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Girls and Women in STEM: A Review of Interventions and Lifespan Developmental Considerations for Increasing Girls' and Women's Participation in STEM

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Executive Summary

Substantial strides in girls' and women's participation in science, technology, engineering, and mathematics (STEM) education and careers have been made over the past thirty years. However, a gender disparity in STEM educational and professional attainment remains. While girls and boys now have nearly equal participation in primary and secondary education, worldwide, the gender gap in completing advanced coursework in STEM subjects, specializing in STEM fields in higher education, continuing into STEM research and professional careers, and leadership within STEM fields remains (UNESCO, 2017). Strengthening girls' and women's participation in STEM has numerous benefits for society and for science. There is currently a global demand for expertise in science, technology, and engineering fields. Reduced participation of women in STEM disciplines limits the pool of qualified, talented, and innovate labor in STEM research and industries. Moreover, women's participation in STEM professions can also improve the practice of science, as science benefits from creative thinking and critique from different perspectives. Lastly, jobs in the STEM disciplines worldwide are often more lucrative, with higher pay and higher demand for technical skills (OECD, 2017; Pew Research Center, 2018; Waite & McDonald, 2019). Therefore, increasing women's participation in STEM professions can also contribute to women's economic parity. Where women and girls achieve educational, professional, and economic parity with men, communities flourish (Chaaban & Cunningham, 2011; Madgavkar, Elingrud, & Krishnan, 2016; McKinsey & Company, 2015; World Economic Forum, 2015).

The present report has three main objectives:

- Identify and describe educational, psychological, and policy-based interventions that were designed to increase girls' and women's participation in STEM
- Review psychosocial factors across the lifespan that contribute to the development of gender disparities in STEM
- Discuss limitations of the intervention case studies and identify gaps in the research on STEM interventions.

For the first aim, our team conducted a literature search for published academic articles that reported on interventions that have been designed to increase girls' and women's interest, performance, motivation, retention, and success in STEM education and careers. Interventions outside of the United States and interventions for which outcomes were published in peer-reviewed academic journals were particularly targeted for inclusion in this report. Due to the importance of the secondary and tertiary schooling years for the crystallization of STEM educational tracks and interest, we focused primarily on interventions that targeted girls and women between 10-22 years of age. For each intervention, we described background, methodology, and outcomes. STEM intervention cases described in the present report were implemented in Australia, Bangladesh, Canada, Chile, Germany, Israel, Kenya, Malawi, New Zealand, Nigeria, Pakistan, Taiwan, Trinidad and Tobago, and the UK. A variety of strategies were represented, including mentorship programs, bridging programs, social-belonging inductions, pedagogical methods such as digital game-based learning, flipped classrooms, and learner-centered education, afterschool enrichment programs, career exploration programs, and single-sex science education. We highlighted ten case studies that were particularly innovative, comprehensive, or representative that we discuss in greater detail in the report.

The second objective of this report was to present a developmental psychological perspective on the design of STEM interventions. To that end, we reviewed barriers to gender equality in STEM education and professions from a lifespan developmental perspective. Psychological, educational, and social barriers occurring from early education through middle adulthood were presented and discussed so that policymakers, executives, and educators can more precisely target the removal of gender-based obstacles to STEM success. For example, researchers have shown gender differences in spatial reasoning, a cognitive ability that has been linked to STEM achievement and to gender-typed differences in play and object manipulation in early childhood (e.g. block play). Other developmental aspects such as teacher influence in middle childhood, peer influence in adolescence, early professional experiences in emerging adulthood, and work-family balance in middle to late adulthood were outlined and connected to efforts to remove the gender gap in STEM interest, commitment, and advancement.

Lastly, we identified and discussed major limitations and gaps in the literature on interventions for girls and women in STEM. Issues such as appropriate methodology for outcomes research, variety and type of outcomes assessed, target population, and broader social, cultural, and structural barriers to gender equality can impede the interpretation of intervention outcomes or limit the impact of interventions. We hope that by identifying areas of need, we can encourage researchers, policymakers, and educators to address gaps in knowledge and suggest improvements to the design and implementation of future STEM interventions for girls and women.

Introduction

Promoting equality of access to education has been identified by international institutions as an important global goal. In 2015, the United Nations 2030 Agenda for Sustainable Development articulated a priority to "ensure inclusive and equitable quality education and promote lifelong learning opportunities for all" (United Nations, 2015). Supporting the economic and educational inclusion of individuals and groups who have been historically marginalized from participating in broad economic activities has also been identified by the World Bank Group Strategy as an important catalyst for poverty reduction (World Bank, 2013). Both sets of global cooperative goals articulate the need to foster inclusion in educational and economic success by reducing group-based disparities and barriers to access -in particular, gender-based inequalities in education and economic participation. When women have greater participation in economies, overall quality of life increases: gross domestic product (GDP) increases, poverty and economic inequality are reduced, overall educational attainment increases, and mental and physical well-being increase (McKinsey & Company, 2015; International Monetary Fund, 2018; OECD 2012; Shannon, Jansen, Williams, Caceres, Motta, Odhiambo, Eleveld, & Mannel, 2019).

Although girls' access to and achievement in education have improved since the establishment of the UN Millennium Development Goals, gender-based disparities in educational attainment, basic proficiencies, and participation in economic development still persist (UNESCO, 2017). Notably, girls' and women's achievement in science, technology, engineering, and mathematics (STEM) fields continues to lag behind that of boys and men (UNESCO, 2017). While interventions to reduce the gender disparity in STEM education and achievement in policy and practice have been implemented at the international, national, and local levels, less is known about the factors that contribute to successful interventions around the world.

The present report reviews the available research on the methodology and outcomes of large scale and individualized interventions for improving girls' and women's participation in STEM education and STEM careers. Limitations and future directions based on the review of past intervention cases are discussed. Lastly, perspectives from developmental psychology are discussed. We present background research on relevant gender socialization processes across the lifespan, the ways that STEM interest is encouraged and supported differently in boys compared to girls during childhood, and challenges that adult women in STEM fields are more likely to face in the workplace and at home. We hope that the summaries and discussions in the present report can inform policies, partnerships, and future research.

A Brief Overview of Gender Disparities in STEM Achievement, Education, and Occupations

Despite significant progress over the past 30 years, gender disparities in achievement, education, and career advancement within STEM fields are still observed, especially at the highest levels (e.g. STEM career selection, leadership, and awards for contributions to STEM research). The worldwide gender achievement gap in math and science has narrowed substantially and completion of math, science, and technology coursework in primary and secondary schooling is now approximately equal for boys and girls (OECD, 2017; UNESCO, 2017). This progress toward gender parity in education and achievement closely parallels the erosion of stereotypes and cultural expectations for traditional gender roles for women and increased concern over equal access to educational opportunity. Nevertheless, the gender gap in STEM widens in more advanced levels of achievement. This "leaky pipeline" effect can be observed in the gender gap in baccalaureate STEM majors, advanced graduate education in STEM fields, and wider still, in the percentage of women who continue into research careers and leadership positions in STEM.

A substantial body of scholarly research demonstrates that the observed gender differences in STEM achievement, education, and professional advancement are largely attributed to social, cultural, and associated psychological barriers to girls' and women's participation in STEM (Halpern, Benbow, Geary, Gur, Hyde, & Gernsbacher, 2007). Social and cultural expectations create environments and experiences that differ by gender and have implications for the development of psychological-level differences in interest, confidence, and feelings of belonging in STEM. For example, on average, boys are more encouraged to pursue instrumental and object-oriented play, which impacts spatial reasoning, a cognitive correlate of math and science achievement (Jirout & Newcombe, 2015). Girls' play and learning environments are less likely to contain rich spatial play and more likely to be oriented toward relational and nurturing activities (Blakemore & Centers, 2005). Parents, family members, and teachers are more likely to notice, value, and encourage mathematics, science, and technology learning and achievement in boys, compared to girls (Gunderson, Ramirez, Levine, & Beilock, 2012; Herbert & Stipek, 2005). Receiving stronger adult and external support and encouragement may motivate boys to persist longer in STEM education.

Sociocultural factors can also influence individual interest, confidence, and success in STEM via exposure to feminine and masculine stereotypes. The degree to which the stereotype that women are better at arts and men are better at science and math is espoused within a country is correlated with the gender gap in performance on the TIMSS standardized science and math exams in the 8th grade (Nosek et al., 2009). Children begin to recognize and internalize gender stereotypes early in life. Young girls who espoused stereotype-confirming beliefs about who excels at mathematics (e.g. drawing a stick figure of a man when asked to draw a person who is good at math) performed worse in math at the end of the year compared to girls that drew stereotype-inconsistent depictions of women as scientists (Beilock, Gunderson, Ramirez, & Levine, 2010). Evidence in the social science literature points strongly to the influence of societal, cultural, and policy-level factors in explaining the gender difference in STEM achievement, education, and professional attainment (Halpern et al., 2007; Master & Meltzoff, 2016). Consequently, interventions that target stereotypes, media portrayals, teacher bias, and that produce changes in the social context of STEM education and careers are compelling catalysts of change.

Achievement. Globally, primary and secondary school students' math and science learning has been compared using two large-scale, standardized assessments administered as part of the Trends in International Mathematics and Science Study (TIMSS) and the Programme for International Student Assessment (PISA). Large-scale, cross-national comparisons of science and mathematics achievement by gender have been published. Patterns of achievement in math and science by gender can be broadly summarized as being 1) less pronounced for science achievement than math achievement, and 2) mixed and reflective of large between and within-country variation.

Worldwide, the gender difference in science and math achievement favoring boys declined at both the 4th grade and 8th grade levels over a 20-year period from TIMSS 1995 to TIMSS 2015 (Mullis, Martin, & Loveless, 2016). The convergence of achievement scores over time was more pronounced for science (Mullis, Martin, & Loveless, 2016). For math achievement, boys are generally more likely to outperform girls in math, however, there is variation in the magnitude of the gender difference across and within nations (Hyde, Mertz, & Schekman, 2009; UNESCO, 2017). In some countries, gender parity has been achieved in science and math learning as measured through TIMSS and PISA -for example, TIMSS 2015 showed that two thirds of countries assessed showed no gender difference in math achievement at the 8th grade level (UNESCO, 2017). The gender differences in the TIMSS and PISA math tend to be small, but in some countries, the gender disparity widens in secondary education (OECD, 2017; Mullis, Martin, & Loveless, 2016).

In some countries such as Bahrain, Jordan, Kuwait, Malaysia, Oman, Saudi Arabia, and Thailand, girls outperformed boys in science and math achievement at either the 4th grade or 8th grade levels (Mullis, Martin, & Loveless, 2016). A cross-national comparison of PISA scores for 15-year old students in seven predominantly Muslim countries showed wide variation in math and science performance (Shafiq, 2013). In Azerbaijan, Tunisia, Turkey, and Jordan, there was no evidence that boys performed better than girls (Shafiq, 2013). However, in Indonesia and the Kyrgyz Republic, boys performed better than girls (Shafiq, 2013). There was no evidence that boys outperformed girls in science for Jordan, Qatar, Tunisia, and Turkey (Shafiq, 2013). In Indonesia and the Kyrgyz Republic, boys performed better than girls on the science test in all but the highest and lowest quantiles (Shafiq, 2013). Across the seven focal countries, Azerbaijan had the highest performance among girls. Alexander & Maeda (2015) examined PISA and Secondary Entrance Assessment (SEA) scores from 2365 adolescent students in 142 schools on Trinidad and Tobago. Girls scored significantly higher than boys on STEM achievement. Furthermore, attending a wealthier school and having a two-parent household were also positively associated with achievement (Alexander & Maeda, 2015).

Outside of cross-national comparisons on standardized assessments, achievement in math and science courses may also be assessed using classroom and school-based metrics such as course grades and GPA. In a study on 2,631 graduates of top engineering colleges in India, women performed better than or equal to men, based on GPA (Cheruvalath, 2018). Scores on high-stakes standardized exams may obscure girls' achievement in math and science courses. Girls' academic achievement, when measured with GPA or grades in math and science courses, may be equal to or outperform boys' academic achievement (Cheryan, 2012; Halpern et al., 2007).

Education. At the primary and secondary education levels, there has been substantial progress in improving gender equality in STEM education. In early secondary education, girls' and boys' educational interests in STEM display greater divergence and decisions made during secondary schooling about choice in educational tracking and advanced coursework in maths and sciences can have enduring effects (OECD, 2017). Beyond secondary education, gender differences in educational attainment in STEM fields reflect two distinctive patterns. One pattern is the difference in enrollment in mathematics-intensive STEM fields compared to more relational and life-science focused STEM fields. Women's enrollment in tertiary studies in biology, psychology, and health/medicine fields worldwide now exceeds or is at parity with men's enrollment in the same fields (Ceci, Ginther, Kahn, & Williams, 2014; OECD, 2017). However, women are less likely than men to pursue higher education in mathematics-intensive STEM fields such as mathematics, engineering, computer science, and physics (Ceci et al., 2014; OECD, 2017). Approximately one quarter to one third of majors in math-intensive fields are women and the proportion of women in these fields has actually declined slightly in the past decade (Ceci et al., 2014; UNESCO, 2017).

A second notable pattern is that of the "leaky pipeline:" smaller numbers of women are found at increasingly higher levels of STEM education. Critical junctures of "pipeline leakage" include secondary education into baccalaureate education, baccalaureate education into graduate/doctoral education, and the transition between completion of graduate school and initiation of STEM careers. Past the baccalaureate level, a smaller proportion of women than men continue to pursue doctoral level education in STEM fields and subsequently enter research and academic careers (UNESCO, 2017).

Careers and occupations. In terms of women's career progression into STEM fields, there are nuances based on STEM field and career type. Women are more likely than men to participate in healthcare and medical work, but less likely than men to work in research-intensive STEM occupations (UNESCO, 2017). In the United States, there are less female faculty than men in mathematics-intensive fields, whereas the proportion of female faculty in life sciences and health/medicine fields now exceeds or is at parity with that of male faculty (Ceci et al., 2014). In Australia, for example, engineering has remained a profession that is stereotyped as fitting a more masculine gender stereotype. In 2009 only 6% of practicing and professional engineers in Australia were women, although in 2016, the percentage of women in the engineering labor force doubled to 12.4% (Kaspura, 2017; Little & León de la Barra, 2009).

