A Blended Engineering Design Curriculum for Informal Settings: Wise Guys and Gals

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Abstract: This paper is a report on the findings from a five year study on an informal learning STEM program. The results have been very encouraging and led us to examine how our approach and curriculum, originally created for middle school youth, could be used in new and different contexts. This paper describes our approach to introducing informal STEM, the challenges we encounter and how we addressed these, and the positive outcomes observed in youth. We then describe the expansion of this framework in other contexts.

Introduction

Much of the workforce demand in science, technology, engineering, and mathematics (STEM) in the United States goes unmet [1]. Over the past five years, we have created and studied an informal learning STEM program. The results have been very encouraging and led us to examine how our approach and curriculum, originally created for middle school youth, could be used in different context. This paper describes our approach to introducing informal STEM, the challenges we encounter and how we addressed these, and the positive outcomes observed in youth. We then describe the expansion of this framework in other contexts.

WISE Guys and Gals (WGG) is the innovative blended STEM learning environment that we created to help middle school age young people develop competences in the day-to-day application of STEM knowledge and engineering design thinking. WGG was created through collaboration between Hofstra University's Center for STEM Research in conjunction with Brookhaven National Laboratory (BNL), The CUNY Graduate Center's Center for Advanced Study in Education (CASE), and 25 Boys & Girls Clubs. WGG's engaging STEM based engineering challenges introduce STEM concepts through activities with both on-line and hands-on components. The blended learning experiences reaches many youth from groups underrepresented in STEM areas, giving them exposure to engineering design concepts that will help them develop new STEM competencies, STEM career awareness, and an appreciation for the civic value of STEM knowledge.

Attracting under-represented middle school youth, particularly females, in STEM has many well-documented advantages [2]. Benefits include not only enhanced mastery and application of STEM concepts in middle school and beyond, but also greater interest in pursing advanced study and ultimately a better STEM prepared workforce [3]. Wise Guys and Girls helps middle school age young people in informal settings to develop crucial competences in the application of STEM knowledge and design thinking. However, we believe this approach

is highly transferrable to any informal setting interested in engaging groups in engineering design activities that are fun, yet challenging.

The opportunity to create physical models is enhanced by leveraging the WISEngineering platform, an open source, on-line learning environment that connects virtual design and physical modeling. Each STEM concept is introduced to youth through virtual mini-challenges (KSBs) that scaffold the learning needed to successfully complete the physical design challenges. Pictures, videos, and multimedia links express content, give context, and guide the youth through the design challenge, allowing for both an appreciation and understanding of the design process and exposure to STEM related careers. When the youths begin building their physical designs they can seamlessly follow the process in the virtual space, allowing for reflection and retention. The Design Wall, a FacebookTM like sharing feature, allows the youth opportunity to upload pictures or drawings of their designs to share their solutions with their peers and thereby facilitates collaborations. This is also a valuable tool for researchers to understand the successes and challenges experienced by youth while developing engineering thinking skills.

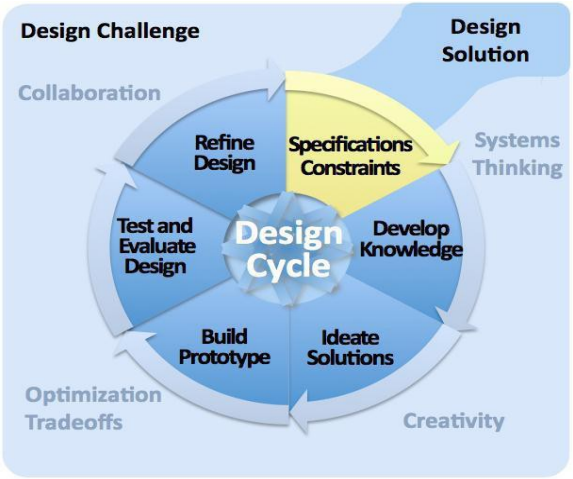
One of the built in attributes of the WISEngineering platform is the capability to provide instantaneous feedback. This has allowed us throughout the project to study the impact that a blended learning environment, created for informal STEM can have on youth, particularly in an environment where facilitator (Boys & Girls Club staff) turnover is great and youth often have an option of "dropping in or out." Additionally, we have found new opportunities to re-purpose the model to work in different contexts. This paper will present key lessons and challenges from the first full year of this project.

