REFLECTIONS ON TWO YEARS TEACHING EARTH SCIENCE AT THE WOMEN IN SCIENCE (WISCI) STEAM CAMP

Emily C. Adams,^{1,2,*} Phoebe Oduor,³ Anastasia Wahome,³ & Githika Tondapu^{2,4}

¹Earth System Science Center, University of Alabama in Huntsville, Huntsville, Alabama, USA

²NASA SERVIR Science Coordination Office, Marshall Space Flight Center, Huntsville, Alabama, USA

³The Regional Centre of Mapping of Resources for Development, Nairobi, Kenya

⁴Universities Space Research Association, Huntsville, Alabama, USA

*Address all correspondence to: Emily C. Adams, Earth System Science Center, University of Alabama in Huntsville, Huntsville, Alabama, USA; Tel.: +256-961-7420; Fax: +256-961-7751, E-mail: emily.c.adams@nasa.gov

In 2018, UNESCO reported just under 30% of all science, technology, engineering, and math (STEM) positions are filled by women. Despite increasing global demand for higher paying, highly technical STEM careers women continue to face substantial barriers to STEM. There are many obstacles women may face throughout their journey to a STEM career, including lack of resources and role models, and discrimination. Studies show a near equivalent interest of boys and girls in STEM fields in early childhood; however, this ratio declines sharply through time due to various pressures girls and boys face. This compounds into considerably fewer women participating in STEAM careers. An increase in women in STEAM fields would not only increase economic activity, but would also provide a diverse perspective to develop and produce unique and innovative technology solutions. While solutions to these issues require substantial time and interventions, the Women in Science or “WiSci” STEAM camp, inclusive of the arts, was organized to try to address some of these issues. WiSci, organized by the United States Department of State and implemented by World Learning and the United Nations Foundation Girl Up program, supports young women on their journey to STEAM careers. Since 2015, Google, Intel, and others have delivered a hands-on, STEAM focused curriculum around the world. These events bring together high school girls from around the world, to expose them to STEM concepts and role models. The National Aeronautics and Space Administration (NASA) participated at the camp in Malawi in 2017 and in Namibia in 2018 through the SERVIR program. SERVIR, meaning to serve in French and Spanish, is a joint NASA and USAID program that seeks to use state of the art science and technology to solve Earth’s greatest challenges. This paper will provide an overview of the camps, the curriculum development, the materials NASA presented, the limitations, and the lessons learned from these important events. The NASA SERVIR team introduced hands-on Earth science applications to participants, with the objective of exposing and inspiring the girls to explore NASA Earth satellite data. The impact of the WiSci Namibia camp was assessed through the use of pre-, post-, and 6 months post-camp surveys. The results of those surveys indicated growth in confidence in the core components of the SERVIR curriculum: understanding computer skills, coding, and geospatial mapping. The surveys also indicated a high interest from all participants to choose a STEM career. The importance of exposure to the STEM workforce at a critical juncture in these young women’s lives may play an important role in their career choices.

KEY WORDS: *STEM, remote sensing, GIS, international development, informal education*

1. INTRODUCTION

Around the world, women face many challenges to meaningfully participating in science, technology, engineering, and math (STEM) careers. Globally, the STEM workforce is highly paid and growing; however, women make up less than 30% of these positions (UNESCO, 2018). Women are less likely to have access and encouragement to pursue STEM courses, or positive female STEM role models (Drury et al., 2011). If women are able to overcome these obstacles, they will likely continue to face challenges throughout their careers, because discrimination, familial obligations, and other unpaid care burdens tend to influence women more strongly than men (Dasgupta and Stout, 2014; Shapiro et al., 2015).

The imbalance of women in STEM careers starts early. False stereotypes, including women are “bad at math” or “not smart enough to understand complex subjects” further degrade the perception of women participating in STEM careers (Rydell et al., 2010). These labels have been proven false time and time again, but nevertheless the bias, often unconscious, persists. A large study from Cimpian et al. (2016) following children through time showed that in the kindergarten years, there is almost no discernable difference between boys’ and girls’ math ability. However, teachers routinely categorized girls’ abilities lower than boys’ despite similar achievements. By the time the girls were in high school, the gap in math success widened, generating the conclusion that teachers’ expectations can deter girls from being successful (Cimpian et al., 2016). This conclusion was illustrated by several other studies (Boser et al., 2014; Riegle-Crumb and Humphries, 2012). In fact, the typical testing environment may not accurately portray a child’s aptitude for math, particularly for girls. Tests themselves may encourage male success while discouraging females, and teachers have systematically given lower test scores when the test taker is known to be female (Lavy and Sand, 2015; Niederle and Vesterlund, 2010).

Significant socioeconomic pressures, particularly in the developing world, also contribute to a reduction in a girl’s access to education compared to her male counterparts for several reasons. Developing countries often do not provide access to education services for free, and when forced to make a choice, most families will support a male’s education before a female’s (King and Hill, 1993; Herz and Sperling, 2004). Cultural implications also play a huge role here; for example, boys may be considered more likely to take care of their parents financially in old age, and thus the parents may be more interested in ensuring their career path is more lucrative (King and Hill, 1993). Girls are also considerably more likely to be asked to leave school to support the home during difficult times and face additional barriers throughout puberty, where access to hygiene products and pain management are rare (King and Hill, 1993). In situations like these, when a girl is prevented from access to education, even for a short period of time, it is often impossible for her catch up and return to school and be successful in a STEM field (Herz and Sperling, 2004).

