What Works: Using Curriculum and Pedagogy to Increase Girls’ Interest and Participation in Science

This article identifies instructional strategies, curricula, and organizational structures in the research literature that have been successful in encouraging girls’ participation and achievement in science: science instruction in pre-kindergarten and kindergarten, relevant curricula that address girls’ interests and provide opportunities for genuine inquiry and tinkering experiences, greater emphasis on physical science and the use of computers, integration of reading and writing in science, attention to how groups are formed in classrooms, activities that build self-efficacy, appropriate role models, messages that science is for everyone, and student-centered teaching. Special attention is given to the needs of children in preschool and kindergarten. In addition, research on the impact of single-sex classrooms and grouping is reviewed, along with the use of children’s fictional literature to teach science. Implications derived from research literature include changes in what is taught, how it is taught, how teachers are prepared, and how these changes are paid for.

There are many research-based instructional strategies that teachers can use to enhance achievement, self-efficacy, and participation of girls in science. Some of these strategies seem self-evident, but others go against common assumptions about what works. But first, let’s take a look at why educators are concerned about girls and science.

Women now earn about half of the overall number of bachelor’s degrees in science. In contrast, they are conspicuously absent in certain subfields, including engineering, computer science, and physics. In fact, women’s share of bachelor degrees in these areas has even declined in recent years (National Science Board, 2010).
Given these statistics, this literature review focuses on science in general, with an in-depth look at physics, which is a gate-keeping subject for engineering and computer science. An in-depth look at these areas is warranted because engineering and computer science are growth areas with increased opportunities for employment.

Strategies to Improve Achievement

According to our national report card (National Assessment of Educational Progress 2010), boys outperform girls in science at grades four, eight, and twelve. This lower performance in science has the potential to put females at an economic and employment disadvantage because the rate of job growth in science, technology, engineering, and mathematics (STEM) fields is 26% greater than non-STEM fields and salaries in STEM fields are three times greater than salaries in non-STEM fields (US Department of Commerce, 2011). Thus, it is important that we encourage and prepare girls for STEM careers, especially in computer science and engineering where women continue to be underrepresented.

Improving achievement requires changes in the curriculum. Standards-based thematic units, framed around a few primary concepts that address real-world experiences of interest to girls, such as investigating bicycle safety helmets to study forces and motion or investigating the relationship of physics to the human body, can make a real difference in achievement when these activities are writing intensive, involve hands-on work, and require genuine inquiry (National Science Foundation, 2003).

Improving achievement also requires changes in how teachers teach. Instructional strategies that focus on the student, rather than the teacher, have been successful in narrowing the achievement gap between boys and girls, especially in the physical sciences in high school. These strategies include real-world experiences of interest to girls, student presentations to classmates, student participation in the development of rubrics to assess their own learning, and classroom interactions that value the students’ points of view (Haus-sler & Hoffman, 2002). In particular, increasing hands-on laboratory experiences and active involvement enhance girls’ achievement, especially in physical science (Kahle & Meece, 1994). Design-based learning, such as building an electrical alarm system to learn about electricity, also enhances achievement, especially for low-achieving middle school African American girls (Mehalik, Doppel, & Schunn, 2008). However, for these strategies to be successful, the teacher must provide sufficient materials so that everyone can participate. Having enough materials to go around prevents some girls from being passive observers and prevents some boys from dominating the use of materials. Furthermore, the teacher must allocate enough time to complete hands-on inquiry activities, including time for revision and discussion.

Providing girls with out-of-school academic activities and homework also contributes to higher achievement (Chambers & Schreiber, 2004). In addition, metacognitive self-management when reading science texts (how much of the text is understood and what to do when the text is not understood) can help girls (Spence, Yore, & Williams, 1999) if they are instructed in how to use reading strategies that focus attention on the structure and organization of the text, accessing prior knowledge of the text topic, identifying the main ideas, using context to define words, and summarizing.

Different grouping strategies can be effective when the goal of grouping is to foster purposeful discussion and understanding. All-girl groups are sometimes more effective than mixed-sex groups (Bennett, Hogarth, Lubben, Campbell, & Robinson, 2010) but, contrary to what many think, single-sex classrooms do not have an impact on science achievement (Baker, 2002).

Strategies to Enhance Confidence, Competence, and Self-Efficacy

Single-sex classrooms do have an impact on increasing girls’ confidence about their work (Rennie & Parker, 1997) and the single-sex environment creates a more comfortable atmo-
Diversity and Equity in Science Education

sphere for asking questions (Streitmatter, 1999; Wollman, 1990). Design-based activities, such as building a mousetrap car that goes the farthest, also increases elementary and middle school girls’ confidence in their technological competence.

