivia. Biology is generally considered a part of a general education at all levels, yet students that do not receive instruction about or that do not accept evolution are less likely to retain the information (Nehm & Schonfeld, 2007) or transfer their understanding to applications outside of the course itself (Nehm & Reilly, 2007; Catley & Novack, 2009; Fowler & Zeidler, 2016).

Instruction Does Not Mean Acceptance

Understanding that evolution is almost universally accepted by scientists, one might postulate that rejection of evolutionary theory is related to general ignorance of the subject matter. This might seem particularly plausible given that most students are unable to properly articulate what evolutionary theory posits (Robbins & Roy, 2007), and there is a correlation between knowledge of evolution and acceptance (Weisberg et al., 2018). As knowledge of evolution generally increases with instruction (Kim & Nehm, 2011; Moore et al., 2011) it has been frequently hypothesized that acceptance of evolution should be positively correlated with instruction and knowledge of evolution, especially natural selection (Anderson et al., 2002; Bishop & Anderson, 1990; Demastes et al., 1995; Lord & Marino, 1993; Nehm & Schonfeld, 2008; Sinatra et al., 2003). However, these studies have revealed no such correlation. For example, Sinatra et al. (2003) found that after instruction about photosynthesis, evolution of animals, and human evolution that students' acceptance of photosynthesis, the non-controversial control, went up significantly, but there was no such increase in acceptance for either animal nor human evolution following similar instruction on these topics. Though some studies have shown an increase in acceptance with instruction (Weisberg et al., 2018; Robbins & Roy, 2007), particularly outside of the United States (Akyol et al., 2010; Kim & Nehm 2011; Ha et al., 2012), it more often seems to be an effective means of temporarily increasing knowledge of evolution, but not acceptance (Bishop & Anderson, 1990; Demastes et al., 1995; Jensen & Finley 1996, Sinatra et al. 2003, Asterhan and Schwarz 2007, Stover and Mabry 2007, Rutledge & Sadler 2011; Deniz & Donnely, 2011; Lawson & Worsnop, 1992; Crawford et al,. 2005; Cavallo & McCall, 2008). Thus, the correlation between understanding and acceptance likely indicates that acceptance is a predictor of understanding and not the other way around (Smith & Siegel, 1994).

If biology is going to remain a meaningful part of a general education, then it stands to reason that we need to teach it in such a way that promotes retention of the material and the application thereof by the students to the real world. If students are going to accomplish these goals, then we need to teach it in such a way that they can accept what is being taught. As acceptance is not, generally, correlated with instruction it leads to the question, what can we do to make instruction about evolution truly effective? To answer this question, we engaged in a detailed look at the literature to see what ideas have been presented and tested that might, if implemented in classrooms, increase the efficacy of biology teaching by increasing acceptance of biological evolution.

The Correlates of Acceptance

Many factors such as per capita gross domestic product (Heddy & Nadelson, 2012), parents' education level (Deniz et al., 2008), conservative political orientations (Nadelson & Hardy, 2015), and feeling of certainty (Ha et al,. 2012), have been shown to be correlated with acceptance of evolution. Some of the most frequently observed correlates are religiosity and basic science literacy (Heddy & Nadelson, 2012, Glaze et al., 2015), particularly with understanding of evolution and of the nature of science (Cofré et al., 2018; Dunk et al., 2017; Lombrozo et al., 2008; Trani, 2004; Glaze et al., 2015; Cavallo et al., 2011; Carter & Wiles, 2014; Weisberg et al., 2018). Generally, religiosity is found to have a negative correlation with acceptance of evolution in that the more religious an individual is, the less likely they are to accept evolution (Heddy & Nadelson, 2012; Glaze et al., 2015). Conversely, correct understanding of the nature of science and of evolutionary theory are positively correlated with acceptance (Lombrozo et al., 2008; Trani, 2004, Glaze et al., 201; Cavallo et al., 2011; Weisberg et al., 2018). As stated previously, knowledge of evolution is not always found to be correlated with acceptance. When knowledge and acceptance are correlated, it sometimes only makes a difference in students that were undecided on the subject before instruction (Wilson, 2005; Ingram & Nelson, 2006). It could be that knowledge and understanding are not always synonymous because constructing such an understanding can be impeded by misconceptions both present in students and taught by instructors (Blackwell et al,. 2003; Sinatra et al., 2008; Yates & Marek, 2014). Assuming a causative relationship between these correlates and acceptance, one could conceivably increase acceptance of evolution by doing any of the following: increasing students' understanding of the nature of science, increasing students' correct understanding of evolutionary theory particularly of "macroevolution", or the idea that the small-scale "micro" evolutionary steps can accumulate and lead to speciation (Nadelson & Southerland, 2010), or by decreasing students' religious conviction.

