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DESIGNING INFORMAL VS FORMAL EDUCATION ACTIVITIES—WHAT WE'VE LEARNED

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This paper examines the differences and challenges encountered when trying to create informal blended (virtual and hands-on) engineering design STEM activities. It contrasts the creation of STEM activities for formal and informal learning environments, stressing that the differences extend far beyond the length of the activity or depth of any learning goals. The discussion begins with an examination of differences between the two learning environments that need to be taken into consideration. These differences include the physical environments, organizational structures, and the goals or reasons for the delivery of STEM activities in both environments. The paper continues by explaining why curriculum developers must be mindful of the context that will be implementing the activities, including space and time availability. The facilitators who deliver STEM activities are likely to have very different backgrounds in formal school settings compared to informal settings. Furthermore, it is important to recognize that youth in informal settings often push back when activities seem too "school-like." The paper concludes by presenting a detailed examination of the iterative process used to develop blended engineering design STEM activities in an informal setting. This process involved several revisions and tests of materials with youth in informal settings.

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INTRODUCTION

This paper presents an overview of the authors' experiences developing informal STEM activities. During the past 20 years, the authors have developed dozens of formal education activities for commercial publishers and as part of STEM research projects funded by the National Science Foundation (see References). These educational activities have been well received, and research shows that they effectively support student learning. Five years ago, the authors made a shift and began working in the informal learning space with funding from NSF on a project called Wise Guys & Gals (WGG)—Boys and Girls as *WISEngineering* STEM Learners (DRL 1422436[1]). This shift occurred after we implemented one of our activities in a classroom that had a social worker from a local Boys and Girls Club embedded as a student support. Although our "formal curriculum" was designed to provide math instruction at the middle school level, the social worker adamantly stressed that the activities should be available to all youth at her Boys and Girls Club. Rather than focusing on math goals (which were our original focus), the focus should be on problem-solving and collaboration. However, we knew such a shift required significant editing of our materials. Originally designed to span six weeks when taught in a formal classroom, we recognized design challenges for an informal setting would need to be shorter, and not require an educator to deliver. Further, our use of standardized "tests" to evaluate success was no longer relevant or possible. In fact, our goals shifted from teaching math to engaging youth. At a very macro level, we began to use the term "youth" not "student" to remind us that out of school is a very different context.

The focus of our work in both formal and informal environments has been the use of blended (virtual and hands-on) engineering design challenges to help youth learn about and practice engineering design thinking. In our formal setting, this approach helped youth learn math. In our informal setting, this approach helped youth learn problem-solving. The framework begins as youth use a smart device to access

[1] See http://www.wiseguysandgals.com/

a virtual learning environment where they learn about the design challenge, along with the specifications and constraints that must be met. They gain the knowledge needed to complete a design challenge by working short *knowledge and skill-building activities* while still in the virtual environment. Youth then leave this virtual environment and construct a physical model of their designs. They test it to see how well the solution meets the design specifications. They then return to the virtual environment to reflect as well as upload pictures or videos of their design work.

As part of Wise Guys and Gals, we worked with Boys and Girls Clubs in three states to develop and study the implementation of 15 brief engineering design focused STEM activities. These Boys and Girls Clubs provide afterschool programming for middle school-age youth. However, unlike many afterschool programs, participation is not mandated, and on a weekly basis, youth have great flexibility to opt-in or opt-out of specific activities. This presented unique challenges. Additionally, the club facilitators (we called them Learning Facilitators) often had limited STEM or teaching experience, and at many clubs, staff turnover was frequent. The formal learning activities were typically complex, took several weeks to complete, had an identified learning outcome, and included procedures for assessing student learning to assign a grade. We found that simply shortening activities, as we initially thought, was not adequate. Developing or transforming activities for an informal environment required several iterations of editing. By the end, we developed a framework and understanding that was successful, and the feedback from the club facilitators and youth was very positive. It should be noted that this paper reports on an evaluation of activity design efforts and it is not not a research study.

