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Collaborations, not competitions, can reduce gender disparities in robotics

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Collaborations, not Competitions, can Reduce Gender Disparities in Robotics

The authors' experiences with robotics and mathematics competitions

Sonia was introduced to robotics in college through a robot competition. While building the robot was fun, her overall experience was lukewarm. Fortunately, Sonia also took a class using robots as tools to understand agency and intelligence – her main interests. She then started working with the professor, who uses robots in his lab. Investigating scientific questions substantially deepened her interest in the field and led to an engineering PhD.

Aly was part of a "gifted" program in middle school in which all students took the AMC 8, a timed competitive math exam. Since all students were enrolled in advanced math courses, high performance was the norm, and the numeric score made for easy social comparison. Aly remembers being very aware of the gap between her scores and those of the highest-scoring boys in the class.

Although the specific circumstances of these experiences are unique, they both reflect larger trends in how competitions affect girls'[1] and women's engagement in math and engineering.

Girls disengage from robotics and engineering competitions due to stereotyping

Robotics competitions are a popular means of engaging students in the field. One of the largest organizations for K-12 competitions, FIRST, boasts 3,225 teams of 80,000 students across 26 countries (FIRST, 2022a). Despite their popularity, such competitions have lower rates of participation among historically excluded groups, including girls (Witherspoon et al., 2016). Such competitions could fail to engage girls because of interlocking stereotypes regarding STEM performance and competition. Decades of research demonstrates that STEM disciplines are stereotyped as masculine, or "not for girls/women" (Carli et al., 2016; Miller et al., 2018; National Science Foundation, 2003). High intellectual ability – perceived as necessary in STEM – is also seen as more common among men (Leslie et al., 2015), and these beliefs are endorsed by children as young as six (Bian et al., 2017). Such stereotypes lead to gender disparities in interest/identification with STEM. Compared to other groups, White men report greater belonging in STEM (Rainey et al., 2018), to the extent that men who earn C's in physics report comparable physics self-efficacy to women who earn A's (Marshman et al., 2018).

Girls and women are also subject to prescriptive stereotypes (i.e. social norms) that they be less agentic and competitive (Prentice & Carranza, 2002), with implications for engagement in competitive domains (Kleinjans, 2009). Stereotype threat – concern about confirming negative stereotypes that interferes with performance in the stereotyped domain (Steele & Aronson, 1995) – has been shown to impair women's math performance (Spencer et al., 1999), and women underperform relative to men in masculine-stereotyped domains to a greater extent when performance is framed as competitive (Gunther et al., 2010). Collectively, this may decrease girls' and women's interest in robotics and engineering competitions.

Mitigating the negative effects of competitions

[1] Categories like "girls" generally refer to the people who identify best with those labels. When discussing another paper, they refer to the participant groups reported on.

One popular option to make robotics and engineering programs more welcoming is to have ingroup mentors and role models (Kim et al., 2018). While effective (Dennehy & Dasgupta, 2017), these interventions demand additional labor from members of excluded groups which may perpetuate inequities. Creating girls-only robotics and engineering competitions (i.e., "counterspaces" [Ong et al., 2018]) can signal that girls' competition is sanctioned and welcomed. However, such efforts reinforce gender differentiation, essentialism, and stereotyping (Yzerbyt et al., 2001), undermining inclusion goals.

De-emphasizing competition may be more effective. Public attendance at robot competitions is higher and includes more girls and women when they include demos and workshops (Riedo et al., 2013). A set of popular robot competitions can provide a natural experiment on the effects of de-emphasizing competitiveness (Table 1). FIRST runs a robot competition for children in elementary and middle school called the FIRST Lego League (FLL). Students initially "build, program, and research" their projects (FIRST, 2021a) using FIRST's educational resources (FIRST, 2022b), and must demonstrate "coopertition" and "gracious professionalism" to advance (FIRST, 2022b). FIRST runs the FIRST Tech Challenge for students aged 12- 18, which goes immediately from the kickoff into a round of competitive engineering challenges (FIRST, 2021b). Witherspoon et al. (2016) reported that 43% of participants surveyed in FLL's 8-14 age range were girls, compared with 26% in FTC. The different age ranges could be a confounding variable, but a second organization that emphasizes the competitive aspect in both age ranges – VEX (Sullivan and Bers, 2019) – can provide a second natural comparison. Witherspoon et al. (2016) reported girls' participation at 27% and 26% respectively in the VEX competitions for the same age groups as FLL and FTC. Front-ending competitions with other educational resources could make a huge difference for girls' engagement in the program by removing the opportunity for boys to provide negative social interactions.

Competition	Ages	Competitive emphasis	Educational resources	% girls
FLL	8-14	Low	High	43
FTC	12-18	High	Low	26
VEX	8-14	High	Low	27
VEX	12-18	High	Low	26

Table 1: Comparison of the FIRST Lego League (FLL), FIRST Tech Challenge (FTC), and VEX competitions for different age groups. The designation of educational resources is based on a combination of the resources that the authors were able to find reference to online, and how much time students have to engage with those resources before the competition starts.

Imagining conventions, not competitions

No matter the strength of a woman's STEM identity or the number of workshops, demos, and educational resources a robot competition provides, we emphasize that these are only mitigating the negative effects of having a competition. This begs the question: Why is the competition aspect necessary? We could imagine robotics and engineering programs that foster collaboration and encourage students to develop projects, and build knowledge, together (Barkley et al., 2014). Just switching programming competitions from time-based coding tasks in which all students solve the same problems to project-based tasks that allow students to choose their projects (Webb et al., 2002; Barkley et al., 2014; Shah & Kopko, 2016) has been shown to increase female participation two- to three-fold (Fitzgerald & Hines, 1996; Vladoiu et al., 2017).

Robotics programs could take a similar approach. This should not only help more girls and women engage in and identify with robotics and engineering (McLean et al., 2020), but also other students who experience discrimination or stereotype threat in STEM, such as gender minorities (Maloy et al., 2022; Yoder & Mattheis, 2016) and students from lower socioeconomic status backgrounds (Almas et al., 2016). We end with a few blue-sky visions of robot conventions.

- Teams randomly select three words related to robotics from a list compiled by the organizers, and complete a project touching on all three topics (Valencia, 2012).
- All teams participating in the program submit a ranked-choice list of problems in their community which could be addressed by a robot. Organizers create "leagues" addressing the most popular problems. Each team chooses one aspect of their league's problem to investigate.
- Each team identifies one area of robotics they want to learn more about and develops a demonstration, workshop, or project to teach others about it. Students present their projects at the end of the year in a public convention.

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