Reduce Religiosity

Considering the negative correlation between religiosity and acceptance of evolution, many teachers and popularizers of science have attempted to confront the apparent incompatibility of science and religion by attempting to discredit the religious beliefs of the students (Dawkins, 2016; Mahner & Bunge, 1996). While this may be effective for some, it is also likely that it simply reinforces the belief that science and religion are incompatible and therefore hinders acceptance in those who are unconvinced that they should abandon their religious beliefs. In addition, promoting an accurate understanding of students' religious doctrine and discussing ways in which science and religion can be reconciled can lead to higher levels of acceptance of evolution even among highly religious students (Brickhouse et al., 2000; Manwaring et al., 2015; Barnes et al., 2017). Winslow et al., (2011) found that among Christian students raised as creationists, acceptance was possible when students were presented with evidence, when they were encouraged to examine the literalness of the scriptural accounts of creation, when evolution was presented as something unrelated to their eternal salvation, and when their professor was viewed as a religious role model who accepted evolution. Holt et al., (2018) found that "The single factor linked with the reduction in both creationist reasoning and in students' perceived conflict between evolution and their worldview through a semester was the presence of a role model."

Along those lines, it is essential to differentiate between accepting and believing in evolution as belief and acceptance are not, necessarily, synonymous (Smith & Siegel, 2004). Evolution is not a belief system, but a rational explanation for a host of facts which, to date, cannot otherwise be explained. One therefore does not believe in evolution but accepts it as the most reasonable explanation we have given the facts. This understanding is likely associated with understanding of the nature of science and its limitations, and if understood could mitigate the belief that accepting evolution threatens ones' eternal salvation (Winslow et al., 2011).

All of this would suggest that, for highly religious students, the best way to promote acceptance might not be to attack their beliefs, but to aid them in reconciling their beliefs with science and serving as a non-hostile role model. In the case that the instructor holds uninformed or antagonistic viewpoints towards religion this approach should only be implemented with great care (Brickhouse et al., 2000). Regardless, presenting science as an antithesis to religion may do more to promote rejection than acceptance. Whether it is effective or not to diminish the religious beliefs of students, Rice et al., (2015) found that, for university faculty, knowledge and acceptance of evolution were positively correlated, even in faculty with creationist viewpoints, suggesting that acceptance and knowledge can increase conjointly irrespective of the religious position of the learners. Attacking the students' religious convictions is likely not the best way to increase the likelihood of accepting evolution.

Reduce Misconceptions

Given the variation in the strength of students' religious beliefs as well as the compatibility of those beliefs with evolutionary theory, in many instances it may be counter-productive to engage those convictions directly or indirectly. Attempting to increase acceptance of evolution by confronting student religiosity may not always be an effective option for instructors. One of the principle issues related to religion and science is that religious students may be at an increased risk of possessing misconceptions that hinder proper understanding of science generally, especially evolution (Dagher & BouJaoude, 1997; Sinatra et al., 2003; Blackwell et al., 2003). To increase the likelihood of acceptance among religious students it may be effective to address those misconceptions in lieu of confronting the religion directly.

The importance of confronting misconceptions is not limited to religious students in any way, but such misconceptions permeate society irrespective of religiosity (Blackwell et al., 2003; Sinatra et al., 2008; Yates & Marek, 2014). In some cases, people may claim to reject evolution based on their religious convictions, but this may not be the actual motivation. Trani, (2004) found that many teachers claimed to reject evolution due to their religion, but upon further analysis it appeared to be more due to a lack of understanding of the actual theory of evolution, and a lack of understanding of the nature of science.

To confront the acceptance barrier of misconceptions one could confront those misconceptions directly in the classroom as a part of the curriculum. Misconceptions about evolution are numerous and include things such as those listed by Gregory, (2009). Wilson, (2005) designed an entire course with the objective of increasing interest in, knowledge and acceptance of evolution. In the course the researchers focused the beginning of the course on the implications of evolution as many of the most common reasons for dismissing the theory come from incorrect assumptions regarding its implications. Although some have chosen to devote the whole of a course to confronting such misconceptions, all biology courses are likely to benefit from taking time to assess and address the misconceptions present in the students.

What may be better than correcting misconceptions would be to begin to teach evolution explicitly as early as possible to students so that they can develop accurate initial conceptions regarding evolution and the nature of science before they have the opportunity to construct inaccurate ones (Weiss & Dreesmann, 2014). Kelemen et al., (2014) found that children from 5 to 8 years of age can be taught basic natural selection using a picture-storybook and retain and apply that information even several months after instruction. Contrary to what many might think, correct understanding of evolution does not seem to be outside of the reasoning ability of even very young students.