Paradoxically, however, the gender gap in the likelihood of progressing from Ph.D. education to a faculty position is actually *greater* in the life sciences and health/medicine fields compared to mathematics-intensive fields (Ceci et al., 2014). In other words, despite the greater participation of women in tertiary education in life sciences and health/medical fields, there is a "leakier" pipeline into academic faculty jobs within these fields (Ceci et al., 2014). This pipeline leakage may reflect opting into healthcare and medical occupations rather than research and academia, barriers to progression in research-intensive occupations, and/or and opting out of the workforce in order to provide care for children and relatives (OECD, 2017). Research intensive and mathematics intensive jobs tend also to carry greater financial rewards, as has been demonstrated through global work-participation research (OECD, 2017). Therefore, women also have less access to the financial benefits of working in mathematics-intensive STEM careers.

Methodology

This report has three primary aims. First, we summarize interventions for improving STEM learning, achievement, and interest among girls and women. We highlight case studies outside of the United States that represent the variety of STEM interventions and innovative approaches to intervention design. Then, we review psychological research on the intersection of gender socialization and STEM identity and interest across the lifespan. Knowledge of key events and unfolding cognitive and social processes at different timepoints in an individual's life can help inform policymakers and educators seeking to address girls' and women's advancement in STEM. Lastly, we present an analysis of limitations and gaps in the research on STEM interventions for girls and women and how the development of programs and outcomes research can be improved.

The case study summary section of this report employed literature review methodology in the social sciences. To that end, our research team searched for, summarized, and critiqued published articles that reported on outcomes data of interventions that targeted girls' and women's STEM education and interest. To conduct the initial literature search, we applied the following search terms to the PsycINFO and Education Research Complete databases:

- Science or technology or engineering or mathematics or stem
- AND girl or women or female
- AND [country]

Separate searches were conducted for each country recognized by the U.S. Department of State and the country name was entered into the third line of the search. Next, we compiled relevant articles into spreadsheets divided by U.S. Department of State regions. We included article titles that indicated relation to any aspect of STEM education, careers in STEM fields, gender stereotypes/inequality/discrimination pertaining to STEM education and careers, and STEM programs that targeted girls and women. Author, title, year of publication, journal of publication, search database location, and country information was extracted from article listings. Lastly, we reviewed article abstracts to identity intervention studies. Research type, number of participants, setting, program name, outcome variables (e.g. dependent variables), and notes were extracted from relevant intervention articles.

The methodology and outcomes data were summarized for each intervention article selected for inclusion in this report. Due to the demonstrated importance of secondary school years in decision-making for STEM educational tracks and the development of STEM career intentions, interventions for secondary school students were especially noted. We highlighted ten cases that we deemed particularly noteworthy in terms of innovation, representativeness, and comprehensiveness. Some cases were selected to provide comparisons of similar interventions. For example, two studies of mentorship programs and two studies of single-sex education were highlighted. In other cases, we chose interventions that varied in scope and outreach, from targeting teaching methods in a single classroom to a country-wide capacity-building initiative in science and technology sectors. The ten highlighted cases are outlined in Table 1 and italicized in the report.

Table 1. Summary of outcomes and targeted samples of ten highlighted case studies

Intervention	**Targeted Education Levels**	**Outcomes Assessed**	**Country**
"Attracting Girls to SET" ASISTM Project (Little & León de la Barra, 2009)	Secondary	Attitudes towards engineering; understanding of engineering concepts	Australia
STEP Social Belonging and Affirmation Training (Walton, Logel, Peach, Spencer, & Zanna, 2015)	University	Attitudes towards engineering and perceived future success in engineering; self-efficacy, self-esteem, perceptions of stress, confidence in managing stress; gender identification, implicit attitudes towards women in engineering; friendships	Canada
CyberMentor (Stoeger, Hopp, & Ziegler, 2017)	Secondary	Quantity and STEM-content of emails exchanged; size of students' STEM networks; intentions of pursuing STEM coursework and careers	Germany

BAMOT Mentorship Program (Bamberger, 2014)	Secondary	Attitudes towards female scientists and engineers; perception of coping with STEM careers; interest in STEM careers	Israel
UNIMA Summer Bridge Programs (Mbano & Nolan, 2015)	Secondary-university transition	Pass rates on STEM subject exams; perception of learning and skills gained from bridge programs	Malawi
Hello Café (Goodyer & Soysa, 2017)	Secondary	Definition of engineering and identification of types of engineering; satisfaction with program; interest in science career	New Zealand
STEPB Initiative (Independent Evaluation Group, 2014)	Secondary, university, and professional	S&T credits earned, enrollment in S&T university programs, graduates of S&T university programs, grants awarded	Nigeria
Digital Learning and Gamification (Khan, Amad, & Malik, 2017)	Secondary	Student engagement in class; chemistry learning test	Pakistan
Single-Sex Schooling (Jackson, 2011)	Secondary	STEM course selection; Secondary Entrance Exam (SEA) and Caribbean Secondary Education Certification (CSEC) test scores	Trinidad and Tobago
Athena SWAN Charter (Ovseiko, Chapple, Edmunds, & Ziebland, 2017)	Professional	Narrative perceptions of Athena SWAN initiatives	United Kingdom

Lastly, limitations of the intervention and outcomes research were identified and discussed in order to provide insight into gaps and future directions of interventions for addressing the gender gap in STEM around the world. Study-level limitations were presented after the summary of methodology and outcomes for each intervention. A broader overview of limitations was discussed after the summary of lifespan developmental considerations for STEM interventions for girls and women. Based on our review of limitations, we suggested recommendations for developing intervention studies and designing outcomes research in the future.

Interventions to Promote Gender Parity in STEM: Highlighted Cases from around the World

Africa (sub-Sahara)

Case #1. The Impact of STEM Bridge Programs on Women's Academic Performance at the University of Malawi (Mbano & Nolan, 2015).

The Malawi Ministry of Education has expressed a commitment to increase women's participation in STEM education at the tertiary level (Ministry of Education Sports and Culture Malawi, 2001). To that end, Malawi committed to a policy of increasing the enrollment of women in male-dominated STEM fields by 2012. This present study examined a method of increasing women's enrollment through academic bridging programs, which provide additional training and education to fill in gaps in students' knowledge before students enroll in a university major program (Mbano & Nolan, 2015). Two bridging programs were examined: one program was directed at girls in Form Three (Year 11) and the other program was a University of Malawi (UNIMA) pre-entry course for women. Researchers examined the impact of the bridging programs on women's academic performance, retention, and perceptions. A post hoc design was used to track students following their participation in one of the two bridging programs. Therefore, researchers were unable to randomly assign participants to a condition and did not construct a control group.

Bridge Program 1. This course was held at the University of Malawi over two weeks in summer and constituted the second phase of the Development Partnerships in Higher Education (DELPHE) project. Participants were 36 average-performing secondary school girls of lower socioeconomic status. 18 science teachers from the same schools as the students were also enrolled in the program and students and teachers both took coursework in career guidance, role modeling, gender responsive pedagogy, and STEM subjects. Course facilitators were university lecturers, female STEM role models, student mentors who were enrolled in university STEM programs, and a Gender Responsive Pedagogy expert. Aside from coursework, students and teachers participated in STEM-related field visits and trips and students were encouraged to collaborate on homework. Three years following the bridge program, researchers examined the effect of the program on girls' performance on the Malawi School Certificate of Education (MSCE) examinations, university selection, intention to pursue STEM careers, and their perceptions of the bridging program. Researchers found that students had a very high pass rate (97-100%) in STEM subjects on the MSCE, compared to the national average for the same year in the same subjects (32-54%). The majority of program alumni were enrolled in university or college at follow up. Students reported that the program had enduring impacts on their work ethic, ability to work in groups, knowledge of life skills, and guidance in selecting careers.

Bridge Program 2. The second bridging program was held at the University of Malawi Chancellor College and The Polytechnic. The one-week summer course included 12 women who were selected into Chancellor College science majors and 14 women selected into the technical education major at The Polytechnic. Women with lower scores in mathematics and science in high school were recruited for the bridge program. The program aimed to enhance women's STEM academic achievement, feelings of belonging, and to address barriers that have detrimental effects on persistence and motivation in STEM education and careers. The course was comprised of 7 learning modules: “Study Skills,” “Critical Thinking and Problem Solving,” “Upgrading and Skill Enhancement for Particular Concepts/Processes in Science and Mathematics,” “Student-centered Pedagogical Approaches to Learning Mathematics and Science Concepts,” “Exploring Science, Technology, and Mathematics (STM) in Society,” “Engaging in Real-Life Mathematics and Science Investigations,” and “Understanding and Addressing Attitudes and Beliefs about Self as a Mathematics and Science Learner” (Mbano & Nolan, 2017, p. 64). In addition, students were introduced to STEM women role models who were leaders and employees in the National Statistics Office, public health, and the university technical education program. Students' examination results after their first year of university and perceptions of the bridge program were collected and analyzed.

Compared to other women students at the university, students who attended the bridge programs had higher pass rates (81% and 100% for bridge students and 62% and 75% for other women students in Chancellor College and The Polytechnic, respectively). Students who completed the bridge program strongly associated the program with STEM education motivation and teaching of reasoning and study skills.

Overall, the bridging programs appeared to have positive long-term impacts on participants' math and science performance, as measured by STEM subject exams and self-reported academic skills and confidence. Due to the interactive nature of the bridge programs, data on students' STEM professional and social networks, friendships, and sense of belonging in STEM fields would have provided valuable information. It is possible that the shared experience and mentorship of the bridge program led to increased social belonging and social support, which enhanced confidence and academic achievement. Future research on bridge programs should seek to examine these potential effects. The intervention is also notable for targeting groups of young women and girls who were disadvantaged due to lower socioeconomic standing. It appears that the bridge programs effectively addressed gaps in knowledge and provided supportive communities wherein the young women and girls could thrive.

A limitation of this research is the lack of a randomized control group. While it is to the study's credit that the researchers constructed a retroactive control group using data from other women at the university, it is unclear if the comparison group was matched to the intervention groups based on major, socioeconomic status, and other individual factors. A second major limitation was that the sample size for both studies was very low. It is unclear how well the outcomes reported in this study would generalize to larger groups or at different universities. Future studies should examine whether similar bridging programs are a scalable intervention for larger groups.

Case #2. The Nigeria Federal Science & Technical Education at Post-Basic Levels (STEPB) Project (Independent Evaluation Group, 2014).

The Nigeria Federal Science & Technical Education at Post-Basic Levels (STEPB) was a World Bank funded initiative of the Federal Ministry of Education in Nigeria. The goal of the initiative was threefold: to support efforts to enhance research, supply grant funding for science and technology proposals, and improve the education and graduation of more qualified students from post-basic institutions (World Bank Projects & Operations, 2013). Central government, secondary and tertiary education, and workforce development sectors were implicated. In addition, funding supported private sector development through job creation and support for entrepreneurship. For example, the initiative funded a number of projects distributed throughout polytechnic schools in Nigeria, including entrepreneurial development at Federal Polytechnic Ede and a center for technology incubation at the Yaba College of Technology. Institutions that produced high quality research, development, and training in science and technology specialties were designated as Centers of Excellence (e.g. Sokoto Energy Research Center was selected as a Center of Excellence in Renewable Energy Research and Development). Although furthering the participation of women in the science and technology (S&T) sectors was not clearly stated as the primary objective of the STEPB initiative, support for women's S&T education and career advancement were measured as outcomes.

Examination of education outcomes reported by the STEPB to the World Bank in 2013 revealed several positive effects on women and girls. In 2013, there was a 32% percent increase in S&T graduates from beneficiary institutions compared to the baseline year 2007. Of these graduates, 57,006 (43%) were women, which also represents an approximately 32% increase in the number of women graduates between 2007 and 2013. There was also a 26% increase in the number of students who enrolled in beneficiary institutions' S&T programs from 2009 to 2013. Of these students, 230,770 (42%) were women, and the number of women enrolling in S&T areas increased 31% relative to baseline. At the secondary school level, there was a 53% increase in the number of students from beneficiary institutions who obtained at least 5 credits from S&T subjects on the national examination. Of these students, 33,924 (60%) were girls. However, only 30% of the Innovators of Tomorrow grants were awarded to women by 2011 (Independent Evaluation Group, 2014).

The STEPB project appears to have had positive impacts on increasing the numbers of boys and girls pursuing S&T subjects in secondary and tertiary schools. The increase in girls' and women's enrollment, coursework, and graduation relative to baseline for member institutions is notable. However, several limitations exist that make it difficult to translate the outcomes of this program. First, public evaluation reports did not provide outcomes data by gender, institution type, and degree. Therefore, it is unclear whether enrollments, coursework, and graduation increased across the board for women and girls or if these were primarily driven within specific institutions and STEM areas. For example, other research has shown that the increase in women's participation in life sciences and medical fields has outpaced women's participation in physics, computer science, mathematics, and engineering (Ceci et al., 2014). Women's participation in mathematics-intensive fields and medical/life sciences fields were not reported in detail in the publicly available outcomes report. Second, publicly available reports do not detail interventions, if any, that were undertaken at member institutions to specifically increase and support girls' and women's interest and success in S&T. This makes it difficult to pinpoint the specific institutional, educational, and outreach-related changes that enhanced girls' and women's participation. Lastly, more information would be useful regarding the gender imbalance in recipients of the Innovators of Tomorrow awards. Greater transparency regarding the application and selection process would yield useful information that would help explain why women won only 30% of the awards.

Case #3. A Descriptive Study of Students' Perceptions and Attitudes towards Gender and Physics Education in Kenya (Oyoo, 2010).

In Kenya, students have the option of taking either biology or physics courses during their secondary science education. Girls' enrollment in physics courses has been low, which also has implications for the number of girls who take the national examination in the physics subject and enrollment in tertiary tracks that require physics as a prerequisite (Oyoo, 2010). The case study outlined below is a pilot study designed to describe the participation of girls in science, particularly physics. An aim of the study was to reveal sources of positive attitudes towards physics in order to develop future means of attracting more girls to the study the subject (Oyoo, 2010). Therefore, the present study does not detail a specific intervention aimed at increase girls' interest in physics. Rather, the study provides descriptive information on boys' and girls' attitudes towards physics and beliefs about the gender difference in physics course selection in Kenya.