Furthermore, the lack of female role models in STEM positions has been shown to erode a girl's interest in STEM. A study completed by Microsoft examined the impact of role models on 11,500 young girls and women, aged 11–30, from 12 European countries (Microsoft, 2018). They reported that only 26% of girls without a role model showed interest in STEM, while 41% of girls who had a role model showed interest. A similar study in the US revealed similar conclusions (Microsoft, 2018). These role models can even include fictional portrayals of women in STEM fields, which are also few. The majority of film and television STEM characters are portrayed by men, 62.9% (The Lydia Hill Foundation & The Geena Davis Institute on Gender in Media, 2018). In this same study 82.7% of girls responded that seeing female STEM characters was important to them.

These issues are compounded by the fact that generally speaking, global societal norms and gender roles dictate that women are more likely to be expected to be keepers of the home, rearing and nurturing children, cleaning, and cooking, while men are the primary household earners (Blackstone, 2003). This stereotype embeds itself in societies in different ways, depending on the culture. Support systems for women in the workforce, including educational opportunities, affordable child care, and paid family leave for men and women are on the rise in the developed world; however, access to affordable options remains challenging in many countries. Even still these systems are typically insufficient for women wishing to pursue highly demanding STEM careers, and consequently, women may start a STEM career, but leave to ensure family stability (Xie and Shauman, 2003; Preston, 1994).

Beyond gender equality and equity, having a diverse workforce is particularly important in STEM fields, where a diverse workforce presents diverse ideas, fostering more innovative solutions (Tadmor et al., 2012). For example, until recently, women were dying from heart attacks at a much higher rate than men. This was because the majority of studies done on heart attacks were performed on men. It was not until a female researcher, C. Noel Bairey Merz, began to investigate female symptoms of heart attacks, that anyone realized they would present differently (Bairey Merz et al., 2006). Male researchers unconsciously siloed the research process toward male participants, but a female researcher provided the diverse perspective to drive a major medical breakthrough, saving lives.

Further, the world is transitioning to a digital, highly technical economy. If women continue to be excluded from the STEM sectors, their ability to transition with the economy will be stymied and the global economy will suffer, both from lack of users and from a limited workforce to support such an economy. Gender equity has been shown to contribute to a more prosperous economy (The World Bank, 2019b). A study by McKinsey & Company concluded that achieving global gender parity would add 12 trillion dollars to the global economy (McKinsey Global Institute, 2015).

There are critical decision points throughout an individual's career where access and exposure to STEM concepts, mentorship, and resources need to align in order for them to succeed (Herrmann et al., 2016). One of these critical points is during mid- to late adolescence (14–17 years). It is during this time that young people are using their

early education to decide career paths. In many cases, students have the ability to choose secondary school courses and activities that support or encourage their journey toward a particular career. It is often during this stage where a positive role model can also have an important impact.

The Women in Science, or WiSci, Science, Technology, Engineering, Arts, & Math, (STEAM) camps, organized by the United States Department of State, were designed to support these young women during these critical times. While the camp focuses on the integration of the Arts into STEM, a.k.a. STEAM, the authors' primary effort and research did not explicitly include the arts, and thus we will refer primarily to STEM. Other parts of the camp's curriculum that are outside of the scope of this paper spoke more directly to the arts.

SERVIR, Spanish and French for "to serve," is a global program jointly supported by the United States Agency for International Development (USAID) and the National Aeronautics and Space Administration, USA (NASA) that builds the capacity of regional institutions in developing countries to use earth observations to support environmental decision making. Within NASA, SERVIR is a capacity building activity within the Applied Sciences Division. While SERVIR focuses the majority of capacity building activities on professionals, we also engage with youth and university students.

SERVIR keeps metrics on the gender balance of the training activities we conduct. In 2018, just over 30% of people engaged through SERVIR trainings self-identified as women. This statistic also includes data for two events targeted exclusively for women, and thus this number may be slightly overinflated when looking at only mixed gender events. In response to clear gender gaps, SERVIR designed and developed gender strategies to support the inclusion of women through our program. All of the regions SERVIR supports have recognized the importance of engaging young women in STEM, before they enter advanced learning or the job market, in order to ensure an increasing number of women available to be engaged in our capacity building activities. Through our participation in WiSci it became clear that supporting such activities would be highly beneficial to NASA, USAID, SERVIR, the regions in which we work, and most importantly the girls themselves.

The core objective of SERVIR participation in WiSci was to design and provide customized, hands-on, NASA earth science curriculum to inspire and empower the next generation of STEM scientists around the world. We also sought to enhance our relationships with partners also participating in WiSci including the United States Department of State, the United Nations Foundation's Girl Up program, Google, Intel, and others, and also to add additional value to NASA education, outreach, and communication.

This paper will discuss the contributions of the SERVIR program to WiSci Malawi in 2017 and WiSci Namibia in 2018. We will discuss camp details, the curriculum development, and lessons learned from the experiences. We also hope that this paper will contribute to the lack of information and research regarding young women in STEM in developing countries, as the gender disparity in STEM fields is often worse, and much less commonly studied (The World Bank, 2019a).