Capability of Teachers

Among the major considerations which may prevent earlier implementation of evolution into curricula is the understanding of the teacher. Being that we are seeking to evade misconceptions among learners, it is important to consider that many teachers of younger students themselves possess these misconceptions (Blackwell et al., 2003; Yates & Marek, 2014). Elementary teachers, for example, may have a single semester or less of biology education before beginning teaching, a single course which may or may not have taught accurate principles of biological evolution. Teachers are often not sufficiently knowledgeable to correctly teach these concepts and may deliberately or inadvertently teach misconceptions explicitly in the classroom. Even among more highly trained biology-specific teachers, such misconceptions are prevalent. Many either teach these misconceptions, or use them, combined with concerns of parent outrage, as an excuse to avoid the topic altogether. Rutledge & Mitchell, (2002) found that 43% of surveyed teachers completely avoided, or only briefly mentioned evolution in Indiana biology classrooms. The principle reasons that the topic was avoided was that the teachers felt ill-equipped in terms of their personal understanding or rejected it themselves. Some teachers do not want to teach evolution, others are incapable (Wiles & Branch, 2008). Though beginning evolution education at an earlier age may increase the likelihood of acceptance, it is unlikely that our current workforce of teachers is adequately trained to do so.

If we are to have teachers that are more equipped to teach evolution in schools then we need a better way to teach not only our students, but our teachers (Weiss & Dreesmann, 2014; Blackwell et al., 2003). Rutledge & Warder, (2000) found that Indiana public high school biology teachers were ill-prepared by their academic qualifications to teach evolution, or the nature of science and that most college and university biology departments do not require evolution or nature of science coursework to obtain teacher certification in biology. Even when attempts are made to design courses to increase instructor knowledge of evolution these courses are frequently ineffective at changing the way that instructors teach. For example, a course taught at the graduate-level to instructors designed to increase instructor knowledge and reduce misconceptions was effective at increasing knowledge and reducing misconceptions, but did not reduce the desire of instructors to teach anti-evolutionary ideas (Nehm & Schonfeld, 2007) suggesting that it did not have an impact on instructor acceptance.

For students and educators that have received quality instruction, but especially for those whose early-life evolution education has left them either uninformed or misinformed about evolution, the question then becomes how do we teach evolution so that they will be most able to understand and accept it?

Constructivism

Alters & Nelson, (2002) suggested teaching using constructivism as a means of increasing the efficacy of evolution teaching. Constructivism, when applied not only as a theory of learning but as a theory of education, should promote conceptual change in learners because it, unlike many other educational theories such as behaviorism, is not capable of ignoring the misconceptions and past experiences of the students. With behaviorism, instructors may elicit desired responses from learners with sustained reinforcement of those behavioral responses. However, the knowledge that they are to attain is not owned by the learner, but is predetermined by the instructor. Understanding is only measured by the learner behaving in the manner desired by the instructor (such as repeating a word or phrase) in response to specific stimuli (such as a test question), which are again determined by the instructor (Scheurman, 1998). Behaviorism treats learners as though they were a blank slate and does not account for the effect that their preconceived notions may have on their ability to learn new material (Ertmer & Newby, 1993). Cognitivism accepts that learners may have preconceived notions that may interfere with their ability to obtain knowledge, but it still views knowledge as something created outside of the learner and therefore something inflicted upon the learner and not constructed thereby (Ertmer & Newby, 1993). Constructivism is arguably a subset of cognitivism that assumes that knowledge cannot be transferred intact from one individual to another, but rather that all people construct within themselves a logical set of explanations for the experiences that they have had (Jonassen, 1999). When we ignore the past experiences of a learner, we are unable to predict how they will incorporate the new information being presented into their existing schemas. A constructivist classroom will raise questions and problems that require students to do things based on their prior beliefs, but that have results or answers which may not fit into their existing schemas requiring students to reexamine their existing schemas to see if they remain credible, or if they need to be replaced (Lawson, 1994). In addition to confronting incorrect schemas that might otherwise go undetected, such experience may increase overall reasoning abilities, which, as suggested by Lawson & Wesner, (1990), should decrease nonscientific beliefs in students. These reasons should, at least hypothetically, make constructivist teaching more effective in terms of promoting acceptance of evolution.

Active Learning

Freeman et al., (2014) in a meta-analysis of 225 studies found that the use of active learning of any kind increased exam scores an average of 6% and that failure rates in STEM courses were 55% higher in non-active courses than in active courses. Active learning was also suggested as a means of increasing knowledge and acceptance of evolution specifically by Alters and Nelson, (2002) because learning tends to increase in active learning classrooms. Where learning increases, instructors have a greater chance of increasing student understanding of the two key knowledge correlates with evolution acceptance: the nature of science and of evolution. Nehm & Reilly, (2007), for example, found that classes taught using active learning achieved higher scores on key concepts of natural selection and had fewer misconceptions than classes taught traditionally. Active learning environments may too provide a greater opportunity for instructors to gain insight into the thoughts and misconceptions of their students and thus more able to address them deliberately in the classroom.