Participants were 100 Kenyan students (50 girls and 50 boys) from four provincial secondary schools, two of which were all-girls' and two were all-boys' schools. All participants were taking physics and had been approved to take the physics national examination. Students completed a survey that asked about students' beliefs and attitudes towards physics and their experience with physics education, their beliefs about their future career prospects, physics self-concept, self-esteem, peer influence, and family background and influence.

Findings from the study revealed important influences that affected girls' enrollment in and attitudes towards physics. Receiving personal encouragement by a physics' teacher and being encouraged and supported by parents and families were important factors that influenced girls' enrollments (Oyoo, 2010). Girls were also more likely than boys to note the importance of peer interest in physics, access to science clubs, and visits from external science professionals and speakers.

Overall, the survey suggested that interventions which focus on addressing family/parental support, teacher, and peer support of girls' interest in physics may be promising. In addition, girls indicated that they wanted more co-curricular and engaging programs that involved connecting with a science community. Incorporating more of these programs within schools and communities may be promising steps towards increasing girls' participation in physics. We note that the present case study focused on the collection of descriptive data and therefore did not provide statistical analyses of the gender differences in attitudes and beliefs about factors that influence interest in physics. Therefore, it is unclear whether there were statistically significant differences between boys' and girls' responses. Future research should seek to clarify whether boys and girls and Kenya vary systematically in their beliefs about the determinants of their enrollment and interest in physics.

East Asia and the Pacific

Case #1. Hello Café Engineering Outreach Program for Girls in Early Secondary School in New Zealand (Goodyer & Soysa, 2017).

Women only comprise 10% of engineers in New Zealand. In an effort to encourage girls to become interested in careers in engineering, the NZ Ministry of Business, Innovation, and Employment (MBIE) produced the Hello Café pilot program in collaboration with UNESCO University Twinning Network UNITWIN at Massey University. Additionally, Hello Café partnered with the national Futureintech initiative to assist with community outreach and recruitment of student participants from different regions of New Zealand. The Hello Café pilot ran from July to December 2016 and targeted girls (10-13 years old) from low income neighborhoods in an effort to encourage girls to think of engineering as a way to serve their communities and to intervene on educational pursuits before girls selected educational tracks in upper secondary education. The program designers devised a name (Hello Café: Creative Problem-Solving Workshops for Girls) and branding that would convey friendliness and avoid masculine STEM stereotypes.

Hello Café was designed to be a free after school club where participants collaboratively solved community-based problems in small groups. The program lasted for 10 weeks and consisted of 10 workshops, each with a duration of 90 minutes. The activities in the workshops focused on practical, social benefits of engineering, with time for discussion. Young women engineers were recruited by Futureintech to serve as role models ("Ambassadors") in the program. Hello Café workshops were held at museums and art galleries. Each workshop presented social dilemmas that could be addressed through problem-solving in engineering. For example, workshops included building road systems that were resilient in the face of natural disasters, developing a sustainable energy plan for a resource-poor island community, and developing a water purification system. Workshop facilitators received training and resource sheets. 104 participants completed pretest and posttest questionnaires assessing their interest in, perceptions of, and knowledge of engineering.

Prior to the workshop, about half of the participants indicated that they knew what engineering was and just 3% could identify the six types of engineering. By the end of the program, 84% knew what engineering was and 62% could identify the types of engineering. The participants expressed nearly unanimous satisfaction and enjoyment of the program. Hands-on activities, building activities, mentorship by Ambassadors, and the social purpose of the workshops were noted as particularly positive and impactful aspects of Hello Café. Interest in engineering as a future career increased in the posttest, relative to the pretest. However, interest in a career in *science* decreased in the posttest, relative to the pretest. One potential explanation for this decrease is that the program did not explicitly emphasize that engineering was a STEM field and connected to basic science research. Rather, the program emphasized problem-solving, innovation, and inquiry, which are typically less emphasized in conventional classroom science education.

The Hello Café outreach program appears to have been successful in educating girls on the value of engineering and to present engineering as a useful tool for social change and social justice. However, there were several limitations to this study. The data reported did not include inferential statistics that indicated whether changes from pretest to posttest were significant. Future research on this program should also compare the intervention group to a control group in order to more rigorously test the causal effect of the intervention on interest in engineering. In addition, future research should consider adding academic outcome measures such as grades in science and math courses, science and math achievement tests, and the actual selection of science and math schooling tracks in the future. Strengths of the program include the involvement of participants from a low socioeconomic status, who are not always well represented in STEM intervention research. Second, the workshops were developed to be scientifically rigorous and address real world problems with direct connections to New Zealand and Oceania (e.g. coping with natural disasters, renewable energy). This approach may lead to a more realistic and personally meaningful characterization of the value of engineering work. Third, the workshops introduced students to a variety of engineering domains (e.g. mechanical, environmental), which increased students' awareness of educational tracks and career options. Lastly, the program was developed in partnership with international groups, national policy initiatives, non-profit organizations, universities, and schools. This reflects a robust collaboration between different sectors, which may contribute to enhanced scalability.

Case #2. The Australian School Innovation in Science, Technology and Mathematics (ASISTM) "Attracting Girls to SET" Project in Middle and Secondary Schools in Tasmania (Little & León de la Barra, 2009).

In 2007, women accounted for only 6% of all professional engineers in Australia. To address this deficit, Australia's Department of Education, Employment and Workplace Relations established initiatives aimed at increasing girls' interest and achievement in engineering (Little & León de la Barra, 2009). One of the programs, Boosting Innovation in Science, Technology and Mathematics Teaching (BISTMT), gave rise to an Australian School Innovation in Science, Technology and Mathematics (ASISTM) project, "Attracting Girls to SET." This project was managed by the University of Tasmania's School of Engineering Outreach Team with the goal of fostering middle and secondary school girls' interest and engagement in engineering by changing the perception of engineering (Little & León de la Barra, 2009). The project sought to do this by emphasizing the ways that engineering can be used to address real-world problems and through active and inquiry-based education in schools.

The project involved collaboration at different levels, including at the national, state (Tasmania), and university levels. Stakeholders and the university and school levels included the School of Engineering Outreach Team, which consisted of engineering professors, a science teacher, and undergraduate engineering students who created learning modules and procured the resources necessary to execute them, and School Project Partners.

The researchers assessed 74 girls in Years 5-9 that attended single-sex institutions in an urban area of Tasmania. Students completed a preintervention survey that assessed their attitudes toward pursuing a career in engineering, understanding of concepts in engineering and technology, and preferred learning contexts and learning styles (Little & León de la Barra, 2009). The preintervention survey revealed that students preferred hands-on activities, experiments, and constructive projects. Based on the responses, the outreach team partnered with teachers to create a curriculum that included students' preferred learning methods for engineering topics like robotics, electronics, and hydraulics (Little & León de la Barra, 2009). Teachers were provided with training workshops led by engineering experts, learning module instructions, resources, and discussion questions that would stimulate inquiry-based learning. A borrowing system for instructional resources was created in order to facilitate access to resources needed for the learning modules. Furthermore, women who were professional engineers visited classes in order to serve as role models to students. The project also led to the development of a website (http://www.stem.utas.edu.au) that housed presentations, links to websites on engineering, and information about the project as a whole. Lastly, the project led to the organization of a science and engineering expo for girls and their parents wherein students could present their course projects to their families.

A postintervention survey was completed by the 74 students recruited for the intervention study. Researchers reported no significant overall changes in attitudes towards engineering careers and understanding of concepts. However, it appeared that girls perceived that they gained skills and knowledge of how to purposefully create objects and devices to solve problems.

While this intervention is laudable for its comprehensiveness, use of preintervention data in formulating learning modules, and involvement of many stakeholders (e.g. national, state, local, university, school, family, professional engineering levels), the assessment of outcomes had limitations. Little and León de la Barra's (2009) published report did not include detailed descriptions of the data collected and analyses performed. It would be valuable to understand whether the intervention impacted girls' performance in school STEM courses. A more rigorous experimental design would be the comparison of the intervention group to a control group. For example, although the researchers did not find significant changes from preintervention to postintervention, it is possible that *without* exposure to the multifaceted initiative, girls would have otherwise held more negative attitudes towards engineering or had less interest in pursuing engineering. Potential buffering effects of the intervention against a loss of interest in engineering cannot be identified with the present research design.

Case #3. Makerspace Hands-On STEM Projects for Primary School Girls in Australia (Sheffield, Koul, Blackley, & Maynad, 2017).

The aim of the Makerspace in STEM (MIS) program was to provide an opportunity for girls to gain experience from female mentors and teachers through playful, hands-on, collaborative projects centered around STEM topics (Sheffield, Koul, Blackley, & Maynard, 2017). By engaging in creative projects in an informal setting, MIS may help spark young girls' interest in STEM education. The present study sought to understand how girls engaged with a Makerspace project and how well they integrated the project with STEM schoolwork and skills.

71 Year 5 and Year 6 girls from an all-girls' Catholic school in Australia participated in the research. High-performing Year 6 students from the school were not represented in the sample due to being on a field trip during the Makerspace event. The Makerspace day took place at the school during regular school hours. Each student was given a bag that contained materials that students could use for their project, which was to create a circuit that could light a bulb in a flower. Female pre-service teachers served as Makerspace mentors for the girls and assisted with projects during the day. Data was collected using a questionnaire, pre-service teachers' observations, and observations of students through video recordings.

Survey responses showed that nearly all participants enjoyed the project and would be willing to complete future Makerspace projects at school. More than 80% of the sample reported that they enjoyed science and planned to continue taking science in Years 11 and 12. Pre-service teachers observed that students were most likely to practice trial-and-error problem-solving and that students seemed to enjoy the project. Observations indicated that students did not connect the flower circuit project to their classroom science learning nor did they seem to have strong conceptual knowledge regarding circuits.

A major limitation of this study was the design: a pretest posttest control group design would provide a model that would enable researchers to observe change in attitudes towards STEM as a result of experiencing the intervention. However, because only an intervention group was examined, it was impossible to identify causal relationships. While the all-girls environment was an intentional component of the intervention, it is important to understand how the impact of the intervention might transfer to different settings that include men and boys. In addition, the high-performing students from Year 6 were absent, resulting in limitations for the generalization of the results. Would the project inspire and motivate high-achieving students in STEM, who are statistically more likely than their peers to continue to pursue advanced STEM education and careers (Ceci et al., 2014). Lastly, the use of a "feminized" project was limiting. Participants were enthused about the flower project. However, using feminized content in STEM education is contested, as this method could entrench stereotypes regarding gender identity and STEM achievement and or, alternatively, it could upend stereotypes and increase inclusivity. Lastly, STEM content education was not a focus of the project. The project did not feature a lesson on circuits nor additional information regarding STEM subjects and STEM careers.

Despite the limitations, interventions such as Makerspace in STEM have potential benefits for girls. The girls were able to successfully arrive at their own conclusions and to explore and experience active learning. Fostering interest and a successful experience of working on a STEM project in a group setting during middle childhood may stimulate interest and motivation to pursue STEM learning in the future.

Case #4. Project-Based Learning for STEM in an All-Girls' High School in Taiwan (Lou, Liu, Shih, Chuang, & Tseng, 2011).

Project-based learning (PBL) involves hands-on, long term, interactive activities wherein students learn knowledge and skills by engaging in problem-solving and collaboration. PBL was implemented in an all-girls' high school in Taiwan along with a five-stage model, PIPER (Preparation, Implementation, Presentation, Evaluation, and Revision).

The present study involved 40 high school students who worked in small teams on a hands-on engineering project. Students had access to a project website that hosted a discussion forum, descriptions of activities and the project, and a presentation area. Students completed a questionnaire that assessed learning methods, perceptions of learning, and the integration between PBL and STEM. Three teams were also selected for interviews on interactions with the online platform activities.

Analysis of the findings showed that girls were capable of learning and mastery of the scientific process using the PBL model. By learning from their experiences, students were able to grasp the key stages of PIPER (Lou, Liu, Shih, Chuang, & Tseng, 2011). In the analysis of the STEM content of the project, technology was the topic that was most frequently discussed by students while mathematics was the least discussed. The interviews revealed that students used trial and error processes and experienced successful breakthroughs that enhanced their motivation to complete the project. Through PIPER and PBL, the female students were able to effectively integrate the project with course content and to demonstrate creativity and innovation in their projects (Lou et al., 2011).

A limitation of this study is that the focus of the intervention was pedagogical, rather than specific to increasing girls' access to and interest in STEM education and careers. However, use of effective pedagogies may result in enhanced learning of STEM content and practice of actual processes used by scientists, which can benefit girls. The present research did not use pretest-posttest assessment methods nor a control group, both of which would lead to more rigorous testing of the effectiveness of the intervention. For example, PBL learning could be compared to more standard lecture-based classroom discussion (for an example, see Hossain & Tarmizi, 2012). If PBL facilitates girls' interest in STEM and learning of STEM content and skills more effectively than conventional lecture-style instruction, then the practice of PBL could be encouraged as one method that leads to more interest in STEM among girls.

Europe and Eurasia

Case #1. Online Mentoring in One-on-One and Group Settings for High-Achieving Girls in Secondary Education in Germany (Stoeger, Hopp, & Ziegler, 2017).

Mentorship by adult women role models can provide support, affirmation, and valuable career information to girls who are interested in pursuing STEM. The present study explored the effectiveness of an innovative mentoring model: online mentoring in individual and group settings. An online format can provide a more cost-effective delivery of mentorships and facilitate access to and communication with women STEM role models.

CyberMentor began as a free, one-on-one online mentoring platform that matched STEM professionals and graduate student mentors with secondary school student mentees. Mentors and mentees maintained weekly communications via chat, discussion fora, and emails for a year. Beginning in 2012, CyberMentor developed a group mentoring platform with a many-to-many approach, pairing two mentors with two mentees. This group mentoring structure could potentially broaden mentees' professional networks, increase the number of interactions with STEM role models, and encourage peer-to-peer interactions and support. Group mentorship using this format would allow more than one point of view to be expressed, which in turn would enable the mentee to consider varied information when making their own decisions.