2. METHODS

2.1 WiSci Camp Background

WiSci began in 2015 with a camp in Rwanda for high school aged girls from the United States and eight African countries. Top technology firms, including Intel Corporation and Microsoft, offered STEAM-based curriculum and mentorship while the United Nations Foundation's Girl Up provided women's empowerment and leadership sessions, among many other contributing partners. WiSci has expanded in the years since, engaging young women all over the world and additional partners. In 2016, the National Aeronautics and Space Administration (NASA) was invited to contribute curriculum for the girls attending the WiSci Malawi camp, to take place during summer 2017. The NASA SERVIR program was identified to showcase NASA Earth Science to engage and inspire the camp participants to make their world a better place.

2.2 Authors' Positionalities

The authors all identify as women from diverse backgrounds that have been working to support women in girls in STEM for several years. However, first we are scientists and work to support data-driven decision making. We realize the potential of the next generation to solve some of the world's greatest challenges, including climate change and its impacts. Adams identifies as a Caucasian, American female; Oduor and Wahome as Kenyan females; and Tondapu as an Indian female. Our global perspectives and experience in male-dominated careers add value to the work.

2.3 Camp Details

For both camps, participants were selected from an application process run by an implementing partner, World Learning. Self-identified girls had to be between 14 and 18 years old and demonstrate an interest in STEAM and leadership in order to be considered. Local chapters of Girl Up and the United States Embassies in the target countries helped promote the application process. For WiSci Malawi the girls were selected from Liberia, Malawi, Rwanda, Uganda, Tanzania, Zambia, and the United States. WiSci Namibia hosted girls from Eswatini, Ethiopia, Kenya, Namibia, and the United States. Racial diversity and socioeconomic background, particularly for applicants from the US, was an important selection consideration. Additionally, the girls in general represented a diverse set of geographies within their home countries, as well as socioeconomic backgrounds. The participants had all expenses paid, including travel to the camp location, accommodation, and food.

The selected participants had a wide range of interests, experience, and skills. For example, some showed interest in the human body and medicine, while others were interested in astrophysics. Some were proficient in computer programming languages, while others had very few computer skills at all. Some had strong exposure to particu-

lar science topics through formal education, while others may not have had the same resources. However, the spirit of comradery and friendship was invigorated quickly through the leadership and team building exercises provided multiple times a day by other implementing partners. The girls were very quick to support their fellow campers in challenging situations. It was very clear that, regardless of circumstances, all the girls were excited to learn about new things.

We also had access to computer labs, projectors and presentation materials, white boards, and other basic classroom accessories for both camps. There were also camp counselors and implementers ready to support any technical issues.

2.3.1 WiSci Malawi

The first WiSci camp in which SERVIR participated was in 2017 in Thyolo, Malawi at the Malawi University for Science and Technology (MUST) from July 30 to August 14. MUST was established in 2012 in Southern Malawi, approximately 25 km (15 mi) northwest of Mulanje Mountain Forest Reserve. The university was closed to students for the duration of the camp and they provided dormitory services, meals, and classroom access for camp participants and curriculum providers. This camp drew 98 participants from the United States, Malawi, Rwanda, Uganda, Zambia, Tanzania, and Liberia.

Two female trainers, one American from the NASA SERVIR Science Coordination Office (SCO) in Huntsville, Alabama, and one Kenyan from the SERVIR Eastern and Southern Africa Hub at the Regional Centre for Mapping of Resources for Development (RCMRD) in Nairobi, Kenya, led the design and delivery of the material. These women were scientists who support the SERVIR program objectives, and were well versed in designing and delivering trainings.

Other partners at this camp included the Intel Corporation, Google, and the American Society for Microbiology who provided STEM content. World Learning and the United Nations Foundation's Girl Up campaign provided empowerment, leadership, and career development trainings, as well as providing basic camp facilitation and organization.

2.3.2 WiSci Namibia

The following year, from June 17 to June 29, 2018, WiSci Namibia took place on the campus of the Namibia University for Science and Technology (NUST), in Windhoek, Namibia. One hundred girls from the United States, Namibia, Ethiopia, Kenya, and Eswatini, were selected to participate.

Building from the successes of the previous year in Malawi, the same trainers traveled to Namibia with two additional colleagues, a Kenyan woman from SERVIR Eastern and Southern Africa at RCMRD and an Indian woman from the NASA SERVIR SCO. Once again all the women supporting the design and delivery of the material were scientists who support the SERVIR program objectives and were experienced in designing and delivering trainings.

2.4 Curriculum Development

The overarching learning goal for both camps was to introduce basic Earth observation concepts to the participants. We sought to illustrate specific applications of remote sensing to the girls' daily lives to connect and inspire them to seek out additional information. We recognized that time was a limiting factor toward substantial learning progress; therefore, we sought to provide a thorough baseline of information for which the girls could build upon their knowledge after camp through provided, self-paced resources.

2.4.1 *WiSci Malawi*

The WiSci Malawi camp implementers requested that SERVIR provide 2 hours of classroom learning. This was to be spread out over three days; 1 hour of in-class curriculum day 1, a field trip day 2, and 1 hour of in-class curriculum on day 3. This allowed for small class sizes during the in-class sessions as they were repeated several times, rotating the girls through various camp activities. Ultimately this led to four sessions with 25 girls in each class on days 1 and 3. The girls were paired to work on the computer when it was relevant, although the computers were not used for the entire classroom session. We were also able to strategically leverage the field trip day 2 and incorporate it into the learning modules.

