



Literature Overview: Gender Differences in Science Achievement



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National trends reveal mixed results with regard to the gender gap in science achievement. In some instances, such as coursework completed, females perform equal to male peers; however, assessments geared to measuring mastery of content, such as the National Assessment of Educational Progress, reveal that differences between males and females in K-12 education surface in elementary school and continue at the high school level (Ingels & Dalton, 2008). Differences in science achievement at the K-12 level are attributed in part to fewer females attaining degrees in science, technology, engineering, and mathematics (STEM) fields (Hazari, Tai, & Saddler, 2007; Madigan, 1997).

The term “science” includes engineering, chemistry, physics, biology, or psychology, among others, or a composite of any or all areas of scientific knowledge. As the data presented show, the content as well as the format within a given science achievement test may influence the magnitude of any gender differences in test scores.

For the purposes of this overview, science achievement is measured by mean scores on nationally administered standardized assessment tools. Achievement is also measured by the number and level of science courses students enroll in and the grade point average attained while enrolled in those courses. At the undergraduate level, science achievement is measured by the number and percentage of science degrees earned.

While some causal explanations for differences between males and females in science achievement are outlined, it is not within the scope or intention of this overview to analyze these explanations. Other overviews that are included in the Assessing Women and Men in Engineering Applying Research to Practice resources such as those related to *Stereotype Threat* and *Self-Efficacy* address causal factors. Those resources can be found online at <http://www.engr.psu.edu/awe/>. The purpose of this report is to facilitate access to current statistical data and their original sources, to highlight statistical trends related to the science achievement as measured by national standardized assessments in K-12 and patterns of degree attainment in science at the undergraduate level, and to outline how practitioners might use the data provided to inform programmatic initiatives related to female representation in STEM disciplines.

National Trends Associated with Gender Differences in Science Achievement among Students at K-12 and Postsecondary Levels

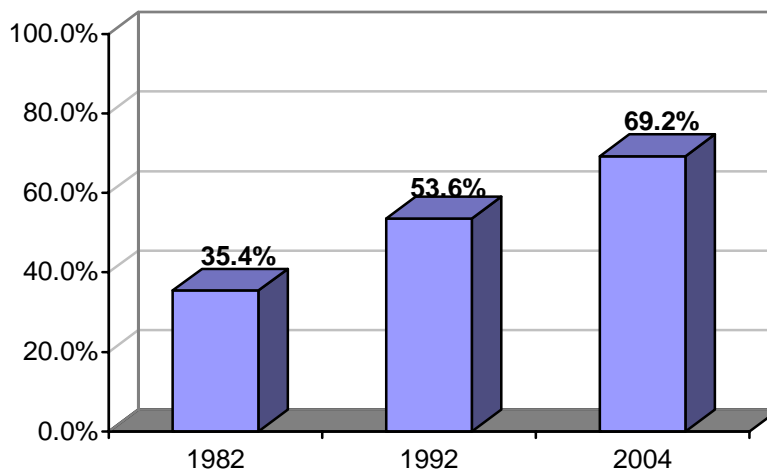
Following are national studies related to the science achievement of males and females. More detailed studies that further explore trends in science achievement between males and females are reviewed in the Meta-Analytic Studies section below.

National Education Longitudinal Study (NELS). This longitudinal study conducted by the National Center for Education Statistics consists of several waves of data collection (1988, 1990, 1992, 1994, 2000, and

2004). Each cohort of students reported on school experiences and took achievement tests in reading, social studies, mathematics, and science when the students were in eighth grade, sophomores, and seniors in high school. Recent examinations of the data set focusing on the 2004 cohort reveal a limited influence of gender on science achievement whereas previous years reveal significant differences by gender on performance in science.

Looking specifically at trends overall in the advance science course-taking patterns among the spring high school graduating classes of 1982, 1992, and 2004, there is an increase in advance science course-taking with students enrolling in and completing more rigorous advanced science courses, and far fewer finishing with low-level courses. For example, smaller proportions of high school graduates finished high school with courses at the two lowest science levels (no or low-level science, or secondary Physical Science and Basic Biology): 29% of graduates finished at these levels in 1982, while only 6% of graduates finished at these levels in 2004. At the same time, growth occurred in the upper half of science courses (i.e., the top three levels). The percentage of high school graduates who completed Chemistry (I or II), Physics (I or II), or Advanced Biology about doubled, from 35% to 69%, between 1982 and 2004 (refer to Figure 1).

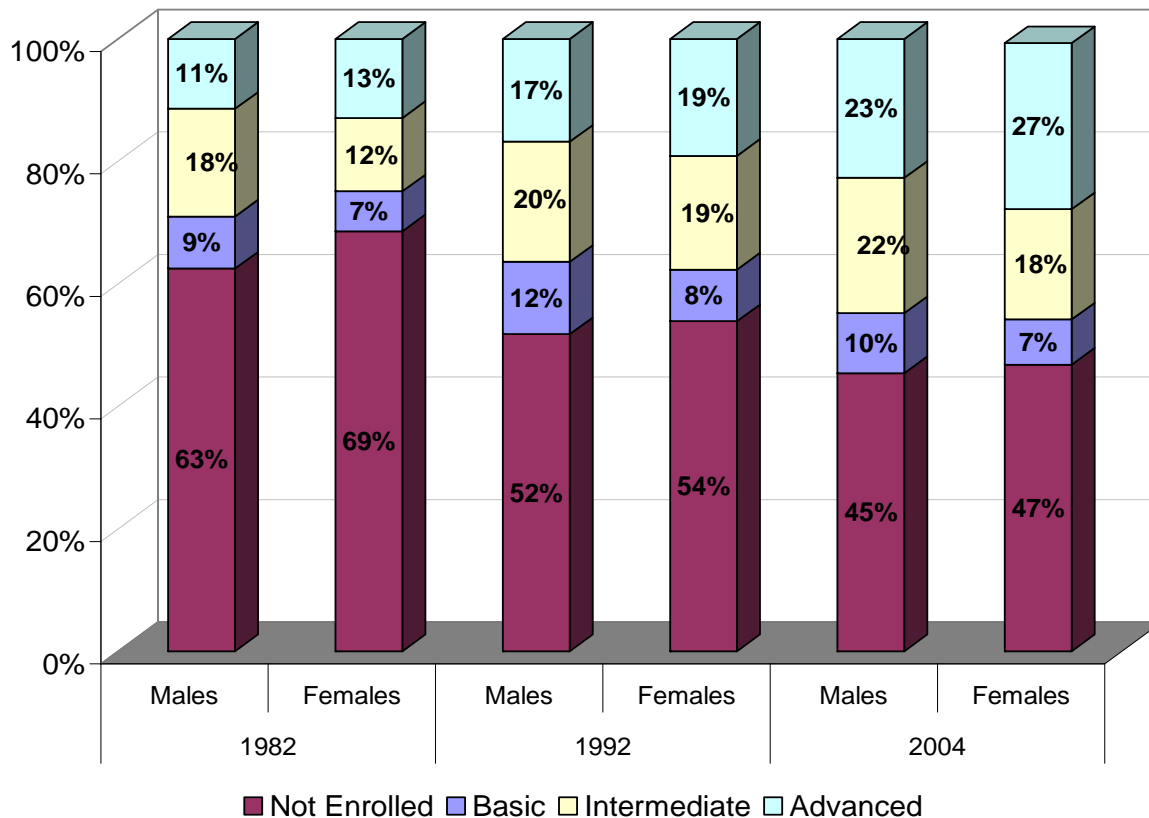
Figure 1: Percentage of High School Graduates Who Completed Chemistry, Physics, or Advanced Biology 1982, 1992, 2004



SOURCE: U.S. Department of Education, National Center for Education Statistics, High School and Beyond Longitudinal Study of 1980 Sophomores (HS&B-So:80/82), "High School Transcript Study"; National Education Longitudinal Study of 1988 (NELS:88/92), "Second Follow-up, Transcript Survey, 1992"; and Education Longitudinal Study of 2002 (ELS:2002), "First Follow-up, High School Transcript Study, 2004."

