STEM in a Hair Accessory

Summer and after-school programs can bring engineering design to underserved communities.

By Hui-Hui Wang, Barbara L. Billington, and Ying-Chih Chen

It was a hot summer day. Naomi and her cousin walked into the community center. She said, "Miss Jones, our moms need to work. They told us to come here and stay for couple hours." This is a common occurrence in communities with low socioeconomic status during the summertime; parents need to go to work, but children are on summer break.

Miss Jones is a school science specialist. She volunteers to organize and teach out-of-school programs for fourth- through sixth-grade girls. The population in the neighborhood is culturally diverse; most of the girls who come to the community center are African American or Asian American. Miss Jones knows girls are at a disadvantage in learning STEM (science, technology, engineering, and mathematics) in many ways. Not only do girls perceive working in a STEM field to be an uninteresting and unattractive lifestyle (Miller, Blessing, and Schwartz 2006), but they also have fewer extracurricular STEM experiences than boys, such as doing science at home (Jones, Howe, and Rua 2000). Miss Jones needed a good project idea that would engage the girls in problem-solving and practicing STEM by connecting to their everyday life experience.

In this article, we share how Miss Jones merged engineering design processes with the *Next Generation Standards* to plan and implement an engineering-design, out-of-school program activity for girls.

Planning a Design Activity

Miss Jones noticed that the girls had diverse hair textures and styles and that they braided each other's hair as a game. Inspired by the girls' behaviors, Miss Jones decided to integrate the 5E instructional model with engineering design to develop an activity that relates to a unique feature of the

girls' hair. The activity was designed to take place over five days, requiring about 1.5 hours each day. It was a simple and safe activity. The only risk management was to help the girls safely use scissors and hot glue guns. For example, Miss Jones told the girls that they should not point scissors at others. She also told the girls that if they wanted to clean the tip of a hot glue gun, they should use a piece of paper because the glue gun was very hot. In addition, girls tested their hair accessory design only on themselves.

CAUTION

By its very nature, engineering design can enhance learners' problem-solving skills and help learners apply their knowledge to a real-world context (Brophy et al. 2008). According to the *Next Generation Science Standards (NGSS)*, all K–12 learners are expected to explicitly learn how to practice engineering design to solve problems. Engineering design in *NGSS* includes three components (NGSS Lead States 2013, Appendix I, p.105):

1. Defining and delimiting engineering problems
2. Designing solutions to engineering problems
3. Optimizing the design solution.

In the activity Miss Jones and the girls designed, we can see how these *NGSS* components embedded in engineering design.

Defining and Delimiting an Engineering Problem

Two elements should be included in the defining and delimiting an engineering problem stage. These include asking questions to elicit students' prior knowledge and setting up a scenario to engage students in an engineering design challenge.

Miss Jones started a conversation, "Does anyone know anything about engineers?" One girl said, "They knock down old buildings and re-fix them." Lucy countered, "No, engineers help people do things easier. I learned that at my school." By asking questions, Miss Jones was able to find out students' prior knowledge related to engineering. Next, Miss Jones started to set the stage for the engineering design challenge. Because girls are often interested in taking care of people, and the biological sciences attract more women than men (Hill, Corbett, and St. Rose 2010), she connected the activity with a medical-related scenario, cancer. She said, "Lucy is right, designing things to help people who have needs is what an engineer does. Now, does anyone know anything about cancer?" The girls started to share their knowledge about cancer, saying things like, "People die because of cancer" and "They lose their hair." Miss Jones asked the girls to use the computers at the community center to search more information about cancer. She told the girls, "Find out some things about cancer that are new and interesting to you and write them down. Later, you will share your findings with others."

When the girls came back from their research, Miss Jones asked them to share their findings. One girl said, "It is not cancer that makes people lose their

FIGURE 1.

Hair accessory prototype sheet.