Journals

Reflective journals are already widely used in other fields of education such as nursing (Blake, 2005; Raterink, 2016; Miller, 2017), counselling (Chabon & Lee-Wilkerson, 2006; Hubbs & Brand, 2005), and statistics (Thropp, 2017). These journals proved an active-learning component to the course allowing the students to reflect on the material (Blake, 2005; Thropp, 2017), as well as giving instructors critical feedback into the understanding and application of the material in their students (Chabon & Lee-Wilkerson, 2006). In Biology classrooms, completing journaling assignments has been correlated with an increase in understanding and acceptance of biological evolution

(Scharmann & Butler, 2015). While the lack of a control in this study prevents us from knowing if journaling caused any portion of the increase in acceptance that the researchers observed, as with other fields, the journals helped researchers gain a clearer view into students' thoughts. Combined with the use of active learning in the classroom, they saw an increase in acceptance of evolution over the course of the semester. Journals may, in and of themselves, increase acceptance, but at the very least journals can inform instructors about the major misconceptions and understanding of their classes so that instructors can modify their curricula accordingly.

Make Evolution Relevant

To most biologists the importance of evolutionary theory is obvious as it not only makes sense of the field, but gives us the ability to understand and predict many real-world, relevant phenomena such as the spread of disease, pest management, and the potential impacts of climactic change. Many students, nonetheless, never see the practicality of the theory. Learning is often impeded because students do not see the relevance of the subject to their lives (Heddy & Sinatra, 2013). One of the great benefits of active learning is that it increases the attentiveness of the students (Prince, 2004), but if the material is trivial and irrelevant then such benefits may be lost (Heddy & Sinatra, 2013). Infanti & Wiles, (2014) found that exposing students to "Evo in the News" (news articles involving evolution) was correlated with increases in student attitudes regarding evolution and its relevance. Thus, we may benefit from not only explaining the historical importance of evolution but focusing on how evolution impacts modern life for our students. Stover et al., (2013) found that acceptance of evolution and other controversial topics in science increased when placed in a context of public health. As is often the case, science is perceived as most relevant when it is directly related to human health and survival. This would include the evolution of diseases, drug resistance, herb and pesticide resistance, communicability of diseases from other organisms, selective breeding and others. There are likely countless examples of ways that evolution impacts modern life, and the more examples we can bring to the students the more likely they are to listen to the content being shared.

Social Identity Theory

Social identity theory is a theory in social psychology that explains much about intergroup behavior based on their perceived membership to a relevant social group (Turner & Oakes, 1986; Tajfel et al., 1979; Tajfel & Turner, 1986). This theory led to the creation of self-categorization theory that describes the conditions under which an individual will identify assemblages of individuals (potentially including themselves) as being a group, and the consequences of identifying people as a group (Haslam, S. A., 1997). Based on these theories, social identities are cognitively signified as group stereotypes that both describe and assign beliefs, attitudes and behaviors that minimize differences with members of one's perceived group and maximize differences with members of other groups whether those groups were formed randomly or non-randomly (Tajfel, 2010). As a result, people tend to be unreasonably critical of ideas that come from individuals outside of their perceived group, and unreasonably accepting of ideas that come from individuals within their perceived group (Tajfel, 2010). While research has not focused on the impact of social identity theory and in-group formation on evolution acceptance specifically, it would explain why acceptance rates vary based on factors such as political party and religious affiliation (Nadelson & Hardy, 2015). It stands to reason that students' perception of their instructor as being either part of their in-group or not part of their in-group could dramatically influence the probability of evolution acceptance among their students. This could potentially be addressed by taking steps to approximate the stereotypes of the students' in-group, or at least not deliberately portray oneself as a member of an out-group (Holt et al., 2018) and also by building a strong in-group culture in the classroom and never to isolate members of the class as being members of some other group.

Conclusions and Future Directions

While our understanding of the importance of accepting evolution and how to increase that acceptance is increasing, we still have much to accomplish. In many cases the implementation of this knowledge is inhibited by the fact that teachers are unable or unmotivated to make the changes necessary to improve the quality of biology education as to increase student acceptance of the fundamental theory of evolution. Despite the obstacles, there is great reason for optimism. A greater focus on student understanding of the nature of science and evolutionary theory promises to increase student acceptance particularly as these topics are presented in an active, constructivist, and relevant way. Gone are the days when we, as scientists, felt the need to engage in the battle of science versus religion to inform our students. We do not need to tear down as much as we need to confront misconceptions and build, as early as possible, correct ideas about the mechanisms and implications of evolution.