Further examination of the science course-taking pattern among five cohorts of high school seniors by gender, reveals that between 1982 and 2004 the gender gap narrowed with regard to female enrollment in science courses. In 1982, 69% of females were not enrolled in any science courses, compared to 63% of males. During this same year, there was no difference between the percentages of males and females enrolled in advanced science courses. In 2004, the science course-taking pattern changed. There was no statistically significant difference in non-enrollment by gender and females enrolled in advanced science courses at higher rates than males: 27% of females and 23% of males enrolled in advanced science courses (i.e., Chemistry II, Physics II, and Advanced Biology) (Ingels & Dalton, 2008) (refer to Figure 2).

Figure 2: Percentage of High School Seniors Enrolled in Science Courses during Senior Year, by Course Level and Gender, 1982, 1992, 2004



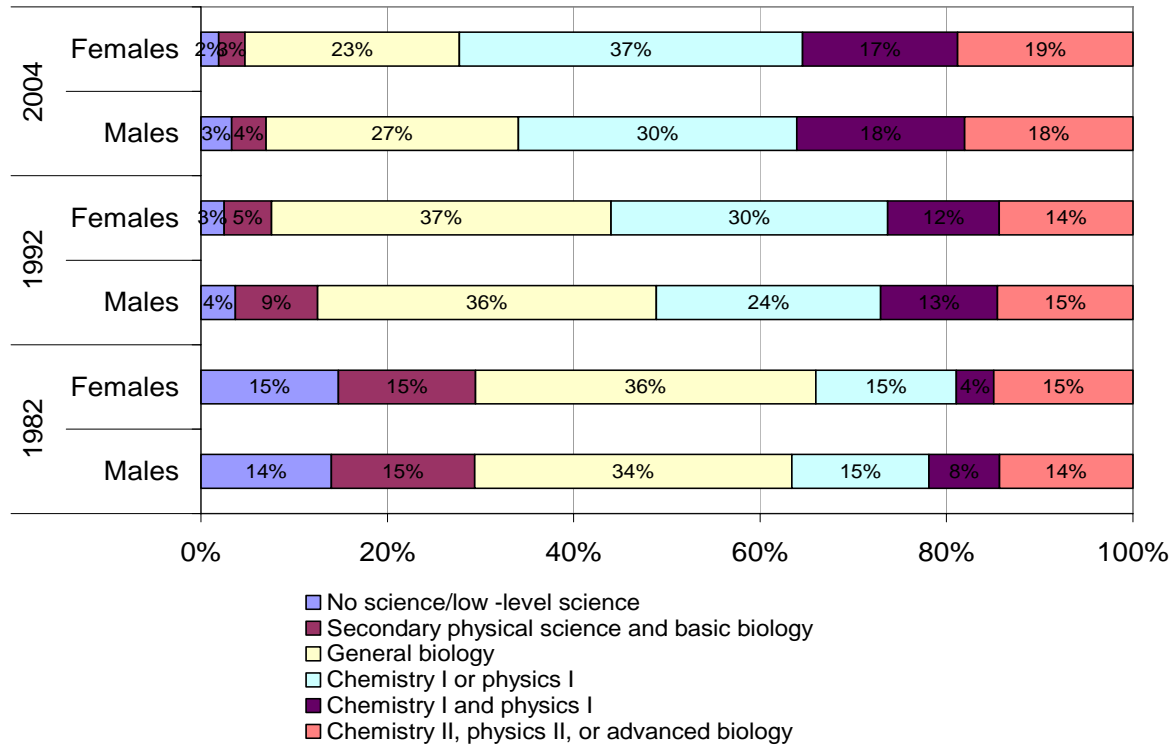
SOURCE: U.S. Department of Education, National Center for Education Statistics, High School and Beyond Longitudinal Study of 1980 Sophomores (HS&B-So:80/82), "High School Transcript Study"; National Education Longitudinal Study of 1988 (NELS:88/92), "Second Follow-up, Transcript Survey, 1992"; and Education Longitudinal Study of 2002 (ELS:2002/2004), "First Follow-up, High School Transcript Study, 2004."

NOTE: "Basic science courses" represent general science, regular and advanced earth science, general physical science, basic biology, basic chemistry, basic physics, and astronomy/meteorology; "Intermediate science courses" represent general biology, chemistry I, and physics I; "Advanced science courses" represent chemistry II, physics II, and advanced biology; these include all AP and IB science courses.

Trends reveal that males and females are becoming more likely to advance through the pipeline of science courses, completing more courses at the top three levels of science course-taking, and less likely to exit science course-taking at the bottom three levels (refer to Figure 3). Specifically, in 2004 both males and females enrolled in the top two most advanced levels of science courses (i.e., Chemistry I and Physics I; and Chemistry II, Physics II, or Advanced biology) at approximately the same rates (35% of both females and males completing courses). Female participation in Chemistry I or Physics I, increased over time with 37% of females completing either of these courses, compared with 30% of males in 2004. The percentage of males taking no science or low-level science courses decreased from 14% in 1982 to 3% in 2004, while the percentage of females doing so dropped from 15% in 1982 to 2% in 2004 (Dalton, Ingels, Downing, & Bozick, 2007). Other data sources show that when looking at the course completion rates among the

graduating class of 2005, females studied biology and chemistry at higher rates, whereas males studied physics, engineering, and engineering/science technologies at higher rates (NSF, 2008).

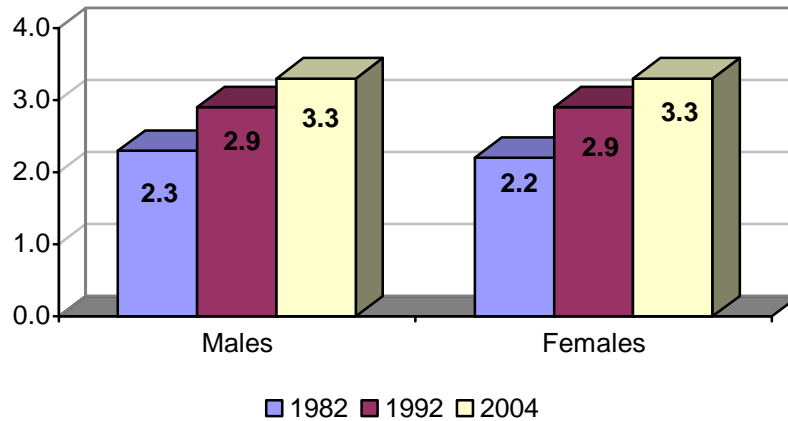
Figure 3: Percentage of High School Graduates Who Completed Different Levels of Science Courses by Gender, 1982, 1992, 2004



SOURCE: U.S. Department of Education, National Center for Education Statistics, High School and Beyond Longitudinal Study of 1980 Sophomores (HS&B-So:80/82), "High School Transcript Study"; National Education Longitudinal Study of 1988 (NELS:88/92), "Second Follow-up, Transcript Survey, 1992"; and Education Longitudinal Study of 2002 (ELS:2002/2004), "First Follow-up, High School Transcript Study, 2004."

The mean number of credits earned in science increased from 1982 to 2004 for both males and females (refer to Figure 4). Males earned 3.3 credits in science in 2004, compared with 2.3 credits in 1982; females also earned 3.3 credits in science in 2004, compared with 2.2 credits in 1982 (Dalton, Ingels, Downing, & Bozick, 2007).

