Is Science To Blame For The Intelligent Design Debate?

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Abstract

The current debate in the United States regarding intelligent design (ID) has been viewed by many scientists as a curious sideshow. We cannot understand how anyone could be deceived into thinking that ID belongs in the scientific realm. It has no testable, falsifiable hypotheses and so is not science. We argue here that the ID debate is only a symptom of a larger and possibly dangerous ignorance of the scientific process among the general public. We suggest this ignorance results from a combination of factors, primarily the rapid growth of information among the sciences and misguided science curricula throughout the U.S. educational system. The overwhelming amount and kind of information combined with an educational system that focuses on content at the expense of conveying the methods by which content information is gathered is troublesome. Debates similar to evolution-ID are developing with regard to topics in public health, food and water supplies, and global climate change and related issues. Failure to enact education reform designed to enhance the scientific literacy of the public will result in more debates of this nature.

Introduction

The current debate in the United States regarding intelligent design (ID) has been viewed by many scientists as a curious sideshow that results from a lack of scientific literacy. The concept has no testable, falsifiable hypotheses and so is not science. However, we feel that this debate is a symptom of a larger underlying disconnection between science and society. This disconnection is national in scale and includes not only the public's disengagement from science but also the failure of scientists and educators to bring scientific knowledge to the public in an effective manner. Recent advances in scientific technologies (e.g., genome arrays) only exacerbate the problem. We argue the lack of scientific literacy within the general public arises from two fundamental factors that are often overlooked or considered too difficult to address. First, the dramatic growth over the past few decades in the amount and complexity of scientific information is daunting even to scientists. A public that is faced with ever increasing demands on its time and energies surely will find it difficult to stay abreast of new scientific developments as well. Second, many secondary school science curricula in the U.S. necessarily focus on facts because the assessment instruments are dominated by content-based test items. The absence of any focus on the scientific method in assessment measures leads to curricula that produce citizens unable to critically evaluate new scientific information. Without a focus on the process of science among secondary school science curricula, our citizenry will find it increasingly difficult to engage in debates about how scientific information is to be evaluated and used (i.e., how scientific knowledge impacts society).

Growth and complexity of information in the sciences

Nowhere has the growth of information in the sciences been more acute and practically difficult to incorporate than in college introductory biology courses. Fifty years ago, biology faculty developing an undergraduate curriculum would have had little difficulty deciding what to include in an introductory Principles of Biology course. Today, faculty find it difficult to do so. Do we discuss how the phases of mitosis work or how RNA interference operates? Both have been shown to be very important to the functions of an organism. Further, do we include the specifics of Mendel's work or how genomics is revolutionizing the entire field? Historical factors clearly play a role in what is currently covered in such a course, but how do we choose what is most important to cover? These questions are becoming more and more common within college biology programs and there are no easy answers. Indeed, these questions are not confined simply to biology, but are reflected in the increasingly interdisciplinary nature of scientific investigation as a whole.

During the past few years, our campus has moved toward more formal scholarship requirements for promotion and tenure. Individual faculty from disciplines outside the sciences have expressed a belief that while collaborative research with colleagues and students provide wonderful opportunities to teach undergraduates about science, we should each have our own research carried out individually. Further, it has been suggested that publications with more than one author are less valid than individually-authored articles. We believe these views by other well-educated faculty members are indicative of a more widespread ignorance by the general public of the manner in which modern science is accomplished. Specifically, we argue that scientific research is often so complex and interdisciplinary as to require the expertise of multiple researchers and that single author publications should be increasingly rare. To address this hypothesis, we chose to determine if the number of scientists necessary to publish an article in a peer-reviewed scientific journal has changed over the past 20 years. We assumed that the number of authors reflects the type and amount of work done to publish the article, and that this has not changed over the past 20 years. We chose three well-established and respected journals in science (*Ecological Monographs, Journal of Biological Chemistry,* and *Cell*) and compared the average number of authors per full article in the years 1985 vs. 2005. We chose the first 50 full articles beginning with the first issue in 1985 and 2005. A sample of 50 was possible within an individual year for both *Journal of Biological Chemistry* and *Cell*, but three (3) years of issues (i.e., 1985-1987 and 2003-2005) were needed to obtain that sample size for *Ecological Monographs*.

