# DESIGN SQUAD GLOBAL

## Research Findings from the Second Round of Implementation

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# Contents

*For other people who don't know about DSG, they should come and find out more about it. When I came, I thought it was something else. I didn't know much about engineering. It gave me motivation. It taught me a lot...that I can design things.... You need your mind, you need your hands. You need only your knowledge – that can help you in order to come up with an idea or product to help motivate.*

DSG Participant, Southern Africa

# Executive Summary

DESIGN SQUAD GLOBAL (DSG) is a web-based, mobile-accessible digital hub and outreach initiative that creates new opportunities to empower middle school youth to solve real-world problems and understand the impact of engineering in a global context. The project builds on the Design Squad model for engineering education (including a television show and website). The ultimate goals of Design Squad Global are to: (1) develop innovative ways to incorporate effective engineering education into informal learning environments; (2) inform the field about promising practices in cross-cultural collaboration, and; (3) gain a better understanding of how engineering activities can successfully enable middle school students to meet the demands of an increasingly interconnected world. DSG emphasizes the development of participants' global competency – meaning the ability to communicate and collaborate with people from different backgrounds, cultures, and perspectives.

A major way in which the project is reaching these goals is through DSG Clubs, an afterschool program for students aged 10-13 that is implemented using a Club Guide and an international partnership with another club in a different country. Research was a core component of the development of the DSG club. The program was implemented in two pilot rounds of seven pairs of clubs, with each round researched to better understand processes and outcomes. These findings led to recommendations for improvement to the model, in an iterative cycle of learning and improvement.

According to the design, each club had approximately 10-15 members, and met for one hour once a week with a Club Leader to participate in hands-on engineering activities. Each club in the U.S. was partnered with a club in Southern Africa (in Botswana, South Africa, and Swaziland). The club also had an exchange component (asynchronous because of the time difference), in which partner clubs shared photos, videos, and audio, mainly related to solving engineering challenges. Prior to implementation, Club Leaders received training either in-person or via webinar in Round 1 and via online modules in Round 2, and were supported by DSG facilitators throughout the club experience.

Learning from the first round of implementation[1] informed a number of revisions that were implemented in the second round. One of the biggest challenges in Round 1 was dealing with calendar synchronization across partner clubs: when working in different countries with different school calendars and different holidays, getting the timing right for partnering two clubs can be difficult. The timing was especially important for the partnership exchanges, which sometimes did not take place because of synchronization challenges. The pilot also revealed that every club had different priorities and constraints, and it would have been helpful to have a few different DSG models for interested clubs to choose from, to best suit their needs. With this in mind, in Round 2, the implementation team decided to test four models of Design Squad Global, with varying lengths and varying intensities of partner exchanges. These models are described below:

- **Model 1:** A ten-week program where the Club Leader guides the club through a series of hands-on engineering and design activities, including a project in which they design and build an engineering solution to a problem in their own community. They are partnered with a club in another country, and participate in four exchanges with the partner club throughout the 10 weeks. They also have some opportunities for interaction with the children in their partner club, facilitated by their Club Leader.

- **Model 2:** The ten-week model is nearly the same as Model 1, but has two partner exchanges, rather than four.

- **Model 3:** A four-week program where the Club Leader guides the club through a series of hands-on engineering and design activities. The club participates in two partner exchanges.

- **Model 4:** A six-week program where the Club Leader guides the club through a series of hands-on engineering and design activities, including a project in which they design an engineering solution to a problem in their own community. The club participates in two partner exchanges.

Across these four models, Round 2 included 16 DSG clubs and eight international partnerships, which are briefly summarized in the table below (partnerships are indicated by the banded colors). Two of the Model 4 clubs dropped out due to logistical challenges and did not participate in the activities or the research, and these are noted in the table, so the final number of participating clubs was 14.

[1] Summarized in the Report, *DESIGN SQUAD GLOBAL: Research Findings from the First Round of Implementation.*

**Table 1. DSG Round 2 Implementation: Participating Clubs and Partnerships**

| Model | Country | Program | Type |
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| 1 | United States | Castle Park Middle School, Chula Vista, CA | In-school |
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| | Botswana | Stepping Stones International 2 | After-school |
| 3 | United States | YMCA Twin Cities, MN | After-school |
| | Swaziland | SOS Children's Village | After-school |
| 4 | United States | Promise Neighborhoods Indianola, MS | After-school |
| | South Africa | YMCA Pietermaritzburg | After-school |
| 4 | United States | Middle Start, Averne, New York **(dropped out)** | After-school |
| | Swaziland | Baha'i School **(dropped out)** | After-school |

Results are reported for all 88 students overall. Although four different DSG models were tested in this round, the number of student survey responses for each individual model was small, and the results were not revealing about differences across models for student outcomes. For these reasons, the data for student and educator outcomes is presented in the aggregate to demonstrate overall changes across all four models. (The data from each DSG models, however, was used to better understand processes, leading to recommendations for improvement to the Club.)

## Research Methodology

Three overarching research questions are answered in this report using action research methodology:

1. To what extent does DSG's model of cross-cultural collaboration build students' understanding of engineering/invention, motivation to participate in engineering/invention activities, and global competencies?
2. What are the challenges, infrastructure, and support needed to inspire and prepare a cohort of young, globally competent engineers in afterschool programs, both in the U.S. and internationally?
3. Can the proposed model successfully be implemented in the US and abroad? Can the model effectively help educators and students achieve the desired outcomes?

Action research activities included pre-post student surveys, Club Leader surveys (post-training and post-club), documentation of student work through the partner exchanges, focus groups with students, and weekly Club Leader surveys with specific questions about the week's activities. In addition, after completing the program, the research team conducted post-club interviews with Club Leaders to better understand their experience of DSG.

## Student Characteristics

In pre-post student surveys, 88 students were matched, and these have been used in the analysis of student survey data. In terms of gender, there were more girls than boys (55% girls, 44% boys, 1% no answer). Children in the sample ranged from third to ninth grade, though more than half attended fifth to seventh grades. In Southern Africa, nearly all (96%) reported an African language as their first language. For ethnic background of the U.S students, nearly half (49%) identified as having Hispanic, Latino, or Spanish origin. For racial background, equal numbers of students identified as either Black or African American (29%) or White or Caucasian (29%). 11% of students identified as American Indian or Alaskan Native, 6% identified as native Hawaiian or other Pacific Islander, and 3% identified as Asian.[2]

> *The most impressive change was the growth in teamwork. During the partner project, they kept building and rebuilding. They were willing to say anything. Someone would say something vague, unrealistic, silly, and the best ideas would come off of that.*
>
> Club Leader, United States

## Student Outcomes[3]

**After DSG, students demonstrated increased understanding of engineering, the design process, and science concepts in the Club Guide.** Key findings:

[2] Students were asked to select all applicable responses when describing their racial background, so the sum of the percentages of students who identify with different racial backgrounds is more than 100%.
[3] All quantitative results are statistically significant at the 99% confidence level.

- There was an increase in the percentage of students who agreed that they know what engineering is after completing DSG. (89% of students after completing DSG, compared to 66% at the start of the program.)
- There was an increase in the percentage of students who agreed that they knew what an engineer does after completing DSG. (90% of students after completing DSG, compared to 72% at the start of the program.)
- There was an increase in the percentage of students who could name key steps in the engineering design process after completing DSG. (46% of students after completing DSG, compared to 10% at the start of the program.)
- There was in an increase in the percentage of students who correctly identified that triangles are the strongest shape after completing DSG. (52% of students after completing DSG, compared to 19% at the start of the program.)

> *When they [DSG participants] saw pictures of the club members in South Africa, and saw that they wear shoes and are fully clothed, they were really surprised. Their experience with Africa has been in history and media, of African tribes, not people in a modern society. They realized that their preconceptions were off, and this fostered an interest in issues that other people are experiencing.*
>
> Club Leader, United States

**In addition, after DSG, students demonstrated increased understanding of how engineering and invention can make a positive difference in the world.** Key findings:

- There was an increase in the percentage of students who understood that engineers and inventors solve problems that help people, after completing DSG. (94% of students after completing DSG, compared to 84% at the start of the program.)
- In qualitative focus group discussions with students, most participants were able to articulate and discuss what kinds of problems engineering could potentially solve.

**Participants that had been in DSG demonstrated increased motivation for participating in engineering activities, classes or clubs.** Key findings:

- There was an increase in the percentage of students who agreed that they had an interest in designing things after completing DSG. (88% of students after completing DSG, compared to 80% at the start of the program.)
- There was an increase in the percentage of students who agreed that they were interested in creating and inventing things after completing DSG.
- There was an increase in the percentage of students who agreed that they were interested in solving community problems after completing DSG. (92% of students after completing DSG, compared to 80% at the start of the program.)
- In qualitative focus group discussions with students during the program, when asked if they might be interested in studying engineering in the future, many participants across both the United States and Southern Africa said yes. In discussing why they wanted to study engineering, their answers often included the following themes: to help others; to solve problems; and because engineering is interesting and fun.

*DSG taught us to think outside the box. It made us to find problems around our society or community. It also taught us that when we are there at home, we should come up with problems that need to be solved within our home. Which gave us motivation to work with our hands, and our brain cells function faster…*

DSG Participant in Southern Africa

**After DSG, students demonstrated an increased interest in people and places around the globe.**[4] Key findings:

- During post-program interviews, Club Leaders consistently reported that their students' interest in people and places around the globe had increased during the course of the program, particularly as related to the students in their partner club and the country and city in which they lived. Several Club Leaders commented on the stereotyped preconceptions that their students had about their partner club before DSG, and how DSG challenged those assumptions and helped students gain more realistic perspectives. For instance, African students commonly thought that American students were all rich, while American students commonly thought that African students were all poor, and the partnership helped build an interest in learning what the students in the partner club were actually like, as opposed to the stereotypes.
- In qualitative focus group discussions with students during the program, participants expressed surprise and interest at the many similarities between themselves and the students in their partner club, as well as fascination with their differences, and there was a great deal of interest in learning more about the students in the other club.

**After DSG, participants demonstrate an increased ability and inclination to take different perspectives, others as well as their own.**[5] Key findings:

- After participating in the program, a significant number of students (60%) changed their perceptions of the differences between themselves and the kids in their partner club, with perceptions moving from general to more specific. For example, one student initially noted general differences in the level of development in their partner club's community and later described more specific differences in accents, entertainment, and houses at the end of the program. (It should be noted that findings in this area were not always easy to interpret, and it will be important to identify improved measures for this impact area in future studies.)

[4] Attempts to measure this construct quantitatively were not successful, due to the difficulty of coming up with appropriate items that did not suffer from "ceiling effects" (high scores in the pre-test that make it difficult to detect any difference in the post-test). Qualitative data were relied upon to measure this impact area.

[5] DSG participants responded to open-ended questions about perceived differences and about what students and homes in the other region looked like. Their responses were then coded and summarized quantitatively.

- When asked to draw or write about what they thought the students in their partner club and their homes looked like, 12% of DSG participants demonstrated more realistic (less idealized/stereotyped) perceptions at the end of the program than they had at the beginning.
- Focus Group discussions, partner exchange documents, and interviews with Club Leaders revealed significant growth in group work and teamwork skills among the participants over the course of the program, indicating that DSG had a positive impact on students' ability to listen to others within their own club, receive constructive feedback from the partner club, and collaboratively develop an engineering solution.

**After DSG, students demonstrated increased confidence that they can solve problems and create change.** Key findings:

- There was an increase in the percentage of students who agreed that they were good at designing things after completing DSG. (85% of students after completing DSG, compared to 69% at the start of the program.)
- There was an increase in the percentage of students who agreed that they were good at creating or inventing things after completing DSG. (87% of students after completing DSG, compared to 66% at the start of the program.)
- There was an increase in the percentage of students who agreed that they could solve problems in their community after completing DSG. (82% of students after completing DSG, compared to 66% at the start of the program.)
- During post-program interviews, Club Leaders consistently noted that the "review" and "present" component of the partnership exchange was well-received by students and was responsible for increased confidence in students.

## Educator Outcomes

**After DSG, all educators demonstrated increased comfort leading engineering activities.** Key findings:

> *DSG definitely increased my confidence. I know WAY more about what makes a sturdy structure than I ever thought I would know!*
>
> Club Leader, Southern Africa

- Through the Club Leader post-survey and interviews, all 15 educators from across the U.S. and Southern Africa reported that, after DSG, they had increased comfort facilitating engineering activities with students.
- Their explanations included increased comfort facilitating teamwork while working on the engineering activities, coming to accept that failure is a normal part of the engineering process and teaching this to students, connecting engineering to students' daily lives, and an ability to help students identify what is an engineering solution, and what is not.

**All educators demonstrated increased understanding of global competence.** Key findings:

- Across the board, despite partnership challenges, DSG's educators experienced clear gains about how to facilitate the global partnership experience for their students - something that few of them had ever done before.
- Even for those whose partnerships were not successful, they were able to learn something about what global competency means and why it is important. They also learned how to "teach" it to their students through DSG.

**Over half of the educators demonstrated increased comfort with collaborating with educators from other cultures/countries.** Key findings:

- The educator-level results in this impact area were more mixed than with their comfort leading engineering activities. Just over half of the respondents (eight of the 14) reported increased skills in facilitating partnerships and working with educators across borders as a result of participating in DSG.
- Of those who did not report growth in this area (six Club Leaders), four felt that they already had a pretty high comfort level in this area before starting the DSG program, so DSG did not improve their comfort level but was an opportunity to practice skills that they already had.
- The other two noted that they did not have successful partnership exchanges so they did not have a chance to increase their comfort levels in this area.

## Results: Understanding Processes

### *Training for Club Leaders*

Based on the post-training survey that was administered to gather feedback on quality and effectiveness (completed by 10 of the 14 Club Leaders), the training was well received. Some recommendations can be considered for the next round of DSG implementation:

- Maintain the flexible, do-at-your-own-pace training format. Maintain the multimedia and interactive aspects.
- Streamline the training modules to reduce the length from approximately 4 hours to approximately 1.5 hours.
- Show more hands-on examples of Club Leaders leading clubs, possibly with footage of a real Club Leader leading an activity with students. Include footage from both the Southern Africa and the U.S. side. Include interviews with Club Leaders to hear more from past educators about how they ran their clubs, dealt with challenges, etc.
- Use one platform, not multiple. Include fewer/shorter videos that focus more on the experience of Club Leaders leading clubs (as described above), requiring as little bandwidth as possible. Provide basic Internet access guidance, noting that a fairly reliable connection is a foundational requirement for the club.
- Club Leaders requested that, going forward, there be at least one person available to answer questions as needed (remotely), particularly for first-time Club Leaders. A page

on the DSG site with Frequently Asked Questions, and possibly a troubleshooting guide, would also be very useful.

