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A Global Perspective of the Variables Associated with Acceptance of Evolution

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Abstract The controversy of biological evolution due to conflicts with personal beliefs and worldviews is a phenomenon that spans many cultures. Acceptance of evolution is essential for global advancement in science, technology, and agriculture. Previous research has tended to focus on the factors that can influence acceptance of evolution by culture or country. Our research explored the relationship on an international scale using secondary data analysis to research evolution acceptance for 35 countries. Our results indicate significant relationships between public acceptance of evolution and religiosity, school-life expectancy, science literacy, and gross domestic product per capita. Implications and future directions for research are addressed.

Keywords Biological evolution · Public acceptance · Globalization

Introduction

Darwin's theory of evolution is the foundation for comprehending biology and all living organisms (Dobzhansky 1973). Regardless of our awareness or attention, evolution is constantly in action. Because of the ubiquitous nature of the theory and the manner in which evolution takes place, it is important for us to understand and accept evolution. Acceptance and knowledge of evolution is essential for understanding developments taking place in medicine, agriculture, beauty and health products, and also influences many other aspects of society (Nadelson and Southerland 2010; Gould 2002; Miller 1999).

For example, through the process of natural selection, bacteria that are constantly exposed to antibiotics may evolve strands that are antibiotic resistant. If the process of natural selection is not accepted or understood, bacterial infections may be treated with medications that they are resistant to, and patients are less likely to recover (D'Costa et al. 2011). The acceptance and understanding of evolution is critical for agriculture and ranching, as evolution concepts such as inheritance and domestication influence how livestock and crops are selected, modified, tended, and marketed. Human evolutionary relationship to other species becomes quite obvious when one examines the use of an array of species to test new medications, health, and beauty products that are being created for humans. Knowledge and acceptance of evolution is critical to understanding how humans are related to other animals and critical to assuring that the correct animals are selected for testing. Similarly, evolution knowledge and acceptance is essential for providing justification for why scientists use animals to test products intended for human use and consumption. Even with the pragmatic and societal implications for the understanding and acceptance of evolution, a strong resistance to the theory remains, influenced by a number of variables (Alters and Alters 2001; Miller 2008; Scott 2005).

The issues pertaining to acceptance of evolution have been widely studied (Alters and Alters 2001; Miller 2008; Scott 2005). With few exceptions, such as the report by Miller et al. (2006), most studies have focused on a specific culture or country. Additionally, many evolution acceptance studies tend to focus on individual characteristics rather than those of societies or populations as a whole. Our research took a unique direction, exploring the levels of evolution

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acceptance of different countries in relationship to variables measured at the country level. Examining evolution acceptance at the country level may provide insight into how nations approach situations involving evolutionary implications as well as science education. Taking a global perspective, our research explored the relationship of four variables (religiosity; science literacy; school-life expectancy; gross domestic product (GDP) per capita) to acceptance of evolution for 35 different countries.

Before we delve into our research project and findings, we lay the groundwork for our study by reviewing the relevant literature in evolution acceptance. We then present our methods and study results. We follow with a discussion of our finding and the implications. We close with some potential limitations of our study and concluding remarks that project our study into the larger context of evolution acceptance.

Theoretical Framework

Many people have difficulties with accepting the scientific theory of evolution generated by Charles Darwin (Alters and Alters 2001; Gallup 2006, 2009; Miller 2008). The concepts of evolution are perceived as conflicting with worldviews such as religion (Sinatra and Nadelson 2011), such that as religiosity increases, acceptance of evolution decreases (Nadelson and Sinatra 2009). Regardless of religion, it appears that as the amount of science that an individuals are exposed to through schooling increases, there is a corresponding increase in their acceptance of evolution (Susteric 2007; Alters and Nelson 2002). There has been much research on how many topics relate to acceptance of evolution; however, the findings have not been reported on an international scale (Paz-Y-Mino 2009; Susteric 2007; Alters and Nelson 2002).