Structure of WISEnginnering and the context of delivery

WGG created, implemented and studied informal STEM learning experiences at over 14 Boys and Girls Clubs in the northeast. The activities were designed to be completed within a 90 minute period; use easy to obtain, inexpensive materials; and be facilitated by a Boys and Girls Club staff member who may have limited STEM background and no teacher training.

The goal of WGG was to create engaging activities that would expose youth to the key engineering design concepts. Although a general framework was created to guide development of the activities, the WGG activities varied in the number of indicators for each of key engineering design constructs, with some activities only including a few constructs. Each Engineering Design Challenges introduces and engaged youth in five key constructs of the engineering design process

- Specifications and Constraints
- Knowledge Development
- Ideate Solutions
- Testing and Evaluations
- Reflection and Redesign



Linking each of these constructs to the overall challenge are a focus on youth collaboration, recognition of optimization and trade-offs, systems thinking and opportunities for creativity.

Data sources and methodology

Studying youth learning in an informal setting, particularly one such as the Boys and Girls Clubs where youth can opt in or out of participating, was challenging. Youth may not persist in answering questions and there are limited opportunities for instruction about an incorrect response. Use of traditional methodologies such as pre-post assessments of knowledge are not feasible for a variety of reasons. Youth participation was inconsistent and most importantly, the clubs did not want any type of evaluation that was similar to what youth encounter during their school day.

Therefore, this study synthesized data from a variety of sources. We examined the following:

- Boys and Girls Club annual reports. Every six months as part of project participation, the Club Director completed a written report required by the project for administrative purposes. These reports documented the number and demographics of youth participants and aspects of program delivery. The focus of this survey was to collect club level data about what had occurred.
- Facilitator surveys and interviews. Facilitators of the WGG activities were asked to complete an online survey about the experience of delivering WGG, youth learning, and challenges encountered. They were also invited to participate in follow up interviews, with approximately half participating
- 2018 WGG Student survey of current and past students. A brief survey was administered to current and past youth about the WGG experience. This survey asked about their perceptions of the experience and attitudes about the design challenge.
- Data collected within WISEngineering. WISEngineering collects data as youth complete the activities. WISEngineering records youth responses to embedded prompts at each phase of cycle as well as pictures and/or videos. The number and format of questions varied by activity to best align with the design challenge. Questions included ones with a single "correct" response, a multi-response question (e.g, three connected questions each with a correct responses), multiple choice that allowed youth to select "all that apply", and open-ended narratives that asked youth to provide an explanation..
- Facilitator feedback collected at end of activity. FAcilators were asked to complete a brief survey at the end of each activity. The questions varied by activity and included questions about a) youth STEM learning b) youth engagement and affect c) facilitator learning or d) preparation for the activity.

Evaluation of youth understanding of the engineering design process was estimated by synthesizing data and evidence collected from multiple sources. Although we had guiding hypotheses, the study used an exploratory approach to build understand.

We began by reviewing all data sources and identifying common themes within and across data sources. As we developed qualitative and quantitative indicators, we reviewed the data a second time and tagged evidence of each. As we synthesized the qualitative and quantitative findings we began to develop understanding of impact of the experience for youth, facilitators and clubs with an eye toward learning, engagement and delivery.

Data analyses were somewhat challenging because WISEngineering was still under development when these data were collected. Technological issues resulted in some data not being properly recorded. Clubs were also inconsistent about their completion of activities, and the youth who participated often varied from week to work. Even the order of delivery varied across clubs, resulting in varied response rates within and across clubs. The project accepted this as a challenge of working in the informal learning space. Participation by facilitators was inconsistent and turnover resulted in new participants

Challenges

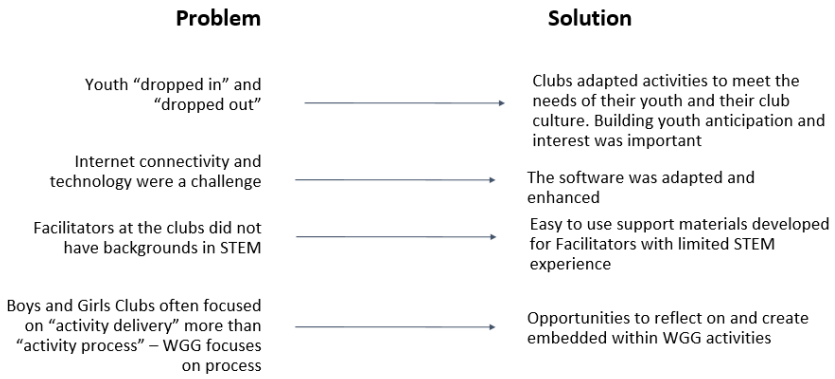
In developing this framework and execution, we encountered several interesting challenges. Studying youth learning in an informal setting, particularly one such as the Boys and Girls Clubs where youth can opt in or out of

participating presented one of the first obstacles. Youth may not persist in answering questions and there are limited opportunities for instruction about an incorrect response. Use of traditional methodologies such as pre-post assessments of knowledge is not feasible for a variety of reasons. This meant that keeping problems simple, and progress easy was key to keeping youth engaged in an informal setting.