Figure 4: Mean Number of Credits Earned in Science by Gender, 1982, 1992, 2004



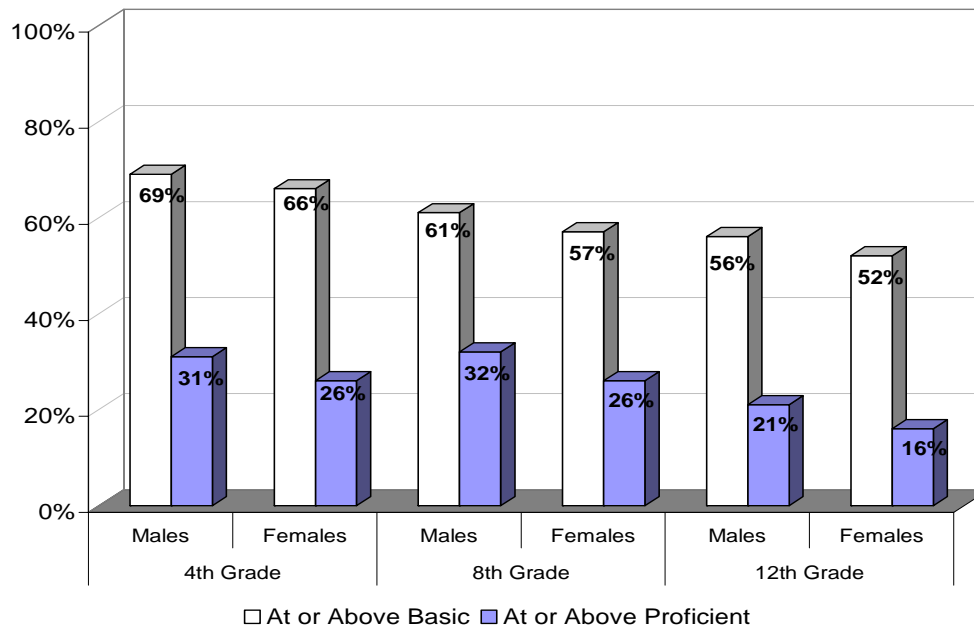
Overall, in terms of coursework, results reveal that the gender gap in science achievement may be narrowing as females are as likely to enroll in advanced science coursework as males at the pre-college level. There is also a consistent pattern relative to the mean credits earned in science being relatively equal between groups.

The Nation's Report Card: Science 2005. *The Nation's Report Card* is conducted by the National Assessment of Educational Progress (NAEP). Assessments have been conducted among a nationally representative sample since 1969 in reading, mathematics, science, writing, history, geography, and other fields. In 2005, a representative sample of more than 300,000 students in grades 4, 8, and 12 were assessed in science. Student scores are reported at three different levels (National Assessment of Educational Progress [NAEP], 2005a):

- Basic: Denotes partial mastery of prerequisite knowledge and skills that are fundamental for proficient work at each grade.
- Proficient: Denotes demonstrated competency over challenging subject matter, including subject-matter knowledge, application of such knowledge to real-world situations, and analytical skills appropriate to the subject matter.
- Advanced: Denotes superior performance.

Analysis of the 2005 results reveals that males outperformed females in science achievement at all three grade levels for the third year in a row, results are not analyzed for statistical significance by gender (refer to Figure 5).

Figure 5: 2005 Science Achievement Levels by Gender and Grade Level



Source: National Assessment of Educational Progress, 2005

When comparing males and female performance within grade-level over time, results are mixed (refer to Table 1) (NAEP, 2005a):

- Both male and female students at grade 4 made gains since 2000.
- Eighth-grade male and female students' average science scores were not significantly different in 2005 than in previous assessment years.
- Average scores for male and female twelfth-graders were lower in 2005 than in 1996.

Table 1: Trend in Average NAEP Science Scale Scores by Gender, 1996, 2000, 2005

| Grade Level | Gender | 1996 | 2000 | 2005 |
|------------------------|---------|------|------|------|
| 4 th Grade | Males | 148 | 149 | 153 |
| | Females | 146 | 145 | 149 |
| 8 th Grade | Males | 150 | 153 | 150 |
| | Females | 148 | 146 | 147 |
| 12 th Grade | Males | 154 | 148 | 149 |
| | Females | 147 | 145 | 145 |

Further analysis shows that twelfth-graders who took biology, chemistry, and physics scored higher than students who took biology and chemistry, and both groups scored higher than those who took just biology or other science courses (NAEP, 2005b). In addition, female high school seniors' GPAs overall and their

combined math and science GPAs were higher than the GPAs of male graduates (2.76 compared to 2.56 respectively) (NAEP, 2005b).

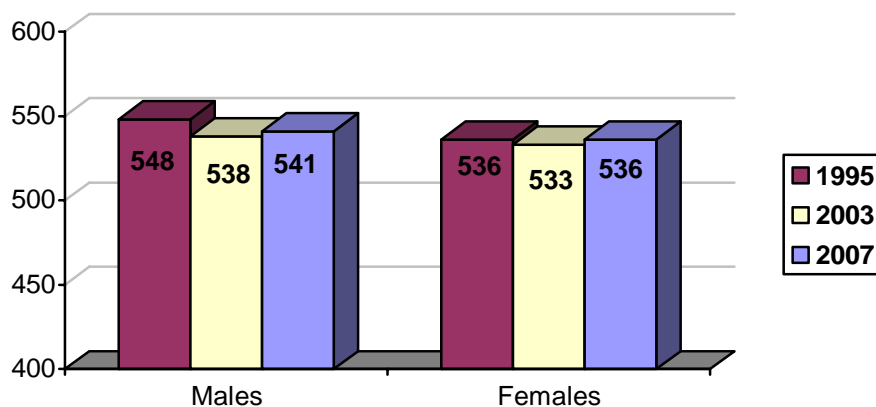
Trends in International Mathematics and Science Study (TIMSS) is conducted by the International Association for the Evaluation of Educational Achievement (IEA), an international organization of national research institutions and governmental research agencies. The assessment provides data on the mathematics and science achievement of U.S. students compared to that of students in other countries. TIMSS data was collected in 1995, 1999, 2003, and 2007. The content domains covered at grade four are *life science*, *physical science*, and *earth science*. At grade eight, the content domains are *biology*, *chemistry*, *physics*, and *earth science* (Gonzales et al., 2008; Gonzales et al., 2004).

The 2007, 2003, and 1999 results are analyzed by overall score differences by gender., Special reports created from the 1995 administration analyzed results by gender on content specific assessments as well as items that asked students about the classroom environment.

Among U.S. fourth-graders trends reveal that the science achievement gap may be narrowing between males and females:

- In 2007, males and females showed no measurable difference in their average science performance. While differences were not significant, examining performance by content areas shows males outperformed in one content area: *earth science* (536 v. 531). There was no measurable difference detected in the average scores by gender in either the *life science* or *physical science* domains.
- Males outperformed females overall in science in 2003, which was also the case in 1995.

Figure 6: Comparison of TIMSS 1995, 2003, and 2007 Fourth Grade Score Results by Gender

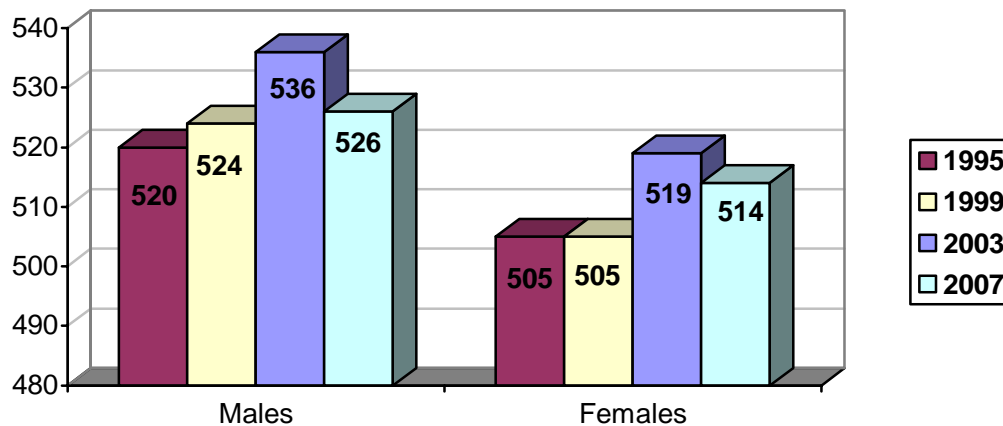


Among U.S. eighth-graders trends reveal continued higher performance in science by males in certain content areas:

- In 2007, males performed significantly higher than female classmates overall in science, scoring higher in three of the four science content domains: *biology* (533 v. 527), *physics* (514 v. 491), and *earth science* (534 v. 516). There was no measurable difference detected in the average science scores of U.S. eighth-grade males and females in the *chemistry* domain.

