RESEARCH ON LEARNING

Life Science Literacy of an Undergraduate Population

STEPHANIE R. MEDINA, EVAN ORTLIEB, SANDRA METOYER

Abstract

Science content knowledge is a concern for educators in the United States because performance has stagnated for the past decade. Investigators designed this study to determine the current levels of scientific literacy among undergraduate students in a freshman-level biology course (a core requirement for majors and nonmajors), identify factors influencing levels of scientific literacy, and make recommendations for improving scientific literacy. Participants (n = 255) answered a one-time, 18-item life science questionnaire. A significant difference in content knowledge was found between participants who engaged in informal science learning weekly and participants who did not engage in informal science learning (i.e., learning outside the classroom).

Key Words: *Scientific literacy; undergraduate; questionnaire; life science; informal science learning.*

The past century has seen record economic growth due to improvements in technology and industrialization – resulting in a call for improved scientific literacy. Scientific literacy is required to fill the increasing number of positions in science fields (Johnson, 2011), but many individuals do not possess well-developed scientific literacy (Odessky, 2011). Even though students construct science meaning from prior experiences (Kern & Crippen, 2008), science misconceptions are apparent among K–16 students and adults. Only 18% of 12th-grade students achieved the status of proficient on the U.S. National Assessment of Educational Progress (NAEP) questionnaire in 2006. Students enter the classroom already having science misconceptions; exposure to science instruction in the classroom helps to revise misconceptions into scientifically supported concepts (von Aufschnaiter & Rogge, 2010), thereby improving scientific literacy.

Scientific literacy is required to fill the increasing number of positions in science fields.

It is the task of the educator to remediate student misconceptions in science to positively influence scientific literacy (Lord & Rauscher, 1991). New scientific claims made daily, usually made widespread by popular media, challenge science educators to address these misconceptions. Educators facilitate an understanding of science to help students validate the reliability of new scientific claims (Allchin, 2004).

Individuals who are scientifically literate possess skills and maintain values related to science. Scientifically literate individuals do not become so by acquiring science content through education alone; scientific literacy develops through multifaceted instruction that encompasses more than just science content (Holbrook & Rannikmae, 2009).

The term *scientific literacy* has a wide range of meanings. The National Science Teachers Association maintains that a scientifically literate individual possesses four specific attributes: (1) higher-order thinking skills – allowing individuals to differentiate between observation and inference; (2) attitude – perpetuating individuals' curiosity; (3) society – allowing individuals to recognize human endeavors; and (4) interdisciplinary – allowing individuals to connect science and technology to other content areas (Holbrook & Rannikmae, 2009).

The present study revisits, replicates, and expands previous research by Lord and Rauscher (1991), comparing levels of undergraduate scientific literacy today to that two decades ago. Both studies report results from a questionnaire containing basic life-science questions for undergraduates classified by gender, age, and major. They also consider the effects of advanced biology courses – having a positive or negative influence – taken by undergraduates when they were enrolled in high school. Our study, however, further considers the same effects of advanced mathematics courses taken during high school, as well as the level of engagement in informal science-learning opportunities.

Certain factors influence the development of scientific literacy. Factors explored here include gender, prior high school experiences, and exposure to informal science-learning opportunities.

○ The Gender Gap in Scientific Literacy

It has long been known that increased interest in science positively affects scientific literacy (Zuccala, 2010). Even when males and females are equally interested in science, reasons for the interest differ

The American Biology Teacher, Vol. 76, No. 1, pages 34–41. ISSN 0002-7685, electronic ISSN 1938-4211.
DOI: 10.1525/abt.2014.76.1.8

between the two groups (Baram-Tsabari & Yarden, 2011). In a study of science aspiration and achievement, both males and females held a personal interest in science; however, females also held a social responsibility for the direct outcomes of science (Chiu, 2010).

The gender gap in science also exists at the university level (Ochonogor, 2011). Even though females hold 58% of all bachelor's degrees and 59% of all master's degrees, <50% of females hold degrees in science. Additionally, males outnumber females 2:1 in doctoral degrees in science and 4:1 in national science faculty positions (Heilbronner, 2009).