An additional drawback to the blended approach was the inevitability of technological hiccups. When Internet connectivity issues arose with tablets, we were able to make changes and updates that provided a greater ease of use based on facilitator feedback. Instant feedback from facilitators allowed us to move quickly with addressing problems as they arose throughout the project.

Another challenge specific to our work with the Boys and Girls Clubs was the facilitator's level of experience both in teaching and in STEM. Many facilitators at the clubs do not have backgrounds in education and may not be comfortable with all the topics WGG covers. We were able to support those facilitators by creating comprehensive guides to each challenge that were easy to access and use and allowed them to successfully prepare and execute each activity regardless of past training. Figure 1 shows some of the challenges and project solutions.

Fig. 1



Promising results

Despite the roadblocks we encountered through out the creation and execution of the Wise Guys and Girls project, we were met with some promising results. Not only did facilitators notice clear improvement in Youths ability to use engineering design process and work in groups, but also noted slight improvements in presentation skills and brainstorming. Additionally, youth reported that they believed teachers would love WGG (28%) Like WGG a lot (36%) or Somewhat like WGG (26%) for reasons that varied from because WGG is fun, they learned something, and the program is hands-on.

Our research showed that not only did youth find the activities engaging but the experience lead to increased understanding of the engineering design process. Successful team building experiences, increased awareness of STEM careers.

In general, youth who participated in more activities demonstrated greater understanding of individual and overall Engineering Design criteria. In our full paper we will discuss the findings in more details but we first wanted to explore the replication of this approach to new informal curriculums.

Moving to new contexts

With the success of the partnership with the Boys and Girls club we determined we could replicate this to reach new audiences. Our framework has wide applications and uses in different settings and anyone can easily and inexpensively replicate these results. For each additional extension, we learned that minor adjustments were needed in order to maximize successful outcomes. Overall, because of the agility inherent in the program, we were able to tweak dissemination techniques to match audiences and had successful test cases that were met with enthusiasm from participants.

Summer programs at two public libraries in Nassau County brought WGG to middle school aged learners facilitated by the institution's librarians. When asked about the outcome of the program the Head of Teen Services at the library said, "I would encourage other librarians to bring the STEMgineering program to their community." As with many informal settings, inconsistent attendance made some evaluation difficult but due to the flexibility of the program, we still found success.

WGG workshops have been conducted with mothers and grandmothers in Savannah, Georgia through Parent University. The lessons we had absorbed from working with the B&GC facilitators were once again very applicable. The parents or grandparents (Mostly mothers and grandmothers) learn the activities through WISEngineering and bring the required materials home to then act as facilitator to share the activities with their children and extended communities. In this way, mothers and grandmothers have become STEM leaders with resultant changes in self-perception and the perception of others.

We conducted 8 weeks of workshops with retirees. Retirees often feel left out of STEM, so through exposure to this informal curriculum we were able to successfully build awareness, interest, and skills in this community. We also found that for this audience there was a need for more hands on facilitation during the on-line portion of the blended experience.

Conclusion

While working closely with Boys and Girls Clubs we learned keys to success include engaging youth, preparing facilitators, and reacting to potential roadblocks with agility. We were thrilled that participants in the program have engaged with the STEM content and theory and showed signs of improvement in comprehension and retention of key concepts. Through the challenges that arose we found adaptable solutions that we then were able to transfer to new contexts. With each new audience we had new challenges that need to be addressed but ultimately found our model to be successful with small adaptations. This approach is highly transferable but you must pay attention to the context and environment of its deployment each requires adaptations to maximize the experience for participants.

Our WGG model uses engaging, approachable activities that encourage collaboration, teamwork, creativity, and adaptability. When all are present we see participants successfully learning engineering design process, and building positive social associations with STEM. The success of this model highlights the power of blended learning engineering design tasks to engage and educate and create community among people of all ages.

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