- In 2003, males outperformed females in science, which was also the case in 1999 and 1995 (Gonzales et al., 2004). In particular, in 1995 statistically significant differences favored males in *overall science*, *earth science*, and *physical science*, but there were no differences in *life science*, *environmental issues*, and the *nature of science*.

Figure 7: Comparison of TIMSS 2003, 1999, and 1995 Eighth Grade Score Results by Gender



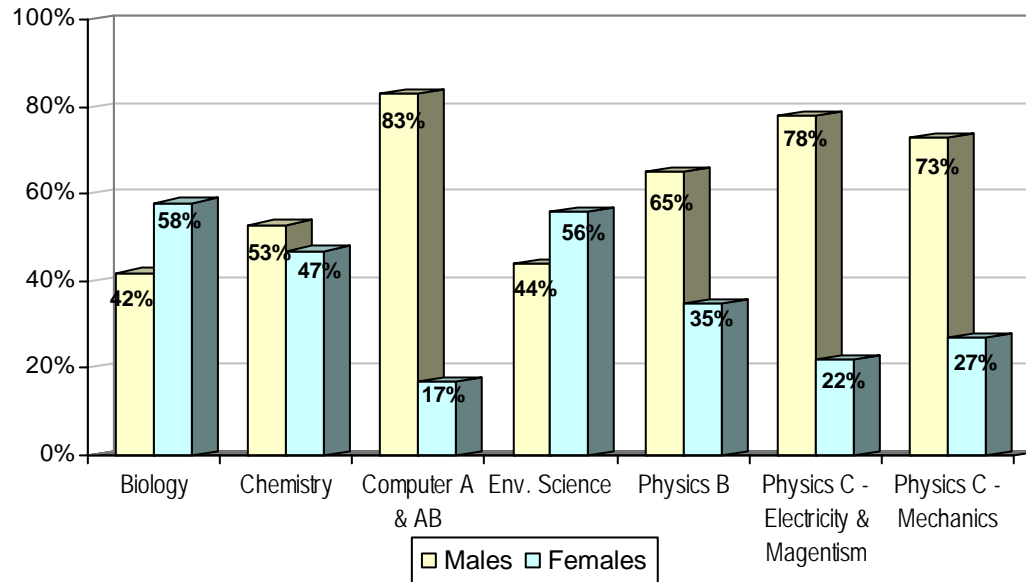
Only eighth graders were included a special 1999 study using TIMSS data (Martin et al., 2001). Among U.S. students:

- Males had significantly higher average science achievement than females in 10 of the 13 benchmarking states.
- The percentage of males reaching the upper quarter level of achievement was significantly greater than the percentage for females in all but three states.
- Gender differences in content were significant for the U.S. as a whole in *earth science* (favoring males), but not *life science* or *physics*.
- Males were more likely to report a highly positive attitude toward science.

Advanced Placement Program (AP) (*National Summary Report, 2007*). The Advanced Placement program of the College Board provides testing for high school students who participate in college level courses to obtain college credit. The tests are graded on a scale of 1 (No Recommendation) to 5 (Extremely Well Qualified), accompanied by a recommendation for approval for college credit. Thirty-five tests are available, several of which cover science: biology, chemistry, computer science A and B, environmental science, psychology, physics B, physics C: electrical and magnetic, and physics C: mechanics.

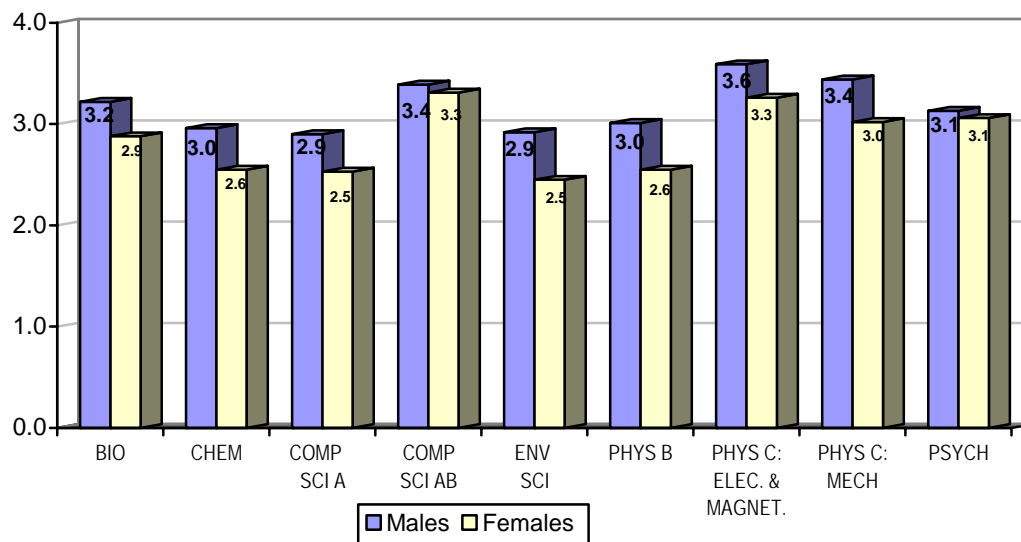
- Male students tended to take the science tests in larger percentages than female students and to score higher. The exception would be in biology and environmental science where rates are comparable (refer to Figure 8).
- Males also scored higher on the subject tests than females, with the exception of psychology (refer to Figure 9).
- A higher percentage of males also received a score of 5 than females in 2007 on science AP tests, with the exception of psychology (refer to Figure 10).

Figure 8: Percentage of AP Science Test Participants by Gender in 2007



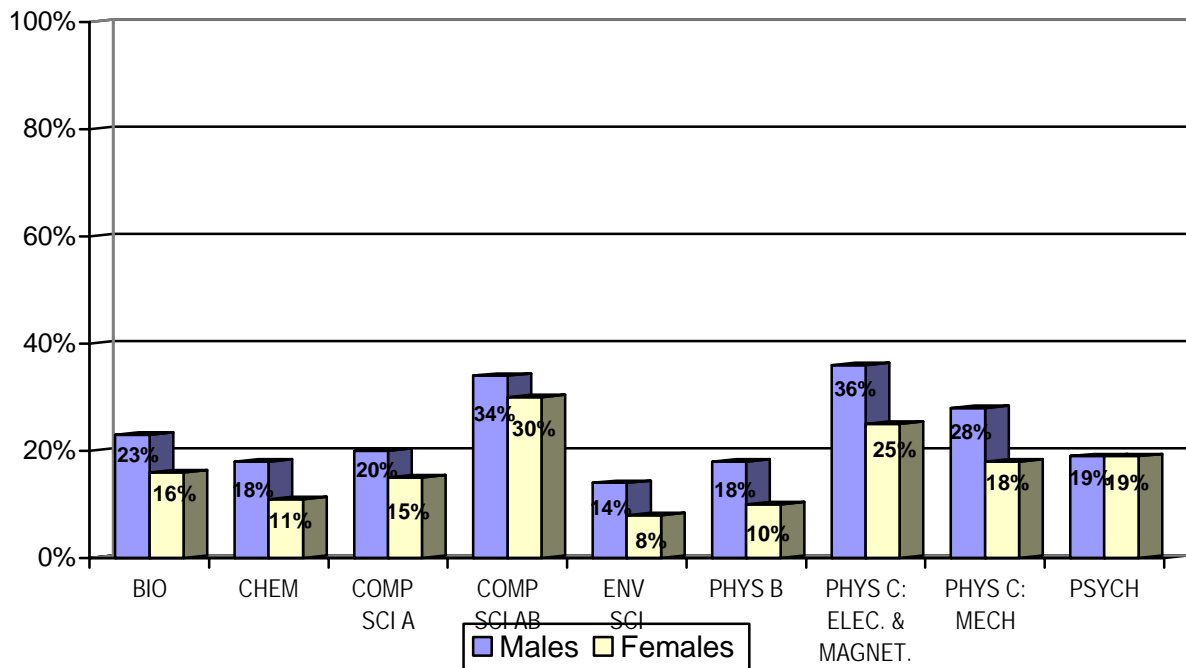
Source: National Summary Report, 2007

Figure 9: Average AP Science Test Results by Subject and Gender, 2007



Source: National Summary Report, 2007

Figure 10: Percentage of AP Science Test Participants Receiving a Score of 5 by Subject and Gender



Source: National Summary Report, 2007

Previous reports highlight differences in score patterns on AP tests by gender. The College Board is aware of the differences in male and female score patterns and has conducted at least one analysis of the question content in an attempt to identify any bias in the content or format of the biology test (Buck, Kostin, & Morgan, 2002). Analysts identified twelve categories as likely to show gender-based performance differences. Of these, males scored better on average on eleven of them. Of the eleven, eight accounted for 65% of the variance in the standardized difference. Females did better in categories related to people, such as human physiology, genetics, and inheritance, as well as cell division, and males did better in atmospheric science and experimental apparatus. When the question called for an open-ended written response, females did better (Buck, Kostin, & Morgan, 2002).