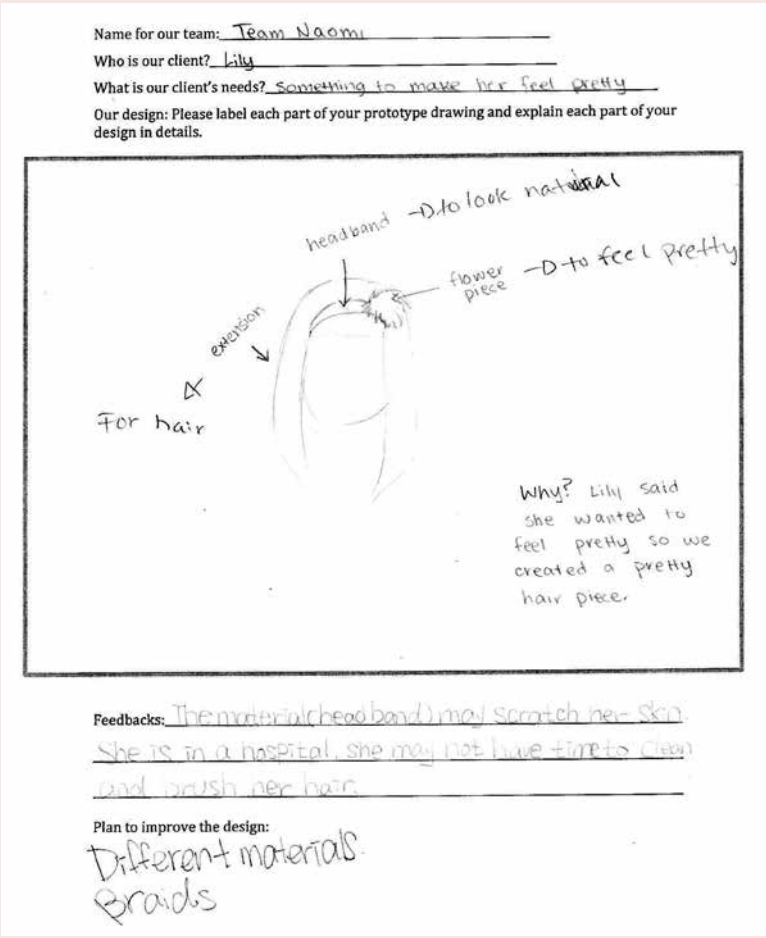

TABLE 1.

Client information.

Name	Age	Gender	Ethnic identity	Type of cancer	Description of the clients' needs
Brie	1	Female	African American	Leukemia	Brie has very short, soft, curly hair. Her mother always has a tough time putting hair clips on her. It is not safe to use hair rubber bands because Brie yanks them out and puts them into her mouth.
Tameca	16	Female	African American	Bone cancer	Tameca used to have slightly curly black hair that reached her earlobes. After chemotherapy, she lost some of her hair on both sides of her head. She loves the colors red, yellow, and purple.
Lily	7	Female	Asian American	Leukemia	Lily is now in a children's hospital. Because of chemotherapy, she shaved her hair completely. She is waiting for her hair to grow back. She does not like how she looks right now. She can use something to make her feel pretty.
Charlotte	38	Female	Asian American	Breast cancer	Charlotte is a breast cancer survivor. She has straight black hair that reaches just above her shoulders. She is a single mom with two children. With her busy schedule, working and taking good care of her children, she can use something to help her get a stylish look in a very short time.

PHOTOGRAPHS COURTESY OF THE AUTHORS

FIGURE 2.

Supplies available for making hair accessories.

Supplies related to design of a hair accessory

- hair clips
- bobby pins
- hair curlers
- hair rubber bands
- hair combs
- cotton elastics
- artificial hair
- hair nets
- decorations such as bow-knots, plastic flowers, sequins, and beads

General supplies

- scissors
- glue and hot glue guns
- double-sided tape
- thread and string
- rulers
- velvet
- thin cardboard or construction paper
- craft sticks

hair, it is the chemotherapy that makes people lose their hair." The girls started wondering why girls their age or even younger can have cancer. Miss Jones used the girls' questions to facilitate a discussion that related to their inquiry about children's cancer. After sharing and discussing, Miss Jones gave the challenge to the girls. She said, "We can do something for them, like an engineer. They lose their hair when they go through chemotherapy. Let's design a hair accessory for patients living with cancer or cancer survivors."

Designing Solutions to Engineering Problems

Designing solutions to engineering problems should be focused on four elements. These elements include identifying a client's need, proposing solutions and selecting the best one to solve the problem, designing a prototype that addresses the client's need, and explaining and sharing the design of the prototype with others (3-5-ETS1-2 Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem).

Miss Jones gave the girls a handout that had information about four clients (Table 1). Two to three girls worked as a team to select a client for whom they wanted to design a hair accessory. Each client had different needs. Miss Jones asked the girls to carefully examine the needs of their clients. Next, she asked the girls to draw a prototype of a hair accessory that addressed their client's needs (Figure 1, p. 55). The girls needed to label all the parts of their design as well as explain the function of each part (ETS1.B: Developing possible solutions). She laid out the materials that the girls could use to design their hair accessories (Figure 2) so they could examine them before they created their prototype. The girls could use only the materials that she provided (ETS1.A: Defining and delimiting engineering problems). At this stage, Miss Jones allowed the girls plenty of time to test the materials that she provided because she knew the girls needed time to decide which materials they wanted to use. For example, the group that had Brie as a client, who had no hair and was a baby, took almost 45 minutes to decide what materials that they wanted to use. Finally, they decided to use cotton elastics as the major part of their design, because their client was too young to use hair clips and rubber bands. When the girls shared their drawings with others, the conversa-

TABLE 2.