The present study compared mentees who experienced the original one-on-one mentoring structure in 2011 with mentees who experienced the group mentoring structure in 2014. Mentees were high-achieving girls between 11-18 years of age in German secondary schools. Mentors were women who achieved university education in a STEM field and were either currently obtaining a graduate degree in STEM or working in a STEM profession. 156 mentees participated in one-on-one mentoring and 191 participated in group mentoring. The study examined the effect of mentoring structure on mentees' intentions to pursue future education and careers in STEM and quality of STEM-related networking and communication.

Overall, the group mentoring experience resulted in more positive effects for mentees and mentors. Group mentoring resulted in significantly more emails exchanged, more STEM-related content in emails, and more STEM-related networking, compared to the one-on-one experience. Mentees in the group mentoring condition had larger STEM networks than mentees in the one-on-one condition. Mentees in the group mentoring condition also had greater intentions of taking STEM coursework and pursuing STEM careers six months after the start of the program.

There were several limitations to this research study. One limitation is the fact that the mentoring programs compared in this study were conducted 3 years apart. Therefore, cohort effects may influence the interpretation of the results. Differences between the two conditions could have been due to differences between the two cohorts of mentees, rather than the interventions. Future research on the effectiveness of group vs one-on-one mentoring should take care to randomly assign participants to a condition, in order to control for cohort effects and individual differences of students. The mentees in the study were all high-achieving girls. It is difficult to generalize findings to a more varied sample of mentees, who may bring different needs to the mentoring relationship.

The many-to-many group mentoring structure examined in this study appears to be an effective way to increase high-achieving girls' commitment to STEM education and careers. Importantly, it developed wider STEM networks for mentees, which may have additional payoffs past secondary education.

Case #2. Perceptions of the Athena SWAN Charter at the University of Oxford in the UK (Ovseiko, Chapple, Edmunds, & Ziebland, 2017).

The Athena SWAN Charter for Women in Science merges two initiatives (Athena Project and Scientific Women's Academic Network) in the UK for increasing gender equality in the academic sciences. Institutions can achieve awards based on the degree to which they propose and implement institutional changes that are aligned with the ten Athena SWAN principles for gender equality in the Athena SWAN Charter. For example, principles include a commitment to reducing the gender difference in pay, addressing the leaky pipeline problem in girls' and women's continuation in STEM education and careers, and addressing transgender discrimination. The three tiers of awards include:

- Bronze: assessment of the state of gender equality at the institution, devising an action plan to address gender equality issues that spans 4-years, and creating an organizational structure that can allow for the implementation of the action plan.
- Silver: institution that has previously attained the Bronze award demonstrated that the action plan was implemented and resulted in positive effects.
- Gold: institution demonstrates sustained and substantial achievements in enhancing gender equality, responding to challenges, promoting best practices for gender equality, and evidence-backed commitment to all Athena SWAN principles.

Crucially, as of 2011, National Institute for Health Research funding is contingent on an institution receiving at least a Silver Award. The present study sought to obtain information about the perceptions of Athena SWAN by employees at the University of Oxford, a member institution (Ovseiko, Chapple, Edmunds, & Ziebland, 2017).

The study was a qualitative analysis of participant responses from previously conducted assessments of organizational culture by the institution. Researchers examined data from 59 respondents who had mentioned Athena SWAN in their comments in a previous survey. Researchers also reviewed the responses of a separate group of 37 women at the institution who were senior scientists in the Medical Sciences Division and Mathematical, Physical and Life Sciences Division. This sample of women provided narrative interviews that were approximately an hour in duration, each.

Analysis of respondents' and interviewees' comments regarding the Athena SWAN initiative yielded common themes. Respondents and interviewees were generally enthusiastic about the encouragement to apply for grants, professional support through mentorship, career development opportunities, and seminars about women in science that emerged out of Athena SWAN initiatives. Employees also noted cultural shifts regarding time use, caretaking, and parental leave, with Athena SWAN leading to positive changes in flexible scheduling, maternity leave, and reintegration after family leave. Athena SWAN was perceived as raising awareness of gender and diversity issues in science and higher education. Employees were more divided regarding the linkage of Athena SWAN awards to receiving research funding. For example, some participants felt that the linkage to funding resulted in more work in applying for the Athena SWAN award, which was work that often fell on senior women in the institution (Ovseiko et al., 2017). Interviewees noted that the documentation process for the Athena SWAN award application led to more formality within departments, which supplanted the previous casual, warm culture. Other responses in this theme were positive -some employees regarded contingent funding as being necessary in order to raise the stakes for achieving actual change in the institution (Ovseiko et al., 2017). Some respondents, primarily men, felt that the use of quotas was a case of positive discrimination and expressed that women were gaining ground at the institution at the expense of men. Lastly, some employees expressed that Athena SWAN would not be able to address broader, societal inequality, systemic issues in institutions and in academia itself, and cultural beliefs about women as nurturers (Ovseiko et al., 2017).

The present study provided an important window into perceptions of employees at an Athena SWAN member institution. There are some limitations of this research that impede the generalization of employee perceptions to other institutions. One limitation is in the research design. Survey respondents were not prompted to comment on Athena SWAN in free response items. Therefore, researchers could only use responses that were voluntarily generated by participants. Out of a total of 2407 respondents, only 59 wrote about Athena SWAN. It is possible that respondents who either felt very positively or very negatively about the charter left a comment. The extent to which their responses reflect those of the broader university is unclear. Future research on this issue would benefit from a greater inclusion of views towards Athena SWAN by employees at the institution. The present study examined perceptions at a large, prestigious research-focused institution. Researchers should consider surveying staff at other Athena SWAN member institutions and noting whether the same themes arise more broadly. Relatedly, a research study of this scope could also provide information about differences in perception across different award levels. Quantitative research, for example, assessing employees' endorsement of stereotypes and implicit attitudes towards women in science at member institutions would provide data that is complementary to the present study.

Case #3. *Discover!*: Careers Wales' and WISE's Informal Science Activity Club for Girls in UK Secondary Education (Watermeyer, 2012).

The *Discover!* program was an informal extracurricular science club that was designed to inspire girls in early secondary education (Years 8 and 9; aged 12-13) to become more interested in STEM education and careers. The program was created by a collaboration between the Women into Science Engineering and Construction (WISE) initiative and Careers Wales, which provides early career exploration and advising for children. WISE is an organization that coordinates joint efforts between public education and industrial sectors to make STEM careers more appealing for girls. The *Discover!* program was a girls-only program with female tutors and session leaders that assisted with activities. Session leaders were comprised of adult women who were active as STEM researchers and scientists. Activities included role-playing as scientists, fun active and immersive learning projects, and "object-based learning" in activities that involved direct manipulation of materials and apparata (e.g. using a telescope). The program was intentionally designed to be focused on fun activities without a strong academic presence. The sessions took place on Saturday mornings and there were 8 sessions.

The researchers evaluated the effectiveness of the program using post-program questionnaires for students and their parents. The questionnaires contained questions about the degree to which the program altered students' interest in STEM and perceptions of women in STEM, students' enjoyment of the program, and perceptions of the female-only aspect of the program. 71 student responses and 65 parent responses were collected. The evaluation found that the majority of students enjoyed the program. The majority of parents thought that the program effectively introduced their daughters to STEM careers and thought that their daughters would pursue STEM academically. However, just 38% of students reported that the program added to their science education. About half of the students reported they had found STEM to be fun and interesting prior to the program. Students and parents had mixed feelings about whether the single-sex structure of the program was essential to its success.

Based on these evaluations, the *Discover!* program was perceived as an enjoyable, fun experience for girls that parents also found meaningful and valuable (Watermeyer, 2012). The intervention is notable for its public-private support and its focus on activities and play, rather than on classroom learning. While the qualitative research methods provided rich information about the experiences of students and parents involved in the program, quantitative analyses on outcomes would provide valuable comparative data. It is unclear whether the intervention had an effect on girls and their parents, compared to a control group that did not experience *Discover!* It is possible that the program bolstered and maintained students' interest when they otherwise may have declined in the absence of supplemental STEM activities. However, this could only be concluded after using a pretest-posttest control group design and comparing average responses between at least two conditions. Lastly, objective outcomes such as actual enrollment into advanced STEM classes and persistence in STEM tracks in school would provide insight into the long-term benefits of participating in the program.

Case #4. A STEM Career Exploration Enrichment Intervention in Lower Secondary Education in the UK (Archer, DeWitt, & Dillon, 2014).

The present case is a study of a six-week intensive STEM careers pilot program that was formulated as part of the larger ASPIRES project (Archer, DeWitt, Osborne, Dillon, Willis, & Wong, 2012). The pilot program intended to expose girls to diverse possibilities in STEM careers: introducing students to the variety of applications and careers that utilize STEM specialization may increase positive attitudes and interest in STEM education.

The participants were 68 Year 9 students (13-14 years old) who attended an all-girls school in London and completed both pretest and posttest questionnaires. The school had an ethnically diverse student population. The intervention was a 6-week intensive program that included visits from guest speakers who were STEM Ambassadors and a STEM researcher in residence at the school, a speed networking event with STEM professionals, a traveling educational show, visits to a science center and a large STEM conference, and participation in teacher-led educational programs on STEM topics. The researchers used the ASPIRES project Year 6 questionnaire in order to assess pretest attitudes and interest in STEM fields (Archer et al., 2012). The questionnaire included questions about science self-concept, parental and peer attitudes to science, perceptions of scientists, and participation in extracurricular activities with a science focus. A modified version of the questionnaire was used for the posttest (parental attitudes and participation in extracurricular activities items were removed). Lastly, researchers conducted two classroom observations and discussion groups six months after the intervention. In these sessions, students discussed their enjoyment of the intervention activities, what they learned about STEM careers, their awareness of the activities' purpose, and how they felt their perception had changed.

Researchers did not find a significant change in attitudes and interest towards science and perceptions of scientists after the intervention, compared to before the intervention. Although there was no significant change in career aspirations or views of science, an unintentional result of the intervention was affirming the interest of girls that were already committed to STEM fields, particularly in medicine. Qualitative data from observations and the discussion session suggested that students enjoyed the activities.

One limitation of the study was that a control group was not used. It is unclear whether students that were unexposed to the special STEM careers programming would have lost interest in STEM, compared to students who received the intervention. Although the intervention did not enhance attitudes and perceptions of STEM careers and professionals, one possibility is that the intervention bolstered already existing positive attitudes and perceptions. Low fidelity in lesson and activity delivery were also potential limitations: researchers noted that some lessons were not executed as originally written and some activities' STEM components were too subtle and light on STEM learning. Thus, similar programs could benefit from more intensive teacher training, adherence to activity protocol, enhancement of science content, and integration of program activities with classroom lessons. Careful selection of highlighted careers can also benefit students exposed to enrichment programs. In the present study, some participants provided feedback that the highlighted careers were highly specialized, challenging, high status, and required heavy investment of time and education. A more diverse selection of careers may better inform students about a variety of occupations that vary in degree of perceived attainability.

Near East (North Africa and the Middle East)

Case #1. BAMOT Mentorship Program for Girls in Secondary Education in Israel (Bamberger, 2014).

The BAMOT program (acronym, in Hebrew, for Girls for Science and Technology) was a project of the Israeli Ministry of Education and was designed to promote interest in STEM education and careers among girls (Bamberger, 2014). This was a private-public program that involved partnerships with Israeli technology companies. The main goal of the project was to encourage girls to pursue STEM education and gain interest in STEM fields through mentorship and exposure to female role models. A published research study investigated the effects of participation in this intervention.

Twelve adult women scientists and engineers (a majority earned a Ph.D. in a STEM field) at a technology company volunteered to serve as mentors in the BAMOT program. 69 female 9th grade students participated in the intervention group and 30 female 9th grade students comprised the control group. The students were recruited from a Jewish modern-orthodox single-sex secondary school located in the same city as the technology company

(Bamberger, 2014). The intervention group was divided into two approximately equal groups that experienced two, four-hour visits lead by the female scientists and engineers at the technology company. During the visits, the mentors introduced themselves and their personal backgrounds, education, and research. The mentors also participated in a question and answer session with the students and discussed work-family balance, gendered perceptions of their occupations, and overcoming challenges. The intervention group students received tours of the company, visited laboratories, and observed demonstrations of the research conducted by women at the company (Bamberger, 2014). Pre-post questionnaires were administered to both the intervention and the control group. The questionnaires assessed students' intended major and career choices, perceptions of confidence regarding STEM careers, and perceptions of women scientists and engineers. The primary investigator on the research project observed students' visits in the intervention group and also conducted a focus group with students at the end of the study. Therefore, this study was analyzed using a mixed, qualitative and quantitative methods approach.

Paradoxically, the study found that there was a decrease in the positive views of female scientists and engineers by students in the intervention group but not in the control group. There was also a significant decrease in students' perceptions of their capacity to cope with STEM careers after the intervention. This effect was not found in the control group (Bamberger, 2014). In the focus groups, students in the intervention reported concerns with work-family balance with STEM careers. Lastly, the intervention group saw a decrease in the number of students who were interested in STEM careers at the end of the intervention compared to at the beginning of the intervention. This effect was not found in the control group.

There were four main explanations provided for why the students exhibited these results. First, there was a cognitive gap between the role models and the students (Bamberger, 2014). Some students expressed that they were intimidated by STEM fields because the role models presented advanced, sophisticated concepts that were unfamiliar to the students (Bamberger, 2014). The second explanation pertained to the developmental gap between role models and students. This program might not have been appropriately calibrated to the knowledge and skill levels of an early adolescent age group. Students at this age may see adult scientists as "too good" or "too smart," and perceive these positions to be distant and unattainable. The third explanation was that there was a lack of long-term relationship development between the female scientists and the students. Lastly, the views expressed by students could have been heavily influenced by the view of women in STEM in the cultural context. The girls that participated in the study were students of a single-sex modern-orthodox Jewish school. Girls may have been more sensitive to traditional women's roles and responsibilities within the family and concerns with balancing a STEM career with family commitments may have surfaced.