The Scholastic Aptitude Test (SAT). The SAT is a national college admissions examination accepted or required by most four-year colleges. In 2007, 1,494,531 students took the test. The *2007 College-Bound Seniors: A Profile of SAT Program Test Takers* (2007) is a report that provides data for students completing the SAT test and the SAT questionnaire during their high school years. The main SAT does not include a science assessment. The SAT II, however, includes subject tests for biology, chemistry, and physics, but the report does not include data disaggregated by gender.

The student self-report portion of the SAT includes student characteristics that may be helpful in understanding preparation in science among college-bound students. Data are not analyzed for statistical differences between groups but provide descriptive information that practitioners may find useful, for example:

- Male and female respondents report taking approximately the same average years of study in the natural sciences (females 3.5; males 3.6), while females report a higher grade point in these courses (females 3.27, males 3.23).
- A higher percentage of females report taking more than four years of natural science courses (52%) compared to males (48%).
- A higher percentage of females than males report taking courses in biology (55% females, 45% males); chemistry (55% females, 45% males), geology, earth science or space sciences (54% females, 46% males), as well as "other sciences" (59% females, 41% males) while both males and females report taking physics in equal proportions (50% females, 50% males).

ACT (*ACT High School Profile Report: HS Graduating Class, 2007*). The American College Test (ACT) assessment is a national college admission examination accepted by most U.S. colleges and universities. In 2007, 1,300,599 students took the test. The ACT consists of four content areas: English, Math, Reading and Science. The content of the Science Test includes biology, chemistry, physics, and the earth/space sciences (for example, geology, astronomy, and meteorology). The maximum score is 36.

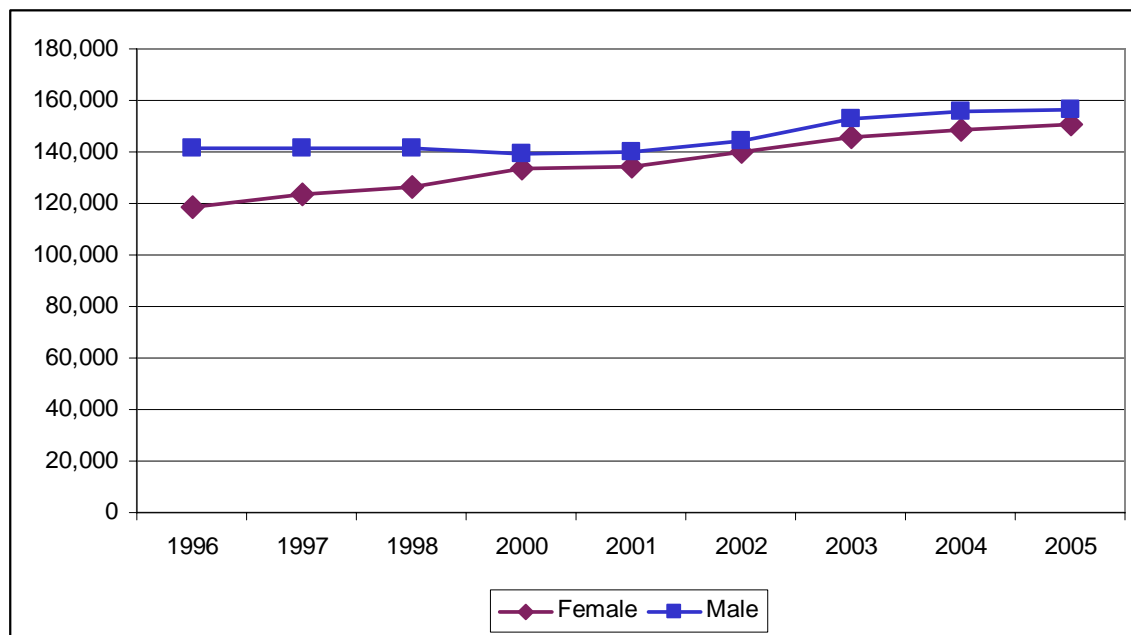
- In 2007 the average ACT score in science for females was 20.5 and for males 21.4. Differences are not analyzed for statistical significance.
- The ACT reports College Readiness Benchmark Scores. A benchmark score is the minimum score needed on an ACT subject-area test to indicate a 50% chance of obtaining a B or higher or about a 75% chance of obtaining a C or higher in the corresponding credit-bearing college courses, which would include an entry-level biology course. These scores were empirically derived based on the actual performance of students in college. During 2007, 24% of females met the college readiness benchmark score in science compared to 32% of males.

One research study by the ACT reports that, when other variables are controlled for such as high school grade point average, course taking, and student self-perceptions among others race/ethnicity or gender explained only 1% to 2% of the additional variance over and above the other variables considered. This finding underscores the minimal role that gender plays in explaining differences in science achievement between males and females (Noble, Davenport, Schiel, & Pommerich, 1999).

Undergraduate Trends

More women than men pursue a postsecondary degree in the U.S.; however this trend is not reflected in the number of females who choose to pursue an undergraduate degree in science or engineering. At the postsecondary level, gender differences in science achievement become more pronounced, with males pursuing and attaining degrees in STEM fields at disproportionately higher rates (refer to Figure 11) (National Science Foundation, 2005; National Research Council [NRC], 2006).

Figure 11: Bachelor's degrees awarded in S&E fields by gender: 1966–2005



Note: National data for 1999 not available; Source: National Science Foundation, Division of Science Resources Statistics, special tabulations of U.S. Department of Education, National Center for Education Statistics, Integrated Postsecondary Education Data System, Completions Survey, 1966–2005.

Closer examination of these trends reveals that in particular, computer science, physical science, and engineering show the greatest differences with males attaining more baccalaureate degrees in these fields while females attain more degrees in biological sciences and psychology (refer to Table 2) (National Science Foundation, 2005).

Table 2: Bachelor's degrees awarded in S&E fields by field of study and gender: 1966–2005

| | 1966 | | 2000 | | 2005 | |
|--------------------------------------|---------|---------|---------|---------|---------|---------|
| | Male | Female | Male | Female | Male | Female |
| Agricultural sciences | 9,884 | 6,504 | 9,780 | 8,464 | 8,380 | 8,731 |
| Biological sciences | 29,216 | 32,865 | 26,946 | 37,958 | 25,699 | 42,283 |
| Computer sciences | 17,773 | 6,772 | 26,914 | 10,474 | 39,329 | 11,235 |
| Earth, atmospheric, & ocean sciences | 2,972 | 1,485 | 2,430 | 1,617 | 2,299 | 1,660 |
| Physical sciences | 9,694 | 5,702 | 8,590 | 5,990 | 8,610 | 6,420 |
| Psychology | 19,965 | 53,863 | 17,540 | 57,114 | 19,103 | 66,833 |
| Engineering | 51,798 | 11,316 | 47,320 | 12,216 | 52,936 | 13,197 |
| Total Degrees Awarded by Gender | 141,302 | 118,507 | 139,520 | 133,833 | 156,356 | 150,359 |
| Total Degrees Awarded | 259,809 | | 273,353 | | 306,715 | |

Note: National data for 1999 not available; Source: National Science Foundation, Division of Science Resources Statistics, special tabulations of U.S. Department of Education, National Center for Education Statistics, Integrated Postsecondary Education Data System, Completions Survey, 1966–2005.

