Learning Engineering Practices Through Drones: Iterative design of an informal learning curriculum

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Abstract: Informal learning programs provide youth with additional opportunities to engage in STEM. Here, we report on an informal engineering program for low-income youth. We describe how a curriculum was modified to reflect the instructional shifts outlined in the *Framework for K-12 Science Education* and how these changes enhanced youth interests and engagement in engineering practices.

Introduction

Afterschool programs are an important part of the science, technology, engineering, and mathematics (STEM) ecosystem, providing youth with opportunities to spark or deepen their interests in STEM, engage in science and engineering practices, and understand the value of STEM for society and future employment. In formal educational settings within the United States, science learning in classrooms is undergoing profound changes, motivated by the *Framework for K-12 Science Education* (NRC, 2012) and the *Next Generation Science Standards* (NGSS Lead States, 2013). There have been numerous studies examining the implementation of new curricula designed to support the instructional "shifts" described in these documents in formal educational settings (see, for example, Severance, Penuel, Sumner, & Leary, 2016). However, there have been fewer studies examining how these shifts influence the design of STEM curricula in informal learning settings. We report on the development and implementation of an afterschool program designed to engage low income, middle school youth in engineering experiences in atmospheric and related sciences.

Theory and Prior Work

Supporting the instructional shifts in the *Framework* and NGSS are central to our approach. The *Framework* advocates for using phenomena to drive instruction in science as a means of sustaining student interests and promoting 3D learning. With this approach, the focus of learning is about figuring out how to explain a phenomenon not learning about a set of topics. Within science, the goal is to build and refine models to explain and predict phenomena, based on evidence (Lehrer & Schauble, 2006). Within engineering, the goal is to engage youth in designing solutions to problems, using evidence of their design's efficacy to inform and motivate iterative improvements. A core premise of this approach is that through "figuring out" youth will be guided to engage in 3D learning, where their knowledge of disciplinary core ideas and cross cutting concepts (such as patterns or cause and effect) is developed through deep engagement with science and engineering practices. Ideally, when asked what they are doing and why, youth should be able to describe how their learning activities are helping them to solve their engineering problem. The ability of youth to understand the purpose behind discrete activities is one way of operationalizing student-centered measures of curriculum coherence. Researchers have proposed storylines as a promising approach for developing coherent curriculum (Shwartz, Weizman, Fortus, Krajcik, & Reiser, 2008). A storyline is a way to represent sequence of lessons where each lesson is driven by youth questions and each activity helps youth to make progress on explaining an anchoring phenomenon.

Context, Methodology, and Analysis

Engineering Experiences is an afterschool engineering curriculum based on Unmanned Aerial Vehicles (UAV/Drones). Participating youth learn how to fly drones and how to use them as platforms for scientific investigations. Figure 1 shows the design of iteration three of the curriculum, where we focused on coherence around a driving question for the semester. This program was studied over the course of three iterations following a design-based research methodology. The first and second iterations were at a middle school that serves youth in grades 6 – 8; 40% of the students at this school are Hispanic while 50% are Caucasian. Almost 45% of the students qualify for free-and-reduced lunch (FRL). The third iteration took place at a PK-8 School where 84% of the students are Hispanic, 12% are Caucasian, and 83% qualify for FRL.

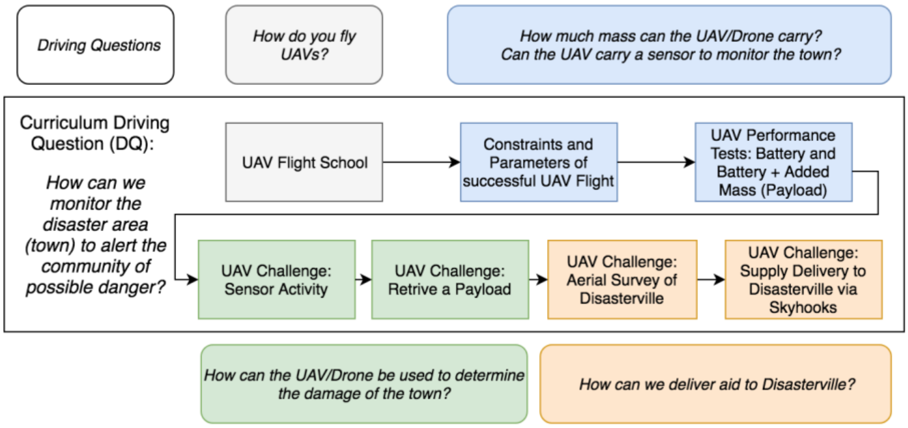

Figure 1. Curriculum Design around a Driving Question in Iteration Three

In each iteration, we collected data using journal prompts, project artifacts, observations, and interviews with youth and adult participants. We used "flight logs" as an unobtrusive journaling notebook for gathering evidence about youths' interests, engagement, and knowledge. In survey questions and interviews, we asked youth to reflect on their interests, performance expectations, relevance of the program to their lives, and their use of engineering practices. Our session observation protocol focused on observing the degree to which youth were engaged in different activities and enacted engineering design practices, as well as how the participating adults supported the youths' experiences. Analysis was conducted collaboratively by the research team.

Results and Discussion

Our results suggest that using phenomena and design problems to drive instruction can help sustain student interests. In all three iterations, participating youth reported that their main reason for attending was their interest in drones – 57% of youth noted that the drone content was pretty important in iteration three. However, in earlier iterations, this interest did not sustain their participation, with attendance declining through the duration. In iteration three, nearly all youth completed the 14-week program, which was longer in duration and intensity than the previous iterations. We observed that youth were deeply engaged in the activities for the majority of the sessions. In earlier iterations, youth would disengage from activities and passively observe. Our observations also revealed differences in youth engagement with engineering practices. Youth were engaging in more testing of specific designs, more iterations of their designs, and ultimately creating more sophisticated designs. In earlier versions, youth were limited in their ability to iterate due to the short durations of each session and interviews with youth revealed that they were not motivated to iterate as they perceived their designs to be "good enough."

We hypothesize that the curriculum's new emphasis in version three on engaging in argument from evidence helped youth to convince themselves that more work was needed to improve their designs. For instance, during interviews, youth often discussed the need to collect data to justify their decisions or processes. One youth stated, "*I would use some research data and say if I tested it on my own processor or designer city I made on my own. So, I would show them evidence and anything else that I used to do with the drone*" [T1]. Thus, building on the framework helped us to create an in-depth afterschool program that built on student interest while engaging them in significant science and engineering practices.

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