The limited amount of time proved challenging to present Earth science topics in a meaningful way. We were also aware that computers and Internet were available, but electricity and strong bandwidth could not be guaranteed. Therefore, we focused on developing hands-on, interactive activities describing how the application of NASA Earth observing satellite data can be used to inform and improve their lives that could be completed offline. As remote sensing and Earth observation generally are more advanced topics, we focused on connecting satellite data to a variety of issues, at least one of which the girls would have likely faced at some point in their lives. We also assumed limited computer skills and made sure the activities were not reliant on quickly accessing computer techniques.

After a round of introductions, the first activity was designed to shift the girls' thinking from how they view their world as an individual to how a satellite sees the world. Photos of key themes we addressed using satellite data were shown to the girls followed by imagery from satellites depicting the same thing. We informally titled this exercise "What do you see?". For example, photos of agriculture were shown, followed by imagery from the Landsat satellite of an area that included crops. We discussed how we were able to recognize those areas as crops and what other things they might notice in the imagery. In some cases before and after imagery was used to highlight tracking changes. For instance, when we showed photos of flooding, we accompanied this with a before satellite image of a region, and an after satellite image of the same region after receiving intense rainfall. The remainder of the session was lecture style introducing key concepts, terminology, and the activity for day 3. We wanted to leverage the field trip as an opportunity to further connect satellite data to their lives; therefore, we highlighted the use of a

SERVIR-developed cell phone application to collect data about the land. We encouraged the girls to install the app on their phone and take observations while out in the field.

The field trip, which was organized by the implementing partners as a regularly scheduled programmatic element unrelated to our curriculum ideas, was to the Mulanje Massif area. Research on this area prior to the camp showed us that there would be several types of land use we could visualize with remote sensing data. Tea plantations surrounded the base of the mountain, which was largely forested, and some small villages were also close by. The field trip included shopping at the villages, and a short hike up into the mountain area for lunch. These various land cover observations were incorporated into the day 3 curriculum.

During the session on the third day, computers were pre-loaded with the following:

- Educational licenses for ESRI ArcGIS software (provided by RCMRD);
- Landsat 8 scenes of Malawi, downloaded for free from NASA Earth Data Search (<https://search.earthdata.nasa.gov/search>);
- Land cover maps of Malawi from 2010 and 2015 identifying areas of agriculture, forest, urban, water, and other land use classes created by the SERVIR program (also available for download for free at geoportal.rcmrd.org/);
- The data points collected from the cell phones during the field trip.

A short exercise was demonstrated using the collected data points, overlaying them with the land cover maps and the satellite data. The girls were asked to compare their collected points with the data and reflect on the process of understanding the land from satellites. The girls were encouraged to follow along and were provided time after the demonstration to explore the data on their own. A short wrap-up session encouraging discussion on what the girls learned, and showcasing several locations where the girls could seek out additional information and resources closed out the SERVIR curriculum at WiSci Malawi.

2.4.2 WiSci Namibia

The curriculum for the second WiSci camp SERVIR supported, in Namibia 2018, built strongly on the lessons learned from the initial camp. Additionally, we were asked to provide 6 hours of total classroom learning time. Thus more curriculum had to be developed. These 6 hours were conducted all in the same day, spread across four sessions of 1.5 hours each with breaks in between. The support of two additional instructors was sought to support the additional classroom time and we were able to maintain the same approach with 25 students per classroom, working on computers in pairs. In Namibia Internet and power access were much more reliable, and thus we did not have as many concerns developing online-dependent computer-based curriculum.

The introductory session remained similar, with the inclusion of a more in-depth overview of geographic information systems, remote sensing, satellites, applications, and visualizing our changing planet with before and after imagery. After this introduction we were able to introduce basic coding applications, particularly JavaScript, in

order to support the primary hands-on activity, interacting with remote sensing data in Google Earth Engine (GEE).

GEE is a free, online platform capable of performing planetary scale analysis with remotely sensed imagery. It has many satellite data products available to access through the platform and leverages the Google cloud for analysis. This tool offered the girls an opportunity to explore their choice of location, and provided the girls access to a system that would continue to be available to them after the camp ended. We also provided the girls with backup data, additional resources, and training manuals on their camp issued thumb drives that they were able to take home.

The hands-on activity included learning the basic JavaScript functions we would be using, followed by implementing them in the GEE Code Editor. The girls were able to pick a location, load imagery for that location, and calculate the normalized difference vegetation index (NDVI) to assess greenness of the area. This was then repeated for the same location at a different point in time and the two resulting NDVI images were subtracted from one another so the girls could see how greenness changed. A written tutorial guide was provided for them to follow alongside the demonstration. This was followed by discussion on what they were able to see and why it might be happening. The session closed in a similar fashion to Malawi where the girls were provided with extra resources if they were interested in learning more and a question and answer session.

Materials from all camps are archived here: <https://sites.google.com/uah.edu/servir-wisci/>.

2.5 Mentor Hours

Beyond the classroom sessions themselves during each camp, mentor hours were organized by the implementing partners. These sessions took place during unstructured time in the evenings. They represented an opportunity for the girls to have conversations with the camp instructors and other invited local leaders around any topic that they would like. The majority of the girls participated and asked very engaging questions on the use of NASA data and environmental decision making career paths. They were curious to know about what courses to study to be successful and to hear more about our particular experiences as women in STEM.