Clewell and Campbell (2002) cite an encouraging development that once women enroll in science majors, they are more likely to complete within 5 years (48.6% of females compared with 40.4% males) and females are less likely than males to switch majors (11.5% of females compared with 19.4% males).

Meta-Analytic Studies of Gender Differences in Science Achievement and Issues Associated with Continued Gender Differences in Science Achievement

Trends highlighted in the previous section show that differences in science achievement between males and females in K-12 education have narrowed over time; however, differences by gender in performance, as measured by multiple assessments, remain. Studies have sought to examine these issues in more detail.

Among high school students, cognitive abilities that include previous science knowledge as well as reading ability as measured by traditional content-based tests have been shown to predict students' comprehension of science passages, science course grade, and state science test scores differently for males and females. Males scored higher on science knowledge and on reading comprehension whereas females scored significantly higher on science strategy knowledge (O'Reilly & McNamara, 2007). In terms of the format of questions and differences by gender on content-based tests, males were shown to score higher on both multiple choice and open-ended questions than females (Penner, 2003; O'Reilly & McNamara, 2007).

The science courses students take in high school influence subsequent performance in advanced courses. A study conducted by Madigan (1997) used national data on science achievement and transcript reports of science course taking of students from the NELS to determine the relationship between student science course taking and the change in student science proficiency level between 8th and 12th grades. Results from the study found overall, 54% of students showed an increase in their science proficiency level, while 35% stayed at the same level and 11% declined. The chances of increasing in science proficiency level varied with the demographic and academic characteristics of students. In particular, male students were more likely than females to increase their science proficiency level between 8th and 12th grades. Gender continued to influence the likelihood of increasing in science proficiency level even after controlling for differences in previous science course taking. Males were more likely to increase in science proficiency than females and they were more likely to have taken physics (31% of males took physics versus 24% of females), but differences in the number of courses taken were not found. Findings suggest that course taking may account for at least some of the observable differences between groups in the likelihood of increasing in science proficiency level. Taking eight or more semesters of science was positively associated with an increase in science proficiency level between 8th and 12th grades even when other factors such as socioeconomic status (SES), achievement level in eighth grade, gender, and race-ethnicity were held constant (Madigan, 1997).

Given the importance of physics in undergraduate coursework for related science degrees, studies have examined what influences the achievement in physics courses in particular for males and females. High school physics coursework (content, pedagogy, and assessment) and confidence in physics courses were

examined to determine their role in predicting introductory university physics performance. Results reveal that high school physics and affective experiences differentially predicted female and male performance. The amount of time spent covering specific topics in physics was a positive predictor for both males and females whereas lack of encouragement at home to pursue a science career had a negative affect on university performance in physics. High school physics courses that required a full understanding of topics seemed to benefit female students more than male students. Alternatively, university physics courses that required memorization seemed to benefit male students more than female students. Females who reported doing long-written problems on a weekly basis performed worse than their male counterparts. Finally, the performance of females increased if they reported that their father encouraged them (Hazari, Tai, & Saddler, 2007).

Several previous studies have focused on score differences by gender in science achievement. However, it is important to note that recent assessments show that gender differences in science achievement have narrowed over time while previous studies using cohorts from prior years have found significant differences in science achievement. However, the findings from these selected studies are still useful as educators consider how to encourage continued advancement of females in STEM disciplines. In addition, repeating these studies using more recent data might provide additional insights, confirming or denying earlier findings. For example, Bacharach, Baumeister, and Furr (2003) examined the science performance among eighth grade students included in the NELS dataset. They found that the average eighth grade science achievement scores were significantly different for males and females. The gender gap in scores grew with age so that females were at an increasing disadvantage by high school. A study by Lee and Burkam (1996) also examined gender difference in eighth grade science achievement found in the NELS data. Although females had better grades in science and a slight advantage in life science, females do not perform as well in physical science; this latter difference is most pronounced at the highest level of ability. The authors suggest that this may be due to differences in laboratory experience. Laboratory experiences were more beneficial to the females than to the males on physical science achievement, but were not common in the eighth grade classrooms surveyed. Further, females were less likely than males to participate in science activities outside the classroom, to visit science museums, and to have positive attitudes about science and about their science classes (Lee & Burkam, 1996).

Gender-biased classroom practices have been shown to negatively impact the performance of females in science. By giving more attention to male students during science instruction, teachers may inadvertently be sending the message that female students are less capable in these areas (Sandler, Silverberg, & Hall, 1996). Negative attitudes about science related disciplines that are driven by gender-biased stereotypes may influence the number of women who pursue degrees in STEM fields. Stereotypical views held by female students as well as parents that science is a male-dominated field may prevent women from seeing benefits related to pursuing a career in science disciplines (National Research Council, 2006). Among those who do enroll in STEM disciplines, stereotypes of science being a male-dominated field are perpetrated as females see few female role models in the STEM careers. Furthermore, females who choose to pursue careers in STEM fields are the minority and find themselves isolated in a male dominated environment (National Research Council, 2006). With regard to postsecondary education, reports suggest that women who enter science majors are likely to have strong family support, high expectations, self-confidence, and appropriate academic preparation. However, following enrollment a variety of environmental factors works to lower confidence and impact the scientific achievement of females negatively (Brainard & Carlin, 1998; Society of Women Engineers, 2008). These factors result in women

undergraduates having less interest, lower expectations for success, and decreased confidence in science related fields than males, ultimately impacting persistence to degree attainment (Xie & Shauman, 2003).

The manner in which subject matter is covered has been highlighted as an important factor affecting the science achievement of females. One meta-analysis found several strategies that had a positive impact on science achievement among students, including females. These strategies include relating learning to students' previous experiences, collaborative learning, varying the level and type of questions asked during lessons, using inquiry based approaches that allow for hands-on manipulation of science material, employing a variety of assessment methods, and incorporating instructional technology into lessons (Schroeder, Scott, Huang, Tolson, & Lee, 2007). In addition, females tend to perform better on areas of standardized science assessments that address the human application of science such as life sciences. In addition, females tend to enroll in advanced coursework and pursue degrees in science fields that have a direct application to improving the human condition (Ingels & Dalton, 2008; NAEP, 2005). These trends suggest that females may be turned off from studying STEM subject matter and pursuing careers in STEM fields due to stereotypes that such fields have little or no impact on the human condition (Green, 2009).

Synthesis of Findings

Effects of Gender Differences in Science Achievement on Individual Performance

The literature reviewed describes the degree to which gender differences in science achievement negatively impacts the pipeline for females into STEM related fields. Implications for practitioners related to these trends and successful interventions can be employed to address gender differences in science achievement.

Implications for Practitioners

Research has sought to identify plausible explanations for differences in science achievement between males and females. Findings have implications for K-16 teaching professionals that should be considered when designing programmatic interventions:

- Assessments at the national level and employed in classrooms used to measure science achievement should be reviewed for gender bias given the reported trends associated with female achievement in high school science courses that is comparable to male counterparts (Sandler, Silverberg, & Hall, 1996).
- Parents' perceptions of their children's ability and expectations for success may be related to science achievement. Specifically, parents held higher perceptions of mathematical abilities and higher expectations of success in STEM education and related careers for males than for females (Wang, 2007; Trenor, 2007).
- Science achievement may be related to students' self-concept and interest. Female engineering students have shown a notable drop in academic self-confidence during their first-year in college (Brainard & Carlin, 1998). The Assessing Women and Men in Engineering Applying Research to Practice resource on *Interest and Academic Self-Concept* found online at <http://www.engr.psu.edu/awe/> addresses this in greater detail.