The motivation for data collection on the international level can be justified based on evolutionary biology-related issues occurring on an international scale (e.g., H1N1 swine flu epidemic of 2009). However, increased access and awareness resulting from globalization has provided researchers with opportunities to conduct studies on national perspectives. Capitalizing on the opportunities that globalization has afforded, researchers have collected international data on public acceptance of evolution (Miller et al. 2006; Hameed 2008) and other data such as religiosity, school-life expectancy, scientific literacy, and gross domestic product per capita (Gallup 2009; Central Intelligence Agency 2007; OECD 2009). Previous research (Paz-Y-Mino 2009; Susteric 2007; Alters and Nelson 2002) explored the relationship between the variables and acceptance of evolution; however, our research extends these findings by exploring their relationship on an international level. Our results provide a framework for the ongoing exploration of evolution acceptance and its relationship to science issues and education of the public on a global scale.

Religiosity and Evolution Acceptance

Religiosity is conceptualized as the degree to which people express that religion is important in their lives (Gallup 2009). Individual level of religiosity may influence how people approach learning and guide how they perceive a wide range of phenomena (Miller 1999; Shermer 2002). For example, religiosity has been found to be negatively associated with public acceptance of evolution (Alters and Alters 2001; Miller 2008; Nadelson and Sinatra 2009; Scott 2005), as the theory of evolution is perceived to conflict with many of the associated belief systems. For example, human origin is considered to be a spiritual matter for many cultures, and therefore, people in those cultures may perceive a conflict between the process of human evolution as conceived by science and their spiritually based perceptions of human origin. Thus, world views are certainly a variable to consider when examining explanations for the acceptance of evolution (Gallup 2009; Scott 2005).

Resistance to science is exaggerated in societies where nonscientific ideologies dominate the culture, such as religious dogma, and the associated structures and people are trusted and revered at higher levels (Bloom 2007). The ramifications are manifested in some societies as resistance to evolution because the notion of speciation, particularly of humans, conflicts with their religious or spiritual ideology. In some religious societies, resistance to science is pervasive and persists through nearly all facets of society (Audi 2000). The lack of trust in science and rejection of evolution is likely to be transmitted by authority and may be especially pronounced in societies where religious leaders are powerful. Politicians, religious leaders, and other trustworthy sources conveying negative views and disbelief about topics such as neuroscience, stem cell research, and biological evolution have been documented in the United States (Dawkins 1986).

In discussions of the influence of religiosity on acceptance of biological evolution, religiosity is often focused upon Christianity-based religions. However, Christianity is not the only religion that promotes perspectives of human origin that are in conflict with the biological evolution explanation of human origin (the idea that humans evolved from ancient animals). Although the rejection of evolution has been studied widely with respect to Christianity, we posit that rejection is likely to be detected in all countries in which a large portion of the general population has high levels of religiosity, regardless of denomination. Therefore, when investigating public evolution acceptance, there is a need to test for possible relationships to societal levels of religious commitment.

School-Life Expectancy and Evolution Acceptance

School-life expectancy is defined as the average years of schooling per citizen within a country. For example, Pakistan has a school-life expectancy of seven years (CIA 2007), which signifies that on average, a given citizen in Pakistan has attended seven years of school in his/her lifetime. In contrast, the United States has a school-life expectancy of 16 years (CIA 2007), which indicates that the average United States citizen has attended 16 years of schooling. How much school a person has attended can influence his/her worldview and understanding of a wide range of concepts.

Evidence indicates that as personal knowledge of science increases, there is a corresponding increase in evolution acceptance (Nadelson and Southerland 2010). The relationship between science knowledge and evolution acceptance is made evident by Nadelson and Southerland (2010) who report that the more college-level science classes students take, the more likely they are to accept evolution. Further, there is research supporting the notion that evolution acceptance is higher among people who are college graduates, and even higher for those with graduate college degrees regardless of degree focus (Nadelson and Sinatra 2009; Susteric 2007). The documented relationship between educational level and evolution acceptance provides justification for examining school-life expectancy as a variable in relation to international levels of evolution acceptance.