Science self-efficacy is a predictor of science performance and scientific literacy. Zimmerman and Bandura (1994) describe self-efficacy as an individual's beliefs concerning attainment and regulation of academic goals and achievements. A student's gender has the potential to affect science self-efficacy (DiBenedetto, 2011). Britner (2008) found that even though females prefer to study the life sciences, as opposed to other sciences, and outperform males, females exhibit lower science self-efficacy and greater science anxiety than male counterparts (Morganson et al., 2010).

○ Effects of Previous Experiences on Introductory College Science Performance

The Factors Influencing College Science Success (FICSS) Project aimed to determine the effects of secondary instruction in science on performance in college introductory science courses, surveying >8000 students and faculty members from across the nation. Schwartz et al. (2008a) identified a major disconnect in what is thought to prepare students for success in college introductory science courses.

In this survey of high school science teachers and undergraduate introductory science faculty, both groups of professionals identified math proficiency as the most important factor influencing success in introductory college science courses (Schwartz et al., 2008b). Educational variables that were surveyed included enrollment in high school calculus, last high school math grade, enrollment in Advanced Placement (AP) science courses, last high school science grade, and Scholastic Aptitude Test (SAT) math scores. Experiential variables that were surveyed included preference for memorization or understanding, number of science labs per month, labs that addressed real-world concerns, pre-lab preparation, graphical analysis, demonstrations per week, mandatory class projects, and class time devoted to critical concepts. Of the variables examined, only completion of high school calculus and increased high school math grades had a positive effect on college science performance, while demonstrations per week, pre-lab preparation, and mandatory class projects had a negative effect on college science performance (Tai et al., 2006).

When analyzing AP exam scores and effects on success in college introductory science courses, the FICSS project identified that the average grade of students who enrolled in an AP science course reflected a four-point increase from the class average; there were insignificant differences between the grades of AP testers and AP nontesters (Sadler & Tai, 2007).

The FICSS Project analyzed data on student autonomy to determine its effect on student success in college introductory science courses. Researchers concluded that although student autonomy provided the greatest opportunity for developing scientific inquiry, structured activities are essential to building schemas. Researchers concluded that autonomy, in combination with structured activities, adds to students' knowledge base (Tai et al., 2007). The FICSS Project also studied the relationship between inquiry-type learning activities and college science performance. Because inquiry is driven by student autonomy, students who engage in inquiry-type learning activities are more likely to show an interest in science, aspire to achieve a science career, and in turn make socially responsible contributions to the field of science (Tai & Sadler, 2009).

The FICSS Project also analyzed data related to depth and breadth of content in high school science courses. Researchers reported that students who were taught one major topic in depth, for 1 month or longer, had greater success in collegiate introductory science courses; conversely, students who reported breadth in high school biology suffered a serious disadvantage in college introductory biology (Schwartz et al., 2008b).

○ Informal Science Learning's Effects on Scientific Literacy

The general public should understand basic life science concepts and think critically. Everyday life depends on science and technology; thus, understanding science concepts allows the public to make informed decisions on a daily basis (Ainsworth & Eaton, 2010).

Informal learning is student-centered, as opposed educator-centered, and occurs differently from one individual to the next (Ainsworth & Eaton, 2010). Also known as "free choice" science learning, opportunities for engagement in informal science learning include visits to the beach, zoos, aquariums, national parks, and science centers. Informal science learning is self-guided, nonlinear, and social (Liu, 2009). The range of informal science learning also includes visiting exhibits, pursuing interests and hobbies, and participating in community education programs (Rennie & Stocklmayer, 2003).

Informal science learning can also support formal classroom learning. In an effort to address the "CSI effect," an increased student interest in forensic science (Ainsworth & Eaton, 2010), teachers are now incorporating forensic science in high school chemistry curriculum. To meet student interest in forensic science, teachers include forensic science trade books, television programs, videogames, and Internet into lesson plans (Guzzetti, 2009).

Gender, high school preparation in mathematics and science, and exposure to informal science-learning opportunities have the potential to influence developing scientific literacies. The scope of this investigation was to examine performance on a life science questionnaire between groups of undergraduates with varying levels of the aforementioned factors.

