Using Virtual Professional Development to Facilitate Engagement and STEM Learning in Informal STEM Learning Environments

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Abstract: Successful STEM education programs require opportunities for robust and effective professional development. Informal learning environments have specific requirements and challenges when it comes to professional development, and instructors often lack a formal STEM or STEM teaching background. This paper describes a virtual professional development model used by WISE Guys and Gals (WGG), an engineering design program for middle school aged youth at Boys and Girls Clubs in three states. Combining written materials and videos, this virtual professional development is brief, inexpensive, and targeted in ways that enable consistent, professional, engaging delivery of the STEM activities.

Introduction

An increasing focus on Science, Technology, Engineering, and Mathematics (STEM) for youth in informal learning environments means youth workers with a wide array of prior experience are being asked to provide instruction in STEM content (National Research Council, 2015). In informal learning spaces such as community centers, after school programs, and Boys and Girls Clubs, program facilitators with little experience in STEM or STEM education may still need to engage youth in meaningful STEM learning activities. To ensure quality instruction and maximize student learning and engagement, instructors need opportunities to develop their own knowledge of STEM content and their ability to engage youth in STEM-focused activities (National Research Council, 2015).

Professional development in informal STEM learning environments can present unique problems. Turnover in the youth development and after school workforce is high, and worker retention is often a challenge (Yohalem, Pittman, & Edwards, 2010). In such an environment, ongoing training for new staff is important. Professional development for STEM educators can take many forms, but formats such as formal trainings, workshops, and mentoring often involve significant time and expense (Peter, 2007). In addition, youth workers often have a diversity of backgrounds and education, making it difficult to design effective professional development activities (National Research Council, 2015).

To address the challenges of STEM professional development in informal environments, a virtual professional development approach was designed for use by WISE Guys and Gals (WGG), an engineering design program for middle school aged youth at Boys & Girls Clubs (B&GCs). The virtual professional development approach enables consistent, engaging, professional delivery of STEM activities in informal learning environments. This professional development is brief, inexpensive and targeted in ways that best enable delivery of the STEM activities.

Background

WGG is a five-year Advancing Informal Science learning project funded by the National Science Foundation (NSF). Youth complete engineering design challenges that are delivered through *WISEngineering,* a computer host platform that includes both the activities and support materials for learning facilitators. Facilitators introduce activities and guide students as they work, providing motivation, structure, support, feedback, and STEM content instruction.

WGG includes 15 informal engineering challenges—for example, designing and building a prosthetic leg, an audio speaker, or a rocket. Youth begin by using a tablet to access a virtual learning environment where they complete short knowledge and skill building activities covering key STEM concepts related to the challenge. Youth then leave this virtual environment and construct a physical model of their designs. They test the model to see how well their solution meets a given set of design specifications. They then return to the virtual environment to reflect as well as upload pictures or videos of their design work. As youth work through their design challenges, they engage in engineering design thinking and learn about engineering careers. The youth at these clubs are typically underrepresented in STEM areas, and the activities help enhance their STEM interest and knowledge.

Informed engineering design is the pedagogical approach that underpins WGG activities (Burghardt & Hacker, 2004)**.** It was developed by examining how engineers create and design intentional, knowledge based solutions. Using this approach, youth create informed design solutions based in STEM knowledge rather than using a trial-and-error or gadgeteering problem solving approach. Youth continuously reflect on their designs and discuss the trade-offs of different choices. Informed design emphasizes the process of working through a design challenge and the application of STEM knowledge over the design outcome. Success requires a high level of engagement and persistence.

Facilitation of WGG Activities

Given WGG's informed design approach, effective professional development for this program must involve strategies for engaging and motivating students as well as opportunities for facilitators to learn key STEM content. There are additional professional development needs specific to WGG. Youth at Boys and Girls Clubs, unlike those in many afterschool programs, are typically not required to participate in an activity, and they often have great flexibility to opt in or out of specific activities. Program delivery and skilled facilitation are crucial to keeping youth engaged and involved. Generating excitement about each design challenge is important to motivating youth to participate. Facilitators must deliberately introduce and structure activities in order to maximize student engagement and provide an optimal STEM learning experience. Any assessment needs to be low-stakes and cannot feel too "school-like."

