

Part II. Developing Interest and Investment in Math and Science

Introduction

On a state or national level, there is a need to set policies and programs to promote women's access to education in math and science. As noted by the *Framework for Integration of Women in APEC* (APEC Secretariat, 1999): "Efforts should be directed to empower and increase the capacity building of women to respond to economic opportunities and challenges, and to eliminate barriers to women's full participation in the economy." Accordingly, the APEC Secretariat has developed practical guides for gender analysis, the collection and use of sex-disaggregated data, and the involvement of women in APEC as tools to complement the Framework and to assist APEC in its implementation.²

Developing systemic approaches to increase the representation and advancement of women in academic science and engineering careers may be done using a comprehensive framework for gender equality that addresses equality of access, equality in the learning process, equality of educational outcomes, and equality of standards. This framework should take into account contextual factors associated with gender equality. For example, a framework for promoting girls in math and science can take into account what girls from poor, geographically or culturally marginalized environments are offered by their schooling, and suggest ways to provide mathematics education in a way that will increase their interest, self-esteem, and access to additional educational opportunities. We provide an example from Peru, showing how the development of awareness of gender equity at the national level takes into particular consideration female students in rural areas.

Experts have suggested that practices aimed at improving attitudes towards mathematics can promote participation and performance in mathematics, science, technology, and engineering. Such practices may include teaching female students that their abilities are expandable, providing informational feedback to support the learning process, showing students female role models in mathematics and related fields, using instructional strategies that make mathematics more interesting and relevant, and providing additional enrichment in areas in which female students show greater difficulty, such as spatial problem solving (Halpern et al., 2007). For those recommendations, the Doing What Works website provides examples of practices from school sites (dww.ed.gov).

The practices recommended by Halpern et al (1997) are elements of project-based learning in Singapore, and the Development and Promotion of Science and Technology Talents Project (DPST) in Thailand. The use of project-based learning is aligned with expert recommendations to spark students' interest through engaging instruction. Project-based learning is aligned with research findings of instructional strategies to promote adolescents' motivation to learn (e.g., Slavin, 2006). That includes student choice, active inquiry, and cooperative learning. In addition, the use of tutors who work with small groups of students to guide their inquiry processes is aligned with expert recommendations for individualizing instruction.

The Development and Promotion of Science and Technology Talents Project (DPST) in Thailand aligns with expert recommendations to spark long-term interest in career goals and to teach students about female role models in math and science. Experts recommend that schools and other educational programs offer students the opportunity to attend conferences, summer

² These tools are available on the APEC Secretariat website at <http://www.apec.org/>.

campus, and field trips at workplaces to teach them about career opportunities that are related to math and science. In addition, providing opportunities for mentoring relationships can also highly motivate students' educational and career aspirations. These activities are among the key components of DPST, a successful model that has been in use in Thailand for more than 25 years.

Awareness at an Economy Level: An Example from Peru

In many economies, gender differences in math and science are of lower priority than the more pressing problems of low overall student achievement and educational attainment. Yet recognizing and addressing the barriers that prevent students—both boys and girls—from succeeding in math and science can address both the focused gender difference issue and the larger achievement issue. One of the most critical issues in Peru is equitable access to education. Almost one-third of the 1.5 million children in Peru who are not in school are rural girls (Valquez & Alvaro, 2009). Further, the majority of the 67,000 children who are in school are achieving below basic levels in math. Some groups of students systematically fare worse: rural students compared to urban students (83 percent of rural primary school students are below basic in math, compared to 55 percent of urban students) and poor students (68 percent of poor students compared to 47 percent of non-poor students). Results are similar—but more extreme—for secondary school. There are also gender differences in math achievement, but on a smaller scale: 60 percent of primary school girls compared to 54 percent of boys are below basic in math, with slightly smaller differences at the secondary level (Saavedra & Garcia-Belaunde, 2010). There are gender gaps—especially in terms of fewer girls participating in secondary school in rural areas—but these are small compared to the gaps across other categories.

Peru has taken the initiative to raise awareness of gender equity at the national level. Peru's national policy has prioritized gender equity in education and a number of other areas. Peruvian Law 28983 mandates equality between women and men in education and other areas, and Plan PIO (Plan de Igualdad de Oportunidades entre Mujeres y Hombres) was drafted to guarantee the right, for both women and men, to equality, dignity, free development, welfare and autonomy. One of the main objectives of the Plan is for both the state and the civil society to adopt equitable practices between women and men in all social spheres. Although it is not specifically directed at rural girls and adolescents, it serves as the framework for gender equity policies nationwide, particularly those drafted by the Peruvian Ministry of Education (MoE), and is the basis for the strategies and actions in place.