○ Methods

Undergraduate students (n = 255) enrolled in Biology I at a 4-year, regional institution during the fall semester of 2011 were the participants for this investigation. The students were selected utilizing a convenience sample from two sections of the course, which allowed participation by the majority of students enrolled in Biology I at a 4-year university in the southwestern United States. Sample size was based on recommendations for populations with finite sizes (Krejcie & Morgan, 1970).

Of the 255 participants, 18.8% were male and 81.2% were female. Further, 84.3% of participants belonged to the 18–20 age group, 9.4% belonged to the 21–25 age group, and 6.3% belonged to the 26 and over age group. When examining students' course of study, 14.1% of participants were biology majors, 53.3% were other science majors, and 31.4% were non-science-majors.

The instrument for this study was an 18-item, multiple-choice questionnaire previously administered by Lord and Rauscher (1991) (see Appendix 1). Questionnaire topics included ecology, taxonomy, human systems, microbiology, biochemistry, and photosynthesis; the topics were gleaned from upper-elementary and middle school life science textbooks. The questionnaire was deemed appropriate for use in the present study. It was administered once by the researcher during the first half of the semester; students, as a group, were tested at the beginning of a regularly scheduled class meeting.

Individual questionnaires were coded for analysis with IBM's SPSS software. Performance on the questionnaire was compared among groups using means and standard deviations. An independent-measures t-test was used to compare mean performance between males and females. Analyses of variance (ANOVAs) were used in conjunction with Tukey's HSD post hoc analysis to compare means among groups of ages, majors, and levels of exposure to informal science-learning opportunities. Main effects and interaction effects of advanced high school life-science and mathematics courses completed were examined for effects on questionnaire performance.

○ Data & Statistical Analyses

The questionnaire was administered to 255 undergraduate students enrolled in Biology I. Percent correct was determined for the whole group (mean ± SD = 62.42 ± 18.21). There was no significant difference in scientific literacy between males (62.54 ± 24.68, n = 48) and females (62.39 ± 16.43, n = 207) ($t_{253} = 0.05$, $P \geq 0.05$).

A one-way ANOVA, including Tukey's HSD post hoc analysis to differentiate means, identified a significant difference (Cohen's d = 0.57, $P \leq 0.05$) in percent correct between the 18–20 age group (61.0 ± 17.39, n = 215) and the 21–25 age group (70.21 ± 14.97, n = 24). An additional one-way ANOVA, also used in conjunction with Tukey's HSD post hoc analysis, did not reveal a significant difference for percent correct among participants of different majors.

Of 255 participants, 61.6% had completed no advanced biology courses, 34.1% had completed one advanced biology course, 2.7% had completed two, 0.4% had completed three, and 0.8% had completed four. Among the same 255 participants, 28.2% had completed no advanced mathematics courses, 57.6% had completed one advanced mathematics course, 12.2% had completed two, and 1.2% had completed three. (Advanced courses were those beyond graduation requirements.)

Neither the number of advanced life science courses completed in high school nor the number of advanced mathematics courses completed in high school had any effect on participant performance. Additionally, the interaction effects of these two types of courses had no bearing on participant performance – there was no correlation between advanced science and advanced math courses in survey performance.

Of 255 participants, 14.9% of participants reported being engaged in informal science learning at least weekly, 21.6% at least monthly, 13.7% at least once every 3 months, 8.6% at least once every 6 months, 23.5% at least yearly, and 15.7% reported that they do not participate in informal science learning.

A one-way ANOVA, including Tukey's HSD post hoc analysis to differentiate means, identified a significant difference (Cohen's d = 0.64, $P \leq 0.05$) for percent correct between participants who engage in informal science learning weekly (68.4 ± 17.5, n = 38) and participants who do not participate in informal science learning (56.8 ± 18.4, n = 40).

Results of the questionnaire indicate that undergraduate biology students do not completely grasp basic life science. Even among those participants who are biology majors, the highest-scoring group, when classified by major, continues to score below the 75th percentile, a characteristic of the group identified by Lord and Rauscher, which has remained unchanged.

Lord and Rauscher (1991) concluded that the more biology courses that a student takes in high school, the higher their score on the questionnaire. However, in the present study, the number of advanced biology courses had no significant bearing on performance. The data collected and the results of statistical analyses are summarized in Table 1.