Assuring that the facilitators at each Boys and Girls Club were adequately prepared to deliver the activities and to stress process over outcome proved particularly challenging. While some clubs include staff who are experienced STEM educators, others have staff with little experience or formal training in education or STEM. At many clubs staff turnover is common and frequent, meaning new facilitators must be trained each year without the benefit of learning from previous WGG instructors. Facilitators are also often hourly employees with limited time to learn how to deliver the program, not to mention the STEM content involved.

Intensive, face-to-face training was initially provided by WGG project staff, and ongoing support was provided through a liaison assigned to each club. However, as WGG expanded to more clubs across three states, it became necessary to support facilitators when it was not possible to be physically present.

To address these challenges, the project team developed an inexpensive, easy-to-create professional development approach combining the use of written materials and brief video supports. For each of the 15 WGG activities, facilitators can access a written guide that details activity preparation, STEM concepts, needed materials, factors that might affect the outcome of the challenge, a rubric for self-assessing the design, and engineering careers related to the activity.

Initial program evaluations indicated that although facilitators relied on the written materials to help prepare for activities, written guides alone were not enough. Facilitators wanted more training and support. However, as the number of clubs increased and their locations were more remote, it was no longer possible to provide face-to-face support.

Using common equipment—including personal phones and tablets—the project team produced, recorded, and edited a series of professional development videos, each less than ten minutes long. A video was created for each engineering challenge, along with a variety of cross-activity support videos (e.g., how to use the virtual *WISEngineering* infrastructure). These videos supplement the written guides and provide facilitators with basic STEM content knowledge and pedagogical support.

The team developed a framework allowing for consistent and logical delivery of professional development content. Each video highlights a central STEM concept (a "STEM big idea") important to understanding the activity —for example, a two-minute primer on electromagnetism for the speaker-building activity. The videos do not aim to make facilitators into content matter experts, but rather to provide them with adequate support so they can effectively help students use STEM concepts to inform their designs. Videos also include information about materials, instructional techniques, and STEM careers related to the activity. An important element in each video involves ideas for introducing the activity and getting youth excited about the design challenge. Facilitators are given ideas for activating prior knowledge by asking guiding questions and getting youth to talk about everyday experiences which relate to the activity. For example, facilitators leading the speaker-building challenge are encouraged to ask youth how they think a speaker works and what they would see if they took a speaker apart. Such pedagogical techniques are intended to create excitement and to allow youth to apply their understandings of the world to the engineering challenges.

To create each video, it was necessary to also complete the design challenge, allowing the team to note any extra difficulties involved. By doing this, it was possible to make direct connections between what is needed to complete each activity and potential challenges. The team documented the model-building process, and video and still images were included in each video guide, as well as a section on "gotchas" or extra considerations that are not covered in the written activity guides. The videos were designed for use by facilitators implementing an activity for the first time, as well as facilitators who want a refresher before delivering an activity they have already implemented. Videos and text guides are accessible through the WGG facilitator website, and videos are also viewable on YouTube.

Data Sources and Analytic Approaches

To study the effectiveness of this virtual professional development model, several sources of data were examined to document and assess how facilitators prepare and deliver WGG activities. Data presented here were collected between fall 2017 and spring 2019 from learning facilitators and club directors at each Boys and Girls Club.

Facilitator Survey: Facilitators completed a survey about their experiences with WISEngineering, the WGG activities and WGG supports and professional development. Facilitators were also asked about their prior experiences with WGG and STEM.

Facilitator Interviews: B&GC facilitators participated in semi-structured interviews lasting approximately 20 minutes. Facilitators were questioned about their club's approach to professional development, activity preparation and delivery. The interviews were recorded and transcribed. Qualitative coding software, NVivo, was used to develop a database of major themes.

WGG Youth Surveys: B&GC youth currently completing WGG activities and youth who had previously completed WGG activities answered survey questions designed to assess student learning and engagement. Their responses were reviewed and reoccurring themes identified.

Club Leadership Interviews: B&GC Directors and/or grants managers were interviewed. These interviews lasted approximately 20 minutes and asked about how club leaders leveraged their participation in WGG providing a context for examining how implementation characteristics are related to program outcomes. Interviews were recorded, transcribed, and analyzed.

WGG Annual Program Reports: Every six months the B&GCs submitted data about their involvement in WGG, the number of youth engaged, and other questions related to planning and delivery.

WISEngineering Embedded Data: As part of each WGG activity, youth answered a variety of questions and their responses were recorded in WISEngineering, the online platform that hosts the WGG activities. While responses to these questions are used to assess youth learning, for purposes of this analysis the data were also used to assess each club's level of engagement in WGG.

