Instructor Gender and Student Confidence in the Sciences: A Need for More Role Models?

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Women are underrepresented in most scientific disciplines, with achievement gaps expanding throughout the career trajectory. Gender differences in perceptions of scientific competence are evident at an early age. We examined the extent to which college-level instructor gender affects the confidence of males and females in their scientific abilities. The presence of a woman in either a primary or secondary instructional role (or both) improves female students' levels of scientific confidence. However, the absence of women in an authoritative role impedes significant gains in confidence levels for female students. We discuss this work in light of recent studies of women in the sciences, innate versus learned abilities, the role of confidence in career choices, and implications for enhancing diversity in the sciences overall.

Women in science, from the perspectives of innate ability, initial interest, lifetime socialization, academic retention, and professional advancement, present issues that plague the disciplines, despite evidence that some fields (e.g., biology) seem to be "closing the gap" (Halpern et al. 2007; Greenfield 1996; Morgan, Isaac, and Sansone 2001; Bleeker and Jacobs 2004; Crowley et al. 2001; Ledin et al. 2007; Tenenbaum and Leaper 2003; Committee on Gender Differences 2009; Xu 2008; Settles et al. 2006; National Science Foundation 2009). Recent work has suggested a connection between same-gender role models, perceptions of competence (Hoffman and Oreopoulos 2007; Bettinger and Long 2005; Lockwood 2006), and student achievement (Carrington, Tymms, and Merrell 2008; Marx and Roman 2002). For example, Hoffman and Oreopoulos (2007) noted a small increase in college student performance and likelihood of course completion when taught by a same-gender instructor. Bettinger and Long (2005) illustrated that women are more likely to take more courses in, or major in, quantitative or technical disciplines when their introductory-level instructor is female. And Marx and Roman (2002), via a series of studies, demonstrated that a female role model can significantly combat the stereotype threat that has been thoroughly documented for women in mathematics (e.g., Quinn and Spencer 2001).

By analyzing responses to a survey by students in several sections of an introductory biology course, we examined the extent to which instructor gender affects the confidence of males and females in their scientific abilities. We hypothesized that female students would be more likely to exhibit confidence gains when taught by female lecturers and laboratory teaching assistants.

Methods

Data for this study were collected from students enrolled in an introductory course for nonmajors, via a pre- and posttest survey administered online during spring and fall 2008. Demographically, the survey population is representative of all of our students. Specifically, each section was comprised of 50%–53% female and 22%–23% nonwhite students. The complete survey included questions about student perceptions of science in general, and evolution specifically, as well as questions about their high-school biology backgrounds. We report here on the first nine survey items, which were designed to measure levels of students' confidence to comprehend, analyze, and communicate scientific concepts, methods, and findings (modified from the SENCER-SALG [Student Assessment of Learning Gains] instrument, available at *www.sencer.net/Assessment/assessmenttools.cfm*).

Specifically, the items asked students to gauge their confidence in discussing science with others, making scientific arguments, posing scientific questions, thinking critically about findings, interpreting presented data, determining the validity of scientific evidence and the difference between science and pseudoscience, understanding the scientific method, and understanding the course content. Confidence levels were measured using a 5-point Likert scale, ranging from *not confident* to *extremely confident*. For our purposes, the scale was coded according to the following scheme: 1 = *not confident*; 2 = *a little confident*; 3 = *somewhat confident*; 4 = *highly confident*; and 5 = *extremely confident*. For the pretest survey, the number of respondents was approximately 400 students (actual response rate varied for each survey item) and for the posttest data, the number of respondents was approximately 300; given that some students opted not to provide identifying information (student identification numbers), pairwise analysis was possible for 125 respondents. Students could skip any or all of the items. Student identification numbers allowed us to access information on student gender and laboratory section.

To minimize the number of potentially confounding variables, we analyzed results from two primary, or lecture, instructors (one male, one female) and several laboratory teaching assistants (TAs). Students may have known the instructors' gender on enrollment but had no way of identifying that of their TA. We did our best to control for teacher quality—both instructors are experienced, award-winning, and engaging teachers. All TAs completed the same TA training program before classes stated. TAs have over three hours per week contact time with students in a small-group setting (18–22 students), whereas primary instructors have three hours of contact time weekly, but in a large, lecture-style setting; each lecture section in this study had over 200 students. The University's Institutional Review Board approved the survey and subsequent analysis.

Results

Males, females, and science confidence

Initially, females as a group were less confident than males on all items. Table 1 presents the results of difference of means tests for the levels of confidence between sexes for each item. All items are highly significant, with males and females exhibiting the smallest difference in their amount of confidence for understanding the science content of the course (0.31 on a 5-point scale; $p < .001$) and the largest difference in their ability to make arguments using scientific evidence (0.62; $p < .0001$). These findings confirm the patterns of academic confidence observed by scholars in other contexts (Lundeberg 1992; Shashaani 1997), whereby males tend to exhibit greater confidence in their academic abilities.