○ Discussion

Higher-education faculty have the opportunity to facilitate the development of scientific literacy and understanding of the nature of science in all undergraduate science courses. Implications of our results include recommending that students engage in frequent informal science learning, based on evidence that those who engage in informal science learning weekly scored higher than any other group. Participants of this study have the potential to be future science leaders. University faculty develop the life science abilities of these students to increase scientific literacy (Desaulniers-Miller et al., 2010).

○ Summary

This study aimed to revisit the study of Lord and Rauscher (1991) in order to compare the level of scientific literacy among students in an undergraduate biology course between two decades. Similar results were found – biology majors continue to outscore students of other majors on the questionnaire. Differences were evident in effects of biology courses completed on participant performance; Lord and Rauscher (1991) found that the more biology courses participants completed, the better they performed on the questionnaire. In this case, the number of biology courses a participant completed had no effect on questionnaire performance.

The results suggest that participants who frequently took advantage of informal science-learning opportunities outperformed those who did not take advantage of informal learning opportunities. Opportunities for further research include identifying inclusion of informal science learning.

○ Acknowledgments

I thank the students who participated in this questionnaire, the faculty member who allowed it during class time, and Christina M. for helping me administer the questionnaire. This work is supported by the Texas Higher Education Coordinating Board's College and Career Readiness Initiative and the Science Faculty Collaborative office.

Table 1. Summary of data and statistical analyses.

Participants	Percent	n	Mean ± SD	P
Gender				
Male	18.8	48	62.54 ± 24.68	
Female	81.2	207	62.39 ± 16.43	
Age group				
18–20	84.3	215	61.00 ± 17.39	0.047
21–25	9.4	24	70.21 ± 14.97	0.047
26 and over	6.3	16	69.84 ± 27.83	
Major				
Biology	14.1	36	69.22 ± 13.80	
Other science	53.3	136	61.45 ± 17.96	
Non-science	31.4	80	62.09 ± 18.79	
Number of advanced biology electives				
0	61.6	157	61.77 ± 17.66	
1	34.1	87	62.94 ± 19.45	
2	2.7	7	69.00 ± 20.89	
3	0.4	1	67.00 ± 0.00	
4	0.8	2	62.50 ± 6.36	
Number of advanced mathematics electives				
0	28.2	72	62.85 ± 19.33	
1	57.6	147	62.22 ± 17.43	
2	12.2	31	60.52 ± 20.07	
3	1.2	3	75.33 ± 14.43	
Time engaged in informal science learning				
At least weekly	14.9	38	68.40 ± 17.48	0.043
At least monthly	21.6	55	66.24 ± 14.00	
At least once every 3 months	13.7	35	59.34 ± 17.32	
At least once every 6 months	8.6	22	57.95 ± 22.02	
At least yearly	23.5	60	64.43 ± 17.94	
None	15.7	40	56.83 ± 18.42	0.043

References

Ainsworth, H.L. & Eaton, S.E. (2010). Formal, non-formal and informal learning in the sciences. [Online.] Available at http://www.eric.ed.gov/PDFS/ED511414.pdf.

Allchin, D. (2004). Error and the nature of science. [Online.] Available at http://www.actionbioscience.org/education/allchin2.html.

Baram-Tsabari, A. & Yarden, A. (2011). Quantifying the gender gap in science interests. *International Journal of Science and Mathematics Education, 9,* 523–550.

Britner, S.L. (2008). Motivation in high school science students: a comparison of gender differences in life, physical, and earth science classes. *Journal of Research in Science Teaching, 45,* 955–970.

Bybee, R.W. (1997). Towards an understanding of scientific literacy. In W. Gräber & C. Bolte (Eds.), *Scientific Literacy: An International Symposium* (pp. 37–68). Institute for Science Education at the University of Kiel, Germany.

Chiu, M.-S. (2010). Effects of science interest and environmental responsibility on science aspiration and achievement: gender differences and cultural supports. *Educational Research and Evaluation, 16,* 345–370.