We learned a great deal through this process, and the philosophical and content shifts required to transition from a formal to informal learning environment. This paper describes our own educational journey and the lessons learned. The findings are specific to the particular sample and therefore may not be generalizable.

THE DESIGN JOURNEY

Differences between Formal and Informal Contexts

Formal learning environments are typically classrooms. Students are required to attend, and teachers are certified content experts for the grade and the materials they are using. In contrast, the facilitator in an informal environment often does not have an education background, and may or may not be a college graduate. Children are not required to attend, but instead can "vote with their feet" if they do not like the experience. Even in settings where attendance is required, youth can usually select from among a variety of activities.

Other environmental differences also had to be considered. The physical layout of schools typically consists of a dedicated learning space, typified by classrooms with chairs and/or tables that allow students to work individually or in teams. Informal learning environments are rarely classrooms, and space may serve several different functions over the course of the day or week. Additionally, informal environments often provide greater flexibility for youth to move about. Whereas movement in classrooms is often a privilege, it is typically the norm in informal environments.

Finally, we found the activities for informal environments needed to be inexpensive to complete and use easily obtained materials available at neighborhood stores, rather than through an educational distributor. Storage of supplies and design models was an additional challenge for most clubs since long-term material storage is often not feasible.

Philosophies and Goals Differ

Regardless of whether design challenges are created for formal or informal learning environments, they must be engaging and interesting. However, the ways youth to demonstrate knowledge was different. An implicit feature of formal learning activities is that student work is used to differentiate among learners. Teachers value materials that can help them assess learning and identify learners who need extra support. In formal environments, questions can be included that students must correctly answer before advancing. In contrast, facilitators of informal learning experiences are typically less interested in assessing understanding or providing remediation. Rather, the goal is to engage the youth, help the youth be successful and to assure the youth satisfactorily complete the activity in the allotted time. While informal learning facilitators want youth to learn, it is not their only objective. Therefore, evidence of knowledge during informal learning ideally needs to occur as part of the experience.

For example, we typically ask learners to identify the specifications and constraints of a design challenge. With a formal education mindset, we typically require the learner to correctly answer a question about specifications and constraints. If the learner is not successful, we provide hints to assist in reaching the correct answer, but a correct response is needed before moving forward. In an informal environment, this approach created an impediment to learner engagements and, ultimately, persistence and completion. Unlike formal environments, the teacher could not insist the youth continue. We quickly learned that an informal activity that presents barriers or, as youth told us, feels too "school-like," often lead to youth walking away.

Relatedly, while we hoped that youth would complete multiple activities, we also recognized this would not always be the case. Youth might not return a second day, which meant activities had to be short (one club period), and it had to be possible to complete each new activity without completing the prior activities. Framing the activity as a design challenge was particularly helpful and important. We used the same basic structure for each activity. In this way, youth and facilitators who completed multiple activities saw connections among them. More importantly, the structure helped us assure consistency across activities. We began each activity with a challenge that had embedded specifications and constraints, and then required testing and evaluating of the final design to see how well it met those specifications.

Informal and Formal Settings Define Success Differently

Being successful was critical to keeping youth engaged. Remembering that a key goal in our informal setting is for everyone to be successful while learning about design, we often provided specific guidance that would lead to success. For example, when introducing slime, the challenge was to make slime that bounces, stretches, and sticks. The youth then tested and evaluated the slime using rubrics associated with each of these specifications. We provided a general recipe that could be varied somewhat, but one that always led to the successful creation of slime. We found both youth and facilitators wanted to successfully construct a hands-on project. The completion of the activity meant the youth was successful. When we tried to include a learning goal as a criterion for success, the clubs pushed back and stressed engagement was a top priority. They noted that without engagement, youth did not feel positive about the completion of the challenge.

One way we found it was possible to engage students from the beginning was to set a compelling scenario, so youth were intrigued and continued. This was accomplished by framing each activity as if the youth were a STEM professional such as a chemical engineer, a mathematician, or a food scientist. The use of visuals rather than words was also important. To help make activities more engaging, we typically included more pictures and visual representations compared to formal materials. The intent was for quick comprehension, rather than deep understanding. Thus, we included pictures of STEM professionals as well as a link to a video of the professional in action.