- Math preparation may influence science achievement. While females have made considerable gains in science achievement, math skills may still be lacking thereby influencing performance in science-related majors (Clewel & Campbell, 2002; Trenor, 2007). Math coursetaking patterns and math achievement by gender are addressed in greater detail in the Assessing Women and Men in Engineering Applying Research to Practice resource on *Gender Differences in Math Performance* found online at <http://www.engr.psu.edu/awe/>.
- Among undergraduates, stereotypes may exist that science is a male dominated field, which is further reinforced by lack of role models in STEM disciplines, affecting persistence. Females are likely to find fewer peer, faculty, and established scientists who are also female, leading to feelings of isolation during their educational experience (Clewel & Campbell, 2002; Trenor, 2007). Perceptions may also impact the interest of females in STEM related careers. Females who anticipated a career to be male-dominated, which could increase the likelihood of occurrences of sexist behavior, had less interest in those fields (Ghariyan, 2007).
- Teacher attitudes and behaviors may vary depending on the gender of the student; possibly creating classroom climates that are biased towards males. Commonly referred to as a “chilly classroom climate” females may be interrupted more often, called by name less often, receive less eye contact, and receive more praise for their appearance than for their work (Sandler, Silverberg, & Hall, 1996).
- School characteristics such as school size and availability of school resources may also influence career choices of females. An increase in school resources led to an increase in females’ interest in STEM-related disciplines (Clewel & Campbell, 2002; Wang, 2007).
- Skills needed for scientific achievement include verbal, cognitive, and quantitative abilities. National assessments used to measure science achievement may target only a narrow portion of these skills. Practitioners should consider using a variety of assessment methods, other than multiple-choice tests, to gauge student achievement in science so that they have a more complete picture of students’ strengths and weaknesses (Halpern, et al., 2007; O’Reilly & McNamara, 2007).
- Results from national assessments reveal that females tend to do better in science content areas that are linked to people. Instructors may want to consider pedagogical strategies that emphasize humanitarian applications of science and engineering concepts as way to address the different interests and learning styles of diverse student groups (Ingels & Dalton, 2008; Schroeder, Scott, Tolson, Huang, & Lee, 2007).

Interventions and Successful Programmatic Initiatives in STEM Disciplines to Address Gender Differences in Science Achievement

Several interventions and initiatives have proved successful with regard to addressing the gender gap in science achievement. In most cases, the programs employed are used in conjunction with one another to comprehensively address issues associated with gender gaps in science achievement (Clewel & Campbell, 2002; Trenor, 2007):

- Recruitment initiatives designed to target females among K-12 students should discuss the careers available, academic preparation needed to be successful, and address stereotypes females entering STEM disciplines. Addressing these factors may better prepare female students and

facilitate retention. These initiatives should include the females themselves and also educate high school teachers, counselors, and parents (Cunningham, 2007).

- Instructional environments that integrate math and science preparation may help address gender gaps in science achievement given the manner in which academic preparation in the two fields is needed for attainment of undergraduate degrees (Brainard & Carlin, 1998). Curricular examples at the undergraduate level in STEM disciplines are provided at <http://www.foundationcoalition.org/home/keycomponents/CurriculumIntegration/intro.html#3> with more detailed information found at http://www.foundationcoalition.org/home/keycomponents/curriculum_integration.html. K-12 professionals may find the Making the Connections materials designed to introduce students to engineering concepts and integrate math and science curriculum found at <http://wepan.affiniscape.com/displaycommon.cfm?an=1&subarticlenbr=38> useful. The materials also designed to dispel gender-based stereotypes.
- At the undergraduate level community support among female undergraduates in the form of living-learning communities may help relieve feelings of isolation and encourage attainment of degrees (Gabelnick, MacGregor, Matthews, & Smith, 1990). These programs can be designed so that students take a cluster of courses together, providing further support and academic integration. Examples of programs underway to support engineering undergraduates are outlined at http://www.foundationcoalition.org/publications/brochures/lc_introduction.pdf
- Instructional environments that utilize a variety of strategies and employ pedagogical strategies that address different learning styles have been shown to encourage female achievement in science classrooms (Schroeder, Scott, Tolson, Huang, & Lee, 2007). Professional development activities that emphasize gender equity in the science classroom have proven to be successful in addressing differences in science achievement by gender (Urban Institute, 2001). *Reaching All Students: A Resource Book for Teaching in Science, Technology, Engineering and Mathematics (STEM)* found online at <http://www.cirtl.net/DiversityResources/resources/resource-book/> contains articles that focus on teaching, learning and diversity for instructors in STEM fields and discusses instructional methods as well as student learning styles.
- Providing a series of integrated programming that incorporates such strategies as mentoring, professional development, career development, and involving the parents of students have been shown to have the most encouraging results related to female involvement in STEM fields (Urban Institute, 2001). A short but useful list of example programs and contact information can be found online at <http://www.aauw.org/education/ngcp/upload/BranchSTEM2007.pdf>
- Among middle school students, science achievement was improved through the use of NSF produced materials, professional development for teachers, and using in-class coaches to reinforce teachers' efforts to use the NSF science materials. Practitioners interested in duplicating a program similar to this would benefit from reading the article by Ruby (2006).

Recommendations for Practitioners

- Practitioners should consider findings from national studies when designing gender based initiatives to address differences in science achievement, focusing on what content areas have shown the greatest differences between males and females in science achievement. Focusing on increasing the skills of females in specific content areas may raise associated performance levels on standardized assessments.

- Given the influence of parent's expectations for STEM education and STEM careers on the future career aspirations among females, practitioners should consider informing parents of female students about career opportunities in STEM fields and what academic preparation is needed to be successful in these fields (Wang, 2007; Trenor, 2007).
- Instructional professionals, including administrators, should examine gender bias that may be inherent in science classrooms including teacher's attitudes, behaviors, and pedagogical strategies (Sandler, Silverberg, & Hall, 1996).
- At the same time, educational experiences should also serve to build confidence among females with regard to application of science knowledge and skills (Brainard & Carlin, 1998).
- At the administrative level, K-12 practitioners should consider emphasizing instructional environments that integrate math and science. Academic preparation in the two fields is needed for attainment of undergraduate degrees. Tracking the number of females enrolling and completing physics courses at the high school level is also important as studies have linked degree attainment in STEM fields to successful completion of high school physics coursework (Clewell & Campbell, 2002; Trenor, 2007).
- Financial support of science education should be reviewed. Schools that devote resources to science education and provide a variety of opportunities such as lab experiences and field trips have seen favorable results with regard to science achievement among females (Clewell & Campbell, 2002; Wang, 2007).
- Practitioners at the undergraduate level should monitor educational environments for overt gender bias and develop community support among female undergraduates in the form of living-learning communities or programmatic interventions such as mentoring. This type of support may help relieve feelings of isolation and encourage attainment of degrees (Clewell & Campbell, 2002; Trenor, 2007).

Research Agenda and Conclusions

Trends in science achievement reveal that there are instances of females performing equally well as their male peers in science achievement as it pertains to courses completed at the K-12 level and performance in those classrooms. However, when measured by standardized tests, gender gaps in science achievement as it pertains to content still exist. Differences in performance on standardized tests as well as lack of interest among females in careers such as engineering have been attributed to some degree to factors that are part of the educational experience of students that affect female performance in science achievement.

Given the disconnect between reported performance on standardized assessments and research that has looked at environmental variables that are part of educational experiences impacting success, additional research is needed to further examine gender differences in science achievement. Future studies would benefit from looking at how ethnicity, gender, and environmental variables interact to influence science achievement and persistence through science coursework. Research can examine whether reform-oriented instructional environments are more likely to encourage science achievement equally among females and males. Standardized assessment tools should be examined for gender-bias given the fact females enroll in and complete science coursework at rates equal to male peers but do not perform as well on some content areas. At the postsecondary level, studies could examine whether institutions with programs to support females in STEM disciplines are more likely to see degree attainment among females in STEM fields. Across levels of education it would be useful to pair GPA data with performance on standardized

assessments and explore differences by gender. Doing so may shed additional insights to how and what students are learning and whether content is being delivered and assessed in an effective manner.

Information about formal learning experiences (such as science coursework completed by gender) among students has been collected; however, informal learning experiences such as participation in science competitions or learning through science-related field trips has not been examined. Teacher preparation in STEM disciplines and the relation to student achievement by gender would also provide useful information. At the postsecondary level, trends related to student involvement in hands-on research experiences and differences among males and females may prove useful to understanding why females exit STEM fields in greater numbers, particularly whether these experiences are with male or female faculty.