### *Setting up a Club*

A number of lessons were learned about how to set up a club, including some new and innovative ideas from some Club Leaders:

- Provide guidance that 10-14 is the preferred age range for DSG participants, with some level of flexibility depending on additional contextual factors.
- Keep the allocated time for each session at 1-1.5 hours.
- Provide guidance on how DSG clubs can consider bringing back former participants to serve as mentors and assist with leading sessions.
- Provide guidance to Club Leaders that providing notebooks to the students for design journaling can be an effective implementation strategy.
- Provide guidance that co-leadership can be a good strategy, particularly with clearly defined roles and responsibilities between co-leaders.
- To the extent possible, make consistent and strong Internet access a core requirement of DSG.

> *The students that came from DSG Round One facilitated some sessions, since they wanted to be part of Design Squad again. Four of them ran two of the sessions. At the beginning they did a recap, showing the way to the other students. They were like mentors for the current participants and they attended every session. This is really important for building leadership skills in our students.*
>
> Club Leader, Southern Africa

### *The Club Guide & DSG Resources*

During post-program interviews with Club Leaders, the Club Guide was very well received, with universal appreciation for its clarity and usefulness. Some minor recommendations include:

- Keep the current content and layout of the Club Guide.
- Develop a set of filler activities available for Club Leaders whenever they need them and provide guidance for how these filler activities can be used to re-synchronize partner clubs.
- In the Club Guide, make it more explicit that a range of substitutions are fine for preferred materials, possibly including pictures of a range of options that are likely to be available in any given context.

> *The Club Guide was great. It was our map that we used for everything. It outlines the program, all the elements, the action research, all the activities. There is nothing to improve. The Club Guide is strong enough AND simple enough for anyone to pick it up and run with it.*
>
> Club Leader, United States

### *Partnerships*

The partnership aspect of DSG is one of the features that makes it a unique and exciting opportunity for participants and Club Leaders. However, it was also the most challenging aspect of the second round of implementation, and the fourteen clubs ended up having a range of partnership experiences, from no exchanges (two clubs) to very active and regular exchanges (four clubs) to somewhat irregular and inconsistent exchanges (eight clubs). Those clubs with more in-depth and regular exchanges were very positive about their partnership experience, and even those that were less successful were anxious to try again next time for a better partnership experience. For these reasons, recommendations to improve this aspect are more extensive than other areas, and include the following:

- Provide additional opportunities to build the global competencies of DSG Club Leaders, possibly through encouraging synchronous communication with each other. Encouraging institutions and Club Leaders to return to DSG numerous times and grow in their ability to develop a partnership may help ensure smooth partnerships.
- Keep the reduced number of partnership exchanges. (In the last round of implementation, there were exchanges each week. In this round, there were less exchanges.)
- Recommend that Club Leaders use email as the primary means of communication with partner Club Leaders. Provide guidance on additional/backup means of communication and sharing, such as WhatsApp and Dropbox, or services that provide similar features.
- Encourage Club Leaders to find ways to set up synchronous exchanges between partner clubs, despite logistical difficulties such as different time zones.
- Recommend an initial in-person call connecting partner clubs, where logistics around communication can be negotiated and tested. Develop ways for Club Leaders to have an initial partnership experience that is meaningful - it is likely to set them up well for being committed to the partnership, because they are able to see the value of the exchange. Recommend beginning with a commitment to partner exchanges as part of their commitment to DSG. Encourage institutions/individuals to continue with DSG over time and potentially between the same two partner institutions, so that partnership experience can be deepened over time and the quality of partnerships can grow. In the training, use the lived experiences of real Club Leaders to: 1) show that the partnership is REALLY important, 2) provide advice for successful partnerships and 3) show strategies for how to deal with a non-active partnership situation and disappointed students.
- Explore the possibility of in-country partnerships as an option in the next phase of DSG.

> *The Skype call in the partner exchange worked magic. All we did was set it up and let them be free to break the ice. They felt that they made friends in USA and couldn't stop talking about it. This increased their level of thinking, boosted their self-confidence and now the students know that in USA and other countries the students are all the same. All they need is a chance to be free and use their imagination.*
>
> Club Leader, Southern Africa

- Consider ways to further streamline the partnership exchange template and process so that it is as easy as possible for Club Leaders.

### *Leading a Club*

While facilitating sessions through both rounds of DSG implementation, DSG's Club Leaders learned important lessons about how to work with the students, maximizing learning and growth.

- Provide guidance for Club Leaders that, where relevant, they may have to interpret Club activities into a language that students better understand. As DSG disseminates around the world, it will be important to carefully consider language barriers that will arise, and consider the possibility of translating some of the resources into different languages.
- Provide guidance for Club Leaders on how to make clubs as fun and as "different from school" as possible – which may be particularly relevant to non-U.S. based club leaders, depending on the context.

## Conclusion

In conclusion, it becomes possible to answer the third research question: Can the proposed model successfully be implemented in the US and abroad? Can the model effectively help educators and students achieve the desired outcomes?

Based on the evidence from exchanges between clubs in the United States and Southern Africa, the answer to both questions is likely to be yes. Through the results of action research, it is clear that DSG has demonstrated growth across all impact areas – both student-level and educator-level, although some of the growth in the area of global competence proved challenging to measure. The DSG model has been significantly improved over the course of several iterations – a pre-pilot, and two pilot rounds of implementation – to a point where, with some final modifications, the model can be successfully implemented in the U.S. and in Southern Africa, and likely in other countries as well.

With this formative research study, DSG is contributing to the development of an evidence base around how to adapt engineering resources and the outreach process needed to work collaboratively across distances and cultures. Informal engineering, when paired with an international exchange, can be an effective discipline through which to develop both engineering and global competency skills in children and youth around the world. The evidence demonstrates that DSG's model of collaboration builds participants' understanding of engineering, motivation to participate in engineering, and confidence in taking effective and informed action on behalf of pressing global problems. In addition, findings demonstrate that a sharp focus on the design process is an effective way to increase interest in engineering and develop problem-solving skills in youth. Through the global partnership that pairs clubs in different countries, students gain a deeper understanding of the role of engineering in improving lives around the world, and specifically in the community where their partner club is located,

opening their eyes to a broad, exciting world of connections and possibilities. In this way, this research project directly contributes to a larger body of work about whether and how engaging with global, collaborative engineering problems leads to broadened perspectives and improved confidence in kids with very different backgrounds, experiences, and opportunities.

# I. Introduction

DESIGN SQUAD GLOBAL (DSG) is a web-based, mobile-accessible digital hub and outreach initiative that creates new opportunities to empower middle school youth to solve real-world problems and understand the impact of engineering in a global context. The project builds on DESIGN SQUAD'S well-honed model for engineering education (including a television show and website: http://pbskids.org/designsquad). The ultimate goals of Design Squad Global are to: (1) develop innovative ways to incorporate effective engineering education into informal learning environments; (2) inform the field about promising practices in cross-cultural collaboration, and; (3) gain a better understanding of how engineering activities can successfully enable middle school students to meet the demands of an increasingly interconnected world. DSG emphasizes the development of participants' global competency – meaning the ability to communicate and collaborate with people from different backgrounds, cultures, and perspectives.

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Learning from the first round of implementation[6] informed a number of revisions that were implemented in the second round. One of the biggest challenges in Round 1 was dealing with calendar synchronization across partner clubs: when working in different countries with different school calendars and different holidays, getting the timing right for partnering two

[6] Detailed in the Report, *DESIGN SQUAD GLOBAL: Research Findings from the First Round of Implementation*.

clubs can be difficult. The timing was especially important for the partnership exchanges, which sometimes did not take place because of synchronization challenges. The pilot also revealed that every club has different priorities and constraints, and it would be helpful to have a few different DSG models for interested clubs to choose from, to best suit their needs. With this in mind, in Round 2, the implementation team decided to test four models of Design Squad Global, with varying lengths and varying intensities of partner exchanges. These models are described below:

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In this report, research findings related to the second round of DSG implementation are detailed. As described above, four different DSG models were being tested in this round, but the number of student survey responses for individual models was small, and the results were not particularly revealing about differences across models, so the decision was made to present the results in the aggregate. Three overarching research questions are answered using these aggregate results, focusing on both outcomes and processes:

1. To what extent does DSG's model of cross-cultural collaboration build students' understanding of engineering/invention, motivation to participate in engineering/invention activities, and global competencies?
2. What are the challenges, infrastructure, and support needed to inspire and prepare a cohort of young, globally competent engineers in afterschool programs, both in the U.S. and internationally?
3. Can the proposed model successfully be implemented in the US and abroad? Can the model effectively help educators and students achieve the desired outcomes?

The findings for the first two questions are presented in this report in Sections II and III, which summarize findings on outcomes (related to research question 1) and processes (related to research question 2). The conclusion brings the reader back to research question 3, drawing some high-level conclusions from all the evidence presented on whether the proposed model can be successfully implemented in the U.S. and abroad, effectively helping educators and students achieve the desired outcomes.

# II. Research Methodology

This section describes the research questions, methodology, processes for data collection, and ethical considerations related to conducting this research.

## Research Questions

DSG's research design is based on the following questions, which seek to gain insight into both outcomes and processes:

1. To what extent does DSG's model of cross-cultural collaboration build students' understanding of engineering/invention, motivation to participate in engineering/ invention activities, and global competencies?
2. What are the challenges, infrastructure, and support needed to inspire and prepare a cohort of young, globally competent engineers in afterschool programs, both in the U.S. and internationally?
3. Can the proposed model successfully be implemented in the US and abroad? Can the model effectively help educators and students achieve the desired outcomes?

## Methods

Action research is a methodology often used in the education sector to allow educators to do their own data collection, learn from the process, and use the findings to learn about their own classrooms and inform their own professional work. For DSG, the action research model made it possible for Club Leaders to collect data, learn from it, and feed it back to the DSG researchers, in order to answer the program's key research questions. Action research activities included pre-post student surveys, Club Leader surveys (post-training and post-club), documentation of student work through the partner exchanges, focus groups with students, and weekly Club Leader surveys with specific questions about the week's activities. In addition, after completing the program, the research team conducted post-club interviews with Club Leaders to better understand their experience with DSG. These methods are described below.

All Club Leaders and students that participated in Round 2 implementation were participants in Action Research activities. There were also two DSG Facilitators – one for the seven U.S. sites, based in Boston, and one for the seven Southern African sites, based in Johannesburg. These two facilitators were also key participants in the Action Research.

### *Student Surveys (PRE and POST)*

Before the first session began, and after the last session ended, Club Leaders were asked to administer a survey to the students, measuring student-level impacts and gathering feedback on the program's strengths and weaknesses.

### *Club Leader Surveys (POST-TRAINING and POST-CLUB)*

After completing the training, Club Leaders received a survey to gather feedback on the quality and usefulness of the training. Also, after completing the club, the Club Leaders received a survey to assess what they learned and gained through their participation.

### *Documentation of Student Work*

For their partner exchanges, Club Leaders were asked to take photographs and/or videos of their students working on DSG activities, and also shared their sketches and ideas. These were sent via email or another method of communication.

### *Focus Groups*

Twice during implementation, Club Leaders were asked to keep students for an extra 10 minutes to hold a focus group discussion on a specific topic related to student outcomes – one related to engineering, and one related to global competencies – using the discussion guides provided. They were asked to record the conversation (audio or video) with a phone or other device so that it could be shared with the Facilitator.

### *Weekly Implementation Surveys*

Once a week, Club Leaders were asked to fill out an online survey answering a series of questions on DSG's implementation. These were a critical source of information for the DSG team to understand how the program was working and what the challenges were, and to be able to make course corrections as quickly as possible.

### *Post-Program Interviews*

As clubs were wrapping up implementation, the research team conducted post-program interviews with the Club Leaders. The purpose of these interviews was to gather overarching feedback on how the program went and to delve deeply into recommendations for improvement.

## Data Collection

Data collection took place over the course of about 12 weeks, from March – June 2016. Data collectors included Club Leaders, Facilitators, and the DSG Research team. Their responsibilities were as follows:

**Club Leaders** (14 total, one at each site): Responsible for student and club leader surveys; documentation of student work through partner exchanges; weekly surveys; and focus groups with students. Club Leaders received guidance on action research as part of their overall DSG orientation and training.

**Facilitators** (2 total, one in U.S. and one in Southern Africa): Responsible for interfacing between the Club Leaders and the DSG Research Team, collecting data from Club Leaders, and responding directly to Club Leaders as challenges arose.

**DSG Research team:** (2 total, based in Washington, DC): Responsible for developing training materials for Club Leaders and Facilitators in research methods; developing instruments; conducting post-program interviews with Club Leaders, analyzing data; and disseminating findings.

## Data Analysis

Results are reported for all 88 students overall. Although four different DSG models were being tested in this round, the number of student survey responses for individual models was small, and the results were not revealing about differences across models for student outcomes. For these reasons, the data for student and educator outcomes is presented in the aggregate to demonstrate overall changes across all four models. (The data from the different DSG models was used to better understand processes, leading to recommendations for improvement to the Club.)

The student survey analysis considered the 88 students who completed both pre- and post-program surveys. It focuses on how student responses changed during participation in Design Squad Global. The student survey included 17 questions that were analyzed quantitatively. These were asked as a combination of multiple choice questions, open response questions, and questions asking students to rate their responses to statements on a five-point Likert scale assessing levels of agreement and disagreement.

Responses to questions using the Likert scale are reported as proportions of students who selected each response option. Skipped responses were coded as missing, and a student who missed a question on either the pre- or post-program survey was excluded from analysis of that question. To test the significance of any changes in the Likert scale responses between the start and end of the program, a paired t-test was used.

The remaining questions on the student survey were recoded as binary variables indicating whether a) a student noted the correct or desired response or b) provided an incorrect answer, an undesired response, or stated they did not know. To measure the statistical significance of these results, a McNemar's test was used to look at pre-program and post-program differences.

Throughout the report, $p<0.10$ was used as a cutoff to determine statistical significance, since this research was exploratory.[7] However, results are often significant at more conservative levels. Where this is the case, they are reported as such using $p<0.05$ and $p<0.01$ as additional thresholds.

Qualitative data analysis was conducted using computer-assisted qualitative data analysis software. Interview and focus group transcripts, responses to open-ended survey questions, and other documents (including photos, videos and other partner exchange materials) were

[7] Meaning that differences in values from pre- to post-test were considered statistically significant (not likely due to chance) when the probability (p-value) of a given statistical value was 0.10 or less.

coded using a standard coding scheme. Coding was followed by an analysis of themes and impacts and the results documented according to each theme/impact. In addition, ongoing meetings between the research team and the DSG facilitators included analysis of the weekly surveys, which fed into the development of codes and themes.