For the posttest data, however, there is a significant difference between the sexes for only two items, determining the difference between science and pseudoscience ($p < .05$) and understanding the scientific processes behind scientific issues reported in the media ($p < .05$), both of which are smaller than in the pretest data. For all other items, the difference between women's

TABLE 1

Difference of means in scientific confidence items between men and women by test, using a 5-point Likert scale.

Items	Pretest	Posttest
Discuss scientific concepts with my friends and family	0.57***	0.30
Think critically about scientific findings I read about in the media	0.53***	0.31
Determine what is and is not valid scientific evidence	0.43***	0.21
Make an argument using scientific evidence	0.62***	0.29
Determine the difference between science and pseudoscience	0.56***	0.44*
Interpret tables and graphs	0.51***	0.26
Pose questions that can be addressed by collecting and evaluating scientific evidence	0.43***	0.27
Understand scientific processes behind important scientific issues in the media	0.47***	0.40*
Understand the science content of this course	0.31**	0.25

Note: Cell entries are the differences of the average male response minus the average female response to each respective item. For the pretest survey, the number of respondents was approximately 400 students (actual response rate varied for each survey item); for the posttest data, the number of respondents was approximately 300.
*$p < .05$ **$p < .001$ ***$p < .0001$

and men's levels of confidence in understanding, analyzing, and using scientific concepts at the end of the course was no longer statistically significant. That is, although students generally experienced improvements in their scientific confidence levels during the course of the semester, the confidence gains made by women outpaced those made by the men. In some cases, mean confidence increased by over a point, on a 5-point scale. The major question that emerges from these findings is: What factor or factors associated with the course might have contributed to the significant gains we observed among the female students?

Effect of instructor gender on confidence of female students

Given that the gender of the instructors and TAs may have contributed to these gains by virtue of a demonstration effect, we first divided the respondents into their respective sections, one of which was taught by a female instructor and one of which was taught by a male instructor. Second, to control for instructional factors unrelated to the gender of the instructor, we further divided students into groups based on the gender of the TA who led the laboratory sections. From the three dichotomous divisions of students (by gender, by gender of TA, and by gender of instructor), we achieved 2^3 (i.e., 8) possible patterns with which we could isolate the impact of gender on changes in scientific confidence levels. The results of our difference of means tests reveal a clear relationship between the gender of instructors, TAs, and students and the changes in levels of scientific confidence (see Table 2).

Female students experienced significant improvements in their levels of confidence regarding the use and comprehension of science with the presence of a woman in a position of authority and expertise. When both the TA and instructor were women, female students experienced highly significant improvements in their lev-

TABLE 2

Percentage change in scientific confidence items by students, TAs, and primary instructors.

Items	Patterns							
	0-0-0	0-0-1	0-1-0	0-1-1	1-0-0	1-0-1	1-1-0	1-1-1
Discuss scientific concepts with my friends or family	40.0***	35.2***	35.3*	13.7	27.2	46.0**	45.9	6.3
Think critically about scientific findings I read about in the media	41.9****	26.7*	50.0***	13.7	27.4	46.9**	51.0	21.4
Determine what is and is not valid scientific evidence	39.9***	34.5**	47.3***	38.9	39.6*	40.1**	47.9	23.3
Make an argument using scientific evidence	39.1****	29.8**	40.8***	28.6	28.7	35.1*	35.5	15.9
Determine the difference between science and pseudo-science	37.4****	25.4*	44.7***	23.4	30.0	48.2**	42.0	36.1
Interpret tables and graphs	33.3**	38.0*	15.2	32.5	1.8	25.6	24.2	36.1
Pose questions that can be addressed by collecting and evaluating scientific evidence	44.1****	36.1**	34.1*	12.5	33.8*	56.0***	23.1	−3.1
Understand scientific processes behind important scientific issues in the media	43.2****	19.0*	14.1**	12.0	31.9	55.4***	41.4	21.4
Understand the science content of this course	46.2****	15.7	31.6	−22.2	46.6**	31.2	−11.1	32.9

Note: Sequence = student–TA–faculty; 0 = female; 1 = male. Cell entries are gain scores. Gain scores represent the percentage of change relative to the possible amount of change from the pretest scores. The formula for calculating gains is as follows: % change = (posttest − pretest)/(Possible change) * 100. Total $N = 125$. TA = teaching assistant.
$^*p < .05$ $^{**}p < .01$ $^{***}p < .001$ $^{****}p < .0001$

els of confidence for all items ($p < .01$ to $p < .0001$). In instances in which the TA was female but the primary instructor was male, female students made significant gains in their confidence levels ($p < .05$ to $p < .001$) for every item except understanding the scientific content of the course. And, when the primary instructor was a female but the TA was male, the gains in confidence levels for women students remained significant ($p < .05$ to $p < .001$) in all instances except understanding course content and interpreting tables and graphs.