Despite additional research that needs to be done in this area, studies reveal that practical changes made within instructional environments can have a positive influence on female interest and success in STEM disciplines across age groups. Creating inclusive classroom climates that address different learning styles among students can have favorable results in relation to science achievement and subsequent interest among both females and males in STEM careers (Clewell & Campbell, 2002; Trenor, 2007).

References

- American College Testing Program. (2007). *ACT High School Profile Report: HS Graduating Class 2007*. HS Graduating Class National Report, Iowa City: American College Testing Program.
- Bacharach, V. R., Baumeister, A. A., & Furr, R. M. (2003). Racial and gender science achievement gaps in secondary education. *The Journal of Genetic Psychology, 164*(1), 115-126.
- Brainard, S. G., & Carlin, L. (1998) A Six-Year Longitudinal Study of Undergraduate Women in Engineering and Science. *Journal of Engineering Education*, October.
- Buck, G., Kostin, I., & Morgan, R. (2002). *Examining the Relationship of Content to Gender-Based Performance Differences in Advanced Placement Exams* (2002-02 ETS RR-02-25). New York: College Entrance Examination Board.
- Clewell, B. C., & Campbell, P. B. (2002). *Taking Stock: Where We've Been, Where We Are, Where We're Going*. Retrieved August 10, 2008, from <http://www.urban.org/url.cfm?ID=1000779>
- College Board. (2007). *National Summary Report, 2007*. Retrieved August 9, 2008, from http://www.collegeboard.com/student/testing/ap/exgrd_sum/2007.html
- Cunningham, C. (2007). Implications of Recent Contributions to Research on K-12 Engineering and Technology Education on STEM Education. Conference Proceedings, 2007 DR-K-12 PI Meeting. September 2007, Arlington, VA.
- Dalton, B., Ingels, S. J., Downing, J., & Bozick, R. (2007). *Advanced Mathematics and Science Course-Taking in the Spring High School Senior Classes of 1982, 1992, and 2004* (NCES 2007-312). Washington, DC: National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education.
- Gharibyan, H. (2007). Gender Gap in Computer Science: Studying its Absence in One Former Soviet Republic. ASEE 2007 Proceedings: 2007 Annual Conference. Retrieved March 1, 2009, from <http://soa.asee.org/paper/conference/paper-view.cfm?id=4013>
- Gabelnick, F., MacGregor, J., Matthews, R. S., & Smith, B. L. (1990). Learning communities: creating connections among students, faculty, and disciplines. *New Directions for Teaching and Learning: 41*.
- Gonzales, P., Guzmán, J. C., Partelow, L., Pahlke, E., Jocelyn, L., Kastberg, D., et al. (2004). *Highlights from the Trends in International Mathematics and Science Study (TIMSS) 2003* (NCES 2005-005). U.S. Department of Education, National Center for Education Statistics. Washington, DC: U.S. Government Printing Office.
- Gonzales, P., Williams, T., Jocelyn, L., Roey, S. Kastberg, D., & Brenwald, S. (2008). *Highlights from the Trends in International Mathematics and Science Study (TIMSS) 2007*. U.S. Department of Education, National Center for Education Statistics. Washington, DC: U.S. Government Printing Office.
- Green, L. (2009, March 7). Despite academic draws, engineering turns girls off more than ever. *Palm Beach Post.com*. Retrieved March 1, 2009, from http://www.palmbeachpost.com/news/content/local_news/epaper/2009/03/07/0307girlengineers.html?cxtype=rss&cxsv c=7&cxcat=76
- Halpern, D. F., Benbow, C. P. Geary, D. C., Gur, R. C., Hyde, J. C., & Gernsbacher, M. A. (2007). Sex, Math and scientific achievement: Why do men dominate the fields of science, engineering and mathematics? *Mind & Brain, November, 2007*.
- Hazari, A., Tai, R. H., & Sadler, P. M. (2007). Gender differences in introductory university physics performance: The influence of high school physics preparation and affective factors. *Science Education, 91*(6), 847-877.

- Ingels, S. J., & Dalton, B. W. (2008). *Trends Among High School Seniors, 1972–2004* (NCES 2008-320). Washington, DC: National Center for Education Statistics, Institute for Education Sciences, U.S. Department of Education.
- Lee, V., & Burkam, D. (1996). Gender differences in middle grade science achievement: Subject domain, ability level and course emphasis. *Science Education*, 80(6), 613-650.
- Madigan, T. (1997). *Science Proficiency and Course Taking in High School: The Relationship of Science Course-taking Patterns to Increases in Science Proficiency Between 8th and 12th Grades*, NCES 97-838, Washington, D.C.: U.S. Department of Education, National Center of Education Statistics.
- Mullis, I. V. S., Martin, M. O., & Foy, P. (2008). *TIMSS 2007 International Report: Findings from IEA's Trends in International Mathematics and Science Study at the Fourth and Eighth Grades*. Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Boston College.
- National Assessment of Educational Progress. (2005a). *The Nation's Report Card: Science*. Retrieved August 8, 2008, from http://nationsreportcard.gov/science_2005
- National Assessment of Educational Progress. (2005b). *America's High School Graduates: Results from the 2005 NAEP High School Transcript Study*. Retrieved August 14, 2008, from <http://nces.ed.gov/nationsreportcard/hsts/>
- National Education Longitudinal Study*. (2004). Washington, DC: National Center for Educational Statistics. Retrieved August 7, 2008, from <http://nces.ed.gov/surveys/nels88/>
- National Research Council. (2006). *To Recruit and Advance: Women Students and Faculty in Science and Engineering*. Retrieved August 3, 2008, from http://www.nap.edu/catalog.php?record_id=11624
- National Science Foundation. (2008). *Science and Engineering Indicators 2008*. Retrieved August 7, 2008, from <http://www.nsf.gov/statistics/seind08/c0/c0i.htm>
- National Science Foundation (2005). *Women, Minorities, and Persons with Disabilities in Science and Engineering*. Retrieved August 11, 2008, from <http://www.nsf.gov/statistics/wmpd/sex.htm>.
- Noble, J., Davenport, M., Schiel, J., & Pommerich, M. (1999). *High School Academic and Non-cognitive Variables Related to the ACT Scores of Racial/Ethnic and Gender Groups* (99-9 [50299960]). Iowa City: ACT, Inc.
- O'Reilly, T., & McNamara, D. S. (2007). The impact of science knowledge, reading skill, and reading strategy knowledge on more traditional 'high stakes' measures of high school students' science achievement. *American Educational Research Journal*, 44(1), 161-197.
- Penner, A. M. (2003). International gender x item difficulty interactions in mathematics and science achievement tests. *Journal of Educational Psychology*, 95(3), 650-655.
- Ruby, A. (2006). Improving science achievement at high-poverty urban middle schools. *Science Education*, 10, 1005-1027.
- Sandler, B., Silverberg, L. A., & Hall, R. M. (1996). *The Chilly Classroom Climate: A Guide to Improve The Education of Women*. ED396984. Washington, DC: National Association for Women in Education.
- Schroeder, C.M., Scott, T.P., Tolson, H., Huang, T. & Lee, Y. (2007). A meta-analysis of national research: Effects of teaching strategies on student achievement in science in the United States. *Journal of Research in Science Teaching*, 44(10): 1436-1460.
- Society of Women Engineers. 2008. Women in Engineering: A Review of the Literature. *Society of Women Engineers*, Summer, 2008.

Trenor, J. M. (2007). *The Women-In-Engineering Pipeline*. Retrieved August 7, 2008, from http://www.eweek.org/site/News/Eweek/2007_marathon/Trenor.ppt#258,7,The%20women-in-engineering%20pipeline

The Urban Institute. (2001). *Summary Report on the Impact Study of the National Science Foundation's Program for Women and Girls*. Arlington, VA: National Science Foundation. NSF 01-27.

Wang, X. (2007). *Gender Gap in STEM Postsecondary Education: Findings from NELS:88*. Retrieved August 20, 2008, from <http://www.niss.org/affiliates/planning200704/documents/wang20070426.pdf>