## Ethical Considerations

This study was approved by FHI 360's Protection of Human Subjects Committee. The Principal Investigator has an up-to-date certification in research ethics.

All program participants were included in the research; there were no inclusion/exclusion criteria. Participation in the program was entirely voluntary. Because the program itself was being researched, participation in the program also required participation in the research. The content of the research was not sensitive in any way. There were limited risks associated with this study, as there could have been a loss of privacy and confidentiality associated with intentional and unintentional release of the photos and videos. There were potential benefits for children all over the world who will be able to participate in DSG clubs in the future. Although there were children involved (ages 10-13) across four countries (U.S., South Africa, Botswana and Swaziland), there were no vulnerable populations, and no child was compensated.

Consent was obtained for all participants to participate in research activities, including Club Leaders and parents of children, and children were asked to sign an assent form. Prior to the beginning of the program, Club Leaders sent all of these forms home. The forms were signed and returned by all students in the program so that the Club Leader could effectively conduct Action Research. All Club Leaders were also asked to sign a consent form for their own participation in the research.

As part of their consent form, parents and club leaders were also asked to sign a release form for the photos and videos, which is a standard part of WGBH's work as a media company. Signing this form allowed WGBH to use and distribute the documentation created during Design Squad Global for promotional purposes, including: personal photographs; video recordings; and engineering presentations.

## Limitations

The limitations of the study relate to the development of survey instruments for difficult-to-measure constructs, and the level of attrition across the clubs.

### *Development of Instruments*

A survey was developed for DSG to measure student-level outcomes. The student survey was based on tools that had been previously used to evaluate U.S.-based Design Squad engineering activities in informal and formal settings, but was adapted to include a new component evaluating global competency, since this was a new aspect of Design Squad. Assessing global competency was challenging for several reasons. First, there are not any publicly available measures of global competency in children, and conversations with organizations that work in

this area revealed consistent challenges in quantitatively measuring these constructs. Advice from practitioners emphasized the use of qualitative data rather than quantitative, and warned against too much dependence on closed-ended questions. Thus, the student survey tool that was piloted during the two rounds of implementation for DSG clubs included both qualitative and quantitative questions to measure engineering and global competency constructs.

### *Student Characteristics and Attrition*

During this round of DSG implementation, there was attrition in the program. Only fifty-two percent (52%) of the students participating could be matched from the pre-survey to the post-survey. In addition, it is clear from the survey results that student participants ranged broadly in age and grade, extending from third grade to ninth grade, which may also account for some of the response rate challenges, since younger children may have a more difficult time completing paper surveys, especially those whose levels of literacy or proficiency with English are low. Although we do not have enough information from each club to understand why the attrition was so high in some of them, it could be attributable to the drop-in nature of afterschool programs, or inconsistent attendance (meaning that they were at the session when the pre-survey was administered, and at other sessions, but were not at the session when the post-survey was administered, or vice versa). See Table 2 for complete description of the DSG clubs and their dates of attrition.

## Table 2. Participating DSG Programs by region and model

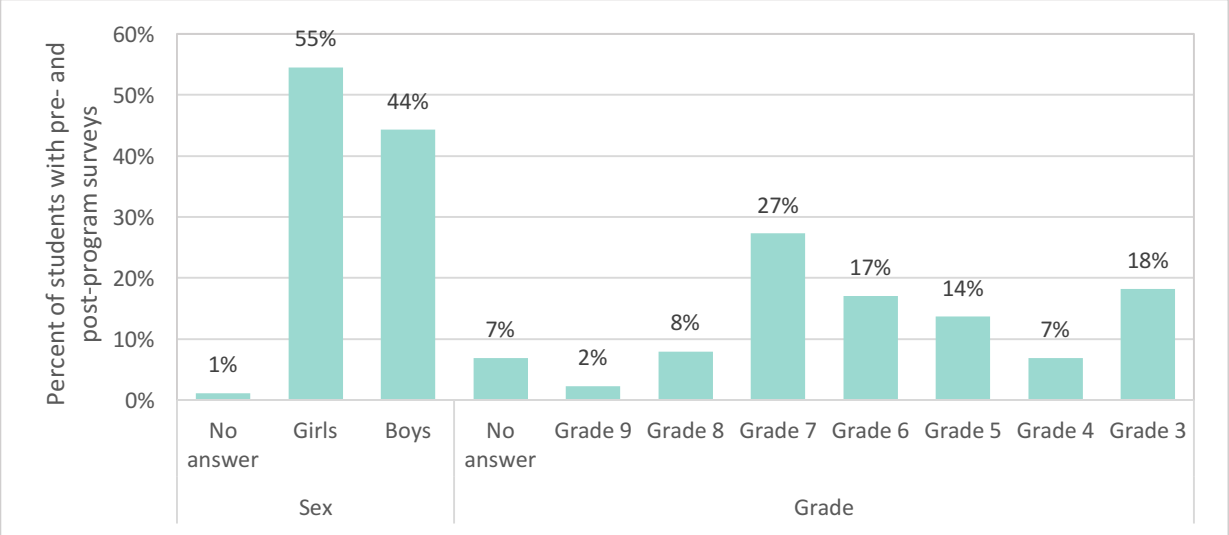
| Region | Program | Model | Students participating at the start of DSG program | Students who started and finished DSG program* | Completion rate (# of students who started and completed program/ # of students who started the program) | Total participating students (includes students who joined the program late) |
|---|---|---|---|---|---|---|
| **United States** | Castle Park | Long, Model 1 | 23 | 7 | 30% | 27 |
| | Granger | Long, Model 2 | 12 | 1 | 8% | 18 |
| | PN Indianola | Short, Model 4 | 8 | 6 | 75% | 9 |
| | Rafael Hernandez | Long, Model 1 | 12 | 5 | 42% | 13 |
| | Twin Cities | Short, Model 3 | 8 | 3 | 38% | 11 |
| | West End House | Short, Model 3 | 9 | 3 | 33% | 12 |
| | YMCA Boston | Long, Model 2 | 18 | 10 | 56% | 19 |
| **Southern Africa** | BGCSA | Long, Model 1 | 12 | 8 | 67% | 12 |
| | Phatsimong | Long, Model 2 | 11 | 10 | 91% | 15 |
| | SAAYC | Long, Model 2 | 8 | 2 | 25% | 16 |
| | SOS | Short, Model 3 | 12 | 7 | 58% | 16 |
| | SSI1 | Long, Model 1 | 10 | 8 | 80% | 10 |
| | SSI2 | Short, Model 3 | 9 | 6 | 67% | 9 |
| | YMCA PMB | Short, Model 4 | 16 | 12 | 75% | 20 |
| **TOTAL** | | | **168** | **88** | **52%** | **207** |

*Had a high rate of attrition/low rate of retention (less than 50% of students retained).

# III. Results: Student Characteristics

Background characteristics for students are presented only for the 88 matched students (those that completed both pre-survey and post-survey). In terms of gender, there were more girls than boys (55% girls, 44% boys). Children in the sample ranged from third to ninth grade, though more than half attended fifth to seventh grades (the survey did not ask about the ages of participants). Seventh grade was the most common grade (27% of participants). Looking at the two world regions, more students from Southern Africa took both the pre- and post-survey—60% of students with matched pre- and post-surveys were from Southern African and 40% from the U.S. (with a total of 53 and 35 students per region respectively). In Southern Africa, ethnic background was measured by looking at home language. Nearly all (96%) reported an African language as their first language, with Setswana the most frequently reported and isiZulu the second most common.

**Figure 1. Percent of students participating by model, grade, and sex**




For the U.S. students, most (80%) reported English as their first language, 11% reported Spanish, 3% Portuguese, and 3% Creole. For ethnic background of the U.S students, nearly half (49%) identified as having Hispanic, Latino, or Spanish origin. For racial background, equal numbers of students identified as either Black or African American (29%) or White or Caucasian (29%). Eleven percent of students identified as American Indian or Alaskan Native, 6% identified as native Hawaiian or other Pacific Islander, and 3% identified as Asian. It is important to note that some students chose more than one category, so the sum of the percentages of students identifying with each category is over 100%.

**Figure 2. Percent of students participating by world region and first language[8]**

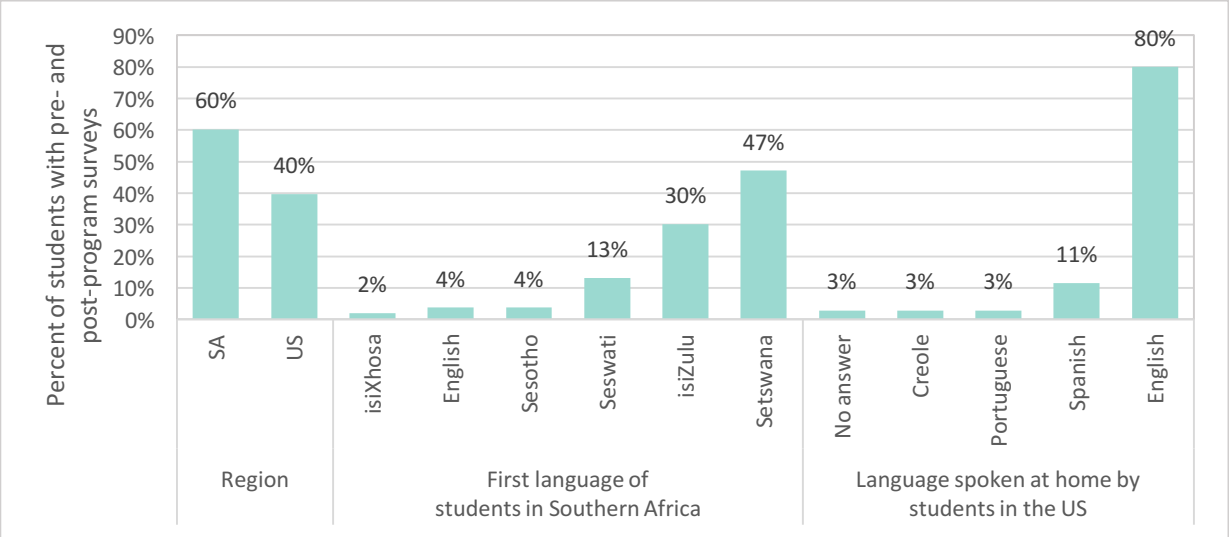
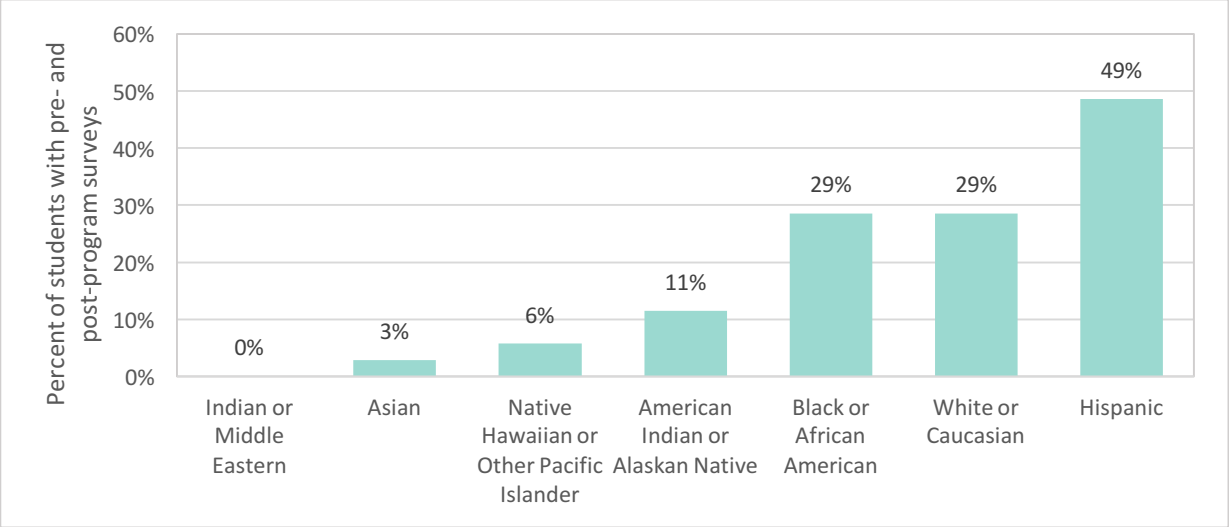



**Figure 3. Percent of U.S. Students Participating by Race/Ethnicity[9]**




[8] In the US, students were asked to name the language or languages they speak at home. The summary in Table 4 is based on the language that students listed first.

[9] Please note that some students identified with multiple groups, and this is reflected in the summary.

# IV. Results: Understanding Student Outcomes

***Research Question:*** To what extent does DSG's model of cross-cultural collaboration build students' understanding of engineering/invention, motivation to participate in engineering/ invention activities, and global competencies?

In this section, research results are presented for the following six student-level outcomes, drawing on data mostly from the student questionnaire but also from additional sources:

| |
|---|
| **S1. Students demonstrate understanding of engineering, the design process, and science concepts in the Club Guide.** |
| **S2. Students demonstrate understanding of how engineering and invention can make a positive difference in the world.** |
| **S3. Students demonstrate motivation for participating in engineering activities, classes or clubs.** |
| **S4. Students demonstrate an interest in people and places around the globe.** |
| **S5. Students demonstrate an ability and inclination to take different perspectives, others as well as their own.** |
| **S6. Students demonstrate confidence that they can solve problems and create change.** |

Of these six outcomes, S1 and S3 focus on engineering outcomes specifically: understanding of engineering, the design process, and science concepts in the Club Guide, as well as motivation for participating in engineering activities, classes or clubs. The other student-level outcomes include some aspect of global competency, which has been defined as the ability to communicate and collaborate with people from different backgrounds, cultures, and perspectives. Global competency was operationalized as an interest in people and places around the globe (S4), and an ability and inclination to take different perspectives, others as well as their own (S5). In addition, two of the outcomes combine engineering and global competency outcomes, which intersect in important ways in DSG: S2 focuses on how engineering and invention can make a positive difference in the world, and S6 focuses on student's confidence that they can solve problems and create change.