Many great ideas have been postulated regarding teaching strategies that are likely to increase acceptance. As we focus on studies that experimentally test these hypotheses, we are likely to have greater and greater clarity as to the most effective ways to present science and biology to modern students. As we understand how to address controversial topics such as evolution we are likely to gain insight into how we might better inform the public about a host of other relevant and important topics that are similarly perceived as being controversial (e.g., reproductive technology, climate change). We have long been fighting this battle, but we are constantly learning which battles really should be fought.

References

AKYOL, G., TEKKAYA, C., AND SUNGUR, S. 2010. The contribution of understandings of evolutionary theory and nature of science to pre-service science teachers' acceptance of evolutionary theory. Procedia-Social and Behavioral Sciences 9, 1889-1893.

ALTERS, B. J., AND ALTERS, S. 2001. Defending evolution in the classroom: A guide to the creation/evolution controversy. Jones & Bartlett Learning.

ALTERS, B. J., AND NELSON, C. E. 2002. Perspective: Teaching evolution in higher education. Evolution, 56(10), 1891-1901.

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE. Benchmarks for science literacy. Oxford University Press, 1993.

ANDERSON, D. L., FISHER, K. M., AND NORMAN, G. J. 2002. Development and evaluation of the conceptual inventory of natural selection. Journal of research in science teaching, 39(10), 952-978.

ASTERHAN, C. S., AND SCHWARZ, B. B. 2007. The effects of monological and dialogical argumentation on concept learning in evolutionary theory. Journal of Educational Psychology, 99(3), 626.

BARNES, M. E., ELSER, J., & BROWNELL, S. E. 2017. Impact of a Short Evolution Module on Students' Perceived Conflict between Religion and Evolution. The American Biology Teacher, 79(2), 104-111.

BISHOP, B. A., AND ANDERSON, C. W. 1990. Student conceptions of natural selection and its role in evolution. Journal of research in science teaching, 27(5), 415-427.

BLACKWELL, W. H., POWELL, M. J., AND DUKES, G. H. 2003. The problem of student acceptance of evolution. Journal of Biological Education, 37(2), 58-67.)

BLAKE, T. K. 2005. Journaling; An active learning technique. International Journal of Nursing Education Scholarship, 2(1), 1116.

BREWER, CAROL A., AND DIANE SMITH. Vision and change in undergraduate biology education: a call to action. American Association for the Advancement of Science, Washington, DC (2011).

BRICKHOUSE, N. W., DAGHER, Z. R., LETTS, I. V., WILLIAM, J., AND SHIPMAN, H. L. 2000. Diversity of students' views about evidence, theory, and the interface between science and religion in an astronomy course. Journal of Research in Science Teaching, 37(4), 340-362.

BYBEE, RODGER W. Achieving scientific literacy: From purposes to practices. Heinemann, 88 Post Road West, PO Box 5007, Westport, CT 06881, 1997.

CARTER, B. E., AND WILES, J. R. 2014. Scientific consensus and social controversy: exploring relationships between students' conceptions of the nature of science, biological evolution, and global climate change. Evolution: education and outreach, 7(1), 1.

CATLEY, K. M., AND NOVICK, L. R. 2009. Digging deep: Exploring college students' knowledge of macroevolutionary time. Journal of Research in Science Teaching, 46(3), 311-332.

CAVALLO, A. M., & MCCALL, D. 2008. Seeing may not mean believing: examining students' understandings & beliefs in evolution. The American Biology Teacher, 70(9), 522-530.

CAVALLO, A. M., WHITE, K. J., AND MCCALL, D. 2011. The Mismatch among Students' Views about Nature of Science, Acceptance of Evolution, and Evolutionary Science Understandings. Science Education Review, 10(2), 37-42.

CHABON, S. S., AND LEE-WILKERSON, D. 2006. Use of Journal Writing in the Assessment of CSD Students' Learning About Diversity A Method Worthy of Reflection. Communication disorders quarterly, 27(3), 146-158.

COFRÉ, H. L., SANTIBÁÑEZ, D. P., JIMÉNEZ, J. P., SPOTORNO, A., CARMONA, F., NAVARRETE, K., AND VERGARA, C. A. 2018. The effect of teaching the nature of science on students' acceptance and understanding of evolution: myth or reality? Journal of Biological Education, 52(3), 248-261.

CRAWFORD, B. A., ZEMBAL-SAUL, C., MUNFORD, D., AND FRIEDRICHSEN, P. 2005. Confronting prospective teachers' ideas of evolution and scientific inquiry using technology and inquiry-based tasks. Journal of research in science teaching, 42(6), 613-637.

DAGHER, Z. R., AND BOUJAOUDE, S. 1997. Scientific views and religious beliefs of college students: The case of biological evolution. Journal of research in Science Teaching, 34(5), 429-445.

DAWKINS, R. 2016. The god delusion. Random House.