These explanations point to possible improvements to mentoring programs in the future. For example, future interventions can utilize students' math and science secondary school teachers to help students understand the concepts described by role models and integrate the experience into classroom learning. Future mentoring programs may consider cultivating more long-term relationships between students and role models and recruiting role models who are closer in age to students and who share similar religious and social values. Just two of the role models in this intervention practiced modern orthodox religion.

There were additional limitations to the study that could have affected the interpretation of the results. Participants self-selected into the intervention and control groups. Due to the fact that the intervention and control groups were not randomized, girls' family backgrounds, science and math achievement, and STEM interests were not controlled in this study. There may also have been interaction between the intervention and control groups, since students were recruited from the same grade level in the same school. Therefore, the control group may not have been completely naïve to the intervention and may have been exposed to the experiences and reactions of students in the intervention group. Girls' perceptions of STEM careers, women scientists and engineers, and confidence regarding their own capabilities in STEM careers are important attitudinal measures. However, it is unknown whether this intervention impacted outcome such as engagement and interest in current science and math coursework, achievement in science and math, and actual choice in educational major, Lastly, the study did not perform subsequent follow-ups with participants. In Israel, students select an educational track after the 9th grade. Whether students in the intervention group continued to major in a STEM field is unknown. Students' perceptions and views towards women in STEM and their own interests in STEM may also change over time. For example, students may not have identified strongly with adult role models in the 9th grade. However, their perceptions of the experience may evolve over their own development and the experience of the intervention may have long term effects that were not captured by outcomes assessed immediately after the program.

Case #2. Single and Mixed Sex High School Education and Enrollment in Advanced STEM Coursework in Israel (Feniger, 2010).

Single-sex education has been proposed as a type of schooling which may counteract stereotypes about gender and math and science performance. The Israeli state school system is comprised of secular, mixed-sex schools, religious mixed-sex schools with same-sex classrooms, and religious, single-sex schools. The present study examined whether type of schooling increased girls' enrollment in advanced math and science courses.

The sample and data for this study were taken from the 1995 Israeli census and from the Ministry of Education's matriculation files (Feniger, 2010). The sample size was 20,816 high school students. The dependent variable of this study was the level of enrollment in advanced courses, specifically, math, physics, computer science, and biology (Feniger, 2010). Basic level classes are determined to be two to three units and advanced level classes are four to five units. The study examined whether type of schooling (mixed vs single-sex) were associated with differences between girls' and boys' enrollment in advanced-level math and science courses.

The study found that girls had significantly lower chances of enrolling in advanced math courses than boys, and there was an overall nonsignificant effect of schooling type on girls' enrollment. For advanced physics courses, the gender difference in enrollment favored boys, but girls in single-sex schools enrolled in advanced physics coursework more than girls' in mixed-sex schools. Girls were more likely than boys to take advanced biology courses across all school types. Lastly, girls in single-sex schooling enrolled in advanced computer science courses more than girls in mixed-sex schooling and there was not a significant difference in enrollment rates among girls and boys in single-sex schooling (Feniger, 2010).

In summary, type of schooling did not substantially impact enrollment in advanced math and science courses (Feniger, 2010). Interesting, the most striking effect was for advanced computer science courses, where attending a single-sex school was associated with increased enrollment among girls. However, the author pointed out that this difference could be due to the way that computer science and other advanced math coursework tend to be "packaged" together in secular coeducational schools but not at religious same-sex schools. This informal tracking pathway into math and science coursework may deter some girls, as opposed to the more "a la carte" advanced science offerings available in religious schools. A further limitation of this study is that it is not a true intervention with a manipulated independent variable. Therefore, the results describe associations between schooling type and enrollment into coursework, but cannot determine whether schooling type causes differences in advanced math and science course enrollment.

South and Central Asia

Case #1: Digital Learning and Gamification in Secondary School Science Classrooms in Pakistan (Khan, Ahmad, & Malik, 2017).

Lessons in Pakistan are typically taught using lecture-based instruction. Khan, Ahmad, and Malik (2017) investigated the impact that game-based learning (GBL) and digital game-based learning (DGBL) has on students' engagement in secondary school science classrooms. In particular, researchers were interested in whether these pedagogies improved student engagement, especially for girls, compared to conventional lecture instruction. Gamification of learning incorporates components (e.g. progression, feedback, rewards, achievements/milestones) that are characteristic of game design into classroom instruction.

The participants in this intervention study were comprised of 72 8th grade students of a low-cost private school in Pakistan. The experimenters used a quasi-experimental design with two control groups and two experimental groups. The control groups remained in lecture-based classrooms and the treatment groups received the game interventions. The design of the treatment groups was based on the Games Based Learning Instructional Design approach wherein researchers determined a suitable content focus (chemistry) based on a previously administered student survey, aligned the gameplay with the Pakistan National Curriculum of Science's learning goals for chemistry, and designed the visual and interactive elements of the game (Khan et al., 2017). Each student in the treatment groups was exposed to the DGBL intervention in a computer lab for five 30-minute sessions over three weeks. Each student in the control groups experienced standard lecture-based instruction in their regular classroom, with their regular teacher. All students completed pretest and posttest assessments on learning outcomes based on the Pakistan National Curriculum of Science. Students' behaviors were observed by trained teachers. Students from the treatment group then participated in a focus group discussion that sought to understand how they felt while participating in the intervention.

Results showed that students in the treatment group were more attentive and excited compared to students in the control group. Girls in the treatment group were more confident and excited than boys. Although there was no overall significant difference in posttest chemistry learning assessment scores between the control group and treatment groups, girls in the treatment groups performed significantly better than boys in the treatment group. In summary, DGBL had a positive impact on student engagement, with especially positive effects on interest and science learning for girls in the treatment group (Khan, Amad, & Malik, 2017).

Limitations of this intervention include the inability to generalize the results to more diverse science math subjects and to different classrooms and student age groups. Information on whether the intervention impacted students' grades in science and whether interest and engagement of students led to eventual decisions to major in STEM fields and pursue STEM careers was not collected. Therefore, it is difficult to generalize beyond the immediate impact of gamification techniques on students. However, the present study presented a compelling reason to incorporate game-based activities in science instruction and to further investigate gamification as a method of increasing girls' interest and learning in STEM fields. Future interventions along this line should also take into account students' access to computers and technology and incorporate game-based learning into computer programming and technology courses.

Case #2: Cooperative Learning in Elementary School Science Classrooms in Pakistan (Saad & Saad, 2017)

In this study, researchers examined the impact of cooperative learning pedagogy in science classes in an all-girls' elementary school in Pakistan. Cooperative learning involves creating teams or groups of students who are given a shared activity and instructed to work interdependently toward a shared goal. Previous research and theorizing on pedagogical methods for increasing girls' interest in STEM fields has suggested that incorporating cooperative learning techniques may be effective (Saad & Saad, 2017). The present study compared academic achievement after exposure to cooperative learning compared to exposure to the more traditional lecture-based teaching model that is typically used in schools in Pakistan.

Researchers recruited 128 grade-VII students at an all-girls' government school. The researchers used a pretest posttest control group design wherein students were divided into either a treatment (cooperative learning) or a control (lecture) group and science tests were used to assess academic performance before and after the intervention. The science tests were content-based multiple choice, true and false, matching, fill-in-the-blank, and open-response items. Students in both groups experienced 13 weeks of science instruction over approximately three months. The cooperative learning instruction was implemented by a teacher at the school. The teacher designed learning activities that required cooperation between students.

There was no significant difference between the experimental and control groups on pretest exam performance. However, a significant difference in mean achievement scores between the cooperative learning and the control group was observed: girls who experienced the cooperative learning environment performed better on the posttest knowledge assessment compared to girls who experienced the traditional lecture-style (control) learning (Saad & Saad, 2017).

Based on this study, cooperative learning in elementary science classrooms can be an effective way to increase girls' science learning in Pakistan. A limitation of the study was the implementation of cooperative learning within the physical characteristics of the classroom and resources available at the school. Fixed classroom furnishings, lack of learning resources, large class sizes (45 students per class), lack of teacher training in cooperative learning pedagogy, and official curriculum restrictions were all identified as potential limitations. These limitations made it difficult to implement innovative teaching techniques, control for appropriate group sizes (recommended class size is 15-20 students) and allow for the seamless implementation of cooperative learning activities (Saad & Saad, 2017).

Case #3: Impacts of Group Learning for Girls' and Boys' Mathematics Achievement in Rural Secondary Schools in Bangladesh (Hossain & Tarmizi, 2012).

Most students in Bangladesh secondary schools experience conventional lecture-style instruction in the classroom. Group learning has been proposed as a pedagogical method that may benefit girls. Group learning (or cooperative learning) involves placing students in small, heterogenous teams to cooperate with one another to solve a problem or task in the classroom.

The participants were 168 male and female ninth-grade students from four secondary schools in rural Bangladesh; one of the four schools was an all-girls school. Researchers used a quasi-experimental pretest posttest design to implement the intervention for mathematics classes. Researchers assigned one section in each school to the control group, which was the use of conventional lecture instruction and one section to the experimental group, which was the use of group learning techniques. The experiment unfolded over the course of 15 weeks. In each school, the same teacher led both sections, control and experimental. Teachers received training for seven days prior to implementing the intervention. The group learning intervention implemented the Johnson and Johnson Learning Together Model, a group learning guideline which involves five elements: positive interdependence, accountability, face-to-face interaction, interpersonal skills, and group processing (Hossain & Tarmizi, 2012). In order to assess learning, researchers administered pretest and posttest Mathematics Achievements Tests (MAT), which had been reviewed and validated by faculty of education and mathematics in Bangladesh and the District Education Officer of Bangladesh Government.

Results showed that the posttest math achievement scores of students who received the group learning intervention were significantly higher than those of the control group. Girls performed significantly better than boys in the group learning setting, and significantly better than girls in the control group. Postintervention interviews with teachers revealed that teachers perceived that students in the group learning condition gained more confidence and interest in mathematics.

The use of the same teachers to lead both the control and group-learning conditions was both a strength and a limitation to the study. On the one hand, the study was able to control for the identity of the teachers, which was consistent across the experimental groups. On the other hand, due to the fact that teachers were not blind to the experimental condition and were not naïve to the goals of the researchers, their instruction may have been impacted by unconscious biases that improved instruction in the group-learning condition compared to the conventional teaching condition. Other strengths of the study were the use of a math assessment that was validated by faculty and the education ministry and the focus on students in rural areas, which are typically underrepresented in education research. A consideration for future research in this area would be to examine whether group-learning positively impacts course grades and scores on standardized exams.

Western Hemisphere

Case #1. Interventions to Increase Women's Social-Belonging and Affirmation During the First Year of Engineering Studies at a Canadian University (Walton, Logel, Peach, Spencer, & Zanna, 2015).

Previous research on the gender gap in STEM fields has pointed to social and identity factors as being important to women's success. The association of STEM with masculine gender identity can present challenges for women, who as a result, may feel concerned about confirming negative stereotypes about women in engineering (stereotype threat) and may not feel that they are welcome or that they belong in STEM fields that are especially male-dominated (Cheryan, 2012; Master & Meltzoff, 2016). In the present study, which was funded in part by the Social Sciences and Humanities Research Council of Canada, researchers examined the impact of two nonacademic interventions intended to address feelings of belongingness and self-affirmation among first-year women engineering students. The study aimed to examine the effects of two distinct interventions on women engineering students' GPA, attitudes towards engineering, confidence in their future in engineering, perceptions of stress, gender identity, perceptions of women in engineering, self-esteem, and friendship groups.

Researchers recruited 228 University of Waterloo engineering students over three cohorts. A total of 92 women were recruited, with 136 men recruited to match the women on ethnicity and major. Prior to the intervention, students completed a preintervention survey during the first months of school. The survey assessed feelings of belonging in the engineering school, enjoyment of engineering, engineering self-efficacy, implicit bias against women in engineering, evaluation of future success in engineering, degree of identification with gender group, and percentage of friends who were also engineers. Participants were randomly assigned to one of three conditions within the "Skills for Transitions to Engineering Project." Two of the conditions were interventions and they each lasted for 45 min-1 hr. In the social-belonging intervention, students were instructed to review summary reports and audio recordings from former engineering students that emphasized that all students initially feel concerned about being taken seriously and whether they belong in the program. Students in this condition were instructed to write a reflection on the student recordings and to write a letter to a future student about the initial difficulty but eventual success in feeling a sense of belonging. In the affirmation training intervention, participants reviewed former students' descriptions about the ways that they coped with challenges and stress by pursuing social support, making lifestyle changes, and managing workload. Participants in this condition also completed a writing assignment, but this time, they expressed the coping processes in their own words and with examples from their own lives and to write a letter to a future student advocating for managing academic stress by seeking support and articulating their own sense of identity. Multiple control conditions were employed, depending on the cohort. For the first cohort, participants in the control condition read about how engineering skills develop over time. For the second and third cohorts, participants in the control condition only completed outcome measures.

Participants all received a keychain based on the condition to which they were assigned. For participants in the intervention groups, the keychain contained a reminder of either the social-belongingness (Waterloo Engineering school logo) or affirmation training (student-selected value written on a slip of paper within the keychain) intervention, in order to be exposed to reminders of the intervention for the duration of the study. Participants in the control condition had a choice of either the Waterloo key chain or the blank, but customizable paper slip key chain.

Following the manipulation, participants filled out a postintervention survey that contained the same questions about attitudes towards engineering, self-efficacy, and future success in engineering as in the preintervention survey. For the next 12 days following the intervention, students completed brief, 5-minute surveys that assessed students' perceptions of daily stressors, self-esteem, sources of stressors, confidence in being able to manage academic stress. Lastly, in the second semester of school, four months after the intervention, Cohort 1 completed a survey assessing the same attitudes towards engineering, gender identification, friendships, and implicit attitudes about women in engineering that were assessed in the preintervention survey. Cohorts 2 and 3 completed two of the same second semester surveys, 3.3 months and then 6 months after the intervention. Their responses on the two surveys were averaged.

