

Executive Summary

To double the number of young women who major in STEM fields, I propose creating the National Robot Library, an organization aimed at propagating the use of hands-on physical computing devices, such as Micro:Bits, Raspberry Pis, and Ozobots, in K-12 schools. The National Robot Library will provide K-12 teachers anywhere in the United States with no-cost loans of physical computing devices coupled with self-paced, online professional development. Teachers apply for a loan, take an online class specific to the kit they requested, and receive in the mail a classroom set of physical computing devices. Teachers keep and use these devices across their school campus for several weeks and then mail them back. Threaded throughout the program is an integrated effort to increase the number of young women interested in STEM: the online classes teachers take promote research-based tactics to engage female students, the suggested activities included with the kits are designed specifically to pique the interest of students unsure about STEM, and the National Robot Library's school selection algorithm ensures that the classrooms it serves maximize its impact on gender equity. Provided sufficient funding, the National Robot Library will aggressively scale the program over the next four years, beginning with 100 loan kits in the first year and steadily growing to a full operational capacity of 5,000 kits, capable of serving 5,000,000 students per year.

The Problem

Our country has a gender equity problem in STEM. In 2016-2017, 478,601 STEM degrees and certificates were awarded to males, while only 225,979 were awarded to females (Figure 1). While the total number of STEM degrees has increased over the last decade, the percentage of STEM degrees earned by females has been relatively stagnant, hovering around 30%. Doubling the number of young women who earn STEM degrees is an audacious goal. The ratio of females to males earning STEM degrees has appeared to be immutable, despite a variety of past and current initiatives targeted at increasing females' interest in STEM. It is in this context that I propose a new approach to solve this problem. The National Robot Library strives to impact the system, not just the girls. In its design, it both inspires females to pursue STEM, while also training teachers to address existing systemic barriers. With this strategy and sufficient scale, the National Robot Library will be able to double the number of young women in the STEM degree pipeline in ten years.

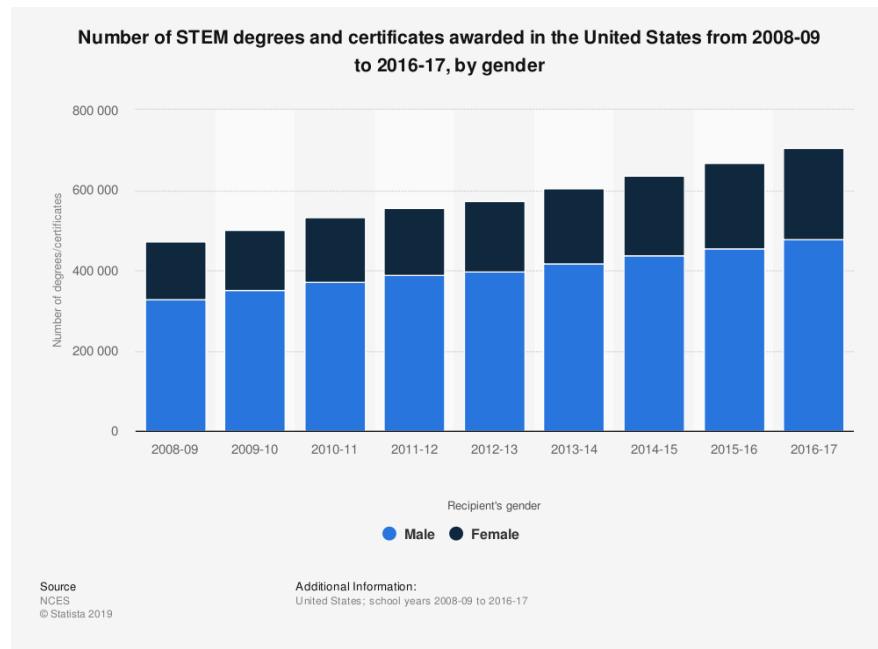


Figure 1.