## S1. Students demonstrate understanding of engineering, the design process, and science concepts in the Club Guide.

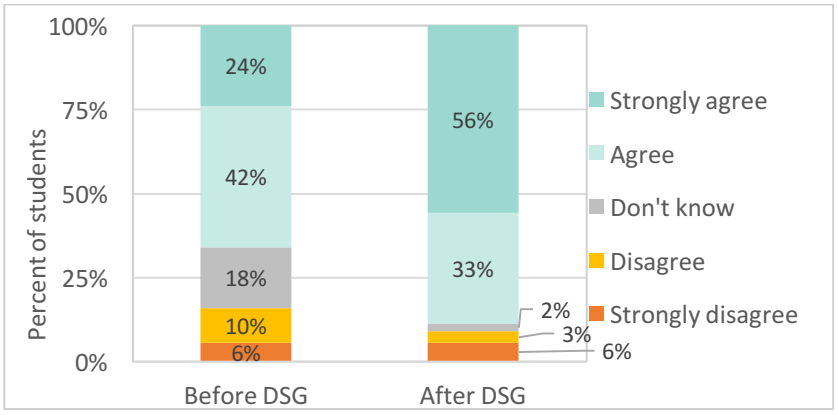
For this outcome, we use the pre-post survey results to see if students showed any gains in terms of having a) a basic sense of what engineering is and what kinds of work engineers do, b) the ability to state the steps of the design process, c) and an understanding of two basic science

concepts from the Club Guide: that triangles are the strongest shape, and how a lever works. We also looked at other sources of data (focus group discussions, interviews with club leaders, and documents from partner exchanges) to triangulate the findings. As demonstrated below, the results show that DSG is effective at building students' understanding on each aspect: what engineering is, the design process, and the science concepts.

### *Understanding of Engineering*

After participating in the program, more students felt they knew what engineering is, with change statistically significant at a 99% confidence level. As shown in Figure 4, 89% of students agreed or strongly agreed that they know what engineering is after completing DSG, compared to 66% at the start of the program.[10]

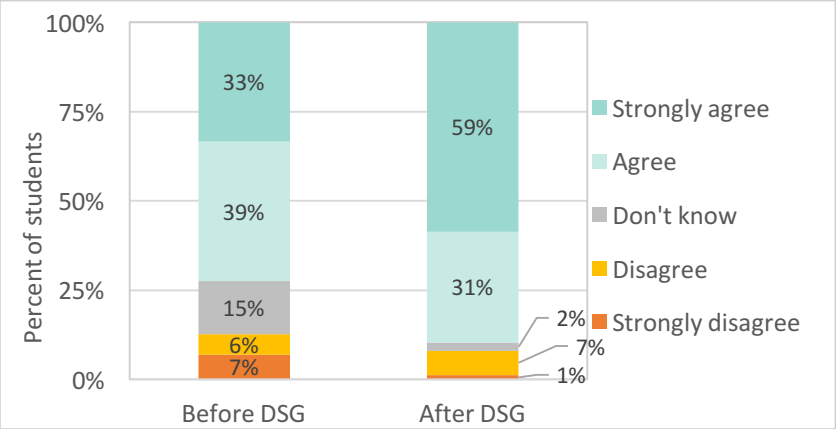
**Figure 4. Student responses to the statement: I know what engineering is (n=88, p<0.01)**




In addition, after participating in the program, more students thought they knew what an engineer does, with improvements statistically significant at a 99% confidence level. Figure 5 shows that 90% of students agreed or strongly agreed that they knew what an engineer does after DSG compared to 72% when the program began.

[10] In this section and subsequent sections, the total percentage of students who agreed or strongly agreed with a statement is discussed in the text. The figures provide a more detailed breakdown, presenting the percentage of students who agreed separately from the percentage of students who strongly agreed.

**Figure 5. Student responses to the statement: I know what an engineer does (n=87, p<0.01)**



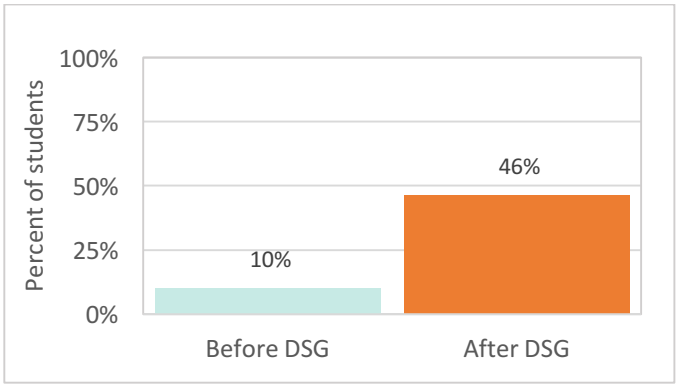

Interviews with Club Leaders supported the idea that the students learned a great deal about what engineering is, and what an engineer does, largely through the process of coming up with their own engineering/invention problems to solve.

According to one U.S.-based Club Leader, when doing a group brainstorm to identify a problem and develop an engineering solution, the students did not at first understand the difference between engineering and non-engineering solutions. It took one and a half sessions to really understand the difference, but they did get there. In the end, they decided to focus on solving a health problem relevant to their own lives – that Band-Aids are not waterproof. They developed a waterproof Band-Aid involving bubble wrap, felt, and tape – a solution that the Club Leader thought was very innovative.

### *Understanding of the Engineering Design Process*

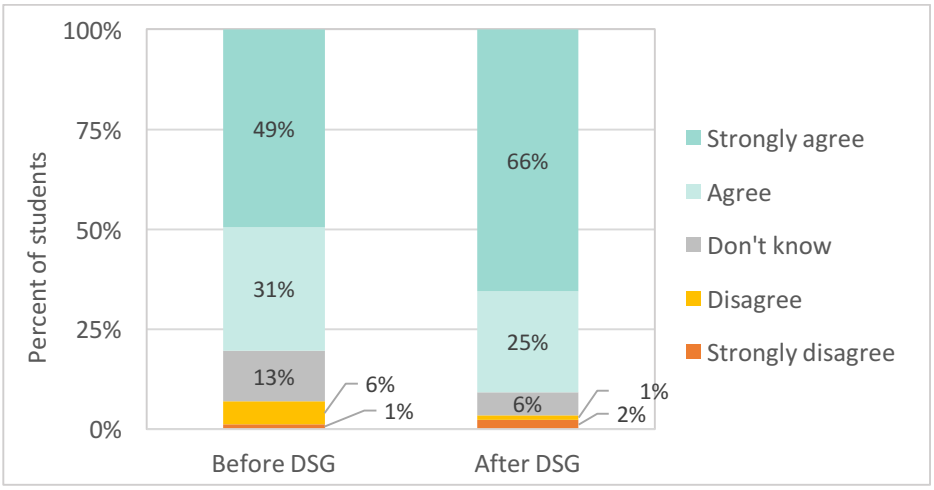
The design process is a foundational concept for DSG, and the student survey revealed that, after participating in the program, there was a significant increase in the number of students who could name the key steps in the engineering design process. Results, which are statistically significant at a 99% confidence level, are shown in Figure 6. At the start of DSG, only 10% of students could name key steps in the design process compared to nearly half (46%) afterwards.

**Figure 6. Percentage of students who could name key steps in the design process (n=80, p<0.01)**




In addition, after participating in the program, there was a significant improvement in student awareness that engineers and inventors sometimes have to test their work and start over again, which is an important aspect of understanding the design process. These results are statistically significant at the 99% confidence level. As shown in Figure 7, 91% of students agreed or strongly agreed that testing and starting over is sometimes necessary in engineering compared to 80% at the beginning of the program.

**Figure 7. Student responses to the statement: Engineers and inventors sometimes have to test their work and start over again (n=87, p<0.01)**




Focus group discussions provided additional evidence on the depth of students' understanding of the design process. Students could do more than just list the steps: they were able to articulate the design process in their own words, and explain what each step meant. For example, students from a DSG club in Botswana made the following statements:

> *Student 1. We find the need first. The need may be a problem which we encounter or see in society. Then we brainstorm—we explain how you will do your thing. The*

*solution—we come up with ideas as a team as a way to solve the issue that we found. Then we design, by sketching the idea. Then we share the solution…we test before, and then we share the solution.*

*Student 2. Defining the need before—for example, if there is no electricity in the house because of a blackout—that's a need. Brainstorming wouldn't be that hard—use information you learned before for the issue you want to address. Designing—it's going to take a bit of creativity and you need people to help you with it. Building—a bit of hard work and practicality.*

In post-program interviews, Club Leaders consistently referred to the design process as a foundational component of DSG that gives the students an anchor around which to design and build. A U.S. based Club Leader reported,

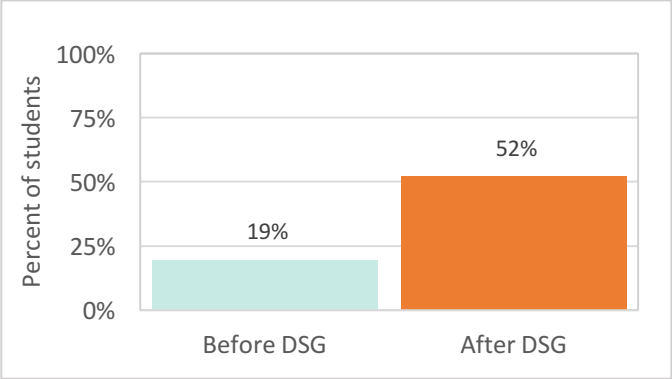
*Just after DSG ended, I saw several of the same students show up to a similar program, and when they walked into the room, they said we need to do this, and this, and this, and they did it, and they had the best products of all the students in the room. The DSG participants really got the design process. I've been doing this kind of work for seven years, and I've never seen anything like that before.*

According to a South African Club Leader, "The most successful part of DSG was going through the design process. If we skipped a step, they would know exactly what they skipped. They followed up."

### *Understanding of Science Concepts*

The key science concepts in the Club Guide focused on triangles being the shape that makes the strongest structure and how levers work. After participating in the program, more students could correctly identify that triangles are the shape that helps make the strongest structure, with improvements statistically significant at a 99% confidence level. At the start of the program, only 19% of students were correctly able to answer this question whereas, at the end of the program, over half (52%) could.

**Figure 8. Percentage of students who correctly identified that triangles are the strongest shape (n=77, p<0.01)**




In photographs, drawings and videos from across the clubs, triangles are very apparent in students' designs. In an interview with a South African-based Club Leader, it was noted that "Every time we design something, there is a triangle in there. They are applying it to everything!"

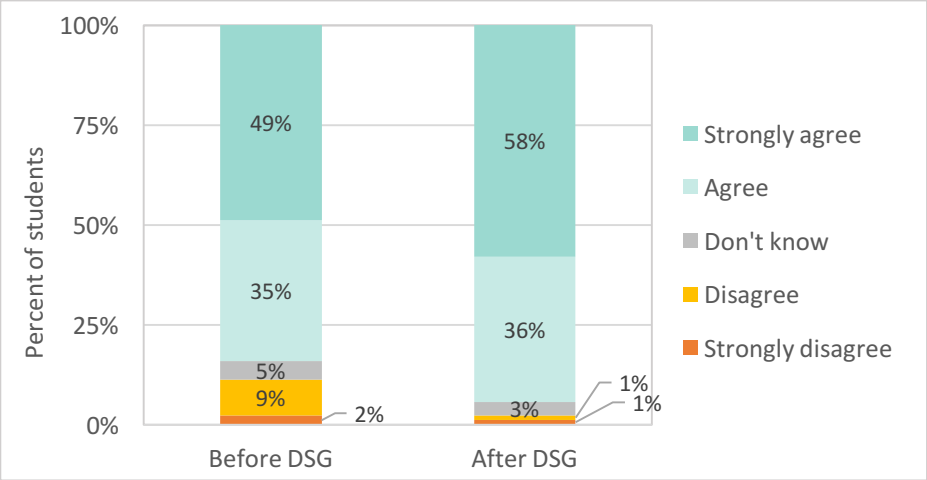
On the pre- and post- student surveys, students were asked to draw a lever and label the parts. Though there was modest improvement in their ability to do so, the results were not statistically significant. Students struggled with this question both before and after the program, with 8% answering correctly initially and 12% doing so at the close of DSG. However, students did apply their knowledge of levers to the design and build of their inventions, particularly during the "helping hand" activity, which gave students an opportunity to design an invention that could help them grab something located higher up than they could reach.

## S2. Students demonstrate understanding of how engineering and invention can make a positive difference in the world.

For this outcome, we looked to see if students gained an understanding that engineers solve problems that help people, and if they could come up with ideas for inventions that could make a positive difference in their community and their world. The findings presented below indicate that DSG does effectively improve students' understanding in this area.

Through the student survey, we found that, after participating in the program, a greater number of students understood that engineers and inventors solve problems that help people, with this change statistically significant at a 95% confidence level. As shown in Figure 9, 84% of students agreed or strongly agreed with this statement at the start of the program. This rose to 94% at the end of the program.

**Figure 9. Student responses to the statement: Engineers and inventors solve problems that help people (n=88, p<0.05)**




There were two additional qualitative survey questions where students showed minor gains, but these gains were not statistically significant. When participants were asked if they could think of (and name) one thing designed and built by an engineer or inventor that they could not live without, the percentage gain in correct answers was very modest: from 58% at pre-test to 60% at post-test. Students were also asked to name a community problem and describe how an engineer could solve the problem; for this question, there was an improvement from 26% to 39% from pre-test to post-test, but the results were not statistically significant. Both questions had open-ended components and were skipped fairly often.

In focus group discussions, most participants were able to articulate what kinds of problems engineering could potentially solve. In this excerpt from a focus group in Southern Africa, the students said:

> *Student 1: DSG taught us to think outside the box. It made us to find problems around our society or community. It also taught us that when we are there at home, we should come up with problems that need to be solved within our home. Which gave us motivation to work with our hands and our brain cells function faster…*
>
> *Student 2: We wanted to solve a problem of where people could sit down and be comfortable while waiting outside. We could design some chairs or a shade or shelter… We need materials that are resistant to the weather when it's too sunny, not crack. Resistant to rain and steady enough so if it's windy it doesn't fall or break. Chairs that are durable—that last—that are not moveable, they have to stay there.*

Ten of the clubs (participants in Models 1, 2, and 4) had the opportunity to develop an engineering solution for a community problem. For example, a club in South Africa designed a special light for use during power outages, which are frequent in South Africa. Along with their design, the club sent the following text to their partner club in the U.S.: "We often run out of electricity and our center gets really dark, and our light will make us see the exit easier. Our

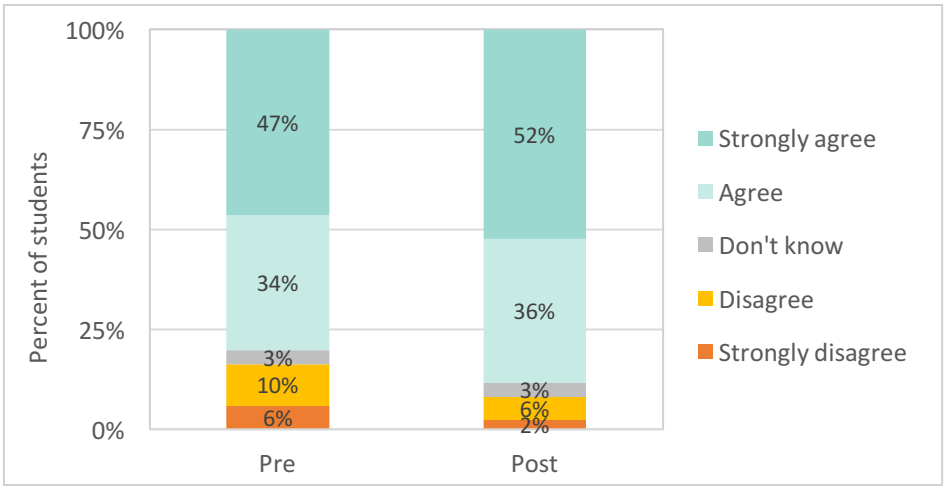
design can be used where light is needed in any environment." Meanwhile, a club in the U.S. decided to tackle the problem of bullying in their school with an idea to develop a "bully button" – a button that could be pushed to summon help when someone is being targeted for bullying. These examples reinforce the finding that students learned how engineering can be used to solve problems in their own environment and in the world.