When female students had a male primary instructor and a male TA, they failed to make any significant improvements in their levels of scientific confidence. In fact, women in those sections actually lost confidence in their ability to understand the scientific content of the course. Thus, the presence of a woman in either a primary or secondary instructor role (or both) improves significantly female students' levels of scientific confidence, whereas the absence of women in an authoritative role impedes significant gains in confidence levels for female students.

Second, in most instances, male students' scientific confidence did not improve at statistically significant levels. Specifically, there was no significant difference between male students' confidence levels for any items either when the primary instructor was female with a male TA or the instructor and TA were both male. When the primary instructor was male and the TA was female, however, male students' scientific confidence levels improved significantly ($p < .05$ to $p < .001$) on all items except interpreting tables and graphs and understanding the science content of the course (a pattern that demands future exploration). And with both a female instructor and TA, male students experienced significant improvements to their levels of confidence in determining what is and is not valid scientific evidence ($p < .05$), posing questions that can be addressed by collecting and evaluating scientific evidence ($p < .05$) and understanding the science content of the course ($p < .01$). Therefore, although the gender of the instructor or TA appears to have a significant effect on female students' levels of scientific confidence, there is no systematically equivalent outcome for male students.

Discussion

If confidence plays an essential role in students' motivation to learn (Fenollar Román, and Cuestas 2007), it is vital that instructors create positive classroom dynamics that promote student learning. Students will enjoy learning and be motivated to learn if they are taught by a motivated role model (Brophy 2004). In particular, females tend to have inaccurately low self-perceptions of their performance on given tasks (Beyer 1999), which may negatively affect their achievement in subjects that are considered masculine (Beyer and Bowden 1997). Many scientific professions have sex-typed stereotypes that develop during adolescence and are reinforced through experiences that precede college-level coursework (Halpern et al. 2007). Although innate gender differences cannot be ignored (Gurian and Ballew 2003) and should not be excluded from our understanding of the role of sex-specific socialization (Bleeker and Jacobs 2004; Crowey et al. 2001; Ledin et al. 2007; Tenenbaum and Leaper 2003), previous studies do not document differences that empirically discourage female participation in science, technology, engineering, and math (STEM).

Work in other disciplines illustrates a similar "role model" effect, whereby male teachers, in traditionally female-dominated disciplines, have a positive impact on the achievement of their male students (e.g., Dee 2007), and a similar pattern is observed for female students with female teachers (Hoffman and Oreopoulos 2007). In STEM disciplines, there is a specific, well-documented gender disparity that expands as science careers progress. Males are more likely to obtain higher ranked positions than females, as illustrated by the steady decline in the proportion of women holding predoctoral, postdoctoral, junior group leader, and professor positions (Committee on Gender Differences 2009; Neugebauer 2006). Because the abilities to understand scientific concepts among male and female students entering college are roughly equal (Hyde and Linn 2006; Moore 2007), it is worth examining what happens to females in college that hinders their representation in future science careers. Although we do not claim that male instructors are a detriment to women scientists, the data presented here confirm the need for educators and others to redouble their efforts at diversity-enhancement in the sciences (see also King 2005).

Our conclusions are based on an investigation in which 125 students were available for pre/post comparison. Although we are intrigued by the significant trends revealed in our analysis, we are aware of the complexity of the issue and the limitations of our study; future work will determine the strength of these initial conclusions. In addition, future work will address whether Native Americans, African Americans, and Hispanics, all of whom are grossly underrepresented in the disciplines (National Science Foundation 2009), would exhibit similar gains in confidence, and thus participation in the sciences, when taught by culturally, racially, or ethnically similar instructors. Regardless, our work suggests a powerful role-model effect (Bettinger and Long 2005; Gilbert 1985; Gilbert, Gallessich, and Evans 1983; Neumark and Gardecki 1998) whereby women benefit from female instructors without harming the confidence of their male classmates. ■

References

Bettinger, E.P., and B.T. Long. 2005. Do faculty serve as role models? The impact of instructor gender on female students. *American Economic Review* 95: 152–157.

Beyer, S. 1999. Gender differences in the accuracy of grade expectancies and evaluations. *Sex Roles* 41: 279–296.

Beyer, S., and S. Bowden. 1997. Gender differences in self-perceptions: Convergent evidence from three measures of accuracy and bias. *Personality and Social Psychology Bulletin* 23: 157.

Bleeker, M.M., and J.E. Jacobs. 2004. Achievement in math and science: Do mothers' beliefs matter 12 years later? *Journal of Educational Psychology* 96: 97–109.

Brophy, J.E. 2004. *Motivating students to learn.* Hillsdale, NY: Lawrence Erlbaum.

