The Value of a College Education: A Longitudinal Study of Science Literacy

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Background

Science literacy refers to knowledge of fundamental scientific facts, understanding of the process of science, and understanding of science's impact on society (Miller, 1989). Science literacy is increasingly important for making informed decisions related to personal health, community and educational initiatives, political debates, and international concerns such as global warming and disease prevention. However, only a minority of Americans is considered scientifically literate (Miller, 2007). Exposure to college-level science courses explains substantial variance in science literacy and has also been credited for America's higher level of science literacy overall relative to other countries (National Science Board, 2010). However, the suggestion that college-level science coursework *leads to* growth in science literacy has not been tested with a longitudinal design that can account for selection effects – the possibility that people with strong science literacy select into coursework in science. Moreover, recent longitudinal studies of American college student development (Arum & Roksa, 2011; Blaich & Wise, 2011) implicate limited growth in analytical thinking during college. Analytical thinking is foundational for science reasoning; hence, these recent findings imply that college-level coursework in science may not lead to growth in science knowledge, scientific reasoning, or appreciation of its positive impact on society. We conducted a longitudinal study to determine whether students in a public, four-year liberal arts university experience growth over three years in science literacy and, if that growth occurs, whether it is robust across gender and discipline of study.

Method

Participants

In the fall of 2009 ("Time 1"), we surveyed 377 students from across campus; over 90% were first- or second-year students. In the fall of 2012 ("Time 2"), we contacted those who were still in the UWEC directory and invited them to complete a follow-up questionnaire in return for $25. We obtained 200 of the original students, 83% of whom had been first-year students at Time 1 and 99% of whom had been first- or second-year students at Time 1. Importantly, those who were still enrolled in the university and who we obtained for follow-up did not differ significantly on any variables of interest from those included only in the initial data collection.

Attitude Scales

At both time points, we assessed students' attitudes toward science and belief in God. Items pertained to moral objections to evolution (2 items, e.g., *People who accept evolution as fact are immoral*) distrust of science (6 items, e.g., *Science and technology have created a world that is full of risks for people*), young earth creationist beliefs (4 items, e.g., *Adam and Eve from Genesis are the universal ancestors of the entire human race*), and ascription to intelligent design fallacies (6 items, e.g., *There is scientific evidence that humans were created by a supreme being or intelligent designer*).

Science Literacy Scales

Participants also completed science literacy scales. Questions were of relatively equivalent difficulty and spanned topics including genetics (13 items, e.g., *More than half of human genes are identical to those of mice*), biology (7 items, e.g., *Antibiotics kill viruses*), evolutionary theory (14 items, e.g., *Natural selection is the only cause of evolution*), inorganic science (7 items, e.g., *Lasers work by focusing sound waves*), scientific reasoning (8 items, e.g., *Good theories give rise to testable predictions*), and probabilistic reasoning (3 items, e.g., *Imagine you are flipping a normal coin, with one side "tails" and one side "heads." You have flipped the coin nine times so far, and each time it has come up "tails." What is the chance that on your next flip, it will come up "heads"?*).

Results

Figure 1: Students showed weak and inconsistent growth in science literacy

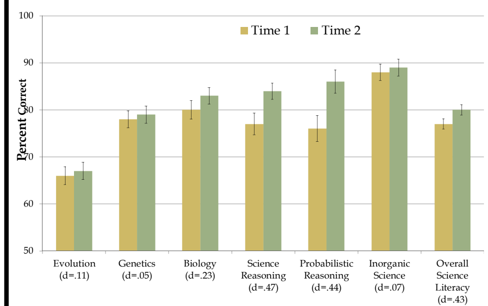
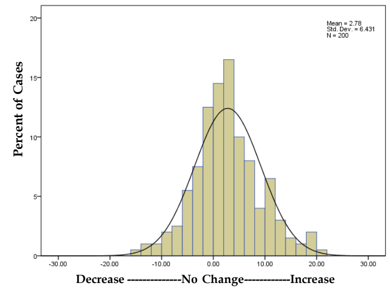
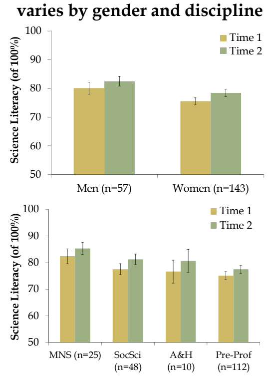


Figure 2: Some students' science literacy scores improved over the college years, and some students' scores declined



Students' performance on the science literacy scales were consistent from Time 1 to Time 2 (test-retest correlation coefficients range from .24 to .45, all *ps* ≤ .001). The sample as a whole showed weak but statistically significant growth in Biology Literacy, Scientific Reasoning, Probabilistic Reasoning, and Overall Science Literacy. As shown in the histogram at upper right, 28% of students showed a decline in their overall score, 9% showed no change, and 63% showed an increase. The typical student showed a 2.8% increase in their overall score.