The Solution

The national statistics show that the largest gaps in female STEM engagement in higher education are found in the fields of computer science and engineering; therefore, I propose a solution that focuses on computer science and engineering (NCES, 2018a). The National Robot Library aims to increase female engagement in STEM by expanding the use of hands-on physical computing devices, such as Micro:Bits, Raspberry Pis, and Ozobots, in K-12 schools while simultaneously providing high-quality support and training for teachers. While most schools in this country have desktops, laptops, and tablets, a relatively small number are investing in physical computing. This is where the National Robot Library comes in. The National Robot Library will provide K-12 teachers anywhere in the United States with no-cost loans of physical computing devices coupled with self-paced, online professional development. Teachers apply for a loan, take an online class specific to the kit they requested, and receive in the mail a classroom set of physical computing devices. Teachers keep and use these devices across their school campus for several weeks, and then mail them back. These devices allow students to see their code come to life in the real world in a way that traditional desktops, laptops, and tablets cannot. Physical computing devices spark joy and pique student interest in

STEM, offering promising long-term impacts, especially when coupled with research-based practices that support gender inclusivity in STEM.

Most traditional solutions to increasing the number of females interested in STEM focus on segregating girls and running programming meant to spark their interest in STEM. Girl Scouts, for instance, has STEM badges to earn; and Girls Who Code runs afterschool clubs to promote girls' interest in computer science. However, the lack of female participation in STEM is a systemic problem, and these solutions only address one area of the system: the girls. The National Robot Library approach is different because it centers around training teachers to not only utilize physical computing devices with skill and tact in their classrooms, but to do so using practices proven to increase female interest in STEM. The unit of transformation will be classrooms and schools, instead of individual girls, and this will lead to a lasting impact, even after the physical computing loans have been returned.

The National Robot Library's online professional development will integrate research-based strategies identified by SciGirls to ensure teachers who receive the physical computing kits are prepared to teach computer science and engineering with equity in mind (Table 1). Every kit will have its own device-specific online professional development, but all will cover the six strategies laid out by SciGirls. Additionally, each professional development will have suggested activities that teachers can do with the devices. These activities will be collaborative, social, and community-oriented. Armed with training in these equitable practices, teachers will deliver learning experiences that encourage and support girls in developing a sense of excitement and belonging in STEM. These positive experiences with physical computing devices are vastly important to building the STEM pipeline.

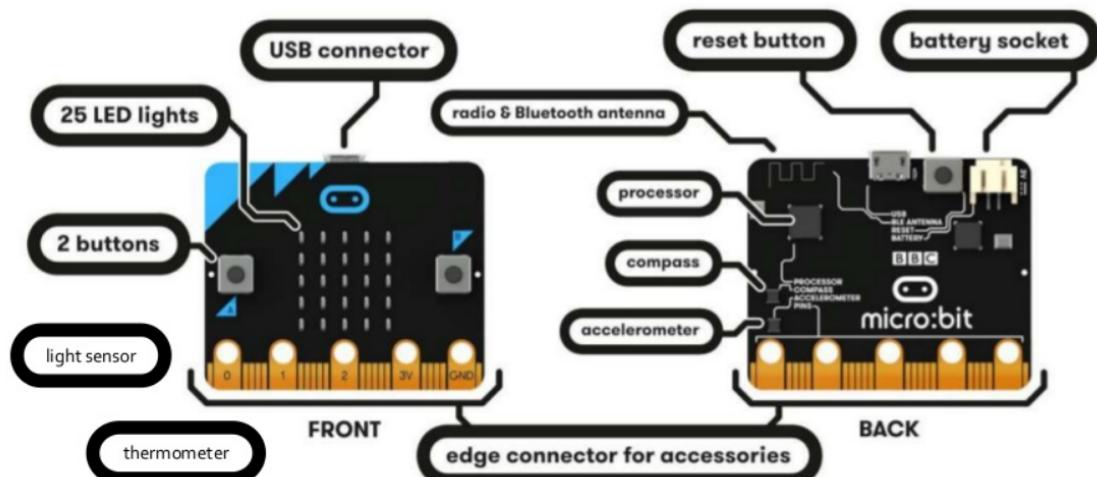


Figure 2 - The Micro:Bit. Smaller than a credit card, these multi-use devices are packed with technology.

The mission to engage all students while simultaneously addressing gender inequity is a unique attribute to this program. When teachers apply to receive a loan from the program, a selection algorithm will give preference to classrooms with more female students; however, the National Robot Library is not exclusionary by gender. The physical computing kits will be awarded to a diverse set of classrooms and will be used by young men and women alike. Additionally, many of the SciGirls Strategies may be applied broadly to benefit any student in the room, including students of racial and ethnic backgrounds who are also underrepresented in STEM.