## S3. Students demonstrate motivation for participating in engineering activities, classes or clubs.

On the student survey, motivation was measured by several items focused on students' interest in designing, creating and inventing things, and solving problems in the community. Focus groups and interviews also sought to measure participants' motivation for participating in engineering and invention-related activities. The findings demonstrate that there is clear evidence, as presented below, that DSG is effective at motivating students to participate in engineering-related activities in the future.

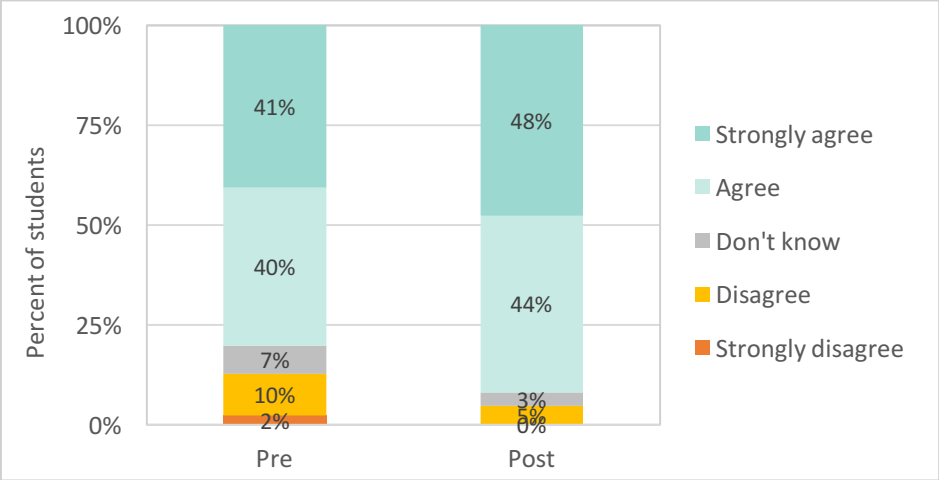
After participating in the program, there was an improvement in student interest in designing things, with results statistically significant at a 95% confidence level. Most students (80%) agreed or strongly agreed that they had an interest in designing things at the beginning of the program, and this rose further to 88% at the end of the program.

**Figure 10. Student responses to the statement: I am interested in designing things (n=86, p<0.05)**



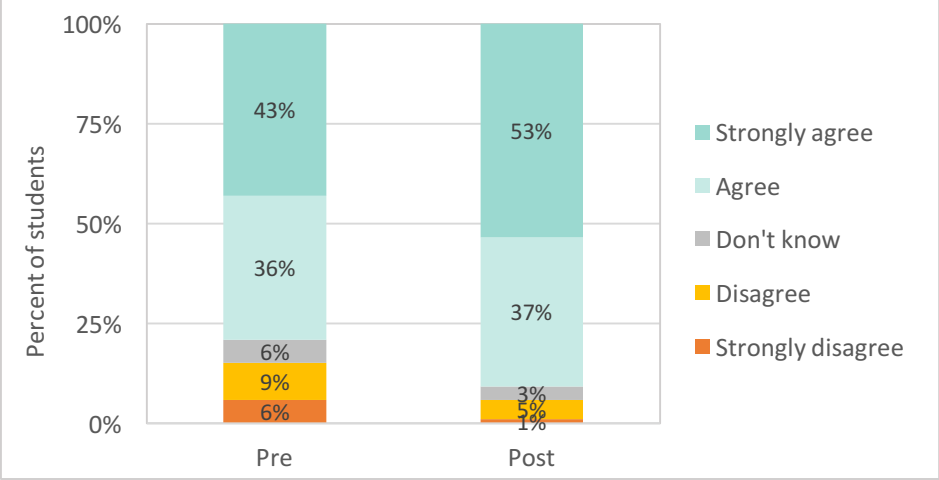

In addition, after participating in the program, there was a rise in student interest in creating or inventing things, with changes statistically significant at a 99% confidence level. Before the program, 80% of students agreed or strongly agreed that they were interested in creating and inventing, and this increased to 92% by the end of DSG, as shown in Figure 11.

**Figure 11. Percent of students who agree or strongly agree with the statement: I am interested in creating or building things (n=86, p<0.01)**




Also, after participating in the program, more students were interested in solving problems in their community, with differences statistically significant at a 99% confidence level. At the outset of the program, 79% of students agreed or strongly agreed that they were interested in solving community problems, and this rose to 91% at the end of the program.

**Figure 12. Student responses to the statement: I am interested in solving problems in my community (n=86, p<0.01)**




Focus groups and interviews supported the finding that participating in DSG was motivational for students. A focus group in Botswana included the following statement from a participant:

> *For other people who don't know about DSG, they should come in and find out more about it. When I came, I thought it was something else. I didn't know much about engineering. It gave me motivation. It taught me a lot...that I can design things... You need your mind; you need your hands. You need only your knowledge–that can help you in order to come up with an idea or product to help motivate.*

When asked during a focus groups if they might be interested in studying engineering in the future, many participants across both the United States and Southern Africa said yes. Their answers often included the following themes: to help others; to solve problems; and because engineering is interesting and fun. In a post-survey interview, a Club Leader explained the participants' enthusiasm for DSG as a result of its project-based nature: "DSG itself is a very hands-on project which is very different from the mainstream school curriculum in Botswana. Therefore, the participants are always excited to get involved and use their hands to build a solution to solve a problem."

## S4. Students demonstrate an interest in people and places around the globe

By connecting Club Leaders and students from different countries and backgrounds, DSG has the potential to dispel stereotypes, and increase kids' understanding and interest in some of the differences and similarities among themselves and the students in the partner club. This process of getting to know each other can potentially foster an interest in issues that other people are experiencing. In the attempt to measure this complex construct, we used qualitative measures to look at the extent to which students were surprised by what they learned about the partner club, what kind of similarities and differences they noticed, and if they generally expressed interest in learning more about each other. For this impact area we used focus group discussions, Club Leader interviews, and the partnership exchanges as the primary sources of data. There were clear findings related to students' increased interest, particularly from the perspective of the Club Leaders, who noticed significant growth in this area.

Across the board, students were surprised by the similarities between them and the students in their partner club, and were interested to discover differences between them and their partners. A U.S.-based club had the following exchange during a focus group discussion:

> *Student 1: [The students in our partner club] aren't very different at all— they live in regular houses, regular education.*
>
> *Student 2: They live in a different country, different accent, different traditions, different rules, different food, different religion.*
>
> *Student 1: They're kind of like us.*
>
> *Student 2: They have different sports… Like net ball… I have no idea what that is.*
>
> *Student 3: I think it deals with nets and a ball. Like basketball.*
>
> *Student 1: They have different weird names-- hard to pronounce. They are just not our kind of names--not weird to them but weird to us. Our names might be weird to them.*

In another focus group, in Botswana, participants thought that the U.S. students' designs would be superior to their own and they were surprised by how similar their designs ended up being.

This feeling of surprise was also revealed in an interview with a Club Leader in South Africa. Kids in the club were amazed to learn that American students are not all rich: "A lot of [my students] thought [the students in the partner club] had money that they didn't know how to spend. When we got the video from Indianola, they're realized they're like us…. This was one thing I know that they learned."

Participants' eyes being opened was also expressed in another interview with a South African Club Leader, who talked about the connection and communication with their partner club in the U.S.:

> *When we did the time-zone different session - students started to understand how the world is, and how it works. Someone the same age as you, the same grade, is going to bed on the previous day. That was mind blowing for them. For them to work with children in the U.S. - they realize we are all so similar. Same music, same types of food (fast food - KFC, McDonalds)… They had a lot of fun with the partnership exchange as part of the sessions because we had to chat about the club and answer the questions. They were very interested in knowing what type of houses, it is busy in the city? Their ideas are all from the movies… before we had the exchanges they didn't know that the students are the same in America.*

A U.S.-based club leader also commented on the preconceptions that her students had about African students before DSG, and how DSG challenged those assumptions.

> *When they saw pictures of the clubs in South Africa, and saw that they wear shoes and are fully clothed, they were really surprised. Their experience with Africa has been in history and media, of African tribes, not people in a modern society. They realized that their preconceptions were off, and this fostered an interest in issues that other people are experiencing. They thought the students in Africa would have much more third world problems.*

Another U.S.-based Club Leader also saw learning in this area, going beyond dispelling stereotypes into really understanding some of the differences and similarities.

> *Through DSG they learned to start from a place of commonality. What makes you similar to someone else? The differences are very slight. When we went over our partner exchanges, one kid was confused about South African nicknames. I said, our nicknames don't sound that clear either! The students got that. One of the students explained his nickname, and they start thinking it through. Even though someone lives across the globe, they have the same things in common. Go to the library, have pets, really into sports, like soccer. Just slight differences that we think are huge, but it's small stuff. [Through DSG] they understood that they are just students like us.*

## S5. Students demonstrate an ability and inclination to take different perspectives, others as well as their own.

The ability and inclination to take different perspectives is a challenging construct to measure. For this outcome, the goal was to identify whether students were not just interested in learning more about their partner club, but if DSG made any difference in students' understanding of the students in the partner club – through more specific ideas about what their lives were like, or through reduced stereotyping. To do this, the student questionnaire posed some open-ended questions, including one that required a text response (how do you think students are different in the United States and Southern Africa? List three ways) and one that had a drawing or text response option ("What do you think students in your partner club and their homes look like? Draw and/or write about them. You can write in any language).

In matched pre-post surveys, the responses were analyzed side by side to look for change over time. Using this rich source of data, we looked at how students' perceptions of the partner club changed over the course of DSG. We also looked how students worked in teams at their own club and how they responded to having their designs reviewed by their partner club.

### *Changes in Participants' Perspectives on the Partner Club*

On the pre-post survey analysis, the results demonstrate that after participating in DSG a significant number of students changed their perspectives of the differences between themselves and the students in their partner club. Overall 61% of students held perspectives of differences that had evolved by the end of the program, with this shift statistically significant at the 99% confidence level. Most commonly, students communicated more specific[11] differences at the end of the program or commented on new types of differences. For example, one US student initially thought that students in Southern Africa were less privileged and at the end of the program noted that most children in Southern Africa have technology, like phones. In another example, a student in Southern Africa initially commented on differences in economic levels, language, and attitude, and at the end of the program commented on pets and houses—topics that may have been influenced by interactions with the partner group—in addition to economic levels. In a final example, one US student initially noted differences in food availability, quality of education, and possessions while at the end of the program the same student observed how similar students from the two regions were, concluding that "they are not different from us" and "they are kids to[o]."

In addition, the team also looked for more realistic (less idealized/stereotyped) descriptions of the students and their homes in the partner club between the beginning and end of the program. The analysis shows that after participating in the program slightly more students (12% of students) held more realistic views of what the students in their partner club and their homes looked like, with differences statistically significant at a 99% confidence level. Box 1

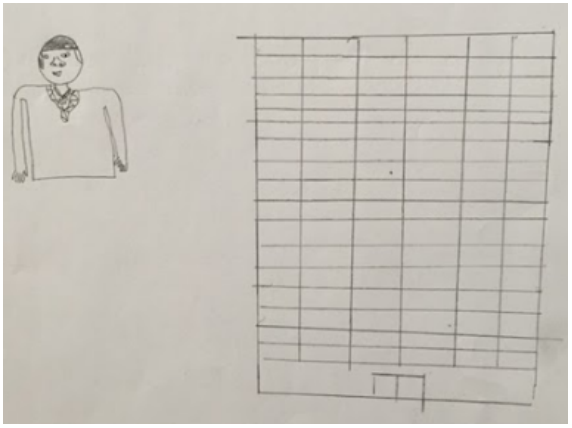
[11] The team looked for responses that became more specific from pre to post, with the hypothesis that the more they know about something, the more specific they would be when asked to write or draw about it.

presents an example from a student from Southern Africa whose drawings were considered more realistic at the end of the program (there is a change from what seems to be a high-rise building to a more regular-sized house).