More specifically focused on girls, the Law to Encourage Education for Girls and Adolescents in Rural Areas (Law 27558) calls for a Multisectorial Commission to set up a roundtable to promote inter-institutional actions to achieve the objectives and goals of the Law. These objectives include guaranteeing gender equity in rural schools; eradicating discriminatory practices based on gender, race, language, and age; ensuring that students learn about the physical changes of puberty, especially female development; and ensuring gender equity for all students, with all teachers treating girls and adolescents in a respectful manner.

Some of Peru's education initiatives aim to help all students value and stay in school, which disproportionately affects girls (who are more likely to leave school to help with their families). Further, many of the efforts of the MoE focus on rural areas, where fewer girls are in school. The Peruvian MoE is working with diverse groups and populations (e.g., the civil society as a whole, other ministries, parents, teachers) to ensure that girls stay in school. Below

are some of the MoE-sponsored actions to promote education, especially for girls and in rural areas:

- 1. Collaborative relationships and a work alliance.** The MoE collaborates with Civil Society on awareness campaigns and publish educational material in rural areas. The MoE prepares workshops with UNICEF and regional governments, and is actively involved in the Quality Commission of the "Florecer" (Blossom) network. The MoE also coordinates with regional councils and Education for All to draft policies on the subject.
- 2. Use of radio to promote education in rural areas.** Various MoE offices participate in a monthly radio program called "Escuela del Aire" (On-Air School), designed to improve access to education through parental involvement. The Ministry of Education broadcasts the radio show once per month, each time from a different rural area, giving parents the opportunity to ask educators questions related to their children's education. For example, the program shares strategies for illiterate parents to use in supporting their children's learning (e.g., talking with the teacher, asking the teacher to help, giving the child time to work with peers, and giving the child more homework time). A parenting handbook, addressing questions on day-to-day and education issues, accompanies this initiative. Together, these activities are designed to raise parental awareness of and involvement in their children's education. These shows are very popular, partly because they provide useful information from knowledgeable sources using an oral tradition. Initial results suggest that these activities have raised student performance in rural schools, although it is not clear whether girls have benefited more than boys.
- 3. Awareness campaigns on gender equity.** The MoE organizes intercultural awareness campaigns, including posters and spots on TV and radio, promoting all girls' right to education, and organizes campaigns and roundtables on education and social inclusion. It has also created a special section for rural girls and adolescents on the Peruvian MoE's PeruEDUCA website (<http://www.perueduca.edu.pe/web/visitante/inicio>). The objective is to disseminate information on gender equity in schools. Further, the MoE has produced an educational video about girls and adolescents in rural areas, specifically in the Amazon region, as a means to show the reality of those schools and students' experiences.
- 4. Technical assistance.** The MoE works with other public entities, like the Ministry for Women and Social Development, to publish statistics on access and continuance of girls and adolescents in school in rural areas and to provide technical assistance to local schools on the issue.
- 5. Alternative schooling options, with increased secondary education opportunities.** As noted above, in rural areas Peruvian girls are less likely to attend school, often because the schools are too far away from the families. There is a special effort to increase the number of high schools and "non-school" schools in rural areas and to promote online education. One initiative to promote education in rural areas is to establish public boarding schools in rural communities. The Ministry of Education works with two non-governmental organizations to offer "alternation" schools where students board for two weeks a

month and are given self-paced materials to use at home for the other half of the month. The Ministry believes that this initiative is keeping girls in schools in rural areas and reducing teen pregnancy rates.

6. **A welcoming climate in schools.** Peru is also making the school environment more welcoming to girls. For example, the MoE is installing separate restrooms in rural schools and developing educational materials with clearly non-discriminatory content. There are also initiatives to fight sexual harassment and abuse of girls in rural areas. These include, among other things, the "I Have the Right to Be Treated Well" campaign; designating an ombudsman for rural zones; developing school, municipal, and community committees; and disseminating a report on the rights of rural girls and adolescents.
7. **Teacher knowledge and awareness.** The Peruvian MoE promotes teacher knowledge and awareness by providing information on rural girls and adolescents in teacher training courses and by including the subject of rural girls and adolescents in the course "Promoting Intercultural Identity Assimilation and Sensibilization" (Cayetano Heredia University and National Institute for the Development of Andean, Amazon, and AfroPeruvian Peoples). As can be seen in all actions, a strong emphasis is placed on rural areas, where the greatest gender gaps are observed.