The data confirm that multiple authors per peer-reviewed article is the norm in scientific journals and illustrate a trend toward increasing numbers of authors per article in each of the three journals (Table 1). In each case, the average number of authors per article nearly doubled. We found articles in 1985 and 2005 with only one author, but the maximum number of authors increased from 10 to 24, respectively. The number of single author papers decreased from

20.7% (31 of 150) in 1985 to 4% (6 of 150) in 2005. We believe these data represent a dramatic increase in the complexity of scientific research questions posed over the past 20 years.

Table 1. Number of authors per full peer-reviewed article in 1985 and 2005 in three scientific journals. Samples sizes are 50 articles per year per journal, numbers represent average ± one standard deviation, and the P-values reflect results of 2-sample *t*-tests between years.

Journal Title	**1985**	**2005**	***P***
*Ecological Monographs**	1.68 ± 0.87	4.00 ± 3.40	< 0.0001
Journal of Biological Chemistry	3.14 ± 1.53	5.44 ± 2.86	< 0.0001
Cell	3.78 ± 1.78	6.82 ± 3.67	< 0.0001

** For Ecological Monographs, the 1985 value reflects 1985-1987 and the 2005 value reflects 2003-2005 (because of the fewer total articles published per year).*

In addition to an increase in the complexity of modern scientific research, there is simply much more of it occurring each year. To our knowledge, no data have been collected to explicitly test the latter statement. Importantly, rapid expansion of scientific knowledge in individual disciplines should make it more difficult for even well educated individuals to remain abreast of the field. To quantify the increase in the rate at which new scientific knowledge is being acquired, we ran searches in the U.S. National Library of Medicine PubMed database on 26 April 2006 using specific search terms and limiting results to the publication years 1985 and 2005. The search terms chosen reflect well-recognized and relatively long-standing areas of research within science. The percent increase is dramatic in both total publications and publications within individual fields of research (Table 2). Although the PubMed database is not considered a primary resource for the field of evolutionary biology, we believe the significant increase in articles related to evolution suggests an increase in interdisciplinary studies in modern science (e.g., evolution and medicine).

Table 2. Number of peer-reviewed articles found in the U.S. National Library of Medicine PubMed database from searches conducted on 26 April 2006. Search terms were typed exactly as shown, except for "all publications" for which no limiting term other than date published was used.

Search Term	**1985**	**2005**	**Percent increase**
All publications	325,809	673,720	107
Evolution	2,164	15,933	636
Molecular	12,848	86,304	572
HIV	1,759	11,515	555
Randomized controlled study	2,487	14,843	497
DNA	13,366	52,501	293
Cell	67,338	158,037	135
Cancer	41,007	81,928	100

The development of entirely new scientific disciplines further reflects both the increase in complexity and total information available to scientists and the general public. To demonstrate the degree to which new disciplines have developed in recent decades, we chose four areas of research that are of importance to modern biology but are relatively new as defined subdisciplines. We then ran searches in the PubMed database on 26 April 2006 using those areas of research as search terms limited by year of publication (1985, 1995, 2000, and 2005). The extremely rapid appearance of what are considered important fields of knowledge to modern biology and the large numbers of peer-reviewed articles in each field (Table 3) suggest that science curricula from primary schools to universities need major and ongoing revisions in order to remain applicable and accurate.

Table 3. Number of peer-reviewed articles found in the U.S. National Library of Medicine PubMed database from searches conducted on 26 April 2006. Search terms were typed exactly as shown and further limited by year of publication.

Search Term	**1985**	**1995**	**2000**	**2005**
Genomics	0	26	733	3,909
Proteomics	0	0	211	2,296
RNA interference	0	0	72	2,427
Bioinformatics	0	10	715	3,002

The Struggle With Science Literacy in K-12 Education

The current reforms in science education began in the mid-1980s with the publishing of *A Nation at Risk* (1983), a report authorized by the Reagan Administration seeking to discover the shortcomings of the American educational system. With the poor outcomes in mathematics and science, the American Association for the Advancement of Science (AAAS) instituted *Project 2061* (1985) as a means to produce a scientifically literate population by the year 2061. As a result of this initiative, several guiding publications were created, including: *Science for All Americans* (1991) and *Benchmarks for Science Literacy* (1994). These two documents provided a broad underpinning for the development of a national set of standards in science education by the National Research Council. In 1996, the *National Science Education Standards* appeared on the scene and have served as the main guide for science education curricula, assessment, program development, and professional development, as well as other areas.