Editing our Designs

We learned that many differences between STEM engineering design challenges for a formal and an informal learning environment could be addressed by revising materials. We significantly decreased the required reading and the need for a written response. This also meant rethinking the format of questions and answers so they could be easy and fun. For example, we used sliders with pre-written responses that youth could children select, rather than having to write a response. The ability to respond quickly and to receive immediate feedback regarding the accuracy of the responses (when there are correct/incorrect responses) was also important. However, when a question asked for an opinion, such as a reflection question, feedback was not provided or needed. The focus was the completion of the activity, not an assessment of the response.

This different type of interface, however, did not preclude the collection of meaningful assessment data. We collected information about the response given, and when relevant, the number of attempts at a question. The goal became to assess if the youth was developing an awareness of the big ideas. In our case, these big ideas were concepts related to specifications and constraints, trade-offs and optimum solutions, testing, and evaluation. While we also often introduced STEM content knowledge, the overall intent of the activities was to expand awareness, engagement, and critical thinking abilities through the big engineering design concepts. It was not to teach specific science or engineering content. Further, we valued promoting a positive attitude towards STEM equally to all other outcomes.

We found if youth completed multiple activities, their knowledge of the big ideas increased. Figure 1 illustrates the gain in engineering design thinking for youth as the number of activities they completed increases. We have similar findings for their being able to reflect on and refine their design, indicating the application of the underlying STEM knowledge of the design challenge

How Activities were Created

Our process for developing informal learning activities involved creation of an alpha version of the activity. Our entire development team then critiqued it. Typically, the team discussed the proposed design challenge, specifications, and general activity format. One member of the team then drafted the activity. Only then now was it shared with

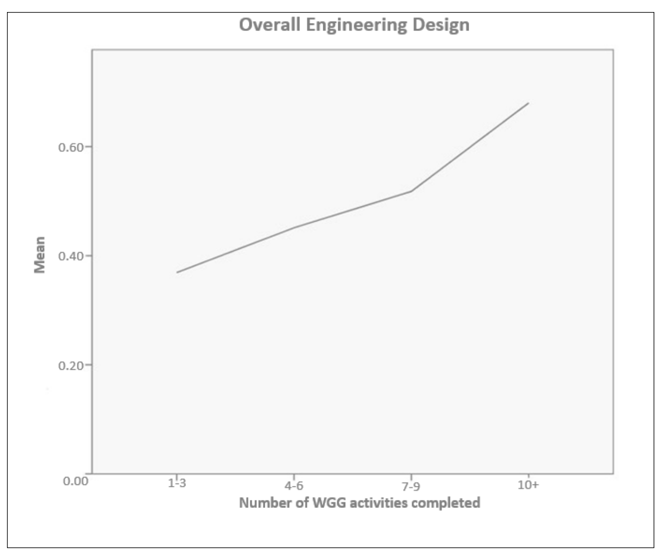

FIGURE 1. Increasing engineering Design Thinking as a function of the number of activities completed.

youth. A beta version was tested at one or more clubs. Facilitators and youth at the club provided feedback about the activity and recommended modifications and enhancements. Revisions were made, and the process was repeated a second time. After following this process several times, we found some common needs, regardless of the club or activity. Most activities needed to be shortened, even though we believed they were already brief. The challenges needed to be quickly introduced, so the time spent before construction was minimal. Generally, for a 75-minute activity, the time spent on developing knowledge, understanding the challenge, and the specifications and constraints needed to be less than 15 minutes. The construction, testing and evaluation, and sometimes redesign and re-testing, needed to take about 45 minutes, leaving 15 minutes for logging in, reflecting, and clean-up.

FIGURE 2. Certificate of Recognition.