DEMASTES, S. S., SETTLAGE, J., AND GOOD, R. 1995. Students' conceptions of natural selection and its role in evolution: Cases of replication and comparison. Journal of Research in Science Teaching, 32(5), 535-550.

DENIZ, H., AND DONNELLY, L. A. 2011. Preservice secondary science teachers' acceptance of evolutionary theory and factors related to acceptance. Reports of the National Center for Science Education, 31(4).

DENIZ, H., DONNELLY, L. A., AND YILMAZ, I. 2008. Exploring the factors related to acceptance of evolutionary theory among Turkish preservice biology teachers: Toward a more informative conceptual ecology for biological evolution. Journal of Research in Science Teaching, 45(4), 420-443.

DOBZHANSKY, THEODOSIUS. Nothing in biology makes sense except in the light of evolution. (1973): 125-129.

DUNK, R. D., PETTO, A. J., WILES, J. R., AND CAMPBELL, B. C. 2017. A multifactorial analysis of acceptance of evolution. Evolution: Education and Outreach, 10(1), 4.

ERTMER, P. A., AND NEWBY, T. J. 1993. Behaviorism, cognitivism, constructivism: Comparing critical features from an instructional design perspective. Performance improvement quarterly, 6(4), 50-72.

FARBER, P. 2003. Teaching evolution & the nature of science. The American Biology Teacher, 65(5), 347-354.

FOWLER, S. R., AND ZEIDLER, D. L. 2016. Lack of evolution acceptance inhibits students' negotiation of biology-based socioscientific issues. Journal of Biological Education, 50(4), 407-424.

FREEMAN, S., EDDY, S. L., MCDONOUGH, M., SMITH, M. K., OKOROAFOR, N., JORDT, H., AND WENDEROTH, M. P. 2014. Active learning increases student performance in science, engineering, and mathematics. Proceedings of the National Academy of Sciences, 111(23), 8410-8415.

GLAZE, A. L., GOLDSTON, M. J., AND DANTZLER, J. 2015. Evolution in the southeastern USA: Factors influencing acceptance and rejection in pre-service science teachers. International Journal of Science and Mathematics Education, 13(6), 1189-1209.

GLAZE, A. L., AND GOLDSTON, M. J. 2015. US science teaching and learning of evolution: A critical review of the literature 2000–2014. Science Education,99(3), 500-518.

GOLDSTON, M. J., AND KYZER, P. 2009. Teaching evolution: Narratives with a view from three southern biology teachers in the USA. Journal of Research in Science Teaching, 46(7), 762-790.

GREGORY, T. R. 2009. Understanding natural selection: essential concepts and common misconceptions. Evolution: Education and Outreach, 2(2), 156-175.

HA, M., HAURY, D. L., AND NEHM, R. H. 2012. Feeling of certainty: uncovering a missing link between knowledge and acceptance of evolution. Journal of Research in Science Teaching, 49(1), 95-121.

HASLAM, S. A. 1997. Stereotyping and social influence: Foundations of stereotype consensus.

HEDDY, B. C., AND NADELSON, L. S. 2012. A global perspective of the variables associated with acceptance of evolution. Evolution: Education and Outreach,5(3), 412-418.)

HEDDY, B. C., AND SINATRA, G. M. 2013. Transforming misconceptions: Using transformative experience to promote positive affect and conceptual change in students learning about biological evolution. Science Education, 97(5), 723-744.

HOLT, E. A., OGDEN, T. H., AND DURHAM, S. L. 2018. The positive effect of role models in evolution instruction. Evolution: Education and Outreach, 11(1), 11.

HUBBS, D. L., AND BRAND, C. F. 2005. The paper mirror: Understanding reflective journaling. Journal of Experiential Education, 28(1), 60-71.

INFANTI, L. M., AND WILES, J. R. 2014. " Evo in the News:" Understanding Evolution and Students' Attitudes toward the Relevance of Evolutionary Biology. Bioscene: Journal of College Biology Teaching, 40(2), 9-14.

INGRAM, E. L., AND NELSON, C. E. 2006. Relationship between achievement and students' acceptance of evolution or creation in an upper-level evolution course. Journal of research in science teaching, 43(1), 7-24.

JENSEN, M. S., AND FINLEY, F. N. 1996. Changes in students' understanding of evolution resulting from different curricular and instructional strategies. Journal of research in science teaching, 33(8), 879-900.

JONASSEN, D. H. 1999. Designing constructivist learning environments. Instructional design theories and models: A new paradigm of instructional theory, 2, 215-239.

KAGAN, DONA M. "Implication of research on teacher belief." Educational psychologist 27.1 (1992): 65-90.

KELEMEN, D., EMMONS, N. A., SCHILLACI, R. S., AND GANEA, P. A. 2014. Young children can be taught basic natural selection using a picture-storybook intervention. Psychological science, 25(4), 893-902.