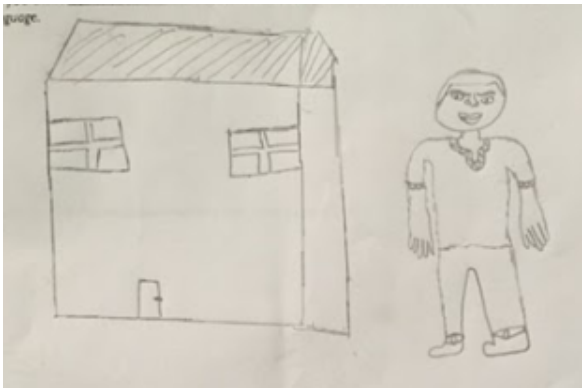
**Box 1. Examples of student drawings that demonstrated more realistic perceptions of what students in the other region and their homes look like at the close of the program**

**Drawings by a student from Southern Africa of Perspectives on U.S. Students**

Student drawing at the beginning of DSG



Student drawing at the end of DSG



### *Growth in Teamwork*

Focus Group discussions, partner exchange documents and interviews with Club Leaders revealed significant growth in teamwork skills among the participants over the course of the program, both those who participated in partnership exchanges and those who did not due to challenges described elsewhere in this document. With both groups, there was clearly a great deal of improvement in the area of teamwork (working with their partner club, as well as with members of their own club), which is also a critical aspect of global competency and contributes to learning to take different perspectives. A focus group discussion from Botswana went as follows:

> *Student 1. Working as a group was a bit challenging. When we shared ideas…. we came up with different solutions that made it a challenge to come up with one solution.*
>
> *Student 2: The challenge is we don't have the same interests. What might be more important or interesting to the other might not be important to me. I've learned that in group work it's a lot about sacrifices. You just need to sacrifice that is good for all of us- not just interesting for me.*

*Student 3: When we were in our groups we had to cooperate and work as a team and respect each other's' ideas toward anything they were doing. That made it easier to work as a team.*

*Student 4: When we were in teams/groups, I realized I have listening skills, I can communicate well, I can put my ideas on the table, then we can work as a team whether or not we agree with each other. We can work together to build those products. It was good to use teamwork…*

*Student 3: When you are in a group you should participate–take part… It was hard for those who are not used to staying in groups–taking them to another level to do teamwork. Taught us something about teamwork.*

*Student 1: As we brainstormed to come up with different ideas, it made it easier to have someone to help come up with a design. I didn't know how to design. I had an idea–maybe my partner would have an idea how to design it.*

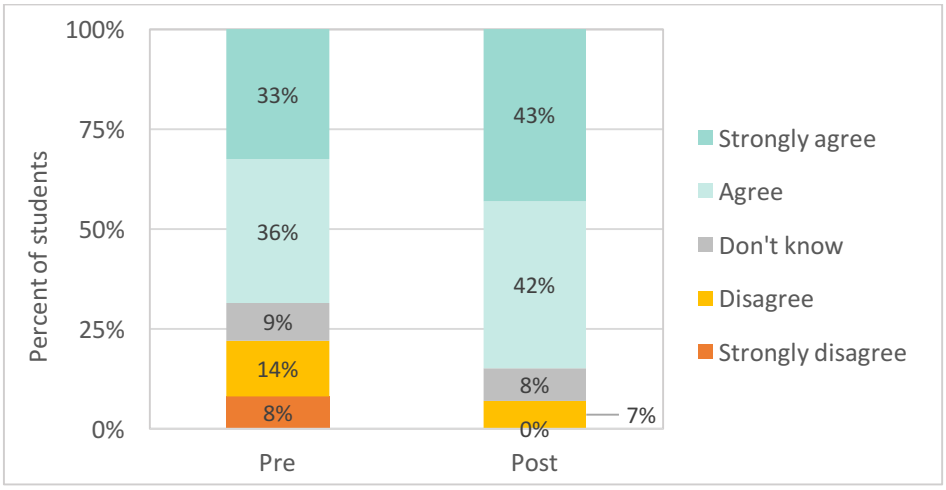
Across the board, Club Leaders were surprised and pleased by the authentic teamwork skills that the students developed through the course of DSG. In one of the clubs in South Africa, there was a diverse group of students, including some students from rural Lesotho who were very shy at the beginning of the club. The Club Leader reported, "Through DSG, self-confidence and presentation skills improved among the students who came from Lesotho, from the village. At the beginning, the ones who are from Soweto felt that they knew better. They had to learn to respect each other's opinion and ideas." Another Club Leader reflected on the increased comfort level students experienced working in teams, "The most impressive change was the growth in teamwork. During the partner project, they kept building and rebuilding. They were willing to say anything. Someone would say something vague, unrealistic, silly, and the best ideas would come off of that."

## S6. Students demonstrate confidence that they can solve problems and create change.

For this outcome, we looked for evidence from the student survey that students had gained confidence in their abilities to design, create or invent things, and that they could solve problems in their community. We also looked at the other sources of data (focus groups and club leader interviews) to triangulate these findings. There were clear gains in this area, as described below.

After participating in the program, there was a significant improvement in how students felt about their design skills, with results statistically significant at a 99% confidence level. After completing DSG, 85% of students agreed or strongly agreed that they were good at designing things, compared to only 69% at the start of the program.

**Figure 13. Student responses to the statement: I am good at designing things (n=86, p<0.01)**




After participating in the program, more students felt that they were good at creating or inventing things, with this improvement statistically significant at the 99% confidence level. Before DSG, only 66% of students agreed or strongly agreed that they were good at creating or inventing things. By the end of the program, 87% felt this way.

Additionally, after participating in the program, there was a significant improvement in students' sense that they could solve problems in their community, with this change statistically significant at the 99% confidence level. At the beginning of the program, 66% of students agreed or strongly agreed that they could solve problems in their community, whereas at the end 82% felt that way.

**Figure 14. Student responses to the statement: I am good at creating or inventing things (n=83, p<0.01)**

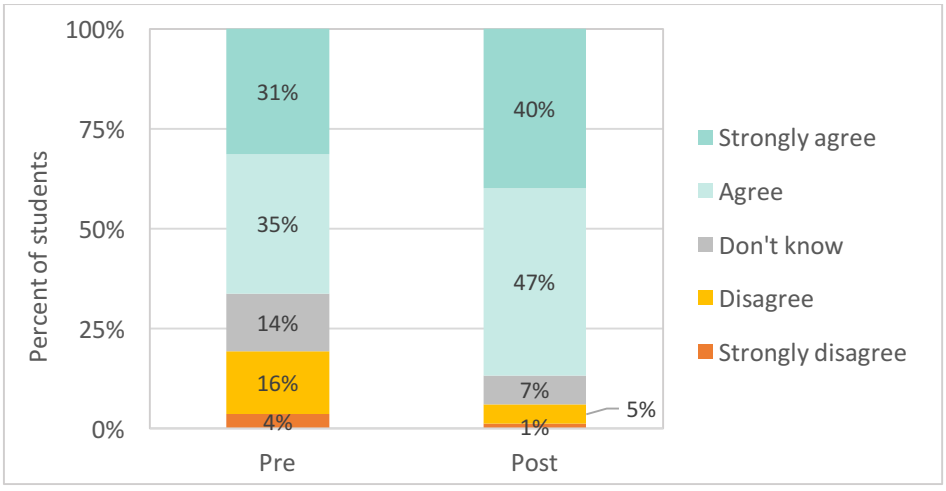
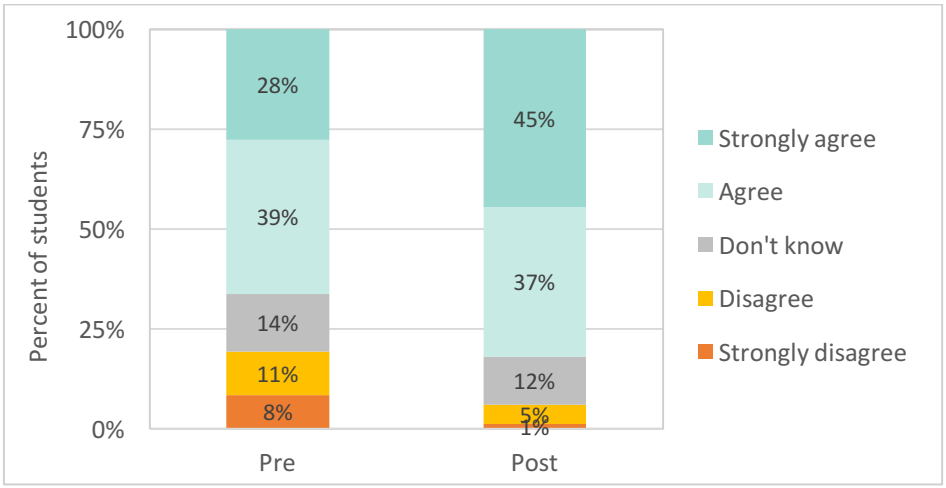


**Figure 15. Student responses to the statement: I can solve problems in my community (n=83, p<0.01)**




Other sources of data triangulated this evidence supporting increases in confidence. In focus group discussions, students talked about how much more confident they felt in designing, building and sharing ideas, demonstrated in this excerpt from Southern Africa.

> *Student 1: When I started DSG and when I first presented my ideas, I felt so bad, I felt stupid in front of the people. Now, I am happy when I present ideas.*
>
> *Student 2: First when we were presenting I was shy, then when DSG was going on I felt there was nothing to be shy about… they were our peers, I was used to them.*
>
> *Student 3: When I started DS, I was very very very very very shy. Then next day, next week, I became alright and saw that these are my friends or family.*
>
> *Student 4: In Design Squad, firstly to present, I was very shy, and I was scared in front of people. But now I am very confident and talkative.*

Many of the participants had an opportunity to present designs to an audience – either within a club, or to the partner club (via video). Interview data revealed that the "review" and "present" part of the partnership exchange was well-received by students, and Club Leaders linked this component to increased confidence. A U.S.-based Club Leader described how his participants loved using iPads to develop presentations to share with the partner club:

> *The students use their iPads for presentations – they present to the iPad, then they watch it back and decide whether or not it was a good presentation, finalize it, and show it to the club. We would test them, and then go back and sit and watch each person's. They were excited to be in front of a camera and sharing with the partner club.*

A Southern African Club Leader noted that presentation and peer review skills that were gained during the partner exchange with the partner club were a highlight of the DSG experience:

> *When they got to design the partner project, with the previous sessions the whole teamwork thing had been coming through, but they had to present to their partner club. I loved how they communicated to each other, for the peer review too. They really respected each other; there was no harsh feedback. The teams really appreciated it… Watching them give their presentations and hearing them give feedback to each other was amazing. Everyone gave really good feedback. Public speaking has been improved a lot.*

Club Leaders also reflected on their students' improved confidence to solve problems and create change in their own homes, their schools, their community, and in the world. In one case, a Club Leader described how a DSG participant had noticed how his baby brother was always taking his phone and playing with it. He decided to build his brother a toy phone to solve the problem, which he did using local materials. This example demonstrates how this DSG participant felt confident to use engineering skills to solve problems and create change in his own home and community.

# V. Results: Understanding Educator Outcomes

Results for educator outcomes are presented below, drawing largely from the Club Leader post-survey:

| |
|---|
| **E1. Educators will demonstrate comfort leading engineering activities.** |
| **E2. Educators will demonstrate comfort with collaborating with educators from other cultures/countries.** |
| **E3. Educators will demonstrate understanding of global competence.** |

A post-test only survey, with a series of qualitative questions, was designed to assess how Club Leaders had grown during their experience leading DSG. A total of 15 Club Leaders and Co-Club Leaders responded to the survey, representing 11 of the 14 clubs that completed DSG in the second round of implementation (some clubs had respondents from more than one leader).

## E1. Educators will demonstrate comfort leading engineering activities.

Through the Club Leader post-survey and interviews, all 15 educators from across the U.S. and Southern Africa reported that, after DSG, they had increased comfort facilitating engineering activities with students. The descriptions of their growth included increased comfort facilitating teamwork while working on the engineering activities, coming to accept that failure is a normal part of the engineering process and teaching this to students, and connecting engineering to students' daily lives and being able to identify what is an engineering solution, and what is not.

Regarding level of increased comfort in abilities to facilitate the engineering activities, a Southern African Club Leader wrote, "Participating in DSG affected my level of comfort in leading engineering activities because it allowed me to use the design process but also be a part of the implementation with the young people who participated. The curriculum really prepared me also." A U.S. Club Leader had a very similar statement: "Participating in DSG helped to increase my comfort in leading engineering activities. Because the curriculum was very thorough, I was able to familiarize myself with the concepts and better explain the activities to our group." Another Club Leader stated, "DSG definitely increased my confidence. I know WAY more about what makes a sturdy structure than I ever thought I would know."

With respect to internalizing the idea that, within engineering, failure is acceptable, and help participants understand that, a U.S.-based Club Leader wrote, "DSG helped me understand and promote the idea of failure as a form of success. By pushing the DSG model students were able to confront design errors in engineering and were able to make corrections without becoming frustrated." Similarly, a Southern African Club Leader stated, "The most valuable lesson that I learnt is that failing is part of the process and that it's ok if things don't work out too well, and I think that is vital when dealing with engineering activities."

In the area of teamwork, a South African Club Leader stated in an interview, "As they are working with the groups, it was kind of hard to get them to work in the group. As time progressed they learned actually to ask. They would try to turn that to me and I wouldn't entertain it and tell them to tell it to their team. That's how I got them to work in their teams, by asking them to share their ideas with their team."

Most frequently, Club Leaders talked about how they learned to help students connect engineering to their daily lives – to their homes, communities and to the world, and be able to identify what engineering solutions look like. Educators used various techniques to do this, from connecting every activity to the "real world", to showing videos, to community interviews, to taking them around the community and helping them identify what was designed and built by engineers. One Club Leader wrote, "I made them imagine if we had no engineers, where would we be? That was very effective for my group." A number of returning Club Leaders also reported increased success with helping their students identify a problem that could have an engineering solution, such as the one Club Leader mentioned above that steered students towards a "bully button" as an engineering solution to the social problem of bullying in schools.

## E2. Educators will demonstrate comfort with collaborating with educators from other cultures/countries.

The educator-level results in this impact area were more mixed than in the area of comfort leading engineering activities. Just over half of the respondents (eight of the 14) reported increased comfort in this area as a result of participating in DSG. One Club Leader wrote, "Participating in DSG helped a bit in increasing my comfort level in terms of working with educators from other countries. This is not something I had much experience with previously, so being tasked with it was something new." Another wrote, "DSG allowed me to share my passion in working with young people and introducing them to new opportunities through STEM education and global competencies. It was a pleasure to share the experiences with like-minded youth leaders."

Those who reported increased comfort in this area also reflected that the process was not completely smooth. However, the challenges – which included communication across time zones, and differential web access – were learning experiences that provided Club Leaders with skills for future collaborations. One Club leader wrote, "It has to be an intentional relationship, that takes time and effort." Another commented,

> *I learned that cross-cultural collaboration can be difficult to achieve, but is a great goal to work towards. There are very logistical challenges that need to be figured out, including difference in time and best method of communication. The organization we were partnered with did not have the best Internet access which made communication via e-mail a challenge. We would have liked to have an initial phone call with them as well, but that would have been challenging due to the time difference.*

Of the remaining six Club Leaders – those who did not report growth in this area – four felt that they already had a pretty high comfort level in this area before starting the DSG program, so DSG did not improve their comfort level, with responses such as "I was pretty comfortable with this already." However, the other two noted that they did not have successful partnership exchanges, and therefore they had not been able to successfully grow in this area. One Club Leader wrote "I still believe I could work on this."

## E3. Educators will demonstrate understanding of global competence.

The global partnership experience was a new experience for 10 of the 14 Club Leaders, and for those that successfully made contact with their partner club (12 of 14 had varying levels of exchanges), they enjoyed and appreciated connecting with a partner Club Leader and partner club in another country. Through the training, educators learned about global competency, meaning the ability to communicate and collaborate with people from different backgrounds, cultures, and perspectives, and then demonstrated how they could help kids develop global competency skills. Educators described a number of techniques that they used to generate excitement and facilitate the development of global competency with their students through the exchange. The clubs started off with a map activity that, according to many Club Leaders, turned into an in-depth discussion on the partner club and their location. A U.S. based Club Leader wrote, "We actually took time researching the country, first its location, then the province, then the country. The students liked to find out about its history and it encouraged research." In Botswana, a Club Leader took a similar approach: "We showed them a slide show about the other city and things that are different and the same about their partner club. We also showed them a map of the world and had them guess where the partner club was and how long it takes to get there."