A rubric to evaluate students' design.

Category	4	3	2	1
Address a client's needs	Clear evidence addresses all the needs for a client.	Clear evidence addresses some of the needs of a client.	Evidence does not clearly address the needs of a client.	No evidence addresses the needs of a client.
Information gathering for design	Accurate information taken from several resources in a systematic manner.	Accurate information taken from a couple of sources in a systematic manner.	Accurate information taken from a couple of sources but not systematically.	Information taken from only one source and/or information not accurate.
Plan and prototype drawing	Plan is neat with clear measurement and labeling for all components.	Plan is neat with clear measurements and labeling for most components.	Plan provides clear measurements and labeling for most components.	Plan does not show measurement clearly or is otherwise inadequately labeled.
Design of the hair accessory	Appropriate materials were selected and creatively modified in ways that made them even better.	Appropriate materials were selected and there was an attempt at creative modification to make them even better.	Appropriate materials were selected.	Inappropriate materials were selected and contributed to a product that performed poorly.

tions were fruitful. They used their everyday life experiences to design their hair accessory. For example, Leanne said, "I don't think we should use bobby pins, because they cannot hold my hair. Our client has hair very similar to mine." After the girls explained and shared their design with other groups, they used the materials that Miss Jones provided to make their hair accessories.

Optimizing the Design Solution

The concept of optimization in engineering relates to the design process of the functionality or effectiveness of a design. Two elements should play a major role in the optimizing the design solution stages: testing the design and re-design/reflection (3-5-ETS 1-3 Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved).

In this challenge for Miss Jones's girls, the hair accessories were designed for cancer patients who were with or without hair. One constraint was the level of comfort of the clients when they used the hair accessories. In the first prototype of design, no groups actually paid attention to this constraint, the girls all focused on the appearance of their design. For example, most of the groups spent a lot of time discussing which color of ribbons to use for their design. Miss Jones pointed this out by saying, "Think about this: when you are sick and in pain, you probably don't want to wear something that is just pretty but not comfortable, right?" One girl replied, "Yes. That wouldn't feel right." Then, Miss Jones asked the girls to trade their designs with other groups. She asked the girls to imagine they were the clients when they evaluated other groups' designs. In this way, the girls could give critical comments to help other groups improve their design. For example, one group gave feedback to the group that designed a hair accessory for a seven-year-old cancer patient who had her head shaved, by saying, "This is really pretty, but your client does not have any hair. We think the materials that you chose would scratch her skin." After re-designing their hair accessories based on the comments, Miss Jones asked the girls to reflect on their experience by sharing their ideas about what they learned and how they could apply the knowledge in a different situation. In the reflection on their experience of the program, the girls focused on the product design. For example, one group said, "You just have to keep trying until it works. At first we glued [artificial] hair on hair clips. We couldn't do it right. Then, we tried double-sided tape, and that solved the problem!" Another group said, "It is not just about what I think is

pretty. It is about what my client needs." The girls also felt that engineers can have fun and at the same time help people in need.

Conclusion

Because this was an out-of-school program activity with a goal of introducing girls to engineering design, there is not a formal assessment, but we have provided an example rubric (Table 2, p. 58). The program did not take the girls out into the community to try the design on a real cancer patients, but this could be added to the program in the future.

The *NGSS* promotes the integration of engineering into science education by raising engineering design to the same level as scientific inquiry in classroom instruction. This activity acknowledges cultural diversity while creatively capitalizing on an interest of minority girls. As engineering education expands in grades K–12, many teachers need good lesson plans that not only engage their female students in learning engineering but also relate to their everyday life experiences. It is our hope that this activity and the structure that we used with core concepts of engineering design in *NGSS* can spark ideas for teachers in diverse settings to craft their own engineering design activities for girls. ■

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Connecting to the Standards

Standard: 3-5-ETS1 Engineering Design

Performance Expectations:

3-5-ETS1-1 Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.

3-5-ETS1-2 Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

3-5-ETS1-3 Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

Science and Engineering Practices:

Asking Questions and Defining Problems

Planning and Carrying Out Investigations

Constructing Explanations and Designing Solutions

Disciplinary Core Ideas:

ETS1.A Defining and Delimiting Engineering Problems

ETS1.B Developing Possible Solutions

ETS1.C Optimizing the Design Solution

NGSS Table: 3-5-ETS1 Engineering Design *www.nextgenscience.org/3-5ets1-engineering-design*