KIM, S. Y., AND NEHM, R. H. 2011. A cross-cultural comparison of korean and american science teachers' views of evolution and the nature of science. International Journal of Science Education, 33(2), 197-227.

LAWSON, A.E. 1994. Research on the acquisition of science knowledge; epistemological foundation of cognition. Pp. 131-176 in D.L. Gabriel, ed. Handbook of research on science teaching and learning. Macmillan, New York.

LAWSON, A. E., AND WESER, J. 1990. The rejection of nonscientific beliefs about life: Effects of instruction and reasoning skills. Journal of Research in Science Teaching, 27(6), 589-606.

LAWSON, A. E., AND WORSNOP, W. A. 1992. Learning about evolution and rejecting a belief in special creation: Effects of reflective reasoning skill, prior knowledge, prior belief and religious commitment. Journal of research in science teaching, 29(2), 143-166.

LERNER, L. S. 2001. Good Science, Bad Science: Teaching Evolution in the States. California Journal of Science Education, 1(2), 117-33.

LOMBROZO, T., THANUKOS, A., AND WEISBERG, M. 2008. The importance of understanding the nature of science for accepting evolution. Evolution: Education and Outreach, 1(3), 290-298.)

LORD, T., AND MARINO, S. 1993. How university students view the theory of evolution. Journal of College Science Teaching, 22(6), 353-57.

LOVELY, E. C., AND KONDRICK, L. C. 2008. Teaching evolution: challenging religious preconceptions. American Zoologist, 48(2), 164-174.

MAHNER, M., AND BUNGE, M. 1996. Is religious education compatible with science education?. Science & Education, 5(2), 101-123.)

MANWARING, K. F., JENSEN, J. L., GILL, R. A., AND BYBEE, S. M. 2015. Influencing highly religious undergraduate perceptions of evolution: Mormons as a case study. Evolution: Education and Outreach, 8(1), 1.)

MILLER, L. B. 2017. Review of Journaling as a Teaching and Learning Strategy. Teaching and Learning in Nursing, 12(1), 39-42.

MILLER, JON D., EUGENIE C. SCOTT, AND SHINJI OKAMOTO. 2006. Public acceptance of evolution. Science-New York then Washington- 313.5788: 765.

MOORE, R., BROOKS, D. C., AND COTNER, S. 2011. The relation of high school biology courses & students' religious beliefs to college students' knowledge of evolution. The American Biology Teacher, 73(4), 222-226.

NADELSON, L. S., AND HARDY, K. K. 2015. Trust in science and scientists and the acceptance of evolution. Evolution: Education and Outreach, 8(1), 1-9.

NADELSON, L. S., AND SOUTHERLAND, S. A. 2010. Examining the interaction of acceptance and understanding: how does the relationship change with a focus on macroevolution? Evolution: Education and Outreach, 3(1), 82-88.)

NATIONAL ASSOCIATION OF BIOLOGY TEACHERS (NABT). Mission statement. http://www.nabt.org/websites/institution/index.php?p=1 (2010).

NATIONAL RESEARCH COUNCIL, ED. 1996. National science education standards. National Academy Press.

NOMME, KATHY M. "Q4B Update." Presented at the UBC Biology Teaching Program Reterat. July 2014.

NEHM, R. H., AND REILLY, L. 2007. Biology majors' knowledge and misconceptions of natural selection. BioScience, 57(3), 263-272.

NEHM, R. H., AND SCHONFELD, I. S. 2007. Does increasing biology teacher knowledge of evolution and the nature of science lead to greater preference for the teaching of evolution in schools?. Journal of Science Teacher Education, 18(5), 699-723.)

NEHM, R. H., AND SCHONFELD, I. S. 2008. Measuring knowledge of natural selection: a comparison of the CINS, an open-response instrument, and an oral interview. Journal of Research in Science Teaching, 45(10), 1131-1160.

OLIVEIRA, A. W., COOK, K., AND BUCK, G. A. 2011. Framing evolution discussion intellectually. Journal of Research in Science Teaching, 48(3), 257-280.

PEW RESEARCH CENTER 2015. Major Gaps Between the Public, Scientists on Key Issues. Washington, D.C.. Accessed from http://www.pewinternet.org/interactives/public-scientists-opinion-gap on 8 December 2016.

PRINCE, M. 2004. Does active learning work? A review of the research. Journal of engineering education, 93(3), 223-231.

RATERINK, G. 2016. Reflective journaling for critical thinking development in advanced practice registered nurse students. Journal of Nursing Education, 55(2), 101-104.

RICE, J. W., CLOUGH, M. P., OLSON, J. K., ADAMS, D. C., AND COLBERT, J. T. 2015. University faculty and their knowledge & acceptance of biological evolution. Evolution: Education and Outreach, 8(1), 1.