The central focus of the National Science Education Standards has always been to provide a framework for K-12 students to experience the process of science in all its forms, including aspects of critical thinking, scientific reasoning, hypothesis generation, experimentation, data analysis, communication skills, relevance to individuals and society, and the ability of students to construct new knowledge based on misconceptions and prior naive conceptions about scientific content. Many educators see this refocusing of priorities in science as a negligent sacrifice of science content for a focus on science processes. Often, the inexperience or epistemological misunderstanding of Constructivism and the inquiry process itself mask the important inclusion of science content in the investigative process. As such, a large negative misconception is generated that science standards may actually promote science illiteracy because of a perceived lack of science content in the curriculum.

In February 2006, the National Science Teachers Association (NSTA) reported the results of a larger study that ranked and graded each state's science standards, focusing on their ability to address the guiding principles set forth by the National Science Education Standards to promote science literacy development. As an example, we chose to illustrate how the Virginia Standards of Learning (SOLs) fared in this process. With great surprise, many K-12 educators in Virginia learned that the Virginia SOLs in science were ranked #2 in the country, with a grade of "A." All SOLs in science are investigation-based, and include a statement of "Students will investigate and understand…" Therefore, all K-12 standards in science in VA are inquiry-focused and modeled after the key points found in the *National Science Education Standards.* If the standards are some of the top in the country, why is it that many students in Virginia are leaving high school with few laboratory experiences and little understanding of the process of science? One critical quote from the report was key here, "…Virginia produced 'exceptional academic standards documents that, if followed in the classroom, would result in excellent science programs…” (Gross et al., 2005) That leads to a logical question: Why are standards documents not being followed in the classroom?

The answer to this question lies not in the standards themselves, but in how those standards are assessed (Linn, 2000). Assessment has become a major player in education over the last several years, primarily because of the legislation passed in the *No Child Left Behind Act* (NCLB). This legislation requires states to redirect their education efforts on what works for all students, and in order to do so, states have been required to report assessment scores confirming their successes and failures. Until now, NCLB has focused primarily on developing students' skills in reading and mathematics. Beginning in 2007, science will become a formal part of the mix as well. The Standards of Learning (SOL's) used as guidelines for NCLB are generated from the National Science Education Standards. Webb (1997), states that alignment of assessments with standards is critical to the success of educational reform. However, the National Science Education Standards and NCLB offer little guidance on how to assess student learning (Atkins et al., 2001).

In order to achieve the mandates of NCLB, Virginia, like many other states, has created state assessment tests to gauge student learning in science. These tests are given periodically during the K-12 education process. In science, the examinations are multiple-choice in format, and focus almost entirely on content-based items. Little attention is paid to science process skills, scientific reasoning, hypothesis generation, and other critical components of the inquiry process. This results in a serious dilemma for teachers and school administrators: should the science curricula focus primarily on science content so that students will likely perform well on their state assessments, or should the science curricula adhere to the spirit of the standards and teach students science by experiencing the scientific process itself? The latter requires formative assessment designed to enhance learning during the learning process (Bell and Cowie, 2000; Black and Wiliam, 1998). Because the assessment tool is applied after the learning process, most Virginia school districts have chosen to teach to the test. Lee and Houseal (2003) identified pressure to meet science standards, as measured by performance on assessment instruments, as a new factor constraining teaching efficacy. As such, students have little exposure to science process skills, critical thinking, the ability to evaluate scientific literature, or the ability to connect science to daily life. This is often complicated by ongoing deficiencies in many districts regarding funding, science facilities and supplies, qualified science teachers, and lack of interest in change or growth.

When examining an issue in science as crucial as the evolution/ID debate, it is little wonder that so much misinformation has been touted as fact. While the educational systems in many states have standards guiding their science curricula that have great potential to promote science literacy and understanding the differences between “good” and “bad” science, we have chosen, as a society, to disregard that approach for a shorter-term assessment-based approach that indirectly requires each state to drastically change their approach to teaching science. State science standards can only be effective when they are implemented and assessed to achieve the goals that they were designed to address (Webb, 1997). Friedrichsen (2001) found that when science standards and assessment tools were aligned, significant improvement in attitudes toward science were recorded.