Club Leaders also talked about how much they had learned about the importance of making global connections, and how to develop global competencies in students through their own teaching and facilitation. A U.S.-based educator wrote, "I learned that in order to be a resource for your community or employer, global competencies are important to develop within young children, because this is the time where they want to learn about the world but also want to feel empowered to make a difference and be part of that process." Another Club Leader wrote, "I encouraged our students to develop an interest in people and places around the globe through shared connections. When our students first started, especially the new students, there were some who didn't understand the point of sharing things that are second nature to them, like their nicknames, the sports they play, etc. By the end, they realized what makes them a kid, is probably the same thing that makes people in any other country a kid too."

# VI. Results: Understanding Processes

***Research Question:*** What are the challenges, infrastructure, and support needed to inspire and prepare a cohort of young, globally competent engineers in afterschool programs, both in the U.S. and internationally?

This section is divided into a number of key topics around which there are clear opportunities and challenges related to how DSG can be successfully implemented. These include Training of Club Leaders; Setting up a Club; the Club Guide and other Resources, Partnerships, Action Research, and Club Facilitation.

## Training for Club Leaders

In the second round of implementation, the DSG Club Leader training was formatted as a series of five self-paced online modules that gave Club Leaders the flexibility to access the training anywhere, at any time, and to complete the modules at their own pace. In view of the recommendation to provide a four week "ramp-up" period for Club Leaders, the first four modules were made available over the course of four weeks (one module per week) prior to the start of the first DSG club session. Each of these first four modules were assigned consecutive completion dates over this period, giving Club Leaders the flexibility to complete each module during the course of the week, but also providing Club Leaders with the structure and accountability necessary for completing the training within the four-week period. The fifth module was created as a just-in-time resource to be used throughout the duration of a particular model of DSG. The first four modules were universal to all DSG Club Models and consisted of text, short videos, quizzes, and assignments. The fifth module was model-specific, providing Club Leaders with short video overviews of each session, intended to be used as a refresher and quick reminder of the main activities within a particular session.

### *What worked*

Overall, based on the post-training survey that was administered to gather feedback on quality and effectiveness (completed by 10 of the 14 Club Leaders), the training was well received. Most Club Leaders felt that they understood the content well after doing the training; they thought it was very thorough. As one Club Leader wrote, "I could do it at any time and wherever I wanted. It was easy to follow and had more than enough information." Club Leaders particularly liked having the opportunity to watch videos of other Club Leaders, and they liked the quizzes and assignments that allowed them to take a hands-on approach. One Club Leader wrote, "I liked the visual and audio aspects to it- it made the training engaging and easy to follow. The quizzes were helpful too as a knowledge check. Overall, I think the information was valuable and well-presented."

*Recommendation: Maintain the flexible, do-at-your-own-pace training format. Maintain the multimedia and interactive aspects.*

### *What needs work*

There were some recommendations for the training that can be considered for the next round of DSG implementation.

**Length:** The survey revealed that some Club Leaders felt that the training was long, and perhaps overly detailed for those who are experienced STEM educators. On average, it took Club Leaders 3-4 hours to complete the training, and there was a general preference for something less time intensive that could more easily fit into the Club Leaders' busy schedule.

*Recommendation: Streamline the training modules to reduce the length to approximately 1.5 hours.*

**Hands-on Examples/Videos:** As mentioned earlier, most Club Leaders appreciated the videos of other Club Leaders, and wanted more opportunities to see how Club Leaders actually ran their clubs and solved challenges along the way. One Club Leader recommended that the training "include short videos on some of the sessions which show the 'feel' of a session and key ideas that leaders should know." Another Club Leader wrote, "I would like to hear more from past educators about how they ran their clubs. I really appreciated the intro video which was able to tap into people's past experiences. Having information from both people in the same situation as me AND the DSG staff would make it more comprehensive." Related to this, another Club Leader requested advice that the training provide "input on what to do if you are having consistent issues contacting your partner," which could be conveyed in the form of Club Leaders' real experience with that issue.

*Recommendation: Show more hands-on examples of Club Leaders leading clubs, possibly with footage of a real Club Leader leading an activity with students. Include footage from both the Southern Africa and the U.S. side. Include interviews with Club Leaders to hear more from past educators about how they ran their clubs, dealt with challenges, etc.*

**Technology:** There are a few recommendations related to technology as well. The two different platforms (the website with the Club resources and the website with the training) were confusing for some Club Leaders, and a reliable internet connection continued to be challenging for some clubs in Southern Africa. As one Club Leader wrote, "There were some challenges with logins for me- logging into the DSH portal AND the Google one sometimes didn't work out." Another described the two platforms as "a bit overwhelming." A third wrote, "Navigating the platform was simple and self-explanatory. The Internet connection in Botswana is problematic and mostly unreliable. Therefore, streaming the videos was time consuming," while another said, "Couldn't do most of the things offline. Internet problems gave some complications."

*Recommendations: Use one platform, not multiple. Include fewer/shorter videos that focus more on the experience of Club Leaders leading clubs (as described above), requiring as little bandwidth as possible. Provide basic internet access guidance, noting that a fairly reliable connection is a foundational requirement for the club.*

**Support during Implementation:** After the second round of DSG implementation was complete, the team conducted post-program interviews with Club Leaders to find out more about their experiences, including whether they felt that it was possible to run the club fairly independently after completing the training, without a lot of extra support. It was clear that some Club Leaders felt fairly comfortable with this, and others were less so, particularly those who were less experienced at leading this kind of program, and for first-time DSG Club Leaders in general. Most of the experienced Club Leaders felt that they did not need much support past the first round of implementation.

*Recommendation: Club Leaders requested that, going forward, there be at least one person available to answer questions as needed (remotely), particularly for first-time Club Leaders. A page on the DSG site with Frequently Asked Questions, and possibly a troubleshooting guide, would also be very useful.*

## Setting up a Club

In the Club Guide, recommendations are made about how to set up a DSG club, including how to recruit students, facility requirements (including internet accessibility), how much time is necessary to complete DSG sessions, required materials, and how to share leadership responsibilities. In the second round of implementation, a number of lessons were learned about how these guidelines worked in practice, including some new and innovative ideas from some Club Leaders that can be shared and possibly taken up by future Club Leaders.

### *What worked*

**Age Range of Participants:** DSG formally recommended that the ideal age group for participants is 8-12 years old. An interesting geographic finding was that, in the second round of implementation, there appeared to be a slight preference in Southern Africa for older students, versus a slight preference in the U.S. for younger students. In one of the clubs in Southern Africa, in the first round of DSG, they had included older students (14 year olds) and in the second round of implementation younger students (students aged 10-12). They found that, comparing the two, the older students got more out of the DSG experience. According to the Club Leader,

> *The students were older last time so they had better English – they were 14 year olds. In Botswana, they start being taught in English at age 10. This time we have some 10 year olds in the group, and they are the ones that struggle with English, and DSG is hard for them. For the older students, they're starting to do subjects in school that relate, and they can think about DSG in terms of how it fits with their education. Last time, they were able to see how DSG relates to a career in engineering. The younger students have not made that connection yet.*

This was not the only Club Leader to make this observation: several of those from Southern Africa recommended that the best age group was a bit older than the official recommendation; including a DSG club made up of older teens (ages 17-19) that had a great experience with DSG in Botswana.

Most clubs in the U.S. had participants in the 10-12 age range, and found this to be appropriate. However, one U.S. Club Leader reported that: "The program is best for the youngest students in my club – the third graders (8-9 years old). We are getting them to think critically and problem-solve on their own." This club had unusually young participants.

*Recommendation: Provide guidance that 10-14 is the preferred age range for DSG participants, with some level of flexibility depending on additional contextual factors.*

**Time Allocations:** The Club Guide recommends that DSG sessions should take one hour. In the second round of implementation, most of the clubs felt that 1-1.5 hours was the right amount of time for each session. In general, clubs in Southern Africa tended to need a bit longer than the U.S. clubs, and cited language barriers as one reason why the clubs took slightly more time than allocated, but these clubs also tended to have more flexible schedules and were able to add an additional 30 minutes or so to their timetable. Meanwhile, clubs in the U.S. were limited to one hour, based on institutional constraints. U.S. Club Leaders mostly felt that this was enough time, although several mentioned they would have been happy to have some extra time to allow the students to build.

*Recommendation: Keep the allocated time for each session at 1-1.5 hours.*

**Participation of Former DSG Club Members**: In one of the DSG clubs that participated in both rounds, the Club Leader found success in bringing back former DSG club participants to mentor current participants and even help lead some of the sessions. According to this Club Leader,

> *The students that came from DSG Round One facilitated some sessions, since they wanted to be part of Design Squad again. Four of them ran two of the sessions. At the beginning they did a recap, showing the way to the other students. They were like mentors for the current participants and they attended every session. This is really important for building leadership skills in our students.*

Based on this club's experience, it appears that there is potential for developing leadership skills in former DSG participants by bringing them back to support current clubs.

*Recommendation: Provide guidance on how DSG clubs can consider bringing back former participants to serve as mentors and assist with leading sessions.*

**DSG Notebooks:** DSG provided design notebooks to the participants during both rounds of implementation. One Club Leader mentioned that they used these to take a journaling approach to designing their engineering solutions.

> *When we got the notebooks, it made them feel like part of a club. They did a scrapbook approach, like a scientific journal, for their designs. At any point, the students could go work on their journal. Our whole center is going to adopt this idea for our STEM programming in general, because it was so successful on DSG.*

*Recommendation: Provide guidance to Club Leaders that providing notebooks to the students for design journaling can be an effective implementation strategy.*

**Co-Leadership:** During the first round of implementation, it was learned that having more than one Club Leader can be a successful strategy to share responsibility and take the full burden off of one person. During the second round of implementation, many of the clubs had more than one leader, and all reported this to be a good strategy. One Club Leader noted that within this shared arrangement, it was very helpful to them to have clear roles and responsibilities:

> *Management-wise, we have clear roles, and this helps a lot. I do everything related to club management, and my co-lead, who speaks the local language, makes the phone calls and works directly with parents and families. During the sessions, we share the work. Last time we did not have clearly defined roles and it got a bit confusing. This time was much better.*

*Recommendation: Provide guidance that co-leadership can be a good strategy, particularly with clearly defined roles and responsibilities between co-leaders.*

### *What needs work*

Within the category of "Setting up a Club," the only real challenge during the second round of implementation was, as was true in Round 1, consistent internet access in some of the Southern African sites. According to a Club Leader from Swaziland,

> *Our biggest problem was Internet access. We had to go to some people in our village, who allowed us sometimes to use the internet, but there was no access at the school where we had our club sessions. It would have been very difficult to do DSG at all without our facilitator's help. I think we need to have the internet for this to work. You can get everything on the Internet. It's too expensive to do it all by phone.*

Another pair of clubs were having a great deal of success with their partnership between South Africa and the U.S., having completed most of their exchanges, when the South African Club Leader lost her internet connection for a period of several weeks and the two clubs were unable to do any of the final exchanges. This was greatly disappointing for everyone involved.

*Recommendation: To the extent possible, make consistent and strong internet access a core requirement of DSG.*

## The Club Guide & DSG Resources

The DSG Club Guide is the guiding document for DSG Club Leaders, and contains many of the elements needed to run a DSG club successfully. After the first round of implementation, a number of recommendations were made to revise the Club Guide. Other resources were also available on the DSG website for Club Leaders to access as needed.

### *What worked*

**Club Guide:** During post-program interviews with Club Leaders, they were all very positive about the Club Guide. One Club Leader said, "It was super straightforward. Whoever put it together did a great job. The students liked it too." Another Club Leader said,

> *The Club Guide was great. It was our map that we used for everything. It outlines the program, all the elements, the action research, all the activities. There is nothing to improve. The Club Guide is strong enough AND simple enough for anyone to pick it up and run with it.*

One Club Leader who joined DSG late and never did the training felt that the Club Guide was strong enough to be used even without having participated in the training:

> *The Club Guide was very very useful, because I didn't get a chance to do the Google classroom training. It was spot on because I knew exactly what was needed for each session and the outcomes I should expect of the students, so it helped me very much.*

**Preparation Time:** Club Leaders, through the weekly surveys, reported it took an average of about 30 minutes to prepare for a session, with some variation depending on the specific session. Club Leaders generally reported that the amount of preparation time for each session was reasonable.

*Recommendation: Keep the current content and layout of the Club Guide.*

**Filler Activities:** During this round, based on the Round 1 experience that it is easy for partner clubs to get off-synch when delays arise such as holidays, a number of clubs ended up doing "filler activities" to create an extra session or two while waiting for their partner club to catch up. These were other DSG activities that weren't included in the Club Guide. They use the design process, similar to the other Club Guide activities, allowing the students to have more experience designing and building. Through the weekly surveys, it was clear that this approach was viewed by Club Leaders as an effective way of keeping students engaged while maintaining a focus on the partnership synchronicity. Club Leaders also mentioned that these filler activities can help reinforce the design process, especially for clubs that are going on to do a partner project.

*Recommendation: Develop a set of filler activities available for Club Leaders whenever they need them and provide guidance for how these filler activities can be used to re-synchronize partner clubs.*

### *What needs work*

**Coverage of Global Competency:** Most Club Leaders felt that the amount of information on "global competency" was enough to sufficiently prepare them to lead the club. One Club Leader, however, did feel that more could be useful. This Club Leader wrote in the post-program survey, "For us, we did not have a ton of information on global competency to share

with our students from the beginning, so I think this inhibited our ability to teach them about it." However, none of the other Club Leaders mentioned this as a concern.

*Recommendation: Ensure that, in the next iteration of the DSG Club Guide, training materials, and accompanying resources, that global competency is well-addressed, and that interested Club Leaders have resources available to them if they wish to learn more on their own.*

**Building Materials:** According to weekly surveys and post-program interviews with Club Leaders, Southern African clubs, particularly in Botswana and Swaziland still struggled to afford and find the appropriate materials for building activities. For dissemination, this could be a challenge in other parts of the world.