2.6 Evaluation of Learning Outcomes through Surveys

Pre- and post-camp surveys were administered via computer by WiSci implementing partner World Learning to all the girls while they were at the Namibia camp in 2018 on the first and final days of the camp. Additionally, a 6 month follow-up survey was delivered via email. These surveys were designed to assess the participants' confidence and understanding of the concepts explored during the whole camp. Thus the questions were not exclusively related to the SERVIR content, but there were several relevant questions. SERVIR was not consulted in the design and delivery of the surveys themselves, but we believe some of the results are relevant to understanding the impact of

our programming in addition to the camp as a whole. Further, these surveys were only administered at WiSci Namibia and thus we do not have similar data for WiSci Malawi. However, due to the fact that the content was considerably different between the camps, it would probably not represent an accurate comparison. In order to maintain the anonymity of the girls who participated at the camp, the data presented in this manuscript were prepared and presented as aggregates and no personally identifiable information was included.

The pre- and post-camp surveys asked the girls the same questions to assess growth. The questions regarding their experience connecting with STEM professionals, having STEM mentors, their likelihood of pursuing a STEM career, their confidence in a series of personal and interpersonal areas, and their understanding of 11 STEM topics covered throughout the camp by all of the curriculum providing partners (see Appendix A for survey questions). The girls were asked to report their understanding of certain concepts on a scale of poor to excellent. The relevant concepts to SERVIR included (1) computer hardware/software, (2) basic programming, and (3) geospatial mapping. Other concepts included circuits, digital marketing, and app creation. It is worth noting that SERVIR was not the only curriculum provider who would have provided information on concepts 1 and 2; however, SERVIR was the only group providing content on concept 3. Another important note is that all 98 girls completed the pre- and post-camp survey as it was administered on site, but only 42 girls responded to the 6 month post survey. This may skew the data toward the girls who already had confidence in computer skills and had easy access to a computer.

3. RESULTS AND DISCUSSION

3.1 General Camp Reflections

Overall the sessions in Malawi went very well for the short amount of time we had. We had assumed a baseline of limited computer skills and no Internet; therefore we made sure to have several backup plans should issues arise. We did have some issues with Internet reliability, which made the deployment of the cell phone app and the collection of the data from the girls challenging. However, our backup plans and data were successful. We would highly encourage the use of offline data backups in situations similar to this, so that the goals of the curriculum can still be obtained.

There were also issues related to the use of proprietary software and licensing, which limited the number of computers we could use at any time. An unforeseen situation on day 3 reduced the number of computers available at the last minute, resulting in three to four girls sharing a computer. This was not ideal, and it was difficult to engage all the girls with limited computer availability. We have since overcome that by focusing on curriculum development using only open source, freely available software packages. We believe this is also important so the girls can have continued access to the resources after the camp. Our experiences in Malawi strongly influenced our curriculum in Namibia. We were sure to develop a package that the girls took home with them to explore on their

own via preloaded camp-provided thumb drives. Additionally, we worked to be sure the content was as hands-on as possible, limiting the lecture portions as much as possible.

The sessions in Namibia also went well. After learning from the challenges in Malawi and implementing the curriculum in GEE we had very few software challenges. GEE does require two-factor authentication in some cases which was challenging when a “code” was texted to the backup phone number associated with an account but that phone was unavailable at that time because most girls were traveling out of country and therefore their phones were off. We were able to work around most of these issues fairly quickly. We also learned that the coding-heavy exercise may not have been as engaging as we had hoped. While we provided the girls with the code to copy and paste into the code editor, most preferred to type it themselves which led to a lot of typos and slow progress. Fortunately we had built in a lot of extra time, but we did lose time during the discussions to accommodate for this. In the future we plan to avoid a hands-on curriculum entirely based on coding, but rather a mixed approach leveraging graphical user interface programs and coding to give the girls a variety of experiences.

In general, at both camps, there was a very wide range of computer skills and experience that was challenging to address. We had assumed a baseline of low computer skills, which we found left those with high skills often waiting for instructions while everyone else caught up. This also left time for distractions in these cases. Our best case scenario was to pair a low skilled individual with a high skilled one; however, this also is challenging. Often low skilled individuals are shy to admit they may not be as proficient as their peers. Alternatively, a high skilled individual may take over the course work and make it difficult for a lower skilled individual to keep up. It is a delicate balance of personalities and skills that course instructors—and of which supporters—need to be aware. In the vast majority of cases these issues were easily overcome as instructors roamed the room to support the classroom learning and answer questions. Future WiSci curriculum will involve computer and non-computer exercises, as well as support from the implementing partners to pair girls prior to their class time to try to overcome these challenges, rather than trying to do it in real time.

We found one of the most valuable times during the curriculum delivery at both camps to be unstructured time for the girls to explore the data on their own or in small groups. This facilitated some very nice reflections and discussions before the class time ended and also helped encourage some creative thinking around data and applications. The “light bulb” moments when the girls experienced a major breakthrough in understanding the content were quite amazing to witness and worth the time and effort put into content and backup content.