We found that youth typically needed guidance to reflect, yet the learning facilitators, who were rarely trained educators, required support to encourage youth to reflect. To help facilitators, embedded within each activity, youth were asked how they might change their design to produce a better product. Asking multiple questions about each specification was too time-intensive, and youth did not answer the questions. The key was any prompt had to be easy and connected to the activity.

Another encouragement we introduced was the use of voice recognition software, so youth could easily and quickly respond to queries and to reflect. Additionally, we added badging and a STEM certificate, so youth who satisfactorily completed sections were rewarded, with a very low bar indicating completion, to receive a badge and STEM certificate.

Delivery of Activity

Initially, we believed that youth could engage with the activity with limited support from the learning facilitator. This proved to not be the case. After several tests, we found it helped if facilitators framed the project with a whole group discussion before youth began working the challenge. During this 5-10-minute discussion, facilitators and youth discussed how the challenge relates to their everyday knowledge (or lack thereof.) For example, the *speaker design activity* begins with a discussion about how a speaker works and then introduces the challenge of designing a speaker for their smartphone. Although we included videos about related STEM professionals during the virtual introduction, we found that reviewing them, even as a whole group, took away from the time needed to design and construct. Instead, we recommended the videos be used as a resource that youth and facilitators could view after the activity or when the activity was introduced during a pre-session meeting.

Detailed Data Analysis of the Prosthetic Leg Activity, Initial and Final Versions

In this section, we describe how one activity was created and the changes needed to ensure it was "informal environment" ready. This activity involves designing a prosthetic leg. Our focus is on the decisions an engineer might encounter when designing a prosthetic leg rather than whether or not a prosthetic is the best choice for an individual. Our project advisors, including a veteran, provided feedback about the relevance of this activity and its value for middle school-age youth. We present data about how individual pages changed as we learned more and edited the design challenge. The transition from the initial to final version required testing the activity at the club, feedback from youth and facilitators, and editing by our design team.

Comparing the two versions, the initial version has 99 words to frame the challenge, the final version 78 words. Streamlining the amount of reading also reduced the number of steps in the activity from 14 to 12. This was accomplished by combining information into a single step, such as listing the materials in the initial challenge design, as well as by decreasing the knowledge required to only what is essential for understanding and undertaking the design solution. In the final version, the materials are listed at the beginning, rather than embedded midway in the activity.