Findings

Although facilitators came from a variety of backgrounds and varied in how they prepared for WGG, most reported using virtual professional development resources. Even those with limited STEM experience were able to successfully use the WGG virtual professional development materials with minimal or no support from the Liaisons. Activities were successfully implemented, and student engagement and learning was reported by facilitators and reflected in *WISEngineering* data.

Facilitator STEM Experience

Facilitators had very diverse levels of experience with STEM content and education, with some reporting very limited STEM experience and others having more than a decade worth of STEM experience. Of 14 facilitators who provided information about their STEM educational background, 50% reported they had minimal or no STEM background. Instead there was a range of backgrounds including arts education, sociology, accounting, and general studies. Only one facilitator had experience with engineering. However, we found the level of experience tended to shift frequently since facilitator turnover at the clubs was common. Across all 16 clubs, there were 23 new learning Facilitators hired between the second and fifth years of the program, and each year there was up to a 50% turnover in the facilitators.

Preparation for WGG Activities

Preparation and training for WGG took many forms. Questions about how the facilitators prepared before delivering a WGG activity, including which resources they found most helpful, were examined as part of most of data collection procedures described above. The results were fairly consistent across data collection tools, respondents, and over time.

Facilitators reported "*always*" organizing materials beforehand (91%), logging into *WISEngineering* to review the activity that they will be engaging in (73%) and watching the WGG videos as well as reading the facilitator guides (both activities were endorsed at 55%). To a lesser degree, they reported "*often*" doing the activity themselves (36%), talking with youth about the activity the week prior (36%), and talking to someone who had completed the activity before or talking to the liaison of their respective clubs (both activities were endorsed at 27%). In contrast, the majority of respondents also reported "*rarely"* or "*never*" talking to someone who had completed the activity before (64%) and "*rarely*" talking to the liaison for their clubs (36%). Table 1 presents these data.

Since staff turnover is often great at the clubs, it was not surprising that the facilitators infrequently sought help from others at their club. The preparation activities that were most common tended to be those that could be engaged in independently without outside involvement or contributions from others and included the resources created specifically for WGG (e.g. *WISEngineering* website, WGG videos). This evidence suggests that WGG has been successful in its efforts to create training and support materials that allow for scalability without intensive face-to-face training.

Preparation Method	Response Option					
	Didn't need to (did in the past)	Never	Rarely	Sometimes	Often	Always
Watch the WGG videos	18.18% (n=2)	0.00%	0.00%	9.09% (n=1)	18.18% (n=2)	54.55% (n=6)
Read the Facilitator guides	0.00%	0.00%	9.09% (n=1)	18.18% (n=2)	18.18% (n=2)	54.55% (n=6)
Log into *WISEngineering* to	0.00%	0.00%	0.00%	9.09%	18.18%	72.73%

Preparation Method	Response Option					
	Didn't need to (did in the past)	Never	Rarely	Sometimes	Often	Always
review the activity				(n=1)	(n=2)	(n=8)
Organize all the materials beforehand	0.00%	0.00%	0.00%	0.00%	9.09% (n=1)	90.91% (n=10)
Talk with youth about the activity the week before	0.00%	9.09% (n=1)	0.00%	45.45% (n=5)	36.36% (n=4)	9.09% (n=1)
Talk to someone who has done the activity before	0.00%	45.45% (n=5)	18.18% (n=2)	0.00%	27.27% (n=3)	9.09% (n=1)
Talk to the liaison for my club	0.00%	0.00%	36.36% (n=4)	18.18% (n=2)	27.27% (n=3)	18.18% (n=2)

Table 1. How Facilitators Prepared for WGG Activities

Evidence for Engagement and Learning

Youth engagement and learning were evident across all data sources. Facilitators and Club Directors reported that youth liked the activities and that they were engaged. One facilitator shared:

> *"…having members asking me day after day: what are we going to be doing for science today? I can see the excitement in their eyes because they really look forward to being a part of science class. WGG focuses on many STEM careers and concepts instead of one particular theme. This makes STEM more engaging for members because they are doing something totally new for each activity."*