Researchers found that the two interventions were associated with stronger effects on GPA for women in male-dominated majors. Compared to women in the control group, where there was a significant gender gap in GPA favoring men, women in the intervention groups who were in male-dominated majors had higher GPAs. There were no differences in GPA of men and women in gender diverse majors in any condition. Intervention group women in male-dominated majors perceived stressors as less important, felt more confidence to manage stress, and had higher self-esteem compared to their counterparts in the control condition. The effect of intervention was not consistent for women in gender diverse majors. In the second semester, months following the intervention, women in male dominated majors felt significantly more positively about engineering and were significantly more confident in their future success when they experienced one of the two interventions, compared to women in the control condition. The interventions did not have an effect on engineering attitudes and future prospects for women in gender diverse majors. Lastly, women in male dominated majors who were in the social-belonging intervention experienced a significant increase in the number of friendships and had less negative implicit attitudes towards women in engineering, compared to women in the control condition and the affirmation training condition. Women in male dominated majors who were in the affirmation training condition reported significantly greater value in their gender identification compared to women in the control condition and social belonging condition.

Both interventions closed the gender gap in women engineers' GPAs in male-dominated majors (Walton et al., 2015). Both interventions resulted in positive effects on engineering attitudes, resilience in the face of stress, confidence, and beliefs about future persistence in STEM for women in male-dominated majors (Walton et al., 2015). Overall, this case was a particularly well-controlled intervention study with a pretest posttest randomized control design. In addition, the inclusion of academic performance metrics (e.g. GPA) was distinct from other intervention studies measuring only attitudinal items. This provided valuable information on the ways that interventions aimed at reducing the gender gap in STEM can influence a factor that is associated with continuation into STEM careers (Ceci et al., 2014). Limitations of this intervention study include the relatively small number of participants who volunteered to participate in the study and who comprised a subset of STEM majors (e.g. the engineering school). In order to generalize the findings, future research should recruit participants from a greater range of STEM majors. It is also unclear how the two interventions, social-belonging and affirmation-training could be combined or which to recommend for educators to implement. The study found positive effects of both interventions but also some distinct effects of one intervention over the other. Interventions could potentially be tailored to students' primary concerns. For example, students could be assigned the social-belonging intervention if they reported feeling isolated and had small initial friend groups in STEM majors. However, future research would be needed to establish whether this would be an effective method of tailoring or customizing interventions.

Case #2. The Effects of Single-Sex Schooling on Girls' STEM Achievement and Course Selection in Trinidad and Tobago (Jackson, 2011).

Single-sex schools may decrease the influence of gender roles on students' course selection and decrease the likelihood of experiencing gender-related conflict in the classroom (Jackson, 2011). In Trinidad and Tobago, students' performance on a standardized exam determines which secondary school the student will attend. Jackson (2011) used a simulation to estimate the effects of single-sex schooling during lower secondary education on gender differences in 10th grade exam performance and course selection while accounting for school preference.

Jackson (2011) examined test scores from the Secondary Entrance Exam (SEA) from the 1995-2002 cohorts and the Caribbean Secondary Education Certification (CSEC) test scores from the 2000-2007 cohorts. In total, the study analyzed data from 219,849 students across 123 schools in Trinidad and Tobago. The SEA data contained students' demographic information, SEA subject scores, and students' preferred schools. This data was then linked with the CSEC data, which contained students' grades and secondary school.

The econometric simulation of SEA and CSEC data revealed that students who attended single-sex schools performed one standard deviation higher, on average, than peers who attended co-ed schools. Girls' achievement in single sex schools primarily accounted for this effect. However, girls who attended single-sex schools were overall significantly *less* likely than their mixed-sex school-attending counterparts to select STEM courses.

While attending a single-sex school was associated with improved academic performance, Jackson (2011) noted several limitations in this interpretation. First, single-sex schools are associated with prestige on Trinidad and Tobago, which can lead to higher achievement due to beliefs in higher quality of education. Second and relatedly, this effect could be accounted for by peer influence. Students who are surrounded by high-achieving peers are more likely to have higher achievement (Jackson, 2011). Notably, single-sex schooling was not associated with greater likelihood that girls would select STEM courses. Therefore, the prediction that this type of learning environment counteracts gender role stereotypes is not supported by the present research.

Case #3: The Effect of Single Sex-Schooling on the Gender Gap in Science Subject Selection and Performance on the Chilean College Admissions Test (Gándara & Silva, 2016).

High school graduates in Chile must complete the mandatory Prueba de Selección Universitaria (PSU) standardized exams. All students are required to take two sections:

mathematics and language. Beyond this, students can choose to take additional subject tests in sciences and social sciences. The Science Test is further divided into optional subject areas, Biology, Chemistry, and Physics. In the present study, researchers investigated whether gender gaps in interest and achievement in STEM fields were associated with type of high school attended (single vs mixed-sex) (Gándara & Silva, 2016). Officials from the Pontificia Universidad Católica de Chile accessed admissions data for 141,090 students (46.5% male and 53.5% female) from 2010 that was. Of the students, 59,019 took the PSU Science Test. Admissions data included students' demographic information, school type, socioeconomic status, academic records, and PSU scores for subject tests.

Researchers found that girls in the sample had a significantly higher GPA than males, but boys and girls were equally likely to have taken a Science Test. School type was not associated with girls' decision to take a Science Test, overall. However, girls who attended single-sex schools were more likely to take the Physics and Chemistry tests, while girls who attended mixed-sex schools were more likely to take the Biology test. There were no gender differences in taking the Chemistry test, but girls were significantly more likely overall to take the Biology test compared to boys, whereas boys were significantly more likely to take the Physics test than girls. In terms of test performance, students who attended single-sex schooling, regardless of gender, had higher scores on all Science Test subjects compared to their counterparts in mixed-sex schooling. For the Biology and Physics tests, the gender gap in achievement favoring boys was larger for students who were in single-sex schooling than for students who were in mixed-sex schooling. For the Chemistry test, the gender gap in achievement favoring boys was larger for students in mixed-sex schooling.

Interestingly although girls in the study had overall higher GPA, boys outperformed girls in all sections of the Science Test. This paradoxical finding should be further examined, especially the degree to which GPA and standardized testing predict the selection of STEM majors in tertiary education and continuation into STEM careers. If standardized testing has an outsized effect on women's continuation in STEM tracks, then this potentially masks women's abilities in STEM. To address this issue, universities may consider admissions policies that assign greater weight to high school GPA. The gender achievement gap on subject tests varied depending on the subject and school type. Nevertheless, it should be noted that both boys and girls in single-sex schools performed at higher levels on all subject tests than their counterparts in mixed-sex schooling. Based on this study, single-sex schooling should not be considered a definitive intervention that reduces the gender gap in STEM education and professions in Chile. In fact, the study showed that boys were the primary beneficiaries of single-sex schooling, according to their science performance relative to boys in mixed-sex settings and girls (Gándara & Silva, 2016). Future research should seek to clarify which aspects of single-sex education will lead to overall higher Science Test scores and which characteristics are linked to heightened gender differences in science achievement.

Case #4. "Flipped Classroom" Pedagogy and Girls' Motivation and Achievement in a Lower Secondary School Chemistry Class in Trinidad and Tobago (Sookoo-Singh & Boisselle, 2018).

Student-centered pedagogy techniques, such as flipping the classroom, may improve students' interest in and enjoyment of science subjects at school. A flipped classroom is characterized by active learning, with instruction outside of the classroom using educational technology (e.g. online learning or homework assignments) and using face-to-face classroom time for students to apply their knowledge, usually in active projects and group collaboration. The present study summarized outcomes from a teacher's all-girls' chemistry class following a change in instructional method (flipping the classroom) (Sookoo-Singh & Boisselle, 2018).

Students were 27 Year 10 girls aged 14-15. The instructor administered a pretest survey assessing motivation. The intervention took place over a 6-week time frame. Within that time, students completed online-learning and instruction in chemistry outside of the classroom and engaged in hands-on activities that applied this learning during class time. Students also provided journal responses that contained reflections on their learning of the subject. A posttest survey assessing motivation and a unit test on student learning were administered after the intervention.

There was an increase in students' motivation from pretest to posttest (Sookoo-Singh & Boisselle, 2018). However, when comparing the unit test score to students' grades in the previous semester, there was no effect of the flipped classroom intervention. Student journal responses indicated positive reception of the pedagogical method, with some exceptions. Students who did not have a positive view of the flipped classroom also experienced difficulties with using the instructional technology (Sookoo-Singh & Boisselle, 2018).

One major limitation of this research is the lack of an equivalent control and an equivalent pretest academic performance measure. Based on the results, it is difficult to definitely conclude that the flipped classroom enhanced motivation. A control group that experienced conventional instruction of the same chemistry concepts should be compared to the intervention group. A separate limitation is student access to technology that would enable participation in a flipped classroom. Widespread use of this instructional method would necessitate improvements to internet access and relevant infrastructure and access to home computers. It is also unclear whether the effects of a flipped classroom are especially beneficial for girls relative to boys. If flipping the classroom increases girls' enjoyment of and motivation to pursue STEM fields like chemistry, it would be important to conduct follow-up studies to examine whether this is sufficient to encourage more girls to take more STEM classes or to enter STEM fields in tertiary education.

Considerations for STEM Education for Girls and Women across Lifespan Development

Carefully designed interventions for increasing girls' and women's interest, motivation, achievement, commitment, and retention in STEM fields should take into consideration cognitive and social change over human development. In this section, we describe lifespan developmental issues that can be useful for policymakers and educators to understand when formulating interventions. We summarize and integrate research from developmental psychology and previously published reviews of the gender difference in STEM achievement, education, and careers that took a lifespan developmental approach to understanding disparities and potential interventions (for previous reviews, see Ceci et al., 2014; Dasgupta & Stout, 2014; Liben & Coyle, 2014). The stages of development outlined herein should be not be regarded as monolithic, rather, psychosocial development progresses along a continuum. However, we organize the present section into approximate age groups from early childhood to middle adulthood that correspond to educational levels and career progression (see Table 2 for an outline). We hope that this discussion will shed a light on social and cultural factors that influence girls' and women's interest in STEM at different age groups.

Table 2. Psychosocial developmental factors to consider when designing interventions across the lifespan

Developmental Period	Developmental Factors	STEM-Related Factors
Early childhood	Mobility, environment and object exploration, play, caregiver reinforcement and modeling, preschool	Spatial reasoning, numeracy, gender-typed play
Middle childhood	Play, caregiver reinforcement and modeling, primary schooling, peer influence, media exposure	Math and science interest and academic performance, implicit attitudes towards gender and STEM, gender stereotyping, role model exposure
Adolescence	Caregiver reinforcement and modeling, secondary schooling, peer influence, media exposure, mentorship, puberty, identity exploration and development, career intentions	Math and science interest and academic performance, course and track selection, implicit attitudes towards gender and STEM, gender stereotyping and gender intensification, role model exposure, STEM identity, confidence, and self-efficacy
Emerging and young adulthood	Tertiary schooling, media exposure, mentorship, identity	Math and science interest and academic performance,

	exploration and development, career exploration, commitment, and development, intimate partner relationships, parenthood and caregiving	course and major selection, implicit attitudes towards gender and STEM, gender stereotyping, role model exposure, STEM identity, confidence, and self-efficacy, work-family balance, professional networks, workplace harassment and discrimination
Middle adulthood	Career development and advancement, intimate partner relationships, parenthood and caregiving	Work-family balance, professional networks, workplace harassment and discrimination, tenure, promotion and leadership, providing mentorship
Late adulthood	Career development and advancement, intimate partner relationships, parenthood and caregiving, transition to retirement	Work-family balance, professional networks, tenure, promotion and leadership, providing mentorship

Early Childhood and Preschool

Infant and early childhood cognition research has largely found that gender differences in quantitative reasoning ability are nonexistent or very small early in life (Halpern et al., 2007). However, expectations regarding gender roles and gendered activities are communicated to children through multiple avenues, beginning early in life. Based on observation and reinforcement, children come to learn about the activities and behaviors that are associated with boys and masculine identity and the kinds of activities that are associated with girls and feminine identity. These associations may lay the groundwork for interest in STEM fields later in childhood and adolescence. One source of information about gender comes from the individuals with whom young children directly interact. According to the social cognitive theory of gender, this unfolds through observing the actions modeled by adult caregivers, preschool teachers and childcare providers, and older children (Bussey & Bandura, 1999).

Adult caretakers have a large role in shaping young children's activities and environments. Clothing, toys, and play are often gender typed from an early age and depictions of boys and girls in media also influence early attitudes regarding the activities and behaviors expected of boys and girls and have enduring effects (Coyne, Linder, Rasmussen, Nelson, & Birkbeck, 2016; Golden & Jacoby, 2018; Pomerleau, Bolduc, Malcuit, & Cossette, 1990). Certain play objects that are gender-typed have also been linked to cognitive abilities considered to be important for math and science achievement. Mental rotation and spatial reasoning, in particular, have been identified as being predictive of success in STEM fields. In a survey of German and Italian women, women who had a preference for spatial toys during their childhood tended to seek STEM degrees and scored higher on mental rotation tasks when compared to women seeking non-STEM degrees that preferred non-spatial toys during their childhood. (Moe, Jansen, & Pietsch, 2018). Interestingly, spatial reasoning is influenced by physical environments and training, for example, through video games and interactive testing, even into adulthood (Cherney, 2008; Jeng & Liu, 2016). German infants' level of experience in explorations of their environments through object manipulation and crawling was predictive of early spatial abilities (Schwarzer, Freitag, & Schum, 2013). A gender difference in spatial reasoning has been documented, with boys demonstrating greater ability in this domain compared to girls (Ceci et al., 2014). Compared to girls, boys' play behaviors, toys, and environments tend to support more practice with mental rotation and spatial reasoning -for example, construction-related toys like blocks and Legos, and mechanical toys like trucks and Tinker Toys (Jirout & Newcombe, 2015). Young girls' toys are more likely to involve nurturing behaviors and domestic tasks, such as through baby dolls and kitchen sets (Blakemore & Centers, 2005). The types of toys that are encouraged in girls are less likely to be as effective forms of practice for spatial abilities as construction, mechanical, and puzzle toys (Jirout & Newcombe, 2015).

In summary, young children are influenced by the messages about what members of different genders should and should not do. If participation and interest in spatial-oriented play and construction toys are seen as gender-typed, then children can internalize these stereotypes, which may influence future interest in STEM. Adults can shape environments early in life to encourage young girls to take interest and be exposed to STEM activities in an age-appropriate manner. Caregivers and teachers can be encouraged to seek out toys, books, and activities that provide positive experiences and practice with numeracy, spatial reasoning, and mechanical ability and that set the groundwork for exposure to mathematical thinking early in life.