In sum, nationally, Peru has made policy changes to promote gender equality in education and other areas, and has followed up with educational improvement initiatives that, although available to all, may especially benefit girls because they address the issues that limit girls' access to school.

Translating Research to Practice: Examples From the Doing What Works Website

Doing What Works (dww.ed.gov) is a website sponsored by the U.S. Department of Education. The goal of DWW is to create an online library of resources that may help teachers, schools, districts, states and technical assistance providers implement research-based instructional practice.

DWW is led by the Office of Planning, Evaluation & Policy Development (OPEPD) at the U.S. Department of Education. OPEPD relies on the Institute of Education Sciences (IES) at the U.S. Department of Education (and occasionally other entities that adhere to standards similar to those of IES) to evaluate and recommend practices that are supported by rigorous research. The DWW website features five research-based practices to promote the participation of girls in math and science based on the IES practice guide, *Encouraging Girls in Math and Science* (Halpern et al., 2007).³

The first practice focuses on explicit communication to students that they can expand their math and science abilities through effort and practice (a "growth mindset"). In addition, this practice recommends that successful students should not settle for good grades if the tests are too easy for them. They should actively seek new challenges and growth opportunities to keep expanding their abilities. The website features an example of one elementary school, in which teachers emphasize that mistakes are learning opportunities. Teachers at the school are using the theoretical model of a "growth mindset" (Dweck, 2006). Teachers found that learning

³ The IES Practice Guide is available at <http://ies.ed.gov/ncee/wwc/publications/practiceguides/?pgid=5>

to have a “growth” mindset about intelligence—believing that effort increases intelligence—helps students view their mistakes differently. That is, students are less likely to avoid challenges when they are not afraid to make mistakes.⁴

The second practice recommends that teachers regularly and frequently provide prescriptive, informational feedback about students’ efforts and learning strategies. This feedback includes step-by-step demonstration of the correct way to solve problems, providing praise and encouragement, and talking about the link between effort and achievement. The DWW website features an example of an elementary school math teacher who continuously gauges student knowledge and understanding, revises her instructional strategies based on this information, and encourages students to persist even when they struggle.⁵

The third practice posits that when girls believe in gender stereotypes like "girls aren't good at math" or "science is for boys," they are likely to have low self-confidence or negative thoughts that affect their performance when being tested in science and math. Role models are vital to mitigating the effects of gender stereotypes. Often, it only takes a single positive role model to make a difference in a girl's academic life. Teachers can use a variety of strategies, (e.g., reading about scientists, inviting female speakers, learning about role models, and collaboration with families) to help students learn about female role models. The website provides an example of a high school physics teacher who invites women scientists as guest speakers to talk to his class about careers in math and science.⁶

The fourth practice is based on the claim that the more interested students are in a subject, the more involved they become in their assignments, putting effort into their studies and engaging in deeper levels of thinking. Experts believe that increased student engagement in math, and science at school will eventually lead to greater involvement in math- and science-related classes, after-school activities, and career aspirations. The website provides an example of a high school physics teacher who engages students through project-based learning and opportunities to learn new topics that are not part of the curriculum. Students tutor their peers during class time. Tutoring helps students better internalizing the material on a deeper level. Also, students being tutored get immediate assistance when the teacher is busy helping other work groups.⁷ Another effective way to spark students’ interest is introducing them to science and math related career opportunities. An example from one middle school shows how students present about a career in science, technology, or engineering as a way to promote their long-term interest and educational and career aspirations. Student presentations include job description, job responsibilities and what they liked about the job.⁸

The final practice is based on research that shows that boys regularly outperform girls on tests involving spatial skills. Helping girls improve their spatial skills will lead to better math and science achievement both in regular and advanced courses at school and in college. Spatial skills help us visualize three-dimensional objects — skills that are especially important in math, science, and numerous professions. Spatial skills help us imagine, draw, and make appropriate changes to representation and organization of objects. These skills are essential to solving a wide range of problems in math, science and engineering. The website features an interview with a high school math teacher who describes how she integrates spatial skills