Youth also shared similar sentiments, saying that they enjoyed WGG *"Because it inspires"* and *"It is fun and you can learn a lot of thing new."* When asked whether they think that teachers would like WGG, youth reported that they would, with only a few exceptions. They gave varied reasons for this, the most common being that "*WGG is fun*" (30%) or "*You learn something*" (23%). Youth also reported teachers would like WGG because "*WGG is about STEM*" (10%) and WGG is hands-on and involves building (10%). Youth also reported that teachers would like WGG for reasons that were not categorized:

> *"Because it's a fun activity that helps kids focus better. (Because they want to listen a lot so they can make cool things.) Also you can learn how to make things and learn about technology."*

> *"My science teacher loves to do hands on activities. I told him about the projects."*

When asked to characterize any differences between WGG and other STEM activities taking place in their clubs, B&GC directors reported that a major difference involved the more rigorous/structured nature of WGG, and that WGG required youth to engage in more steps to complete each activity. To illustrate, one club stated that WGG activities contained more *"questions and data entry [which made] this more 'scientific' and more 'like school' than a regular STEM activity at the club […] WGG participants are more committed to seeing the projects through to the end, because they are entering their own data and giving feedback on the results."* This result further demonstrates the need for adequate facilitator training and preparation, as WGG activities are rigorous and may require facilitators to be highly involved in helping students successfully complete their projects.

Analysis of data extracted from *WISEngineering* also showed evidence of learning. Youth responses were evaluated for evidence of understanding or application of five engineering design constructs: specifications and constraints, knowledge development, solution ideation, testing and evaluation, and reflection and redesign. An understanding score (ranging from 0 – no evidence of understanding to 1 – evidence of deep understanding) was assigned to each construct for each activity. Looking across all activities completed by an individual youth, youth who demonstrated deep understanding of a construct for at least one activity were identified. Using this criteria, at least half the youth demonstrated high understanding of each engineering construct.

Construct	WGG Youth Showing Deep Understanding
Specifications and constraints	72%
Knowledge development	57%
Solution ideation	69%
Testing and evaluating	82%
Reflection and redesign	87%

Table 2. Deep Understanding of Engineering Constructs

Facilitators also reported youth were learning about the engineering design process. This is illustrated in the following quotes:

> *"The success of the WGG was the exposure to these activities, learning about following a process, probably most importantly solving problems on their own using each other, logic, and trial and error."*

> *"After the experiment was completed, in groups they began to work together to create the ULTIMATE prototype. Watching our middle school members challenge each other to take the activity further was not only inspiring but a great acknowledgement to their own personal learning process."*

> *"As they designed, tested, re-designed, and re-tested, the group was really getting excited about how well they were doing. Their excitement caught on to the other groups and now the other groups were trying to better that design. It was really fun to watch the kids use critical thinking skills, along with friendly competition."*

Conclusions

A background in STEM or STEM education is not required for excellent facilitation of WGG activities. Excellent facilitation does require that the facilitator is prepared to motivate and engage students, interact with STEM content, and emphasize the engineering design process over design outcomes. Multiple data sources show that WGG facilitators were able to successfully deliver WGG activities, and youth were engaged and learning STEM concepts. Facilitators prepared for WGG activities using virtual professional development resources, having supplies ready, and often completing the activity before presenting it to youth.

Implicit in these findings is that the virtual professional development model developed for WGG is robust and effective. Most facilitators reported frequently using the video and written guides to help them prepare for activities, allowing for less reliance on face-to-face training and addressing issues of high staff turnover and varying levels of training and experience. Understanding how Boys and Girls Clubs prepared and delivered WGG is critical for continued development and dissemination. This virtual professional development model has the potential to improve professionalism, content, pedagogy, and fidelity of implementation in other widely dispersed STEM education programs.

References

Burghardt, M. D., & Hacker, M. (2004). Informed design: A contemporary approach to design pedagogy as the core process in technology. *Technology Teacher*, *64*(1), 6–8.

National Research Council. (2015). *Identifying and Supporting Productive STEM Programs in Out-of-School Settings*. Retrieved from https://www.nap.edu/catalog/21740/identifying-and-supporting-productive-stem-programs-in-out-of-school-settings

Peter, N. (2007). Promising Practices in Out-of-School Time Professional Development. *Departmental Papers (SPP)*. Retrieved from https://repository.upenn.edu/spp_papers/97

Yohalem, N., Pittman, K., & Edwards, S. L. (2010). *Strengthening the youth development/after-school workforce*. Washington, DC: The Forum for Youth Investment.