Figure 3: Overall science literacy varies by gender and discipline



MNS=Math and Natural Sciences; SocSci=Social Sciences; A&H=Arts and Humanities; Pre-Prof=Pre-Professional (education, nursing, business)

Within sex and discipline (even Arts & Humanities, which was under-represented in the sample), students were highly consistent from Time 1 to Time 2 (r = .58-.74). As shown in the panels above, small increases in science literacy did occur in both sexes and in various disciplines.

Table 1: Religious attitudes and attitudes toward science predict students' science literacy

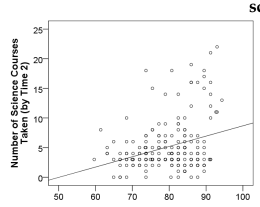
(Time 1 correlations are above the main diagonal; Time 2 correlations are below.)

	Belief in God	Young Earth Creationist Beliefs	Distrust of Science/ Technology	Intelligent Design Fallacies	Moral Objections to Evolution	Science Literacy
Belief in God	*.76*	.65	.21	.57	.29	-.16
Young Earth Creationist Beliefs	.70	*.75*	.33	.76	.64	-.33
Distrust of Science/ Technology	.28	.40	*.56*	.32	.32	-.21
Intelligent Design Fallacies	.64	.83	.38	*.70*	.55	-.29
Moral Objections to Evolution	.16	.56	.35	.50	*.55*	-.30
Science Literacy	-.29	-.38	-.28	-.38	-.34	*.65*
Time 1 Mean	7.65 (of 10)	4.67 (of 10)	3.96 (of 10)	4.79 (of 10)	2.38 (of 10)	76.83 (of 100)
Time 2 Mean	7.09 (of 10)	3.93 (of 10)	3.66 (of 10)	3.96 (of 10)	1.94 (of 10)	79.61 (of 100)
T1 vs T2 *d*	0.25	0.35	0.20	0.49	0.21	0.43

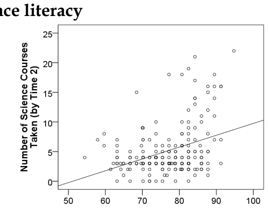
Note. Italicized coefficients along the main diagonal represent degree of consistency in response from Time 1 to Time 2. All Time 1–Time 2 mean differences (shown below the correlation matrix) are statistically significant.

From Time 1 to Time 2, students showed a decrease in Belief in God and, related to that, a decrease in Young Earth Creationism and Intelligent Design Fallacies (however, these decreases were relatively weak). At both time points, participants reported minimal Moral Objections to Evolution (despite poor performance on the Evolution Knowledge subscale). At each time point, having strong religious beliefs, having moral objections to evolution, and distrusting science and technology were negatively associated with science literacy.

Figure 4: Exposure to science coursework is positively associated with science literacy, but it is not a cause of science literacy



At each time point, number of college level science courses was positively associated with overall science literacy (see Time 2 association at left). However, incoming science literacy predicted number of science courses taken by Time 2, (see figure at right); moreover, the association between science coursework and science literacy at Time 2 ($r(200)$ = .34, p < .001) was diminished when we controlled for science literacy at Time 1 (partial $r(197)$ = .09, p = .192). Thus, science literacy appears to be a cause of exposure to science coursework rather than a result of it.



Discussion

In this study, we surveyed 200 students at the beginning of their college career and again three years later. Our results revealed (1) statistically significant but limited growth in overall science literacy (which was driven by growth in biology literacy, science reasoning, and basic probabilistic reasoning); (2) weak but consistent declines in religious beliefs, moral objections to evolution, and distrust of science and technology; and (3) strong consistency in students' responses from Time 1 to Time 2 (supporting the validity of our measures). Students with high science literacy scores at Time 1 tended to have high scores at Time 2; students with strong belief in God at Time 1 tended to maintain that belief over time. Some students experienced more change than others, but we found no systematic predictors of degree of change; the weak growth we saw in overall science literacy was consistent across gender and discipline.

In national data, exposure to college-level science coursework explains substantial variance in science literacy; we replicated that association. That is, students with higher science literacy scores had more coursework in science (and math). Our study is the first we know of to explicitly test, using a longitudinal design, whether college-level science coursework *leads to* growth in science literacy. In fact, we found that it does not. Science literacy at Time 1 predicted the number of science courses students had taken by Time 2, and controlling for students' incoming science literacy diminished the association between exposure to science coursework and Time 2 science literacy. In other words, our data suggest that science literacy is not the result of engaging in science coursework; instead, people with strong science literacy *select into* science coursework.

We acknowledge that our measures are limited in scope and that what it means to be "scientifically literate" is debatable. We do know that the knowledge base in science and technology is expanding rapidly and that some critical level of scientific reasoning skill and knowledge of biology, genetics, and probabilistic reasoning (among other disciplines) is increasingly relevant for daily living and major life decisions. For example, people need to make informed medical decisions, ensure ethical use of genetic information (Haga & Willard, 2006), and evaluate the benefits and costs of technical gadgets and scientifically engineered products. Arguably, society will increasingly look to college graduates to be leaders in important decisions surrounding societal applications of scientific knowledge (Vice Bowling, Acra, & Wang et al., 2008). One must ask: Are colleges creating these leaders?

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