Middle Childhood

For many children around the world, the period of time between approximately 6-11 years of age is characterized by enrollment in formal schooling at the primary or elementary school level. Gender stereotyping of STEM interest and ability occurs early in childhood (Cvencek, Meltzoff, & Greenwald, 2011). Below, we summarize some experiences and activities that have had demonstrable links to STEM education and interest among girls and are more frequently encountered during development in middle childhood.

Primary school/elementary school. Girls in primary school rated their math skills lower than boys' ratings of the same skills, even when girls actually attained the same level of math achievement as boys (Herbert & Stipek, 2005). Teachers may intentionally or inadvertently communicate differing expectations of who can excel in STEM fields. One way that teachers unintentionally influence students' confidence and achievement in math is through modeling their own interest and confidence, or lack thereof, in math and science. Around the world, primary educators are predominantly women (OECD, 2017). Teachers' math anxieties influence instruction styles and are negatively associated with students' math confidence (Gunderson, Ramirez, Levine, & Beilock, 2012). A study by Beilock and colleagues found that U.S. first and second grade teachers' math anxiety was correlated with their female students' math achievement and belief in gender stereotypes about math (2010).

Specifically, when female teachers had greater math anxiety, female students but not male students were less likely to succeed in mathematics at the end of the school year (Beilock et al., 2010). Classroom observations have shown that teachers may give different types of academic feedback based on gender and this differential treatment may have consequences for how girls conceptualize obstacles and challenges to learning STEM topics. Teachers are more likely to attribute girls' academic performance to ability and intellectual characteristics, which reflects a fixed mindset that portrays STEM success as an innate trait (Gunderson et al., 2012).

Other aspects of classroom setting during primary schooling can also impact girls' interest and confidence in STEM fields. Some research studies have shown that activities emphasizing the applied and altruistic benefits of STEM fields can increase girls' interest in STEM (Geist & King, 2008). A study conducted among Taiwanese primary school children showed that use of interactive features in tests of spatial ability resulted in reduced gender differences on spatial tests compared to use of standard, static tests of spatial ability (Jeng & Liu, 2016).

Parental support. Parents continue to exert a strong influence during primary school years (Dasgupta & Stout, 2014). Parents may encourage daughters and sons to encourage different types of educational experiences. Parents may also have different beliefs about their sons' and daughters' achievement and potential in STEM fields and these beliefs are strongly associated with children's reported confidence in their own math ability (Frome & Eccles, 1998). Studies have shown that during the primary school years, parents tend to rate daughters' math skills as weaker than sons' math skills, even when girls outperformed boys or when boys and girls did not differ significantly on actual math achievement test performance (Frome & Eccles, 1998; Herbert & Stipek, 2005). When parents endorse prevailing gender stereotypes for STEM success and occupational choice, they are more likely to value and expect STEM interests in sons compared to daughters (Gunderson et al., 2012). Elementary-school aged children with mothers who endorsed counter-stereotypical attitudes towards gender were more likely to have career aspirations that were more counter-stereotypical (Fulcher, 2011).

Studies have also shown that children in primary school and their parents are sensitive to gender stereotypes and may encounter challenges when reconciling feminine identity with interest in science. The large scale ASPIRES project collected data on students and their parents over a 5-year period in 11 schools with representation from a diverse array of ethnic and socioeconomic backgrounds (Archer, DeWitt, Osborne, Dillon, Willis, & Wong, 2012). One study from this overall project found that girls who were highly interested in science and their parents noted that it was challenging to be perceived as feminine and having a "feminine science identity" while also being committed to STEM (Archer et al., 2012). Other girls who were highly interested in STEM deemphasized their feminine identity and engaged in less stereotypically feminine activities but reported feeling ostracized and bullied by peers (Archer et al., 2012).

Adolescence

Adolescence is the period of transition between childhood and adulthood. The adolescent years are characterized by substantial changes, with maturation of the brain and body rivaling only the first three years of life. The development of secondary sex characteristics during puberty, brain maturation (synaptic pruning and myelination), and a host of psychosocial changes make adolescence a dynamic period. Adolescence generally overlaps with secondary school (or middle and high school). Upper secondary and high school are crucial periods for selecting educational tracks, enrolling in advanced coursework, exploring vocational interest, and considering tertiary education. This is also a period during which gender differences in selection of advanced STEM coursework and STEM educational tracks, and the consideration of STEM careers are heightened (Dasgupta & Stout, 2014; Mullet, Rinn, & Kettler, 2017; UNESCO, 2017). For example, high school students who participated in the International Science Olympiad indicated that high school science projects and science teachers were important factors that influenced their interest in science (Sahin, Gulacar, & Stuessy, 2015). In this section, we highlight key developmental processes occurring in adolescence that may be useful to consider when designing and implementing gender inclusive STEM education programs and interventions for girls.

Puberty. A major physiological event of adolescence is the attainment of reproductive maturity through a cascade of endocrinological events. Educators and mentors who work with adolescents and policymakers who seek to design interventions and policies that impact adolescents should be aware of the needs of adolescents that are experiencing puberty. For example, access to clean water and sanitation at school and in other menstrual hygiene resources and programs have been identified as a key facilitator of adolescent girls' educational success (Sommer, Figueroa, Kwauk, Jones, & Fyles, 2017; UNESCO, 2018).

Over the past century, there has been a decline in the onset of puberty worldwide. In other words, children today are entering puberty and experiencing the hallmarks of puberty (e.g. vocal change, menstruation) at an earlier age than in the past (Pathak, Tripathi, & Subramanian, 2014; Patton & Viner, 2007). This trend has been observed across the world and has been attributed to several environmental and social factors, including the availability of higher quality and more calorically dense nutrition, decline in childhood malnutrition, and exposure to endocrine-disrupting compounds in household products, plastics, and food (Bourguignon, Juul, Franssen, Fudvoye, Pinson, & Parent, 2016). Due to these changes, we recommend that policymakers and educators consider ways to develop infrastructure and provide resources (e.g. adequate sanitation, waste disposal, availability of feminine hygiene products) beginning in primary school and lower secondary school.

Self-esteem, self-concept, and self-efficacy. Adolescence is an important time for exploring and evaluating one's sense of self. Research in developmental psychology has highlighted changes to self-esteem, self-consciousness, and identity explorations that take place during this time. Importantly, gender differences in these aspects of adolescent development should be taken into consideration when crafting policies and programming that are responsive to adolescent needs and experiences. Despite receiving similar course grades in math, lower secondary school girls in Germany reported that they have more trait-based anxiety towards math and feel like they are less competent at math compared to their male counterparts (Goetz, Bieg, Lüdtke, Pekrun, & Hall, 2013). Girls in the United States who were transitioning into adolescence felt more distressed about grades and academic performance than boys, despite attaining higher grades than boys in a variety of subjects (Pomerantz, Altermatt, & Saxon, 2002). A study of math and science achievement among 8^{th} grade girls and boys in gender-segregated education in Saudi Arabia showed an interesting correlation between gender and self-concept. Abu-Hilal, Dodeen, Abdelfattah, Shumrani, & Abduljabber (2014) found that although girls outperformed boys in math and science achievement, boys tended to have a more positive, self-enhancing self-concept pertaining to their ability to achieve in math and science, compared to girls.

Positive relationships with caring, non-parental adults can help cultivate a positive STEM identity for adolescent girls interested in these subjects. Research shows that adult women scientists who serve as mentors and role models can positively shape adolescent girls' perceptions of their belongingness in STEM fields (Stoeger, Hopp, & Ziegler, 2017). A research study in Taiwan found that high school girls' STEM self-efficacy beliefs and professional commitment to engineering careers were positively associated with exposure to and awareness of female engineer role models (Liu, Lou, & Shih, 2014). Further research should be conducted on when mentorship interventions for secondary school girls are successful and when they are not (e.g. Bamberger, 2014).

Gender roles and stereotypes. The gender intensification hypothesis states that social expectations based on gender become more heightened during adolescence (Hill & Lynch, 1983). Evidence from cross-national studies and reviews shows that adolescent boys and girls are aware of and influenced by gender-based stereotypes, including expectations regarding choice of occupation and interest (Galambos, Almeida, & Petersen, 1990; Kagesten, Gibbs, Blum, Moreau, Chandra-Mouli, Herbert, & Amin, 2016; Sinclair & Carlsson, 2013). In a study of adolescent French boys' and girls' reactions to STEM stereotypes, researchers found that girls who did not believe the stereotype that women were less capable of achievement in STEM fields were more likely to increase their desire to pursue STEM careers (Selimbegovic, Chatard, & Mugny, 2007).

Textbooks convey gender stereotypes through visuals and narrative examples. An analysis of textbooks in secondary schools in Bangladesh, Indonesia, Malaysia, and Pakistan revealed that textbooks commonly depicted men and women in stereotypical roles (Islam & Asadullah, 2018). Women were included less frequently than men and were more likely to be portrayed as passive, dwelling indoors, and involved in domestic activities (Islam & Asadullah, 2018). Men were more likely to be portrayed as active, autonomous, capable of leadership, and having more prestigious occupations (Islam & Asadullah, 2018). A UNESCO-led analysis of school textbooks found that men were more likely than women to be portrayed in STEM occupations (UNESCO, 2017). Stereotyped depictions of STEM fields as being more suitable for men and boys may send the message to girls that they are less welcomed in STEM occupations or that STEM interest is incompatible with feminine gender identity (Cheryan, 2012).

Peer groups and peer influence. A hallmark of adolescence is the increasing importance of peers, or other children of the same age group. Peer groups can be impactful in positive ways by influencing academic interest and success. Adolescent girls are influenced by their peers' support of their math and science achievement and peers' engagement in academics (Dasgupta & Stout, 2014; Leaper, Farkas, & Brown, 2012). In the United States, female friends of adolescent girls exerted a stronger influence than male friends on interest in enrolling in advanced STEM coursework (Riegle-Crumb, Farkas, & Muller, 2006). A meta-analysis of 148 studies across 11 countries found that peer academic collaboration was predictive of increased academic achievement and quality of relationships (Roseth, Johnson, & Johnson, 2008). Interventions that aim to increase interest in STEM fields among adolescent girls can capitalize on these aspects of adolescent development. For example, creating projects that involve group collaboration, organizing summer study programs, and providing opportunities for girls who are interested in STEM fields to meet other similarly-aged girls with the same interests can be impactful experiences.

Emerging/Early Adulthood

Recently, emerging adulthood has been proposed as a transitional life stage between 19-29 that retains some aspects of the familial dependence and identity exploration of adolescence (Arnett, 2000). This extended period of fledgling independence, completion of education and training, and gradual adoption of "adult roles" has been observed worldwide (Crocetti, Tagliabue, Sugimura, Nelson, Takahashi, Niwa, Suigiura, & Junno, 2015; Luyckx, Goossens, & Soenens, 2006). The concept of emerging adulthood as a developmental period distinct from adolescence and early adulthood is not without its critics: researchers have pointed to cultural differences and broader economic and societal shifts that extended the period of educational specialization and continued financial dependence on parents and families (Côté, 2014; Lancy, 2015).

Emerging adulthood presents unique opportunities to intervene in women's interest in, pursuit of, and persistence in STEM fields. Continued emphasis on identity and career exploration can target women who are interested in pursuing careers in STEM. In a study of German university women pursuing STEM degrees in fields that were particularly male-dominated (women comprised less than or equal to 30% of students in the major; e.g. electrical engineering, computer science), researchers found that stereotypes about women's relational focus, STEM-related achievement and abilities, and academic interests detrimentally impacted women's academic self-concepts (Ertl, Luttenberger, & Paechter, 2017).

Canadian researchers examined motivational and emotional variables that account for persistence and achievement in STEM for young women and men in the transition between high school and university (Simon, Aulls, Dedic, Hubbard, & Hall, 2015). In their survey of 1,309 first year college students (15 to 19 years old; 46% male and 54% female), researchers found that students with higher levels of positive mood and academic achievement, defined as the mean grade of students' math, physical science, physics, and chemistry classes, were more likely to enroll in STEM programs in university (Simon et al., 2015). In particular, women who had stronger performance orientation were especially likely to have higher achievement in STEM classes (Simon et al., 2015). Research in Canada has also found that providing social-belonging messages and stress-attribution and management training to women enrolled in male-dominated engineering majors resulted in positive effects on self-esteem, attitudes towards engineering, management of stress, and academic achievement for women (Walton et al., 2015).

Opportunities for young women to join supportive professional networks can be especially important for developing research partnerships and promoting a sense of belonging in the professional community (Dasgupta & Stout, 2014). Professional organizations and academic conferences can provide opportunities for mentorship. A study of women engineering students in the Dominican Republic found that women's self-efficacy and persistence in STEM were enhanced by encouragement and persuasion by friends, mentors, and family members, vicarious experiences, and mastery experiences (Barouch-Gilbert, 2018). Vicarious experience was described as a combination of positive messages, guided learning, and comparing oneself to role models. Being guided by a friend or aspiring to be like a role model pushed students to further their studies. Mastery experiences, or past experiences of success, helped students cope with academic challenges by reminding them that they were capable of achieving success (Barouch-Gilbert, 2018).

Unfortunately, traditionally male-dominated professional networks, conferences, and scientific field research sites have also been locations where young women in STEM fields have reported experiencing sexism, discrimination, and sexual harassment (Clancy, Nelson, Rutherford, & Hinde, 2014; Settles & O'Connor, 2014). Professional organizations would benefit from integrating policies, practices, and changes to professional culture in order to prevent and effectively address discriminatory and illegal practices. Calls have been voiced by senior women scientists for organizations to enact policies such as removing research funding when primary investigators have perpetrated sexual harassment (Marín-Spiotta, 2018). The Athena SWAN Charter in UK is one example of a broad initiative that could support the development of such initiatives. Promoting safety, respect, and inclusive cultures at conferences, field sites, and professional organizations is an important area of development for addressing gender discrimination in the sciences.

Middle and Late Adulthood

Women who work in STEM professions can face challenges and barriers to leadership and advancement in their careers. The challenges highlighted below have been shown to impact women, more than men, and are not necessarily unique to STEM fields.