Carrington, B., P. Tymms, and C. Merrell. 2008. Role models, school improvement and the "gender gap": Do men bring out the best in boys and women the best in girls? *British Educational Research Journal* 34: 315–327.

Committee on Gender Differences in the Careers of Science, Engineering, and Mathematics Faculty; Committee on Women in Science, Engineering, and Medicine; Committee on National Statistics; National Research Council. 2009. *Gender differences at critical transitions in the careers of science, engineering, and mathematics faculty*. Washington, DC: National Academies Press. Available at *www.nap.edu/catalog.php?record_id=12062*.

Crowley, K., M.A. Callanan, H.R. Tenenbaum, and E. Allen. 2001. Parents explain more often to boys than to girls during shared scientific thinking. *Psychological Science* 12: 258–261.

Dee, T.S. 2007. Teachers and the gender gaps in student achievement. *Journal of Human Resources* 42 (3): 528–554.

Fenollar, P., S. Román, and P.J. Cuestas. 2007. University students' academic performance: An integrative conceptual framework and empirical analysis. *British Journal of Educational Psychology* 77: 873–891.

Gilbert, L.A. 1985. Dimensions of same-gender student-faculty role-model relationships. *Sex Roles* 12: 111–123.

Gilbert, L.A., J.M. Gallessich, and S.L. Evans. 1983. Sex of faculty role model and students' self-perceptions of competency. *Sex Roles* 9: 597–607.

Greenfield, T.A. 1996. Gender, ethnicity, science achievement, and attitudes. *Journal of Research in Science Teaching* 33 (8): 901–933.

Gurian, M., and A. Ballew. 2003. *The boys and girls learn differently action guide for teachers.* San Francisco: Jossey-Bass.

Halpern, D.F., C.P. Benbow, D.C. Geary, R.C. Gur, J.S. Hyde, and M.A. Gernsbacher. 2007. The science of sex differences in science and mathematics. *Psychological Science in the Public Interest* 8: 1–51.

Hoffman, F., and P. Oreopoulos. 2007. *A professor like me: The influence of instructor gender on college achievement* (Working Paper 13182). Cambridge, MA: National Bureau of Economic Research.

Hyde, J.S., and M.C. Linn. 2006. Gender similarities in mathematics and science. *Science* 314: 599–600.

King, J. 2005. Benefits of women in science. *Science* 308: 601.

Ledin, A., L. Bornmann, F. Gannon, and G. Wallon. 2007. A persistent problem: Traditional gender roles hold back female scientists. *EMBO Reports* 8: 982–987.

Lockwood, P. 2006. Someone like me can be successful: Do college students need same-gender role models? *Psychology of Women Quarterly* 30 (1): 36–46.

Lundeberg, M.A. 1992. Highly confident, but wrong: Gender differences and similarities in confidence judgments. Paper presented at the annual meeting of the American Educational Research Association, San Francisco, CA.

Marx, D.M., and J.S. Roman. 2002. Female role models: Protecting women's math test performance. *Personality and Social Psychology Bulletin* 28 (9): 1183–1193.

Moore, J.W. 2007. Achieving chemistry's full potential. *Journal of Chemical Education* 84 (2): 199.

Morgan, C., J.D. Isaac, and C. Sansone. 2001. The role of interest in understanding the career choices of female and male college students. *Sex Roles* 44 (5): 295–320.

National Science Foundation, Division of Science Resources Statistics. 2009. *Women, minorities, and persons with disabilities in science and engineering: 2009* (Special Report NSF 09-305). Arlington, VA: National Science Foundation. *www.nsf.gov/statistics/wmpd/*

Neugebauer, K.M. 2006. Keeping tabs on the women: Life scientists in Europe. *PLoS Biology* 4 (4): 494.
Neumark, D., and R. Gardecki. 1998. Women helping women? Role model and mentoring effects on female Ph.D. students in economics. *Journal of Human Resources* 33 (1): 220–246.
Quinn, D.M., and S.J. Spencer. 2001. The interference of stereotype threat with women's generation of mathematical problem-solving strategies. Special issue, *Journal of Social Issues* 57 (1): 55–71.
Settles, I.H., L.M. Cortina, J. Malley, and A.J. Stewart. 2006. The climate for women in academic science: The good, the bad, and the changeable. *Psychology of Women Quarterly* 30 (1): 47–58.
Shashaani, L. 1997. Gender differences in computer attitudes and use among college students. *Journal of Educational Computing Research* 16 (1): 37–52.
Tenenbaum, H.R., and C. Leaper. 2003. Parent-child conversations about science: The socialization of gender inequities? *Developmental Psychology* 39: 34–46.
Xu, Y.J. 2008. Gender disparity in STEM disciplines: A study of faculty attrition and turnover intentions. *Research in Higher Education* 49: 607–624.

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