We also found the mentor hours during the week to be just as important as the curriculum itself. Providing these young women with time to address their personal questions and concerns was just as enlightening for the trainers as it was for the girls. There were wide ranges of personalities at each camp, and while some of the girls were more than happy to raise their hands and ask questions in the class, others preferred a more intimate experience. We would imagine this would be true no matter the educational setting, and would encourage others to think creatively about ensuring there are spaces

provided that engage all personality types. We received a wide range of questions, from access to scholarships and education to in-depth discussions on SERVIR projects and life in general as women in STEM fields. There were also occasions where some girls remained in contact with the trainers and provided additional follow-up advisement. It was also great to have a diverse group of women to train with, and it was obvious that the girls from African countries were eager to hear from African trainers on their experiences.

3.2 Survey Responses

The pre-camp and post-camp survey responses showed an increasing confidence and knowledge in the key areas where SERVIR was focused (Fig. 1). There was a 30% increase in the number of girls rating their computer hardware and software knowledge as good or excellent, a 65% increase in the number of girls rating their understanding of basic programming as good or excellent, and a 46% increase in the number of girls reporting their abilities in geospatial mapping. Further evaluating the 6 months post survey data showed girls rating their understanding of geospatial mapping as good or excellent increased eight additional percentage points. This was the largest increase of any category from the survey. These data may be an indication that the girls were able to digest what they had learned at camp and perhaps continued their exposure after the camp ended. We believe that our intentional focus on using open source, free tools and providing additional materials on their thumb drives allowed the girls to continue to explore geospatial mapping beyond the camp, resulting in this increase. While basic

FIG. 1: Trends in camp participants' confidence in computer hardware and software, basic programming, and geospatial mapping before, after, and 6 months after camp (World Learning, 2019). Results show a distinct increase in confidence after camp and a continuing confidence in computer hardware and software, and geospatial mapping (For specific survey questions please refer to Appendix A).

computer skills are prevalent in society today, basic programming and geospatial mapping are not, and we would expect that continued understanding in these fields is due to individuals seeking out additional resources or information.

It is clear from the post-Namibia survey that SERVIR is having a positive impact on the girls' STEM exposure. Additionally, the survey indicated that most respondents (90%) plan to pursue post-secondary education in STEM fields. While we recognize that self-report surveys have limitations, these results do help us to understand the confidence behind girls' abilities to succeed in STEM fields, which is often a major limitation for success. Finer-grained analyses would also have been useful; World Learning, who conducted the survey, would only release these aggregated data. Nevertheless, we think these results do show promise for applying these methods to new cohorts of students.

Mentorship is imperative for a diverse workforce, yet research labs, universities, and other STEM professional opportunities do not often place much importance on mentorship (Clement et al., 2020; Herrmann et al. 2016). It is rare for mentorship to be included in performance plans, and there are few opportunities for individuals to seek out support in developing strong mentorship skills. In 2019, the National Academies of Science, Engineering, and Medicine detailed nine major recommendations for more productive mentoring, including driving systemic change by integrating mentorship and mentorship quality into tenure and promotion packets (National Academies, 2019).

Experiential types of activities are extremely important for encouraging young women and minorities to pursue and persist in STEM academics and careers (Jin et al., 2019; Boakes, 2019; Mason et al., 2018). The hands-on interactive content, games, and access to mentors seems to result in inspiring the girls to engage with STEM content in new ways. While NASA participation in these activities has been limited to only two years, surveys indicate that these women are continuing to look toward STEM careers. SERVIR also looks forward to participating in future WiSci events and exploring additional NASA researchers' support. Typically opportunities for girls to engage with science content developed for them and delivered by experts and role models are few, but incredibly valuable. Although only privileged girls with access to computers and specific networks of people knew to apply for this camp, it is also worth noting that girls of this age group who pursue STEM careers must have access to and awareness of STEM considerably earlier than high school. Additional educational programming more broadly at the primary school level would be required to drive education equity, particularly in lower income areas, and is beyond the scope of WiSci itself. It is also important to acknowledge that this was an all-expenses-paid opportunity, therefore reaching a population that otherwise may not have had opportunities to have this experience.

For the 2017 and 2018 camps the trainers were all women. Other implementing partners such as Google and Intel had male and female trainers. We do see value in bringing a diverse team to the camps. We think it is important to expose the girls to positive male and female role models. While it is most common that individuals tend to look for people who are similar to them, in the case of racial and ethnic minorities it can be challenging to find those mentors. However, there are allies, role models, and mentors that can play significant roles in anyone's career development and progression. Drury et

al. (2011) report that female and male role models are effective in recruitment of STEM, whereas female role models are important during the retention phase. Due to the imbalanced nature of women in STEM positions, which is further exacerbated in leadership positions and in the developing world, it is highly likely that these girls will require both male and female mentors in order to be successful. Ultimately individuals seek mentors for a variety of reasons, and the personal connection and trust that is built between mentor/mentee pairs is essential (Knezz, 2021).

There are costs and benefits to having gender-segregated spaces, such as this WiSci camp. For example, a lot of women may feel more comfortable speaking and participating in activities in a women-only environment. This is especially true for women from patriarchal societies, such as most of the participants' home countries. From our perspective, because this camp was focused on girls' empowerment and confidence building, in addition to STEM experience and knowledge, it is very appropriate to take a gender-segregated approach. This helps to ensure the critical component of confidence building takes shape. Engaging men and boys in constructive and well-developed counter-programming may be a useful next step to further reduce the barriers women in the workforce face, although this is outside the scope of our current contributions. Nevertheless, this camp represents a small but meaningful contribution to the vast landscape that is women's economic empowerment in the workforce.