ROBBINS, J. R., AND ROY, P. 2007. The natural selection: identifying & correcting non-science student preconceptions through an inquiry-based, critical approach to evolution. The American Biology Teacher, 69(8), 460-466.

RUTLEDGE, M. L., AND MITCHELL, M. A. 2002. High school biology teachers' knowledge structure, acceptance & teaching of evolution. The American Biology Teacher, 64(1), 21-28.)

RUTLEDGE, M. L., & SADLER, K. C. 2007. Reliability of the measure of acceptance of the theory of evolution (MATE) instrument with university students. The American Biology Teacher, 69(6), 332-335.

RUTLEDGE, M. L., & WARDEN, M. A. 2000. Evolutionary theory, the nature of science & high school biology teachers: Critical relationships. The American Biology Teacher, 62(1), 23-31.

SCHARMANN, L. C., AND BUTLER JR, W. 2015. The Use of Journaling to Assess Student Learning and Acceptance of Evolutionary Science. Journal of College Science Teaching, 45(1), 16.

SCHEURMAN, G. 1998. From Behaviorist to Constructivist Teaching. Social Education, 62(1), 6-9.

SINATRA, G. M., BREM, S. K., AND EVANS, E. M. 2008. Changing minds? Implications of conceptual change for teaching and learning about biological evolution. Evolution: Education and outreach, 1(2), 189-195.

SINATRA, G. M., SOUTHERLAND, S. A., MCCONAUGHY, F., AND DEMASTES, J. W. 2003. Intentions and beliefs in students' understanding and acceptance of biological evolution. Journal of Research in Science Teaching, 40(5), 510-528.

SMITH, M. U., AND SIEGEL, H. 2004. Knowing, believing, and understanding: What goals for science education?. Science & Education, 13(6), 553-582.

STOVER, S. K., AND MABRY, M. L. 2007. Influences of Teleological and Lamarckian Thinking on Student Understanding of Natural Selection. Bioscene: Journal of College Biology Teaching, 33(1), 11-18.

STOVER, S. K., MCARTHUR, L. B., AND MABRY, M. L. 2013. Presenting Global Warming and Evolution as Public Health Issues to Encourage Acceptance of Scientific Evidence. Bioscene: Journal of College Biology Teaching, 39(2), 3-10.

TAJFEL, H., TURNER, J. C., AUSTIN, W. G., AND WORCHEL, S. 1979. An integrative theory of intergroup conflict. Organizational identity: A reader, 56-65.

TAJFEL, H., AND TURNER, J. C. 1986. "The social identity theory of intergroup behaviour". In S. Worchel & W. G. Austin (eds.). Psychology of Intergroup Relations. Chicago, IL: Nelson-Hall. pp. 7–24.

TAJFEL, H. 2010. Social identity and intergroup relations (Vol. 7). Cambridge University Press.

THROPP, J. 2017. Using Reflective Journaling to Promote Achievement in Graduate Statistics Coursework. International Journal of Learning, Teaching and Educational Research, 16(1).

TRANI, R. 2004. I won't teach evolution; it's against my religion. And now for the rest of the story…. The American Biology Teacher, 66(6), 419-427.)

TURNER, J. C., AND OAKES, P. J. 1986. The significance of the social identity concept for social psychology with reference to individualism, interactionism and social influence. British Journal of Social Psychology, 25(3), 237-252.

VERHEY, S. D. 2005. The effect of engaging prior learning on student attitudes toward creationism and evolution. BioScience, 55(11), 996-1003.

WEISBERG, D. S., LANDRUM, A. R., METZ, S. E., AND WEISBERG, M. 2018. No missing link: Knowledge predicts acceptance of evolution in the United States. BioScience, 68(3), 212-222.

WEISS, M., AND DREESMANN, D. C. 2014. Aspirations and Expectations: Comparing Scientist and Teacher Views as a Source of Ideas for Teaching Evolution. Universal Journal of Educational Research, 2(5), 421-431.)

WILES, J. R., AND BRANCH, G. 2008. Teachers who won't, don't, or can't teach evolution properly: a burning issue. The American Biology Teacher, 70(1), 6-7.)

WILSON, D. S. 2005. Evolution for everyone: how to increase acceptance of, interest in, and knowledge about evolution. PLoS Biol, 3(12), e364.)

WINSLOW, M. W., STAVER, J. R., AND SCHARMANN, L. C. 2011. Evolution and personal religious belief: Christian university biology-related majors' search for reconciliation. Journal of Research in Science Teaching, 48(9), 1026-1049.

YATES, T. B., AND MAREK, E. A. 2014. Teachers teaching misconceptions: a study of factors contributing to high school biology students' acquisition of biological evolution-related misconceptions. Evolution: Education and Outreach, 7(1),