Self-efficacy is a more specific form of competence/confidence. Rather than a general belief about one’s ability to be successful, self-efficacy is the belief that one can be successful in well defined areas such as science. Increasing self-efficacy in science is particularly important for girls, especially gifted girls, because they often have less belief in their competence on tasks they think of as masculine (Usher & Pajares, 2008). For example, girls often do not take courses like chemistry in high school because they fear failing and do “not wish to move out of their comfort zone” (Cousins, 2007, p. 724) and because they have received messages from their peers that chemistry is difficult and a male subject. As a consequence, instructional strategies and curriculum that builds self-efficacy is a must.

Self-efficacy can be increased for girls by providing them with opportunities to increase their mastery experiences through the successful completion of science-related tasks. Girls also need to receive positive messages about their competence in science from those who count most, such as their teacher and school principal. Vicarious experiences, such as observing others like themselves (peer models) succeed at science-related tasks, is another way that teachers can increase girls’ self-efficacy in biology, physical science, and especially Earth science (Britner, 2008). Increasing girls’ self-efficacy results in the perseverance and resiliency to pursue careers in science-related fields (Zeldin & Pajares, 2000). All of these strategies work best in a threat-free environment where risk taking is encouraged.

Strategies to Increase Participation

Increasing participation is, in part, dependent upon developing a science identity and interest in science careers. The most effective role models for girls are women near their own age, such as female undergraduate science majors or graduate students who can talk about their experiences in nontraditional fields (Evans & Whigham, 1995; National Science Foundation, 2003). However, before bringing role models into the classroom, the teacher should provide some coaching to insure equitable interactions with male and female students in terms of asking questions and providing feedback to questions (She & Barrow, 1997). Female teachers can also serve as role models, especially if they are seen as experts. Having a female science teacher can increase female students’ self-efficacy, identification with a domain of science, and increased commitment to science careers (Stout, Dasgupta, Hunsinger, & McManus, 2011).

A curriculum that has a strong conceptual framework and is contextualized with real-world problems, rather than abstract problems, also contributes to girls’ science identity, especially in physics (Hazari, Sonnert, Sadler, & Shanahan, 2010). A curriculum that has a strong affective component and relevant topics that addresses girls’ concerns, such as saving the Earth and helping animals and people, is another way to enhance girls’ interest in science (Baker & Leary, 1995) as does a curriculum that emphasizes the aesthetics of science, technology, and engineering (Tobin, 1996). Using the learning cycle (sometimes called the five E cycle) where there is an expectation that students will find the answers to investigations and develop concepts for themselves, while working in groups, also results in girls liking science more and increases their intentions to take more science courses in the future (Cavallo & Laubach, 2001).

However, to create a girls’ science identity, more than the curriculum must change. The messages sent during instruction must also build a science identity. Teachers who talk about the innate science talent of both women and men, refer to scientists as smart women and men, use gender neutral language and examples of women in science, and do not create classroom hierarchies that place boys at the top of the class send messages that science is for everyone.
(Carlone, 2004; National Science Foundation, 2003).

Again, contrary to what many think, single-sex science classrooms do not have an impact on girls’ intentions to take more science courses in the future (Forgasz & Leder, 1996), but single sex-classrooms have increased the number of girls in some technology courses that emphasized computer programming with girl-friendly design and drawing activities (American Society of Engineering Education, 2011). In addition, single-sex classrooms provide more opportunities for girls to participate in science activities and have more interactions with the teacher than coeducational classrooms (Parker & Rennie, 2002). The conclusions one can draw from a large body of research on single-sex education is that, although it does no harm, the evidence for benefits is equivocal and context specific (Mael, Alonzo, Gibson, Rogers, & Smith, 2005).

Grouping arrangements within classrooms also have an effect on increasing girls’ participation in science. Placing middle school girls in mixed-sex groups in classrooms where inquiry is the norm results in increased interest in science and intentions to take more science courses in the future (Lee & Burkham, 1996; Mathews, 2004). Future participation can also be increased by providing girls with a variety of science experiences in the early years of school (K–5). Many women scientists report that their experiences in the early grades, such as science projects and science investigations, were important in developing a life-long interest in science and choosing their science careers (Maltese & Tai, 2010).

**Strategies for Effective Use of Computers**

Volman and van Eck (2001), in their large review of the research on gender and computers, found that compared to boys, girls did less well with problem solving using computers and had less general computer literacy. They also noted that girls had less confidence in their computer competency. In particular, girls from poor families had less interest in computers. In addition, computer-based work did not enhance girls’ achievement in physical or life science (Burkham, Lee, & Smerdon, 1997). As a consequence, Burkham et al. recommended more time and experience with computers for girls, such as exploring a Lego/logo computer building environment to increase girls’ technological confidence (Beisser, 2005). In addition, attention must be paid to the type of computer-based science work. More girls than boys perceived computers as useful tools for conducting science investigations, graphing and organizing data, and understanding concepts in greater depth (Lawrenz, Gravely, & Ooms, 2006). These studies suggest that how much, and in what ways, the computer is used is critical in supporting girls in science.