SERVIR was also scheduled to participate in WiSci Ethiopia in 2019, but that camp was canceled due to civil unrest, and the 2020 camps have also been postponed due to COVID-19. However, we look forward to continuing to provide content at future WiSci events.

4. CONCLUSIONS

STEM professionals are in a unique position to provide support through skills building and mentorship to the next generation. This is particularly true for minority and underserved populations such as women, racial and ethnic minorities, indigenous groups, LGBTQI+, and people from emerging economies. This will likely require creative and unique strategies for engagement such as WiSci. The SERVIR team who participated in WiSci Malawi and WiSci Namibia saw growth in interest and ability of the girls who attended our curriculum. We encourage others to assess how they are engaging with the STEM pipeline to ensure a more diverse and equitable future workforce.

ACKNOWLEDGMENTS

The authors would like to thank the entire WiSci team, including Sabrina Abu-Hamdeh at the U.S. Department of State, Laurén Ettinger and Amirah Nelson with World Learning, and Bailey Leuschen with the UN Foundation's Girl Up program among the many others involved in the organization and implementation of WiSci. Additional support from the entire SERVIR program, including Nancy Searby, Daniel Irwin, Ashutosh Limaye, Jenny Frankel-Reed, Kevin Coffey, Pete Epanchin, Emmanuel Nkurunziza, John

Boscom Kyalo Kiema, Robinson Mugo, Katherine Casey, and Robert Griffin. It has also been a great pleasure working alongside the representatives from Google, Intel, the Association of Microbiologists, and additional STEM content providers. Finally, the authors would like to recognize the support of the anonymous reviewers in providing comments to support the development of this manuscript and the journal editors. Support for this work was provided through the joint U.S. Agency for International Development (USAID) and National Aeronautics and Space Administration (NASA) initiative SERVIR, particularly through the NASA Applied Sciences Capacity Building Program, NASA Cooperative Agreement No. NNM11AA01A.

REFERENCES

- Bairey Merz, C. N., Shaw, L. J., Reis, S. E., Bittner, V., Kelsey, S. F., Olson, M., Johnson, B. D., Pepine, C. J., Sunil, M., Sharaf, B. L., Rogers, W. J., Phohos, G. M., Lerman, A., Quyyumi, A. A., & Sopko, G. (2006). Insights from the NHLBI-sponsored women's ischemia syndrome evaluation (WISE) study. Part II: Gender differences in presentation, diagnosis, and outcome with regard to gender-based pathophysiology of atherosclerosis and macrovascular and microvascular coronary disease. *Journal of the American College of Cardiology*, 47(3 Suppl.), S21–9. doi:10.1016/j.jacc.2004.12.084.
- Blackstone, A. (2003). Gender roles and society. In J. R. Miller, R. M. Lerner, & L. B. Schiamberg (Eds.), *Human ecology: An encyclopedia of children, families, communities, and environments*. Santa Barbara, CA: ABC-CLIO.
- Boakes, N. J. (2019). Engaging diverse youth in experiential STEM learning: A university and high school district partnership. *International Online Journal of Education and Teaching*, 6(2), 245–58.
- Boser, U., Wilhelm, M., & Hanna, R. (2014). The power of the Pygmalion effect: Teacher expectations strongly predict college completion. *Center for American Progress*, 1–7.
- Cimpian, J. R., Lubinski, S. T., Timmer, J. D., Makowski, M. B., & Miller, E. K. (2016). Have gender gaps in math closed? Achievement, teacher perceptions, and learning behaviors across two ECLS-K cohorts. *AERA Open*, 2(4). doi:10.1177/2332858416673617.
- Clement, L., Leung, K. N., Lewis, J. B., & Saul, N. M. (2020). The supervisory role of life science research faculty: The missing link to diversifying the academic workforce? *Journal of Microbiology & Biology Education*, 21(1). doi:10.1128/jmbe.v21i1.1911.
- Dasgupta, N., & Stout, J. G. (2014). Girls and women in science, technology, engineering, and mathematics: STEMing the tide and broadening participation in STEM careers. *Policy Insights from the Behavioral and Brain Sciences*, 1(1), 21–9. doi:10.1177/2372732214549471.
- Drury, B. J., Siy, J. O., & Cheryan S. (2011). When do female role models benefit women? The importance of differentiating recruitment from retention in STEM. *Psychological Inquiry*, 22: 265–9. doi: 0.1080/1047840X.2011.620935.
- Herrmann, S. D., Adelman, R. M., Bodford, J. E., Graudejus, O., Okun, M. A., & Kwan, V. S. (2016). The effects of a female role model on academic performance and persistence of women in STEM courses. *Basic and Applied Social Psychology*, 38(5), 258–68. doi:10.1080/01973533.2016.1209757.
- Herz, B., & Sperling, G. B. (2004). *What works in girls' education: Evidence and policies from the developing world*. Washington, DC: The Council on Foreign Relations.
- Jin, L., Doser, D., Loughheed, V., Walsh, E. J., Hamdan, L., Zarei, M., & Corral, G. (2019). Experiential learning and close mentoring improve recruitment and retention in the undergraduate environmental science program at an Hispanic-serving institution. *Journal of Geoscience Education*, 67(4), 384–99. doi:10.1080/10899995.2019.1646072.
- King, E. M., & Hill, M. A. (Eds.). (1993). *Women's education in developing countries: Barriers, benefits and policies*. Baltimore, MD: The World Bank, The Johns Hopkins University Press.