Science Literacy and Evolution Acceptance

Science literacy is widely discussed as being critical for societal engagement in scientific issues that enter the societal realm (National Research Council 2011). There is ongoing discussion regarding how science literacy should be defined (National Research Council 2011). For our purposes, we embrace the Organisation for Economic Co-operation and Development (2006) definition for science literacy which states, "scientific knowledge and use of that knowledge to identify questions, to acquire new knowledge, to explain scientific phenomena, and to draw evidence based conclusions about science-related issues, understanding of the characteristic features of science as a form of human knowledge and inquiry, awareness of how science and technology shape our material, intellectual, and cultural environments, and willingness to engage in science-related issues, and with the ideas of science, as a reflective citizen" (p. 12). There is a positive correlation between science literacy and individual understanding of evolution (Nadelson and Southerland 2010). Through exposure to science ideas and deeper exploration and explanation of evolution, students can develop a greater knowledge of scientific thinking and evidence, which in turn leads to greater understanding of evolution. If students do not accept the tenets of evolution, there is often a corresponding lack in scientific literacy, understanding of the nature of science, research literacy, and engagement in academia in general (Alters and Nelson 2002). Because evolution is critical to foundational comprehension of the biological sciences (Dobzhansky 1973; Fail 2008; Gould 2002; Mayr 1982) and science in general, an understanding of science is nearly inextricably linked to the acceptance of evolution.

Acceptance of evolution increases with scientific literacy due to two factors: understanding the nature of science and becoming familiar with the processes of biological change (Paz-Y-Mino 2009). When an individual becomes more science literate, he/she is more likely to comprehend how the process of change takes place and how outcomes of change over time are manifested in living organisms. One who is scientifically literate is also better equipped to understand emergent and complex systems that are inherent to scientific theories such as evolution (Hmelo-Silver and Pfeffer 2004). Exposure to and grappling with systems thinking and evolutionary processes such as natural selection increase science literacy. We contend that the potential influence of scientific literacy on evolution acceptance provides merit for examining the construct in relationship to international acceptance of evolution.

Gross Domestic Product per Capita and Evolution Acceptance

GDP per capita is related to the worldview of a populace. For example, countries with higher GDP per capita may have a populace whose worldview is formed by the opportunities that are afforded by an advanced economy, which allows for more focus on education and science (Jaumotte et al. 2008). Similarly, the populace from countries with low GDP per capita may have worldviews that are formed based on lack of opportunities to engage in a range of formal and informal educational activities. Building upon our previous discussion of the relationship between education and acceptance of evolution, it is likely that GDP per capita is a predictor of evolution acceptance that is not fully accounted for in assessments of school-life expectancy. GDP per capita is likely to reflect access to an array of formal and informal educational opportunities such as schools, colleges, universities, museums, science centers, nature centers, libraries, science presenters, and the Internet. Even if access is available, the luxury of spending time contemplating and discussing ideas may be influenced by economic pressures.

Citizens residing in low-GDP countries may have more pressing issues to be worried about than acceptance of evolution, such as food for their family and personal safety. Further, higher GDP per capita provides opportunity to gain a greater perspective of change and provides additional time and support for the consideration of the complexity of the natural world and the role of humans (Diener and Diener 1995). Due to the unique aspects of evolution acceptance that GDP

per capita may predict, we argue that this variable should be taken into consideration when examining international levels of evolution acceptance.

Research Questions

Based on our search of the literature and knowledge of evolution acceptance, we generated the following questions to guide our research:

- What is the relationship between public acceptance of evolution and religiosity on an international level?
- What is the relationship between school-life expectancy and public acceptance of evolution internationally?
- What is the relationship between public acceptance of evolution and science literacy globally?
- What is the international relationship between GDP per capita and public acceptance of evolution?

We predicted that there would be a negative relationship between public acceptance of evolution and religiosity. We also predicted that there would be a positive correlation of public acceptance of evolution with school-life expectancy, science literacy, and GDP per capita.