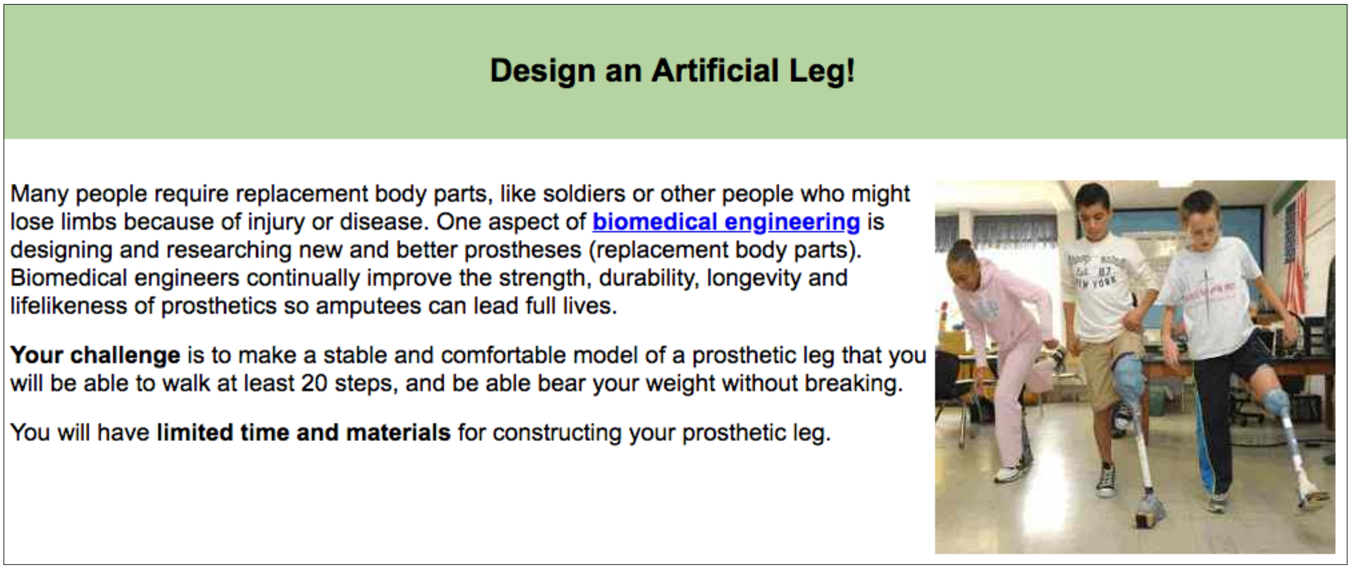

FIGURE 3. Initial version Step 1 Prosthetic Leg Design Challenge.

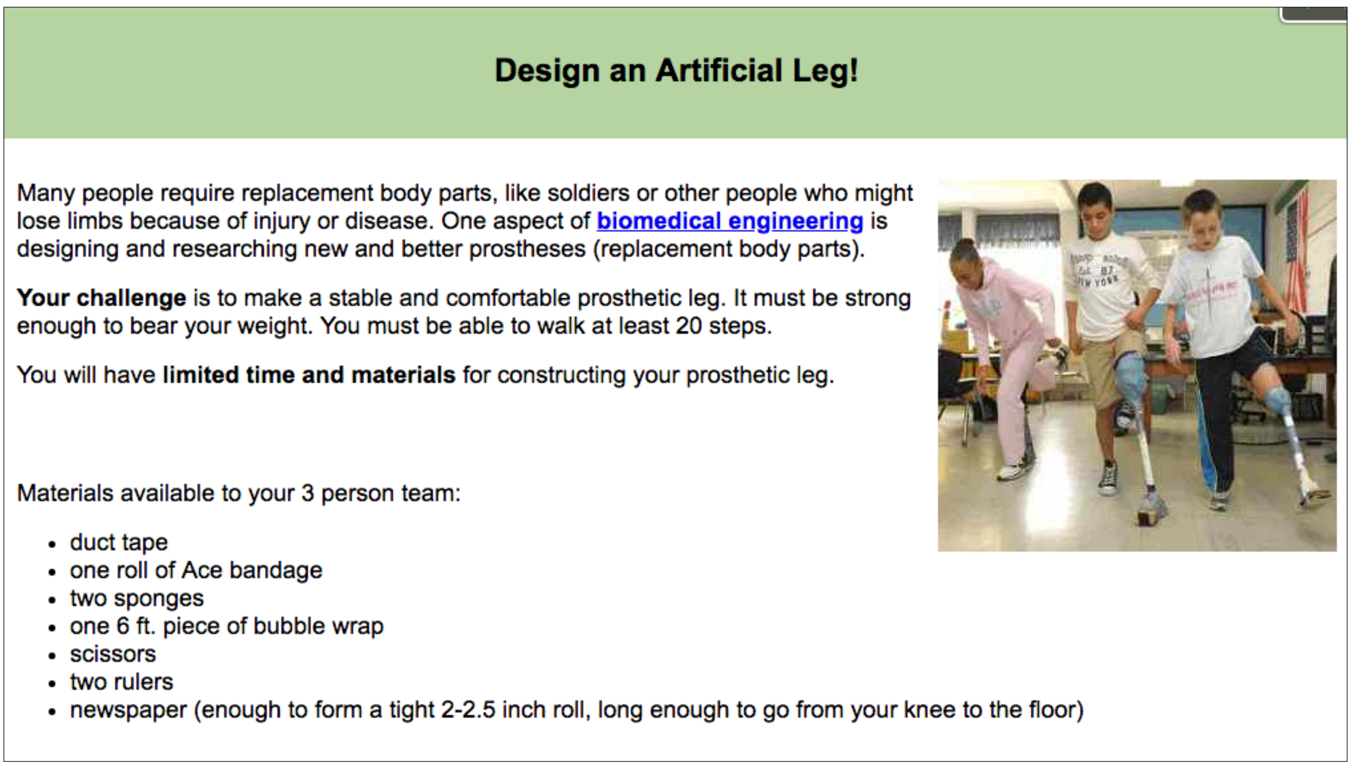

FIGURE 4. Final version Step 1 Prosthetic Leg Design Challenge.