- Knezz, S. (2021). We need STEM mentors who can reduce bias and fight stereotypes. *Scientific American*. Retrieved from <https://www.scientificamerican.com/article/we-need-stem-mentors-who-can-reduce-bias-and-fight-stereotypes/>.
- Lavy, V., & Sand, E. (2015). On the origins of gender human capital gaps: Short and long-term consequences of teachers' stereotypical biases. *National Bureau of Economic Research*. doi 10.3386/w20909.
- Mason, N. A., Brunner, R. M., Ballen, C. J., & Lovette, I. J. (2018). Cognitive and social benefits among underrepresented first-year biology students in a field course: A case study of experiential learning in the Galápagos. *Frontiers: The Interdisciplinary Journal of Study Abroad*, 30(3), 1–9.
- McKinsey Global Institute. (2015). *The power of parity: How advancing women's equality can add \$12 trillion to global growth* (Report). Chicago, IL: McKinsey & Company.
- Microsoft. (2018). *How role models are changing the face of STEM in Europe*. Retrieved from <https://news.microsoft.com/europe/features/girls-in-stem-the-importance-of-role-models/>.
- National Academies of Sciences, Engineering, and Medicine. (2019). *The science of effective mentorship in STEMM*. Washington, DC: The National Academies Press.
- Niederle, M., & Vesterlund, L. (2010). Explaining the gender gap in math test scores: The role of competition. *Journal of Economic Perspectives*, 24(2), 129–44. doi:10.1257/jep.24.2.129.
- Preston, A. E. (1994). Why have all the women gone? A study of exit of women from the science and engineering professions. *The American Economic Review*, 84(5), 1446–62.
- Riegle-Crumb, C., & Humphries, M. (2012). Exploring bias in math teachers' perceptions of students' ability by gender and race/ethnicity. *Gender and Society*, 26(2), 1–19. doi: 10.1177/0891243211434614.
- Rydell, R. J., Shiffrin, R. M., Boucher, K. L., Van Loo, K., & Rydell, M. T. (2010). Stereotype threat prevents perceptual learning. *PNAS*, 107(32), 14042–7. doi:10.1073/pnas.1002815107.
- Shapiro, M., Grossman, D., Carter, S., Martin, K., Deyton, P., & Hammer, D. (2015). Middle school girls and the “Leaky Pipeline” to leadership: An examination of how socialized gendered roles influences the college and career aspirations of girls is shared as well as the role of middle level professionals in disrupting the influence of social gendered messages and stigmas. *Middle School Journal*, 46(5), 3–13.
- Tadmor, C. T., Satterstrom, P., Jang, S., & Polzer, J. T. (2012). Beyond individual creativity: The superadditive benefits of multicultural experience for collective creativity in culturally diverse teams. *Journal of Cross-Cultural Psychology*, 43(3), 384–92. doi:10.1177/0022022111435259.
- The Lydia Hill Foundation & The Geena Davis Institute on Gender in Media. (2018). *Portray her: Representations of women STEM characters in media*. Retrieved from <https://seejane.org/wp-content/uploads/portray-her-full-report.pdf>.
- The World Bank. (2019a). *The little data book on gender 2019*.
- The World Bank. (2019b). *Women, business and the law, 2019*.
- UNESCO. (2018). Women in science: The gender gap in science. *UNESCO Statistics*, (51), 1–4. Retrieved from <http://uis.unesco.org>.
- World Learning. (2019). *WiSci girls STEAM camp 2018 six months post-program survey*.
- Xie, Y., & Shauman, K. A. (2003). *Women in science: Career processes and outcomes*. Cambridge, MA: Harvard University Press.

APPENDIX A

The exact question posed to WiSci Namibia STEAM Camp participants related to STEAM pursuits, curriculum and skills, and mentorship are as follows:

1. Since the conclusion of the 2018 WiSci girls STEAM camp in Namibia, how likely are you to pursue post-secondary studies or careers in STEAM fields?
2. Have you joined any classes, activities, or clubs related to STEAM since your return from the WiSci camp?

3. If you answered yes to participating in classes, activities, or clubs related to STEAM, how often do you participate in those?
4. Presented as a percentage of respondents who answered “Good” or “Excellent” to the posed question,
 - a. Please rate your current understanding of the following concepts:
 - i. Computer hardware/software
 - ii. Basic programming
 - iii. Computing operating systems
 - iv. Electricity/circuit design
 - v. Digital/analog circuits
 - vi. Design thinking
 - vii. Digital marketing
 - viii. App creation
 - ix. Fabrication/design
 - x. Health/medical procedures
 - xi. Geospatial mapping
5. If you connected with a STEAM or business professional during WiSci camp mentor hours, did you continue that connection after camp?
6. If you answered yes to continuing a connection with a STEAM or business professional, how often have you stayed in contact with them?
7. If you answered yes to continuing a connection with a STEAM or business professional, how do you continue to connect with them?
8. If you answered yes to continuing a connection with a STEAM or business professional, for what do you utilize those connections?
9. Have you stayed in contact with any girls from the 2018 WiSci Namibia camp?
10. If you answered yes to continuing a connection with any fellow participants, how often have you stayed in contact with them?