Table 1. Sci Girls Strategies

Strategy	Supporting Research
Connect STEM experiences to girls' lives.	Boucher et al., 2017; Sammet et al., 2016; Bonner & Dornerich, 2016; Erete et al., 2016; Stewart-Gardiner et al., 2013; Civil, 2016; Verdin et al., 2016; Cervantes-Soo, 2016.
Support girls as they investigate questions and solve problems using STEM practices.	Buckholz et al., 2014; Kim, 2016; Scott & White, 2013; Farland-Smith, 2016; Munley & Rossiter, 2013; Civil, 2016; Riedinger et al., 2016.
Empower girls to embrace struggle, overcome challenges, and increase self-confidence in STEM.	Blackwell et al., 2007; Dweck, 2000; Halpern et al., 2007; Kim et al., 2007.
Encourage girls to identify and challenge STEM stereotypes.	Allen et al., 2017; Carli et al., 2016; Cheryan et al., 2015; Robnett, 2016; Carlone et al., 2015; Sammet et al., 2016; Scott et al., 2014; Tan et al., 2013; Dasgupta et al., 2014; Verdin et al., 2016; Civil, 2016; Boucher et al., 2017.
Emphasize that STEM is collaborative, social, and community-oriented.	Capobianco et al., 2015; Diekman et al., 2015; Leaper, 2015; Riedinger et al., 2016; Robnett, 2013; Parker & Rennie, 2002; Scantlebury & Baker, 2007; Werner & Denner, 2009; Cakir et al., 2017; Sammet et al., 2016; Boucher et al., 2017; Clark et al., 2016; Leaper, 2015.
Provide opportunities for girls to interact with and learn from diverse STEM role models.	Koch et al., 2015; Leaper, 2015; Adams et al., 2014; Jethwani et al., 2017; Kessels, 2014; O'Brien et al., 2016; Levine et al., 2015; Hughes et al., 2013; Cheryan et al., 2015; Weisgram & Diekman, 2017.
Source: SciGirls Strategies, http://www.scigirlsconnect.org/scigirls-strategies-engage-girls-stem/	

In addition to the research backing the National Robot Library's professional development and suggested activities, part of the organization's core value proposition is connecting innovation to the classroom. The physical computing devices themselves are the result of decades of advances in educational technology. From the first physical computing devices used in classrooms by Seymour Papert, the creator of the Logo turtle, to the plethora of devices available now, the National Robot Library rests on the shoulders of countless researchers and innovators.

Implementation Description

I strongly believe in the importance and power of getting these devices into the hands of students, and as a result, have already completed a small pilot of this program. Feedback from the two teachers in the pilot was very positive. Teachers successfully completed an online training, utilized the kit of Micro:bit devices in their classrooms, and found that students were very engaged in the activities. This pilot was a promising first step, but there is much more work to be done to achieve the goals of the National Robot Library.

Given a public/private investment of up to \$1 billion, the National Robot Library would aggressively scale up the lending library of physical computing kits within four years, starting at 100 kits as the groundwork is being laid and expanding to a full-capacity total of 5,000 kits. Each loan kit would be able to serve five schools per year. At an average of 200 students served per school, the total students served would be five million per year when at full capacity. Assuming these numbers, **if the National Robot Library is able to inspire approximately two out of every hundred girls it serves to go into a STEM field, it would accomplish doubling the amount of young women on track to pursue STEM degrees within ten years.**

The National Robot Library model is inherently scalable by design. The reliance on web-based training and national mail service providers allow for the possibility of rapid expansion.

Rapid expansion of the capacity of the National Robot Library, however, does not directly translate into success. There will be hurdles along the way. Our team will need to swiftly increase awareness of our program; our team will need to execute our logistics as flawlessly as possible; and our team will need to constantly iterate on our program offerings, gathering feedback and measuring results in order to drive continuous improvement.

During Year 1, the National Robot Library will expand to 100 kits and have 1 full-time staff member (Table 2). In Year 2 through Year 4, the National Robot library will increase the number of kits as well as the number of types of physical computing devices available for teachers to request. As the National Robot Library expands in Year 2, I will hire on staff as needed, ending up with approximately 11 full-time staff members by the end of Year 4. The staffing split will consist of the Executive Director; two staff members devoted to maintaining and expanding the professional development and curriculum offerings; two staff members in charge of marketing; four staff covering logistics and operations; one administrative coordinator; and one staff member responsible for fundraising and grant writing.