Science Literacy and The Evolution-ID Debate

The lack of science literacy is a critical component of the evolution-ID debate. A failure to understand basic science results in the popular misuse of scientific terminology and failure to understand the peer-review process as a mechanism by which to insure the highest quality research is published. As a result, confusion and debate between scientifically derived theories and popular answers that have not yet been subjected to scientific testing is common. In popular culture, the term theory has replaced hypothesis, and in many cases, the 'theories' that are put forward have no basis in science because they cannot be tested.

We argue that the popular misuse of terminology has eroded the degree of certainty associated with scientific terms. For example, a common misconception among students in introductory science courses is that a theory is nothing more than an educated guess to explain an event or observation. However, scientists understand that a hypothesis is a tentative, testable explanation that is similar to an 'educated guess,' whereas theories unite laws and hypotheses into a coherent whole that explains a large number of related processes. In the context of the Evolution versus ID debate, ID is more correctly labeled as an untestable hypothesis than as a 'theory.' The primary failure of the ID hypothesis is that it is not falsifiable. Any evidence that cannot be explained through testable means is simply rationalized away as being too complex to explain and must be evidence of the presence of some 'designer.'

We note with dismay that the misuse of scientific terminology is not confined to the general public. Scientists themselves often misuse the terminology of science. One of the best examples is the use of terminology associated with string 'theory' in physics. This 'theory' argues that quantum mechanics and relativity can be reconciled if all matter is composed of vibrating strings of energy. There is one small caveat: to date no one has been able to design a test of string theory in which the results would be different from what our current understanding of physics predicts (Krauss, 2005). String 'theory' is not a theory at all; it is an untestable hypothesis. By carelessly using terminology, scientists themselves create a climate in which untested and untestable hypotheses are given the same credence as well-tested and defined scientific theories.

Bridging the Gap: Using Civic Engagement to Enhance Science Literacy

Increasingly, science, mathematics, and technology play a greater role in understanding questions facing citizens of local, national, and global communities. However, over the past decade, the number of United States students pursuing major courses of study in science, technology, engineering, and mathematics (STEM) has decreased steadily (McCray et al., 2003). Science literacy is crucial if citizens are to be able to assess competing claims, and form thoughtful opinions with respect to issues of public debate (e.g. Evolution and Intelligent Design).

Courses designed to provide a connection between science and social issues have been shown to be particularly effective tools for science education, especially among non-scientists, women, and minorities (Weston et al., 2006). This approach is fostered by the National Center for Science and Civic Engagement through a national dissemination project funded by the National Science Foundation. The project, deemed SENCER (Science Education for New Civic Engagements and Responsibilities), provides support for the development of courses that teach science through issues of public concern. The SENCER model is a different approach that focuses on the science that underlies issues of importance to the general public. Students learn specific science content in a context to which they easily relate. By linking content directly to an area of interest, student apprehension is reduced and interest in science is stimulated. This 'Trojan Course' approach creates a unique opportunity to provide science education in a meaningful fashion.

Results of a recent five-semester study that included 215 courses and over 7,000 students conducted through the National Center for Science and Civic Engagement, indicate that women, non-science majors, and lower achieving students gain interest in science, and are more confident in their understanding of science after participating in a SENCER-style science course (Weston et al., 2006). When combined with inquiry- or case study-based learning experiences (van Driel et al., 2001), gender and major-non-major gaps narrow further (Weston et al., 2006). Furthermore, courses utilizing civic-themed learning objectives and project-based assessment are associated with larger gains in confidence in science skills and overall interest in science. Of particular interest is the observation that inquiry experiences for pre-service teachers increase the probability that the teachers will use inquiry-based learning in their classrooms (Windschitl, 2002). Participating faculty generally are positive about the SENCER approach, and courses with a science and civic engagement theme are becoming a permanent part of departmental curricula (Weston et al., 2006).