Career advancement and leadership. Women are less likely to be represented at top executive and leadership positions in STEM fields and to be awarded the most prestigious achievement awards in science and mathematics (Mullet, Rinn, & Kettler, 2017). As of 2018, 51 out of 935 Nobel Laureates are women and just one Fields Medal has been awarded to a woman. In an ethnographic study of 42 women working in STEM careers in Singapor, the two themes that were consistently identified by respondents were the influence of Asian patriarchy and familial roles and the gendered structure of organizations in STEM fields (Dutta, 2018). Holding a leadership position was perceived as fitting more closely to masculine gender roles that emphasize assertiveness and aggression. Some interviewees noted that assertiveness was necessary to get a higher position, but assertive women were not culturally acceptable. Many interviewees prioritized balancing their careers with familial roles over leadership roles. They felt that being a mother was intrinsically tied to their feminine identities and that they received insufficient assistance with household and childcare responsibilities from their partners (Dutta, 2018). The interviewees perceived that Asian women in STEM careers were viewed as being more focused on being a mother or wife, and were subsequently less likely to be offered leadership positions (Dutta, 2018).

Stereotypes about who is a successful STEM researcher or professional are not only limited to gender. Gender, race/ethnicity, and sexuality tend to have interactive effects. For example, the lack of representation of women, individuals of historically marginalized racial/ethnic groups, and LGBT+-identifying individuals in STEM fields can lead to feelings of marginalization. An ethnographic study of Colombian women scientists who also identified as black, indigenous, or lesbian illuminated issues of intersectionality in STEM (Pérez-Bustos & García-Becerra, 2013). Respondents in this study reported that they felt at times marginalized in STEM and academic institutions, but were aware that their presence and participation in these areas had the power to transform institutions (Pérez-Bustos & García-Becerra, 2013).

Caregiving and work-life responsibilities. Women with careers outside of the home often face a double-bind: the desire to excel in the workplace and the expectation to engage in substantial domestic and family care. Women in midlife may be in the "sandwich generation," engaging in elder caregiving as well as childcare responsibilities. Research has shown that despite progress in women's acceptance and success in the workplace, women are still performing more caregiving and domestic duties at home, compared to men (Yavorsky, Dush, & Schoppe-Sullivan, 2015). On average, having children is negatively associated with workplace productivity for women in STEM research careers, but not for their male counterparts (Ceci et al., 2014).

Social and cultural shifts in expectations for women's labor are necessary to counteract barriers to women's advancement and leadership within STEM fields. Since many of these barriers are endemic to environments that had traditionally favored men in leadership positions, broader adjustments are likely needed to remove impediments to women's success in these contexts. Some changes can be supported by policies. For example, family-friendly workplace benefits such as parental leave and flexible work scheduling have been shown to be especially appealing to women who are managing various roles within the home and workplace (Ovseiko et al., 2017). On a societal level, policies that support the wider adoption of family leave, transitions back into the workplace, and availability of affordable healthcare and childcare may support adult women's participation in the STEM workforce.

Sexual harassment and discrimination. Lastly, sexual harassment in workplaces is more commonly experienced by women compared with men, and causes detrimental consequences for physical and mental health, motivation, and career advancement of victims (Clancy, Lee, Rodgers, & Richey, 2017). The occurrence of sexual harassment is not limited to STEM fields; however, sexual harassment and bullying are more likely to occur in workplaces where there is a larger gender imbalance in favor of men or the presence of "token" women and individuals of racial/ethnic minority status (Kanter, 1977; Willness, Steel, & Lee, 2007). Negative workplace culture and climate are associated with occurrence of sexual harassment (Willness, Steel, & Lee, 2007). STEM workplaces should consider implementing clear and robust policies to prevent to address harassment and discrimination, for example, instating a zero-tolerance policy with swift, decisive, and punitive actions against perpetrators and providing multiple avenues where confidential reports can be made (e.g. ombudsperson, human resources representatives, mentors).

Limitations and Recommendations

Based on the review of the cases highlighted in this report, we present the following discussion of gaps in the research on interventions for increasing girls' and women's advancement in STEM. The limitations can be broadly categorized into gaps in outcome measures, gaps in tracking impact over time, flaws in research methodology, participant samples, lack of sufficient empirical outcomes data, and consideration of broader social and structural issues pertaining to gender inequality. Below, we outline common limitations and suggest ways that researchers and STEM program development teams can address issues when designing and implementing outcomes research in the future.

Outcome measures. The present summary of case studies around the world assessed an array of outcome measures, including classroom observation, size of professional networks, number of contacts with mentors, self-esteem, confidence in STEM, implicit attitudes, attitudes towards women in STEM, participant responses in focus groups and interviews, survey research, GPA, course selection, and performance on knowledge tests. Despite the diversity in assessments, self-reported attitudinal data (e.g. interest in STEM careers and topics, liking of STEM intervention) was the most common outcome assessed in intervention studies. Although attitudes and interest are predictive of behavior, they are not to be equated with actual behavior and objective performance measures. Selection of STEM courses, enrollment in STEM programs, and completion of STEM degrees would be more objective measures of STEM educational advancement and commitment. Grades in STEM courses and scores on STEM subject exams would provide greater validity as measures of STEM achievement and knowledge. Lastly, commitment to STEM professions could be assessed by outcome measures such as completion of STEM internships and continuation into STEM careers. Initiatives to enhance girls' and women's participation and success in STEM are ostensibly concerned with behavioral and objective outcomes. However, publicly available academic reports of the evaluation of intervention programs rarely report on the success of programs defined by behavioral measures. We recommend that future intervention research increase the use of objective and behavioral measures of STEM advancement.

Tracking impact over time. Longitudinal research is resource-intensive and challenging to implement. However, long-term tracking of the impact of STEM interventions would provide a powerful examination of how interventions unfold over time. In some cases, interventions that have immediate positive impacts may not necessarily have long term impacts. In other cases, interventions that do not appear to register immediate effects may actually have powerful effects in the long term. In still other cases, interventions with small initial effects may cause a "domino"-like cascading effect with substantial benefits into the future (Yaeger & Walton, 2011). Without longitudinal data, information about the effectiveness of intervention programs is ultimately incomplete and limited in scope. Therefore, we encourage the implementation of longitudinal research methods that can potentially provide richer and more complete information on the effectiveness of interventions.

Flaws in research methodology. Robust intervention studies should ideally follow a pretest posttest randomized control group design. In this design, participants complete assessments prior to and following exposure to the intervention or control. Random assignment to intervention or control group provides the best experimental control for individual differences in demographic and academic characteristics, for example, race/ethnicity, socioeconomic status, age, major, and intelligence. When participant groups are limited in size, matched groups designs wherein participants in the intervention and control groups are matched on key relevant characteristics (e.g. math subject test score) are recommended. Improved research methodology can clarify the interpretation of outcomes data. In some cases, the actual effectiveness of STEM intervention programs may have been masked by the lack of appropriate research methodology. For example, interventions that appeared to result in negative or no effects may have actually led to improvements compared to the absence of intervention. However, without a comparison (control) group, it is impossible to document this change. For example, Goodyer and Soysa (2014) found that girls' interest in science decreased after the intervention. However, was this decline in interest actually less steep compared to the potential decline in interest of their counterparts who did not participate in Hello Café? If this were the case, it is likely that the intervention would have been considered a success. Therefore, we strongly recommend that future outcomes research on interventions utilize appropriate research methods so that appropriate conclusions can be made and that the true benefits of STEM interventions are not obscured by research artifacts and interpretability problems.

Participant samples. We applaud efforts to develop programs that reach diverse groups of students. Collectively, the studies outlined in this report were directed towards high-achieving students, low-achieving students, national school systems, science courses, ethnically diverse samples, and students from lower socioeconomic status communities. We highlight the need for more research that seeks to understand why high-achieving girls opt out of STEM. According to reviews of the development of STEM interests and expertise, students who are high achievers in math and science courses are more likely to continue into STEM careers, compared to their peers (Ceci et al., 2014). A potentially powerful approach to designing interventions for increasing women's participation in STEM careers would involve targeting high-achieving girls in efforts to address "leaky pipeline" problems that may hinder progression into STEM careers and advancement within those careers. Such an approach would reach the population of students that is statistically more likely to continue into STEM careers. Two highlighted case studies, the CyberMentor research by Stoeger, Hopp, and Ziegler (2017) and the STEP program by Walton and colleagues (2015), targeted high-achieving students. The participants in the CyberMentor study were high-achieving girls in secondary school and the participants in the STEP program study were university students who were already in their first year of a prestigious engineering school. Moving forward, we recommend the development of targeted intervention programs or scaling up preexisting programs like CyberMentor and STEP in order to enhance women's persistence in STEM careers.

Empirical outcomes data. The present review of STEM intervention research around the world focused on published studies of outcomes data. We emphasize the general need for continued investment in outcomes research for several reasons. First, assessment of intervention programs can provide meaningful feedback that is helpful in improving and refining programs meant to benefit girls and women. Assessment of targeted outcomes can yield information about the efficacy of programs to communities, educators, and stakeholders. Second, published research or publicly available data on outcomes of intervention programs is essential to the efforts of the scientific community. Access to empirical outcomes data drives the critique of relevant theories and development of new research projects. In addition, the synthesis of existing empirical research through literature reviews and quantitative metaanalyses yields impactful summaries of effects across different types of interventions (e.g. mentoring, stress-management, bridge programs), different samples (e.g. high-achieving, primary school, tenure-track professors), and different cultures and settings (e.g. rural, urban, online, community-based). Empirical intervention research can be time and resource intensive. To that end, we recommend cross-cutting partnerships between policymakers, educators, nonprofit organizations, private companies, and universities. Social scientists who are interested in gender equality research, education research, learning, motivation, and vocational psychology can provide consultation on research design methodology, outcomes assessment, implementation, and data analyses. Partnerships between academic social scientists and intervention programs can yield fruitful arrangements for outcomes research that contributes to program evaluation in addition to the scientific examination of learning, social interventions, and gender socialization.

Structural and systemic considerations. Interventions are typically designed to address deficits in individuals' skills, confidence, and access to resources. However, individuals are nested within larger social, political, and cultural systems that transmit values and incentivize actions that are sometimes at odds with achieving gender equality in STEM. Individual interventions may provide important sources of support to bolster girls' and women's sense of belonging in STEM fields, however, they do necessarily change systemic and structural issues that caused disparities in women's STEM participation. Educational interventions are also supported by access to transportation, educational materials, and the support of families and communities. For example, public transportation, sanitation infrastructure at schools, home internet access, school laboratory resources, and ownership of digital devices such as laptops may all contribute to students' success in STEM but are not necessarily addressed in STEM intervention programs (e.g. Kafui & Johannes, 2018). Even interventions that are designed to address disparities at the level of the institution (e.g. Athena SWAN) do not necessarily change broader cultural norms around expectations of women's caregiving labor and men's contributions to caregiving and household labor (Ovseiko et al., 2017). When evaluating the outcomes of STEM interventions for girls and women, it is important to consider this limitation. Interventions do not take place in a vacuum and individualized interventions occur within the context of broader systemic and cultural structures that impact girls' and women's participation and advancement in STEM.

Conclusions

The present report reviewed examples of STEM interventions intended to bolster girls' and women's interest in, positive attitudes towards, and achievement in STEM. Due the academic interests of our course, we focused on interventions that targeted girls and women during the crucial developmental periods that overlap with secondary and tertiary schooling, spanning from approximately 10-22 years of age. This aligns with research emphasizing the importance of these developmental periods for committing to STEM educational tracks, selecting university majors, and pursuing careers in STEM (UNESCO, 2017). The present report also focused on summarizing published or publicly available outcomes research on STEM intervention programs for girls and women *outside* of the United States. To that end, we collected information on STEM programs and initiatives of varying scope and aims from Australia, Bangladesh, Canada, Chile, Germany, Israel, Kenya, Malawi, New Zealand, Nigeria, Pakistan, Taiwan, Trinidad and Tobago, and the UK. STEM intervention programs described herein were mostly successful in their aims, though some findings were mixed.

Our review of intervention outcomes research yielded information on gaps in current international research. First, in some cases, mixed findings may reflect flaws in research design, rather than actual problems with the intervention. We suggest that future endeavors to conduct program evaluation implement robust research designs, preferably with a well-constructed control group. Second, we recommend assessment of long-term outcomes and non-attitudinal outcomes, when possible. While immediate attitudinal outcomes such as positive feelings towards and confidence in STEM subjects, willingness to pursue a STEM career, and positive perceptions of the intervention program are all useful metrics, they are not necessarily good proxies for the types of behavioral outcomes which are of interest to many educators and policymakers: STEM subject grades, enrollment in STEM subjects and educational tracks, math and science achievement test performance, and completion of tertiary education in STEM majors. While such behavioral measures are not necessarily the only metrics for STEM success, we advocate for more richness and complexity in outcomes research, starting with addressing this gap in assessment of outcomes. Third, more international research is needed to explore why some programs are successful and others are not. For example, CyberMentor in Germany was an effective STEM mentoring intervention while BAMOT in Israel was associated with decreased positive attitudes towards and interest in STEM careers. Although both programs involved partnerships with private companies, mentoring by adult women in STEM careers, and targeted secondary school girls, there are several explanations for differences in the programs' outcomes. Differences could be due to duration of the program (yearlong vs short term), strength of relationship-building, content of STEM communications, frequency of communication, setting (online vs in-person), mentee to mentor ratio, achievement levels of targeted students, national differences, and cultural values. In addition, the studies assessed different outcomes, which makes direct comparison more difficult. Without additional research that can distinguish among mechanisms that drive differences in the effectiveness of similar interventions, it is difficult to suggest conclusive recommendations to policymakers and educators based on the outcomes reported by the case studies highlighted in this report.

We are hopeful that innovative, practical, and developmentally sensitive interventions will contribute to the overall goal of increasing gender equality in STEM. Evidence from intervention outcomes research, international assessment data, and historical trends generally shows that educational, psychological, and social interventions can be effective tools, that there is global variation and malleability in gender differences in math and science achievement, and that STEM achievement gaps have been narrowing over time.

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