Methods

Sample

Our study included data from 35 countries around the world (Miller et al. 2006; Hameed 2008). The countries we included in our study were: Denmark, Sweden, France Japan, the UK, Norway, Belgium, Spain, Germany, Italy, the Netherlands, Hungary, Ireland, Slovenia, Finland, Czech Republic, Portugal, Switzerland, Slovakia, Poland, Austria, Croatia, Romania, Greece, Bulgaria, Lithuania, Latvia, Cyprus, United States of America, Turkey, Indonesia, Pakistan, Egypt, Malaysia, and Kazakhstan. We chose these countries for our study because public acceptance of evolution, school-life expectancy, science literacy, and GDP data were available for each from a variety of sources. However, we were not able to obtain science literacy data for Cyprus, Pakistan, Egypt, and Malaysia.

Data Collection

Evolution Acceptance We conducted secondary data collection by accessing data previously gathered in studies of international acceptance of evolution (Hameed 2008; Miller et al. 2006). Miller et al. (2006) collected data for a survey in which participants were asked to respond true or false in one format or definitely true, probably true, probably false, or definitely false in another format to the statement, "Human beings, as we know them today, developed from earlier species of animals." Results were combined to get an overall score for 34 different countries. Of the 34 countries, 32 had at least 999 participants while Norway had 976 participants and Cyprus had 505 participants.

Hameed (2008) collected similar data from six middle-eastern countries including Kazakhstan, Turkey, Indonesia, Pakistan, Malaysia, and Egypt. Participants were asked to respond true, probably true, never thought about it, probably false, or could not possibly be true, to the question, "Do you agree or disagree with Darwin's theory of evolution?" Countries with less than 999 respondents were Kazakhstan (970), Malaysia (803), and Egypt (786).

Religiosity The religiosity data we used in our study were originally collected by Gallup (2009). In 2006, 2007, and 2008, Gallup asked citizens of 143 countries to answer yes, no, don't know, or refuse to answer to the question, "Is religion important in your daily life?" There were approximately 1,000 citizens sampled per country in the form of telephone and face-to-face interviews. Limitations with Gallup survey methods include sampling error (±4%) and question wording due to potential variations in meaning due to translation.

School-Life Expectancy and GDP per Capita We secured school-life expectancy and GDP per capita for the 35 countries in our study from the Central Intelligence Agency (2007). The Central Intelligence Agency reports data for the average years of schooling per citizen and GDP per capita for almost all countries. Although information for school-life expectancy is considered accurate, caution is recommended when comparing internationally because countries may have different educational systems and grades may not be considered equivalent.

Scientific Literacy We gathered scientific literacy data from the Program for International Student Assessment or OECD (2009). In 2009, PISA reported on the performance of 15-year-olds in science literacy scores in 65 countries including 34 OECD countries and 26 non-OECD countries. International experts developed a test and submitted it to each country to explore possible bias. A large number of students were tested in each country including 5,233 in the United States. We were able to obtain data for 31 of the countries that we included in our study. Once again, scientific literacy data were not provided for Cyprus, Pakistan, Egypt, and Malaysia.

Data Set Development

We compiled our table using the values we extracted from the various data sets. Thus, for each country we listed, the level of acceptance by percentage of those sampled, school-life expectancy in average numbers of years of school, GDP per capita

in U.S. dollars, religiosity in percentage of those sampled, and scientific literacy are the values provided by PISA data. All data were examined for consistency prior to analysis.

Results

We began our analysis by conducting a bivariate correlation using our five variables. The results of our analysis are displayed in Table 1.

It is apparent from our calculations that our four indicator variables overlap; however, it is also important to note that the largest coefficient of determination associated with these variables was between religiosity and school-life expectancy, r^2=.39. This suggests that about 39% of the variation in religiosity can be explained by school-life expectancy, which still leaves over 60% of unique variation between the variables. Further, the correlations reflect the irreducible nature of these data, as it is unlikely that any indicators of social and economic status are going to be independent. Therefore, we proceed with the recognition that there is some overlap of the data; however, there is also likely to be substantial unique contribution by each of the measures in association with evolution acceptance.