The University of Virginia's College at Wise has begun offering SENCER-styled courses as part of the general education curriculum. Initial qualitative results suggest that students who participate in these courses experience increases in their confidence in their scientific skills, their ability to evaluate data, and their ability to assess the validity of scientific statements based on evidence derived during scientific investigations. While these data are qualitative and preliminary, they are similar to those shown by Weston et al. (2006).

Conclusions

Maintaining A Scientifically Literate Population

The amount of information available today is enormous relative to that available 20 years ago. In a traditional content-focused approach, the knowledge base or foundation expands rapidly, resulting in information overload. To counter the explosive growth in information, scientists and science educators must focus on communicating the process of science to learners and the general public. The development of educational approaches that foster an understanding of science as a process will aid in providing to citizens a means of educating themselves with respect to issues of critical importance. These approaches must include courses that tie science to social issues of specific interest to learners and provide inquiry- or project-based learning opportunities whenever possible.

Assessment that focuses on the process of science rather than on specific content items is of crucial importance in fostering science literacy at all educational levels. Current assessment tools that are content-focused must be redesigned to provide process-based evaluation or be replaced by new rubrics that focus on the process of science in addition to content. Furthermore, science education outreach programs must be carefully constructed such that information is disseminated in a manner that is accessible to learners, educators, and the public. Learners then will be able to critically evaluate scientific data and statements and better understand the complexities of issues of regional, national, and global importance.

The impacts of science on modern life often are overlooked by a populace that increasingly is disinterested in science. While revolutionary discoveries get the press, it is the pervasive advancement of science that most impacts modern society. Scientifically literate citizens will be better able to understand the ramifications of such advances, both in terms of quality-of-life and ethical issues.

Consequences Of Failure

The consequences of failure will be far-reaching in scope and serious in nature. Already, debates such as evolution-ID are cropping up not only in the United States, but in the United Kingdom and other modern countries. The evolution-ID debate may appear fundamentally to be a result of religious tension in public education (Doerr, 1998). However, we believe that these debates are not wholly science versus religion, and are exacerbated by the explosion of scientific information, an ignorance of science as a process, and the failure to link science to society. The evolution-ID debate is only one of a series of debates that stem from these fundamental failures. Other ongoing and crucial debates involve human health, food/water supply issues, and global climate change and biodiversity.

Current human health debates include disagreements over juvenile vaccine programs, the threat of global pandemics (e.g., bird flu), and treatment of HIV/AIDS. In each case there is overwhelming scientific evidence that supports the widespread use of specific protocols (vaccinations, condoms). Furthermore, while global pandemics are a very real possibility, the average citizen is more likely to be killed in a car accident on the way to work. Scientifically literate citizens are better able to choose proper courses of action based on the likelihood they will be affected by a specific health issue.

Managing global food and water supplies is of crucial importance as global population continues to increase. While there is a debate among scientists as to the timing and degree of severity of the onset of water scarcity in a global sense, there is little doubt that without curbing population growth, water resources will become increasingly important in a global geopolitical sense. Without a proper scientific foundation, debates concerning foreign food aid, drinking water programs, and genetically engineered agriculture products will be at the mercy of political manipulation.

It is perhaps in the arena of global climate change that the disconnect between scientific understanding and public perception is most apparent. There is little disagreement among climate scientists that human activities play some part in global climate change. However, because the public does not possess the necessary science education, and because addressing global climate change is controversial in both political and economic terms, a public debate concerning the validity of climate change has erupted. Among the more interesting features of this debate are the emergence of a novelist as a government ‘expert’ on global climate change, and claims that there is too little data to assess the degree to which climate change is natural or the result of human activities.

Education And The Intelligent Design Debate

The evolution versus intelligent design debate is a symptom of a larger, fundamental disconnection between science and society. This disconnection is rooted partially in the massive increase in scientific information, the failure of scientists and science educators to provide adequate training in the process of science, and the inability of the public to critically evaluate scientific evidence. A new educational approach that focuses on the process of science, especially as it relates to issues of social interest, combined with inquiry-based learning and assessment tools that are aligned to educational expectations is crucial to maintaining a scientifically literate population. If scientists and educators fail to enact reform in a timely fashion, more debates of this nature will result and it is likely that debates will become more contentious as the gap between science and society widens.

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