⁴ Listen to an interview at this link http://dww.ed.gov/see/?T_ID=18&P_ID=34

⁵ Watch a slideshow and listen to an interview at this link http://dww.ed.gov/see/?T_ID=18&P_ID=35

⁶ The interview is available at http://dww.ed.gov/see/?T_ID=18&P_ID=36&c1=414#cluster-1

⁷ Watch video clips about this practice at http://dww.ed.gov/see/?T_ID=18&P_ID=37

⁸ Watch an interview about this activity at http://dww.ed.gov/see/?T_ID=18&P_ID=37#cluster-2

training into geometry class. She explains how this training improved her students' skills and beliefs about their abilities.⁹

Additional examples from schools, tools and templates for school, district, and state-level professionals, information about the research base and interviews with experts are available for each practice.

Promoting Students' Learning Goals: An Example from Singapore

Research suggests that innovative instructional methods, especially project-based learning, group work, and innovative tasks, can better capture students' interest (Halpern et al., 2007). Building interest is especially critical for girls, who often internalize the message that "math and science are not supposed to appeal to girls." In Singapore, the Republic Polytechnic (RP), the newest of the five Polytechnics in Singapore, aims to develop practice-oriented and knowledgeable middle-level professionals through project-based learning (PBL). PBL is an educational approach that emphasizes learning through problem solving. PBL aims to enhance students understanding and skills in math and science and to prepare them for post-secondary education. The instructional process takes into account the fact that students come to postsecondary education with varying abilities in math and science. PBL focuses on real-world applicability of knowledge and skills.

The PBL approach builds upon six key principles:

1. Learning takes place as a process of constructing meaning rather than absorbing information.
2. Students are more motivated to learn when they are empowered by choice.
3. A sense of belonging and school connectedness are important conditions for learning. Cooperative learning can promote these feelings.
4. Supports for learners should promote independence rather than promote dependence on the teacher.
5. Different students rely on different modalities (e.g., auditory, visual) to process information. Learning processes should be constructed to allow flexibility in using different modalities.
6. Learning processes should include time for self-reflection.

This instructional approach, as it is implemented in RP, uses a daily routine of regular practice and feedback. Every morning, students receive a problem as a focal point for their daily learning. As described by Alwis and O'Grady (2002): "The problem could be a challenge or a description of a difficulty, a curious outcome, or an unexpected happening, it could also be an incident where there are interesting elements, or an episode or happenings that requires either a solution or some explanation." Groups of five students (up to 25 students in a classroom), with the help of a tutor, examine the problem, clarify what it is they know and do not know, and formulate possible hypotheses. They identify learning issues they will investigate, and collect relevant information. During the middle of the day, the groups of five meet individually with the tutor to briefly discuss their progress. At the end of the day, each

⁹ Listen to an interview at http://dww.ed.gov/see/?T_ID=18&P_ID=38

group presents its findings to the other groups for evaluation. Then they reflect on their learning using a self-reflection journal.

The independent exploration in cooperative learning groups addresses the developmental needs of students to be empowered by their own choice of learning process and to be connected to their peers. The daily written feedback from tutors, daily grades, peer evaluation, and self-evaluation provide students with ongoing support directed toward helping them become independent researchers.

Initial research on the effectiveness of PBL suggests that student learning is deeper, and more reflective, and that test scores improve (although more dramatically after one than two years of the intervention). Data shows that PBL equally benefits male and female students. In addition, some research also shows that PBL promotes students' learning goals (in contrast to achievement goals) by sparking their interest and focusing their attention on the learning process rather than the outcome (O'Grady & Choy, 2006). Students with learning goals are more likely to choose challenging tasks regardless of whether they think they have high or low ability relative to other students. According to experts, having learning goals can potentially counteract the effects of gender stereotypes, as students with learning goals are more likely to relate their level of effort to their performance rather than to a fixed ability (Halpern, 1997).

Providing Opportunities to Gifted Students: An Example from Thailand

Leaders in Thailand noticed that science and technology were becoming more important in terms of national and international development, and fewer talented students were enrolling in these areas. It was critical to encourage talented students—especially girls, who might not identify with science and technology—to explore these areas. To develop students' interest and skills in math and science, the Development and Promotion of Science and Technology Talents Project (DPST) was initiated in 1984. The DPST project encourages more students to choose science as their major through financial, academic, and social supports.