Religiosity and Evolution Acceptance Our first research question asked, "What is the relationship between public acceptance of evolution and religiosity on an international level?" To answer this question, we examined the bivariate correlation between religiosity and public acceptance of evolution. As we anticipated, religiosity had a strong negative correlation with public acceptance of evolution, r=−.81, p<.0005. Interpreted, our results indicate that the higher a country's citizens' religious commitment, the lower their evolution acceptance.

School-Life Expectancy and Evolution Acceptance Our second research question asked, "What is the relationship between school-life expectancy and public acceptance of evolution internationally?" To answer this question, we examined the bivariate correlation analysis between country level of school-life expectancy and evolution acceptance. Our analysis revealed a strong positive correlation between school-life expectancy and acceptance, r=.76, p<.0005. The result suggests that as the average years of schooling per citizen in a country increased, there was a corresponding increase in their evolution acceptance.

Science Literacy and Evolution Acceptance Our third research question asked, "What is the relationship between public expectance of evolution and science literacy globally?" To answer this question, we examined our bivariate correlation between country-level science literacy and evolution acceptance. Our results revealed a strong positive relationship between evolution acceptance and science literacy, r=.67, p<.0005. Interpreted, our finding indicates that the more scientifically literate a country's populace, the more likely they were to accept evolution.

GDP per Capita and Evolution Acceptance Our fourth research question asked, "What is the international relationship between GDP per capita and public acceptance of evolution?" Similarly, to answer this question, we analyzed our bivariate correlation, examining the relationship between country-level GDP per capita and evolution acceptance. Our results revealed a strong positive correlation between GDP and public acceptance of evolution, r=.65, p<.0005, such that as GDP per capita of a country increased, there was a corresponding increase in public acceptance of evolution.

Table 1 Correlations between country-level evolution acceptance, religiosity, school-life expectancy, science literacy, and GDP per capita

	Evolution acceptance	Religiosity	School-life expectancy	Science literacy	GDP per capita
Evolution acceptance	–	−.81**	.76*	.67*	.65*
Religiosity		–	−.63*	−.54*	−.59*
School-life expectancy			–	.57*	.63*
Science literacy				–	.58*
GDP per capita					–

*p=.01 or higher showing significant correlation

Discussion and Implications

As we discussed previously, evolution acceptance has many potential ramifications. There are aspects of evolutionary biology associated with how we develop and test medicines and beauty products, how we grow or modify foods, and how we stay healthy or treat diseases. Thus, acceptance and understanding of evolution has implications for the most basic and vital aspects of our life, food and health, and increasingly, global impact. Previous research and the availability of international data led us to examine several variables as possible predictors of evolution acceptance.

As previously reported (Sinatra and Nadelson 2011; Nadelson and Southerland 2010), we also found a strong negative relationship between religiosity and public acceptance of evolution. Unique to our study was the breadth of possible religiosity foci, rather than the previously reported influence attributed to single religious philosophies. Our data indicate that many countries in which the majority of citizens are committed to religions other than Christianity

scored low on public acceptance of evolution, which suggests that religiosity in general, and not the denomination, is related to acceptance. Our results indicate that rejection of evolution is likely to occur due to a commitment to a variety of faith-based and religious views of the origin of human beings. It is important to note that we were not able to secure evolution acceptance data for many countries in Africa, Asia, and South America; however, our conclusions are based on the best available data. Seeking data from a wider range of countries, representing a broader range of religious beliefs, would be an excellent direction for future research. Gathering data from a wider range of countries would allow for the exploration of evolution acceptance among populations committed to non-authoritative religions such as Hinduism, Buddhism, and Shintoism.

We speculate that the mechanism by which religion influences acceptance of evolution is followers' trust in authority. Religious authorities, both people and doctrine, may convey messages that communicate ideas that contradict the theory of evolution, and because of the expectations of trust, the messages are likely to promote followers to embrace rejecting evolution. The conflation of the worldviews of religion and science has resulted in tension and the development of positions that equate the two as similar in their epistemologies (Taylor and Ferrari 2011). However, we contend that it would be productive to help citizens realize that evolution and religion do not have to be at conflict and that authorities can come in many forms. Developing and studying such interventions is an excellent direction for future research.