Figure 3. The Ozobot. A tiny programmable robot that reads sequences of colors on a line and executes programs accordingly.

Table 2. Implementation Timeline

Implementation Timeline	
Phase	Description
Dev R1: Fall 2018 - Present	Small Pilot
Dev R2: Present - Summer 2020	Achieve 501(c)(3) status, Begin teacher recruitment
Y1: School Year 2020 - 2021	Expand to 100 kits; 3 physical computing device offerings; Target Grades K-6
Y2: School Year 2021 - 2022	Expand to 1,000 kits; 6 physical computing device offerings; Target Grades K-8
Y3: School Year 2022 - 2023	Expand to 2,500 kits; 8 physical computing device offerings; Target Grades K-12
Y4: School Year 2022 - 2023	Expand to 5,000 kits; 10 physical computing device offerings; Target Grades K-12
Y5+: School Year 2023 and beyond	Stabilize at 5,000 kits; 10 physical computing device offerings; Target Grades PreK-12

The funding requirements for the program reflect my emphasis on running a lean organization while balancing the realistic challenges I anticipate. In the first four years, the National Robot Library's costs will include procuring the physical computing devices, at a total cost of \$4,000,000 for the 5,000 kits (Table 3). I have budgeted this expense as a temporary startup cost, separating it from the operating expenses of the organization. To maintain the physical computing kits, I have budgeted in the cost of replacing 10% of the devices each year due to damage or loss. After this initial growth period, operating expenses for the organization level out at \$2,500,000 per year.

The Moonshot for Kids competition's assumed one billion dollars of investment would get the National Robot Library through the first 10 years of operation and well beyond that point. If that level of funding was not available, I would develop a long-term, sustainable funding plan where approximately 30% of revenue would come from corporate donors and sponsors, 25% of revenue would come from foundations, and 25% of revenue would come from government grants. The remaining 20% of revenue would be generated by fee-for-service professional development purchased by districts or states.

Table 3 Funding Timeline

Funding			
Phase	Operating Expenses	Initial Device Expenses	Total
Y1: School Year 2020 - 2021	\$320,000	\$80,000.00	\$400,000
Y2: School Year 2021 - 2022	\$1,000,000	\$720,000	\$1,720,000
Y3: School Year 2022 - 2023	\$1,150,000	\$1,200,000	\$2,350,000
Y4: School Year 2023 - 2024	\$2,500,000	\$2,000,000	\$4,500,000
Y5+: School Year 2024 - 2025 and beyond	\$2,500,000	No new initial device expenditures, only replacement.	\$2,500,000

Incorporating Feedback

The success of the National Robot Library depends on the positive end-user experience of teachers and students who utilize our physical computing kits. The program is competing for the time and attention of teachers, a notoriously overworked group. Our execution in teacher recruitment, professional development, and logistics is vital to our success as an organization.

To track effectiveness, the National Robot Library will employ a system of continuous collection of feedback. This information will be especially vital during the first few years of the program to ensure that the overarching goal of increasing the number of females in the STEM pipeline is being achieved. Each teacher will be surveyed at three distinct points in their journey: before the online professional development course, after completing the course, and shortly after the teacher returns the physical computing kit. Survey items will target overall user experience, the program's impact on teaching practices, the perceived impact on students, the perceived impact on female students, and other relevant topics. When possible, the National Robot Library team will do classroom observations and visits to see our program in action and gather important data.

Formal evaluation efforts, such as those required by large-scale government grants, will be conducted through partnerships with teams of researchers with deep expertise in evaluating computer science education projects, such as Sagefox Consulting or the STEM evaluation team at Expanding Pathways in Computing. These partners not only deeply understand the type of evaluation required by large-scale funders, but also are committed to working closely with programs to provide meaningful evaluation and feedback.

Conclusion

The National Robot Library has the potential to change the face of STEM education in the United States. This is an innovative program that can make computer science and engineering come alive in classrooms and inspire students. Together we can empower teachers to be champions of change, simultaneously infusing their classrooms with innovative activities and equity-focused strategies.

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