**Special Consideration for Young Science Learners**

Although all of the curricular changes and instructional strategies recommended in this article work equally well for elementary and secondary school students, albeit with some modifications for the younger students, there are some instructional strategies and curricular issues that are unique to preschool and elementary students. The earlier girls participate in science, the greater their interest in science is likely to be. Even girls in kindergarten engage in gender stereotyped behavior, and pre-K girls are unlikely to choose science for their free choice activities. Thus, a focus on what works for the young students is important (Patrick, Mantzicopoulous, & Samarapungavan, 2009).

A popular instructional strategy with young children is to use literature, both nonfiction and fiction, as part of science instruction. However, care must be taken to choose the right combination of literature and instructional strategies. When nonfiction literature is integrated with inquiry, kindergarten girls understand science better and perceive themselves to be competent science learners. Traditional science instruction using thematic units with fictional literature leads to opposite results—less understanding, motivation, and perceived competence (Patrick et al.,
Listening to books being read aloud that explore nonstereotypical male and female roles, in concert with role playing and visits from role models, can reduce even preschool children’s perception of male and female stereotypical occupational roles (Tropanier-Street & Romatowski, 1999). However, when using children’s literature, the teacher must be careful to examine the materials carefully because many contain science content errors and misconceptions, fantasy, gender stereotyping, and anthropomorphisms (Sackes, Trundle, & Flevares, 2009).

Elementary school girls like messy science and should have as many experiences as possible to engage in tinkering (National Science Foundation, 2003) and to develop competence in using tools (Kinnear, Treagust, & Rennie, 1991). Perceived science competence and liking of science is also enhanced for girls in kindergarten when they are given the opportunity to engage in inquiry activities in biology, such as the life cycle of the butterfly (Samarapungavan, Mantizicopoulos, & Patrick, 2008). The science curriculum should also include more physical science topics because, as early as kindergarten, girls engage in more science activities in biology at home and are more interested in biology than physical science in school (Appleton, 2007). Older elementary girls also benefit from complex problems, longer wait-time, authentic assessment, and class discussions about gender-related issues (Beisser, 2005).

A Summary of Curriculum and Pedagogy That Works for Girls

We can summarize what works for girls in science as follows:

1. Early science instruction beginning in pre-kindergarten,
2. Relevant curriculum that addresses girls’ interests and provides many opportunities for genuine inquiry and tinkering experiences,
3. Greater emphasis on physical science and the use of computers,
4. Integration of reading and writing in science,
5. Careful attention to how groups are formed,
6. Activities that build self-efficacy,
7. Appropriate role models,
8. Voiced and unvoiced messages that science is for everyone, and
9. Student-centered teaching.

Implications for Educational Policies

Proposed revisions of the Elementary and Secondary Education Act (No Child Left Behind; US Department of Education, n.d.) include a greater emphasis on STEM and a focus on innovation, initial teacher preparation, and professional development. These policy changes and the research on increasing girls’ achievement and participation in science have significant policy implications.

The most important implication is the need for a focus on systemic change that addresses how teachers are prepared, their roles in schools, the science curricula taught, certification and recertification requirements, and professional development. District policies regarding the number of teachers hired, the positions for which they are hired, and the nature of their responsibilities would also have to change to allow for a greater degree of specialization at the elementary and secondary levels.

In addition, school funding policies would have to be rethought to support science specialists and to purchase increased amounts of materials and expendables, as well as computers, to support curricula that emphasize genuine inquiry, building and tinkering opportunities, and increased time and access to computers. Revisions to science curricula would have to include more girl-friendly topics and inquiry activities that involve real-world experiences, while still addressing standards. Finally, teachers would need professional development to learn how to teach the revised curriculum using appropriate pedagogies.

However, rather than waiting for the entire system to change, teachers can jump-start the process to increase girls’ achievement and participation in science. They (a) can increase opportunities to learn science content, particu-
larly the physical sciences through mentoring and encouragement, (b) engage girls in genuine science inquiry, and (c) develop their pedagogical content knowledge through professional development. More specifically, early childhood and elementary teachers can become science specialists through professional development and secondary teachers can use professional development to acquire the expertise to integrate science with other content areas.

High-quality professional development to increase girls’ participation and achievement in science can be obtained through opportunities provided by the National Science Teachers Association (NSTA) at regional and national conferences. In addition, the NSTA Web site includes resources for do-it-yourself learning and on-line seminars and classes.

Systematic change is not easy, but teachers play a major role in bringing it about. Every journey begins with a single step and although this is a big step, it can be done.

References