Desaulniers-Miller, M.C., Montplaisir, L.M., Offerdahl, E.G., Cheng, F.-C. & Ketterling, G.L. (2010). Comparison of views of the nature of science between natural science and nonscience majors. *CBE Life Sciences Education, 9,* 45–54.

DiBenedetto, M.K. (2011). Within the pipeline: self-regulated learning and academic achievement among college students in science courses. Paper presented at the Annual Meeting of the American Educational Research Association, New Orleans, LA.

Guzzetti, B. (2009). Thinking like a forensic scientist: learning with academic and everyday texts. *Journal of Adolescent and Adult Literacy, 53,* 192–203.

Heilbronner, N.N. (2009). Jumpstarting Jill: strategies to nurture talented girls in your science classroom. *Gifted Child Today, 32,* 46–54.

Holbrook, J. & Rannikmae, M. (2009). The meaning of scientific literacy. *International Journal of Environmental & Science Education, 4,* 275–288.

Johnson, K. (2011). Occupy Wall Street protests illuminate frustrations with the mismatch between available jobs in STEM occupations and the skilled people to fill them. PRWeb, 14 November. [Online.] Available at http://www.prweb.com/releases/2011/11/prweb8963852.htm.

Kern, C. & Crippen, K.J. (2008). Mapping for conceptual change. *Science Teacher, 75*(6), 32–38.

Krejcie, R.V. & Morgan, D.W. (1970). Determining sample size for research activities. *Educational and Psychological Measurement, 30,* 607–610.

Liu, X. (2009). Beyond science literacy: science and the public. *International Journal of Environmental & Science Education, 4,* 301–311.

Lord, T.R. & Rauscher, C. (1991). A sampling of basic life science literacy in a college population. *American Biology Teacher, 53,* 419–424.

Morganson, V.J., Jones, M.P. & Major, D.A. (2010). Understanding women's underrepresentation in science, technology, engineering, and mathematics: the role of social coping. *Career Development Quarterly, 59,* 169–179.

Ochonogor, C. (2011). Performance analysis of science education undergraduates: a case study of biology education students. *US-China Education Review A, 5,* 682–690.

Odessky, J. (2011). Keeping STEM rooted. *Columbia Spectator*, 14 November. Available online at http://www.columbiaspectator.com/2011/11/14/keeping-stem-rooted.

Patrick, H., Mantzicopoulos, P. & Samarapungavan, A. (2009). Motivation for learning science in kindergarten: is there a gender gap and does integrated inquiry and literacy instruction make a difference. *Journal of Research in Science Teaching, 46,* 166–191.

Rennie, L.J. & Stocklmayer, S.M. (2003). The communication of science and technology: past, present and future agendas. *International Journal of Science Education, 25,* 759–773.

Sadler, P.M. & Tai, R.H. (2007). Advanced placement exam scores as a predictor of performance in introductory college biology, chemistry and physics courses. *Science Educator, 16*(1), 1–19.

Schwartz, M.S., Hazari, Z. & Sadler, P.M. (2008a). Divergent views: teacher and professor perceptions about pre-college factors that influence college science success. *Science Educator, 17*(1), 18–35.

Schwartz, M.S., Sadler, P.M., Sonnert, G. & Tai, R.H. (2008b). Depth versus breadth: how content coverage in high school science courses relates to later success in college science coursework. *Science Education, 93,* 798–826.

Shamos, M. (1995). *The Myth of Scientific Literacy*. New Brunswick, NJ: Rutgers University Press.

Tai, R.H. & Sadler, P.M. (2009). Same science for all? Interactive association of structure in learning activities and academic attainment background on college science performance in the USA. *International Journal of Science Education, 31,* 675–696.

Tai, R.H., Sadler, P.M. & Maltese, A.V. (2007). A study of the association of autonomy and achievement on performance. *Science Educator, 16*(1), 22–28.

Tai, R.H., Sadler, P.M. & Mintzes, J.J. (2006). Factors influencing college science success. *Journal of College Science Teaching, 36*(1), 52–56.

von Aufschnaiter, C. & Rogge, C. (2010). Misconceptions or missing conceptions? *EURASIA Journal of Mathematics, Science & Technology Education, 6,* 3–18.