*Recommendation: In the Club Guide, make it more explicit that a range of substitutions are fine for preferred materials, possibly including pictures of a range of options that are likely to be available in any given context.*

## Partnerships

The partnership aspect of DSG is one of the features that makes it a unique and exciting opportunity for participants and Club Leaders. However, it is also the most logistically challenging aspect of the club, and not all clubs ended up having a strong partnership experience, although those that did have partnership experiences were extremely positive about them. Lessons learned related to this important and innovative aspect of DSG are presented below.

### *What worked*

**Increased Global Competency of Club Leaders:** Overall, Club Leaders that were able to connect with one another – especially Club Leaders that had synchronous (phone, video chat) connections with the partner Club Leader - had positive experiences and felt that their global competence had grown. One Club Leader wrote in the post-program survey,

> *Participating in DSG made collaboration with educators from other cultures and countries more normative. It's become easier to understand and work around things like time differences, some language barriers, etc.*

Related to this, Club Leaders who participated in both rounds of implementation appeared to have better partnership experiences, possibly because of have more opportunity to develop their own global competency skills. In a post-program interview, a U.S.-based Club Leader that had participated in the DSG pre-pilot, as well as both rounds of implementation, said,

> *This time it was a lot easier as far as the partner exchange. We were communicating quite a bit, sending pictures and so on. For the students, there was an expectation that I would send an exchange, and the partner club would respond and send it back. In our focus group, the students said the students in SA are just like us, the exchange was so*

*tight. We were able to build that relationship through conversations over the phone and through WebEx. Last time I did DSG, the exchange was not as tight.*

*Recommendation: Provide additional opportunities to build the global competencies of DSG Club Leaders, possibly through encouraging synchronous communication with each other. Encouraging institutions and Club Leaders to run DSG clubs numerous times could help them to grow in their ability to develop a partnership and may help ensure smooth partnerships.*

**Reduced Number of Exchanges:** In the second round of implementation, across all four models, the number of exchanges was reduced. Returning Club Leaders were generally happy with this change. One Club Leader reported in an interview, "Last year we had quite a longer model with a lot more exchanges and that made it more difficult. We had an exchange every session, and that was quite hectic." Another stated, "I definitely like this format better, with fewer exchanges. There is less pressure for sure, and more time to put into the activities with the students." Another Club Leader mentioned that she did not mind the weekly exchanges, because it became part of her regular routine and she never had to wonder whether or not an exchange was supposed to happen that week, but she also concluded that fewer partnership exchanges was much more realistic for a busy schedule.

*Recommendation: Keep the reduced number of partnership exchanges.*

**Communication Channels:** From the weekly surveys, it was clear that Club Leaders prefer to communicate with their partner Club Leaders via email; there were very few exceptions. It was easier to just use email, rather than another platform, because they are used to checking it regularly and did not have to learn something new. Because it is phone-based and "lighter" than email, WhatsApp may be a good backup in cases where internet is unreliable. However, most U.S.-based Club Leaders did not have experience with WhatsApp (it was very common among Southern African Club Leaders). A number of clubs have used Dropbox for partner exchanges, as well, because of the size of the files, especially videos.

*Recommendation: Recommend that Club Leaders use email as the primary means of communication with partner Club Leaders. Provide guidance on additional/backup means of communication and sharing, such as WhatsApp and Dropbox, or services that provide similar features.*

**Synchronous Exchanges between Students:** Although there were only a few examples, Club Leaders that were able to organize synchronous communication between Clubs (real time phone or video chat) had a strong appreciation for how valuable the experience was for their students. According to one Club Leader in the post-program survey,

*The Skype Call in the partner exchange worked magic. All we did was set it up and let them be free to break the ice. They felt that they made friends in USA and couldn't*

*stop talking about it. This increased their level of thinking, boosted their self-confidence and now the students know that in USA and other countries the students are all the same. All they need is a chance to be free and use their imagination.*

*Recommendation: Encourage Club Leaders to find ways to set up synchronous exchanges between partner clubs, despite logistical difficulties such as different time zones.*

### *What needs work*

**Logistical barriers.** During both the first and second round of implementation, logistical barriers posed challenges to Club Leaders that inhibited their ability to communicate with their partner club. These challenges included time differences, scheduling challenges (including overly busy Club Leaders), and uneven access to the Internet.

One Club leader said, "The experience this time reminded me how difficult it can be talk across time differences and schedules." Another Club Leader had a partner that lost their internet access for the last several weeks and their collaboration "just stopped." Nevertheless, the same Club Leader said that "even with this obstacle, the students really enjoyed seeing another culture." A U.S.-based Club Leader who never heard back from his partner said in an interview,

*Communication was a huge challenge. We see emails, and we want to respond, but then we forget. Maybe there's some barriers with Wi-Fi not working, and we are figuring out time zones, and we want to know: what's the best approach? Each week I sent an email to my partner Club Leader, but I never heard back, which is a bummer. Eventually, I stopped talking about it to the students.*

Another Club Leader wrote in a survey response, "The partner exchange for this second round has not been active between us and the partner. Both the partner and us have been unable to coordinate the sessions and keep with the timeline. Cross-culturally, time and coordination is a challenge for all."

Despite challenges, most Club Leaders were still positive about the opportunity to try to connect with another club. One Club Leader wrote,

*I wish we could have had more success in partnering with our partner program. I imagine that is the biggest hurdle in a program like this. I hope to run the program again next year, and would love another chance to connect with another program, allowing our little engineers with a chance to share.*

*Recommendation: Recommend/require an initial in-person call connecting partner clubs, where logistics around communication can be negotiated and tested. Develop ways for Club Leaders to have an initial powerful partnership experience - it is likely to set them up well for being committed to future partnerships, because they will be able to see the value of the exchange. Recommend beginning with a commitment to partner exchanges as part of their commitment to DSG. Encourage institutions/individuals to run DSG clubs multiple times and potentially between the same two partner institutions, so that partnership experience can be deepened over time and the quality of partnerships*

*can grow. In the training, use the lived experiences of real Club Leaders to 1) show that the partnership is REALLY important, 2) advice for successful partnerships, and 3) strategies for how to deal with a non-active partnership situation and disappointed students.*

**In-country partnerships:** In some cases, where logistics are particularly challenging or where clear connections already exist, in-country partnerships may be a viable option. Although these were not tested during either round of DSG implementation, one of the Southern African clubs suggested that, because of the struggle they had with their U.S. based partnership, this might work better. The Club Leader said, "If our partner was located in another school that is in the same city, or in a nearby region, I think the partners would gain almost as much as they would with an international partner." The communication challenges would probably be much less of a concern with this type of set up.

*Recommendation: Explore the possibility of in-country partnerships as an option in the next phase of DSG.*

**Templates for Partner Exchanges:** After the first round of implementation, it became clear that templates for the partner exchanges were needed to make Club Leaders' jobs easier. The templates were very much appreciated by Club Leaders in the second round. Although they made things easier, partner exchanges can still be time consuming. One Club Leader said it took an hour to compile and scan all the Partner Exchanges.

*Recommendation: Consider ways to further streamline the partnership exchange process so that it is as easy as possible for Club Leaders.*

## Leading a Club

While facilitating sessions through both rounds of DSG implementation, DSG's Club Leaders learned important lessons about how to work with students, maximizing learning and growth. A few important lessons emerged in this second round of implementation.

**Language Interpretation:** In Southern Africa, most participants were English language learners and had different levels of proficiency in English. In such cases, Club Leaders found that they sometimes needed to interpret for students, using the local language to help clarify different aspects of the club. This was especially true for clubs that had younger students that had been more recently introduced to English. From a Club Leader in Botswana:

> *Language has been a challenge. We say they are the "shy ones," but they are really the ones who don't speak English as well. I always explain it separately in Setswana. There are a few girls and few boys who are really strong in English, and others who don't understand English at all. Sometimes it's hard to gauge their understanding, because some will say "yes" and others follow suit.*

A Club Leader in South Africa had a similar experience. "The major challenge is having to teach them in English. For most of them it was not their first language, it was their first additional

language. At times it was hard for them to understand. At times I had to explain to them in their home language."

*Recommendation: Provide guidance for Club Leaders that, where relevant, they may have to interpret for the students into a language that they better understand. As DSG disseminates around the world, carefully consider language barriers that will arise, and consider the possibility of translating some of the resources into different languages.*

**Making DSG Enjoyable and Different:** Club Leaders from all countries talked about how important it was for Leaders to lead the club in a way that was as fun and enjoyable as possible. A U.S.-based Club Leader said "my best advice is to have fun, be in the moment, have fun with the students, and take it as it comes."

The Southern African Club Leaders spoke at length about leading the club so it felt different from school. Because schools in Southern Africa tend to be more lecture-based than U.S. schools, and because there are fewer informal after-school programs such as DSG, this is not surprising. One South African Club Leader said in an interview,

> *You shouldn't make it a school set up. Where a child feels like "I'm in school now," they are not comfortable. They should be free and have fun in the sessions, they should not know that they are learning. Have icebreakers, play Simon Says in between the sessions… that keeps them concentrated, and they won't get bored during the sessions.*

Another South African Club Leader said:

> *Allow students to think outside the box. Let them run wild. Don't try to control them. Make sure you remove all their needs – food, transport; make it possible for them to come to DSG easily. They get lost in the program, the students love being active. You want your session to be different from school, make it not a school environment – make it exciting.*

A Club Leader in Botswana reported:

> *Before they start, they talk about how their days were, how their weekend was. We make it informal, not a classroom situation. It brings us closer together. It is great for opening students up… You want it to be fun, not too serious. Also, never show them how to do something. There have been times when I have walked by and they are trying to figure something out. I try to use questions, not statements. I don't say "you can add a pole there," instead I say "what do you think you could add there to support it?" The ideas are always their own, even if they are prompted by you. Also, this makes them think more, and sparks different ideas.*

And finally, South African Club Leader had this advice for other Club Leaders:

> *The ideas and concepts of math and science can be presented in a very fun way early on in DSG, so that they can use those same skills in the final designs. When they start their partner project, they forget the simplicity of these ideas and concepts once they start to define the need. It starts to feel like a mammoth task; they forget that they can*

*use simple tools of math and science and architecture. Those concepts, if they remember then, will allow them to design simpler ideas that are quicker and easier to make. We are teaching students to edit without feeling like a failure. If they remember that the idea of simple is not "weak" or "less" – in fact, less is more.*

*Recommendation: Provide guidance for Club Leaders on how to make clubs as fun and as "different from school" as possible – which may be particularly relevant to non-U.S. based club leaders, depending on the context.*

# VII. Conclusion

The research findings presented in this report include important lessons about the links between engineering and global competency, demonstrating how DSG's innovative approach to combining informal engineering education and global competency education can help students gain skills and confidence in both fields, and how to best design and implement a program of this nature in the U.S. and internationally.

Global competency education is a relatively new field that is growing at a rapid pace. Our research findings demonstrate that DSG's focus on informal engineering education with partnership exchanges between clubs in different countries has led to promising outcomes for students who would otherwise not have the chance to interact and learn about each other. As a result of DSG, students discovered that teamwork and collaboration—both within their own club and with their partner club—can lead to deeper understanding and more effective engineering solutions, which is a critical aspect of global competency. As a result of participating in DSG, through some of the engineering activities and particularly through the project that they co-developed, students in both the U.S. and Southern Africa demonstrated an understanding of how engineering and invention can make a positive difference in their own community, and in their partner's community. Students demonstrated an interest in learning more about their partner club, both about the students and the places where they live. In addition, while participating in the club, students demonstrated an ability to listen to and communicate with the members of their partner club, treating each other with empathy and respect. Moreover, through DSG, students demonstrated an openness to new ideas, ways of thinking, and unfamiliar situations. This was especially evident among the students who participated in a greater number of partner exchanges. Finally, through DSG, students began to think of themselves as actors who can solve problems and create change in their communities.

The research findings also reveal important lessons about the challenges, infrastructure and support needed for an afterschool program to inspire and prepare a cohort of young, globally competent engineers in the U.S. and internationally. Training for Club Leaders needs to be short, easy to watch, self-paced, and efficient at conveying critical topics, including modeling implementation with concrete examples. In addition, Club Leaders need ramp-up time in between the training and program start to troubleshoot technical issues, become familiar with the Club Guide, gather materials, build a relationship with their partner leader, and recruit students. DSG should also encourage open recruitment of students with flexible age ranges, balanced with targeted recruitment of students that may particularly benefit from the program. Interested sites need to ensure that they have at least one dedicated Club Leader (two if possible, with clear division of responsibilities), a space for open-ended building activities once a week for an hour or more, notebooks for design journaling, and a base level of Internet connectivity.

The partnership between clubs, and how to best support communications and collaboration between Club Leaders, was an important area of learning for DSG. Communication was very

challenging, and synchronization and time zone challenges hindered timely communications between partner Club Leaders. This led to some clear recommendations for opportunities for Club Leaders to connect directly, and for giving clubs some options in terms of the number of the partnership exchanges expected. Providing more structured templates for partnership exchanges was also a strong recommendation. Despite the challenges, the idea of the partnership was consistently exciting to both Club Leaders and students, and there is clear motivation to make the partnerships work. The students demanded more exchanges with their partner club, and were especially interested in increased intercultural communication, in addition to the engineering-based exchanges.

In conclusion, based on all of the results presented in this report, it becomes possible to answer the third research question:

***Can the proposed model successfully be implemented in the US and abroad? Can the model effectively help educators and students achieve the desired outcomes?***

Based on the evidence from exchanges between clubs in the United States and Southern Africa, the answer to both questions is likely to be yes. Through the results of action research, it is clear that DSG has demonstrated growth across all impact areas – both student-level and educator-level, although some of the growth in the area of global competence proved challenging to measure. The DSG model has been significantly improved over the course of several iterations – a pre-pilot, and two pilot rounds of implementation – to a point where, with some final modifications, the model can be successfully implemented in the U.S. and in Southern Africa, and likely in other countries as well.

With this formative research study, DSG is contributing to the development of an evidence base around how to adapt engineering resources and the outreach process needed to work collaboratively across distances and cultures. Informal engineering, when paired with an international exchange, can be an effective discipline through which to develop both engineering and global competency skills in children and youth around the world. The evidence demonstrates that DSG's model of collaboration builds participants' understanding of engineering, motivation to participate in engineering, and confidence in taking effective and informed action on behalf of pressing global problems. In addition, findings demonstrate that a sharp focus on the design process is an effective way to increase interest in engineering and develop problem-solving skills in youth. Through the global partnership that pairs clubs in different countries, students gain a deeper understanding of the role of engineering in improving lives around the world, and specifically in the community where their partner club is located, opening their eyes to a broad, exciting world of connections and possibilities. In this way, the research findings directly contributes to a larger body of work about whether and how engaging with global, collaborative engineering problems leads to broadened perspectives and improved confidence in kids with very different backgrounds, experiences, and opportunities.