The description of what bioengineers do has been removed since it does not advance understanding of the immediate challenge. This information is instead included in the video, when youth have the opportunity to view it. Overall, the revisions made the activity more concise and easier to follow.

Here is an example of how the content from Developing Knowledge was refined and slimmed down.

In this case, the word count decreased from 217 words in the initial version, to 171 words in the final version. This is a 21% decrease on this page alone.

When we analyzed the entire activity, we were able to decrease the word count by 30% with is consistent with a decrease in characters of 31%.

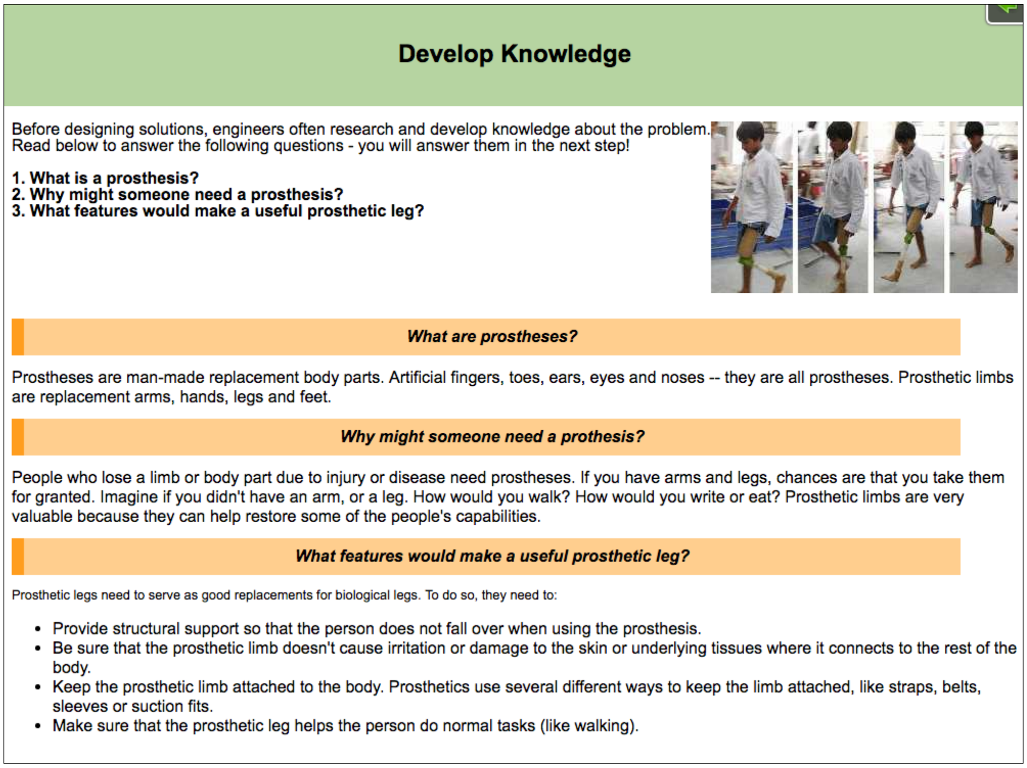

FIGURE 5. Initial Version Step 6.