Zimmerman, B.J. & Bandura, A. (1994). Impact of self-regulatory influences on writing course attainment. *American Educational Research Journal, 31,* 845–862.

Zuccala, A. (2010). Open access and civic scientific information literacy. *Information Research, 15*(1). [Online.] Available at http://informationr.net/ir/15-1/paper426.html.

STEPHANIE R. MEDINA is a Graduate Research Assistant in Educational Leadership, Curriculum, and Instruction at Texas A&M University-Corpus Christi, 6300 Ocean Dr. Unit 5818, Corpus Christi, TX 78412-5818; e-mail: stephanie.medina@tamucc.edu. EVAN ORTLIEB is a Senior Lecturer at Monash University, Frankston, Victoria 3199, Australia; e-mail: evan.ortlieb@monash.edu. SANDRA METOYER is a Research Associate with the Education Research Center at Texas A&M University, 4232 Texas A&M University, College Station, Texas, 77843-4232; e-mail: sandra.metoyer@cehd.tamu.edu.

Appendix 1. Life science literacy questionnaire. Life science questions were created by Lord and Rauscher (1991).

Demographics Questions

1. Gender (circle one)
   a. Male
   b. Female
2. Age group (circle one)
   a. 18–20
   b. 21–25
   c. 26 and over
3. High school life science courses completed (circle all that apply)
   a. Biology
   b. Advanced Placement (AP)/International Baccalaureate (IB) Biology
   c. Environmental Systems
   d. Advanced Placement (AP)/International Baccalaureate (IB) Environmental Systems
   e. Aquatic Science
4. High school mathematics courses complete (circle all that apply)
   a. Algebra I
   b. Algebra II
   c. Geometry
   d. Pre-Calculus
   e. Math Models
   f. Advanced Placement (AP)/International Baccalaureate (IB) Statistics
   g. Advanced Placement (AP)/International Baccalaureate (IB) Calculus
5. Major (circle one)
   a. Biology
   b. Other science
   c. Non-science
6. Time engaged in informal science learning on a regular basis (i.e., hobbies, museums, science centers, aquariums, zoos, environmental centers, etc.) (circle one)
   a. At least weekly
   b. At least monthly
   c. At least once every three months
   d. At least once every six months
   e. At least yearly
   f. Not at all

Life Science Questions

1. Animals that eat other animals are called:
   a. Herbivores
   b. Carnivores
   c. Cannibals
   d. Parasites
   e. Don't know

2. Warm-blooded animals always keep the temperature inside their body the same as the outside surroundings.
    a. True
    b. False
    c. It depends on the animal
    d. It depends on the location of the animal
    e. Don't know
3. The organ that produces sperm in male animals is the:
    a. Scrotum
    b. Prostate
    c. Penis
    d. Testes
    e. Don't know
4. In female animals the egg cells are produced by the:
    a. Ovaries
    b. Uterus
    c. Vagina
    d. Cervix
    e. Don't know
5. AIDS (Acquired Immune Deficiency Syndrome) is caused by a bacterial infection.
    a. True
    b. False
    c. Don't know
6. Cholesterol can be a problem for people who eat too much:
    a. Sugar
    b. Flour
    c. Saturated fats
    d. Protein
    e. Don't know
7. Plants release oxygen from their leaves during the day.
    a. True
    b. False
    c. Don't know
8. A spider is an insect.
    a. Always true
    b. Always false
    c. It depends upon the type of spider
    d. Don't know
9. Which of the following are animals?
    a. Elephant
    b. Bird
    c. Snake
    d. Fish
    e. b and c
    f. a, b, and c
    g. a, b, c, and d

10. Which of the following are animals?
    a. Frog
    b. Grasshopper
    c. Clam
    d. Worm
    e. a and b
    f. a, b, and c
    g. a, b, c, and d
11. Which of the following have bones inside them?
    a. Dogs
    b. Whales
    c. Turtles
    d. Crabs
    e. a and b
    f. a, b, and c
    g. a, b, c, and d
12. Which of the following have no bones in their bodies?
    a. Worms
    b. Spiders
    c. Lobster
    d. Snakes
    e. a and b
    f. a, b, and c
    g. a, b, c, and d