The positive correlation that we found between school-life expectancy (years of schooling) and public acceptance of evolution is consistent with previous research (Paz-Y-Mino 2009). It is likely that the more educated a populace, the more likely they are to consider complex systems and evidence for multifaceted explanations. Regardless of the focus on science, more education leads to the ability to think critically about a wide range of ideas in multiple domains. Further, the relationship between school-life expectancy and science literacy suggests that there are elements of additional education that lead to evolution acceptance that are not associated with science literacy. The international relationship between school-life expectancy, critical thinking, and evolution acceptance is an area that warrants ongoing investigation.

Our finding of a strong positive relationship between scientific literacy and public acceptance of evolution supports previous findings (Paz-Y-Mino 2009; Susteric 2007). We assume that science literacy is associated with science education efforts. Although not all science education may include a focus on biological evolution, the topic is certainly more likely to come up and be explored as more science content is learned. Scientific literacy is important for understanding, applying, and integrating concepts from a range of domains such as mathematics, chemistry, engineering, and physics, all of which are integrated into explanation for the theory of biological evolution. Comprehension of these domains improves scientific advancement leading to a greater frequency of societal applications of science. Thus, the association between science literacy and evolution acceptance internationally may be an indicator of a greater perspective of the importance and use of science and technology in society. How evolution acceptance may influence other science developments is an excellent direction for future research because it will allow us to explore potential positive consequences of public acceptance of evolution.

Our finding of the positive relationship between public acceptance of evolution and GDP per capita may arguably be a spurious relationship for education and literacy. However, consider the possibility that populations from high-GDP countries may have different worldviews because their advanced economy allows them to explore a wider range of formal and informal educational opportunities, experience higher levels of reading/writing literacy and everyday experiences that ultimately lead to deeper understanding and acceptance of evolution. Low-GDP countries may be concerned with day-to-day survival and/or may have less opportunity for a wide range of formal and informal educational experiences that could lead to a deeper understanding and acceptance of evolution. How economic level influences acceptance of evolution is an excellent direction for future research.

Limitations

Perhaps the greatest limitation of our study is the nature of the data sets that we used for our analysis. Because we used secondary data, we had to make many assumptions about the quality, consistency, and methods used to gather the data. We used the best available data to conduct our analysis. Yet, given the scope and research questions of the study, we argue that our investigation was a preliminary study which should lead to more research questions accompanied with the collection of additional primary data.

Another notable limitation is the limited number of countries we used in our study. There are about 193 counties in the world (Worldatlas.com 2011), and we were only able to secure data for about 18% of them. While we were able to gather data on the most populous nations, our study did not include many African, Asian, and South American countries. Again, data from these countries were not readily available. Securing additional data from a wider range of countries may or may not shift the results, as our sample may be representative. However, as we stated previously, examining the same relationships using a wider range of data collected from a greater diversity of countries representing a broader spectrum of worldviews would be an excellent direction for future research.

The final limitation regards the nature of our analysis and the interpretation of results. Because others collected the data we used, our interpretation of the meaning of the data in the context of our study–acceptance of evolution–may not be fitting. We made the assumption that the data could be interpreted regardless of context; however, further exploration into the validity of using the data in relation to evolution acceptance is certainly worth considering.

Conclusion

We set out to determine what variables might influence acceptance of evolution from a global perspective. As predicted, religiosity, school-life expectancy, science literacy, and GDP per capita were strongly correlated with public acceptance of evolution. Although our findings were consistent with previously conducted research, this is the first study we are aware of that examined these variables across many countries rather than within a single country. How evolution acceptance may be addressed on a global scale is likely associated with addressing the four variables we found to influence evolution acceptance. The globalization of industry, communication, and commerce has implications for biological evolution. Similarly, understanding and accepting evolution has profound implications for technological, scientific, and economic developments.

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