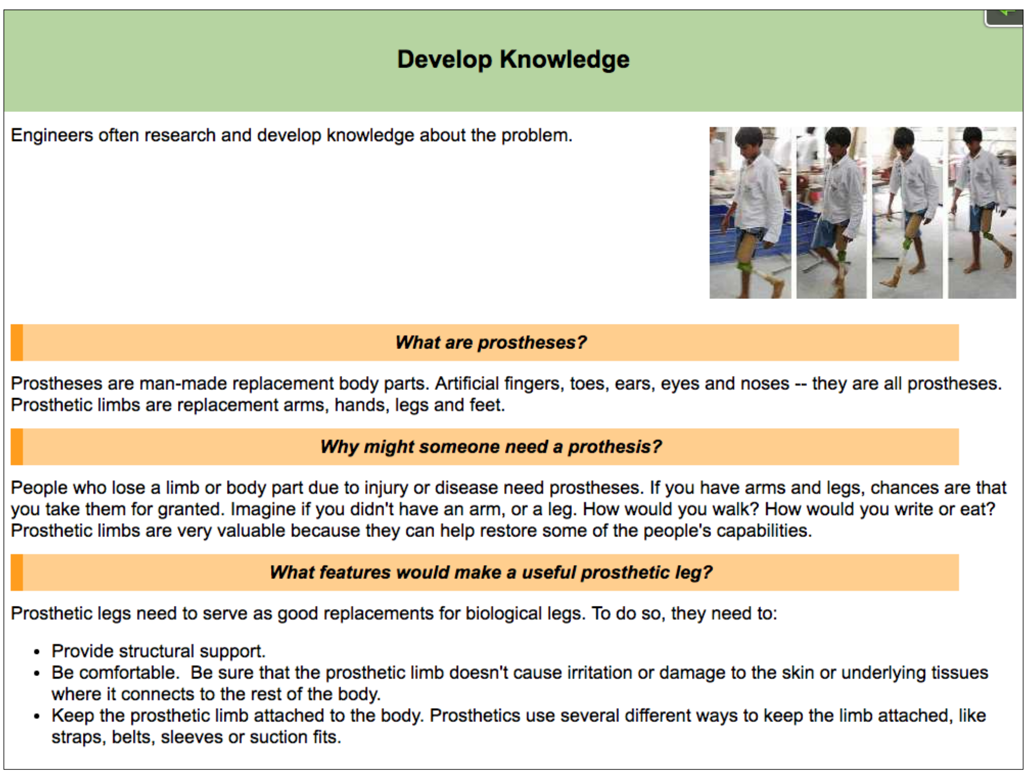

FIGURE 6. Final Version Step 4.

CONCLUSION

The authors learned that designing activities for informal learning environments requires a significant shift in their mindset. While it is unknown if these shifts would generalize to other developers, the authors learned a great deal about their own work. Prior to developing informal STEM activities or trying to transform formal activities into informal activities, it is important to understand the environment where the activities will take place, time allotment, facilitator background and availability, and the organization's overarching goals. Even with this information, several iterations will be necessary before a beta version of the activity is created.

In terms of the WGG project, activities were tested in a variety of club settings, one operating out of a church's basement, to modern dedicated facilities with gymnasiums and swimming pools.

We found that activities used in an informal environment need to engage youth but they also need to appeal to facilitators. Overseeing engineering design activities can be initially daunting. So ease of construction and guarantees of success for youth assist greatly in minimizing facilitator stress. The facilitator learns from the experience as well. The appeal of activities, like learning how speakers work, is also important.

We did find while youth enjoyed and engaged with a single activity when provided opportunities to engage with multiple activities, they, developed a greater understanding of the big concepts.

Facilitators reported it was sometimes a struggle to conduct these blended learning activities in less than an hour. However, engaging youth in activities that required them to be intentional using informed engineering design provides more opportunities to develop an understanding of the engineering concepts we were introducing. This is very different from gadgeteering, where youth make something, test, and re-do it until it works. While this approach may be easy to facilitate, it is unlikely to lead to real understanding of the underlying principles.

It is a great deal of fun to create activities that are not strictly governed by learning standards (although ours did meet many of the NGSS standards); by not being limited to typical 40-minute class periods; by not requiring teacher content knowledge; and by not being integrated into school environments. We found engaging, quirky, inexpensive, and informative must drive the design of informal activities.

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