DPST is jointly administered by the Ministry of Education (the Office of the Basic Education Commission and the Office of the Higher Education Commission), the Ministry of Science, Technology, and Environment, and the Institute for the Promotion of Teaching Science and Technology (IPST). The IPST, an agency under the Ministry of Education, has several goals that encompass research, teacher professional development, student training, preparation of materials and resources, ensuring standards and quality assurance, developing talent, and advising organizations and centers on those topics. IPST and the Office of the Basic Education Commission are in charge of the upper secondary (high school grade levels) education program for DPST students, the selection of successful candidates for DPST, and the selection of upper secondary schools for DPST. Additional activities conducted by IPST include hosting the project, developing the enrichment programs, managing the science camps and other activities, coordinating with the project partners, and monitoring and evaluating project implementation and outcomes. The Office of the Higher Education Commission is in charge of the higher education program for DPST students, the selection of successful candidates for DPST, and selection of higher education centers for DPST. The DPST project currently works with seven upper secondary schools and seven universities in Thailand. Each school is connected to a university center, so that students can automatically enroll in their respective universities.

The project has three main components: (1) scholarships for secondary education in Thailand and post-secondary education in Thailand and/or abroad, (2) financial support for

DPST students at all grade levels to participate in academic activities in Thailand and/or abroad, and (3) financial support for staff from DPST school and university centers to participate in educational tours and academic activities in Thailand and/or abroad. DPST students participate in enriched science and math programs (which tend to be more challenging than the regular curriculum) in specially equipped rooms at their schools, student and researcher conferences, summer science camps, field trips to learning centers, summer internships with a math or science mentor, and social events. Social and networking events such as DPST brotherhood and sisterhood programs are available to DPST students to provide them with social support and increase their sense of belongingness.

DPST students are guaranteed college placement for a bachelor's degree in the faculty of science at designated DPST university centers, with the exemption of university entrance examinations. Scholarships include funds for tuition fees, academic activities fees, conferences, books, and research expenses. Students may continue their studies abroad or continue to a master's degree at their university. Finally, DPST graduates are guaranteed job opportunities in the government sector for science and technology research and development work or teaching and research positions in universities.

The DPST project currently identifies and selects 60 ninth grade students and 60 12th grade students every year (in addition to the 60 ninth grade continuing DPST students which makes the total of 120 12th grade students). Students who enter in 12th grade receive scholarships and other forms of college support. The program recruits and serves equivalent numbers of male and female students.

Since its initiation, the DPST project has had about 3,000 scholars. About 689 DPST students (347 female and 342 male) have already graduated. Of these, 632 individuals already have job in related fields. Most of the graduates received their degree in chemistry, biology, or physics, with the remaining graduates receiving a degree in mathematics, computer science, or geology. Additionally, of the project graduates, 34 individuals are award winners.

The DPST model appeals to young gifted female students by providing opportunities to meet with other female students who are interested in math and science. An important value nurtured by the DPST project is the value of friendship; the project recognizes it as an important source of emotional and social support to project participants. DPST also provides greater exposure to role models through annual conferences, field trips, summer work experience with researchers, and other enrichment programs. Experts recommend this kind of exposure to negate negative gender stereotypes and to demonstrate that women can succeed in math- and science-related careers (Halpern et al., 2007).

DPST also encourages students to “learn for learning’s sake”; it does not emphasize excelling but rather promoting positive attitudes toward science and mathematics. This helps the students develop learning goals and explore new challenges. Finally, DPST gives students a glimpse of the “real world” in an attempt to spark their interest in long-term career goals in science-related fields.

It should be noted that the DPST project has led to greater interest in science education and to additional initiatives. For example, organizations in Thailand have provided more scholarships to study science and mathematics, and the Ministry of Education has increased its efforts to promote the science enrichment class in schools.

Summary

Together, these examples demonstrate strategies currently being used to improve access to and interest in math and science. Peru has a number of policy initiatives and programs to raise awareness in gender issues and to promote greater involvement in schooling. Educators in Singapore have developed a problem-based approach to learning math and science to raise interest in the subjects and deepen content knowledge. Thailand operates a project to identify, mentor, train, and support young mathematicians and scientists through secondary school, higher education, and into their careers. While some of these strategies are not gender specific, and many appear to help both girls and boys, they are likely to differentially affect girls because girls historically have had more limited access to and interest in math and science. For example, programs that make secondary school more accessible in rural areas may especially help girls, who have more limited access than boys.

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