Future Technologies Conference (FTC) 2017
29-30 November 2017 | Vancouver, Canada

Additive Manufacturing and Collaborative Learning for Pre-hospital Care Environment

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***Abstract*—A new initiative at Texas Tech University uses hybrid education and collaborative learning modules to integrate new designs to solve real world medical challenge problems. Prehospital care encompasses everything from point of injury in the field to the receiving definitive care facility, and comprises 87% of combat fatalities. The environments span rural settings, wilderness, and extreme environments, both civilian and military, and provide a broad opportunity for innovation in technology to optimize outcome. Our target audience is elementary schools and focus is STEM mentoring and critical problem solving. Through rapid prototyping of new concepts that will enhance quality of life and ultimately, accelerates to full functionality and sustainability, in relatively austere environments students gain an appreciation for the scientific process. We will demonstrate our process and a minimum of two devices that incorporate green energy technologies applicable to this interdisciplinary domain.**

***Keywords*—Pre-hospital; experiential; additive manufacturing**

I. Methods

A modular hands-on, highly interactive program was developed to provide focused problem-solving experiential learning to elementary students attending an institution in the Department of Education designated East Lubbock Promise Neighborhood (ELPN). This neighborhood is plagued by low socioeconomic and health indicators and is making a concerted effort to immerse kids in science and technology ecosystems that stimulate discovery and critical problem solving skills. Our teams are mentored and closely supervised by undergraduate students from Texas Tech University, most with interested in the biomedical engineering and life sciences. In addition, participants are selected and closely monitored by elementary school teachers. The specific challenge problem assigned was design of a 3D printed prototype of an oropharyngeal airway device for personal protection during a severe dust storm or toxic atmospheric release. Each student team was assessed with specific systems engineering design metrics for usability and functionality for the target population.

II. Strategy

The development of this hybrid education and collaborative learning curriculum was inspired by the need for a more hands on, applicable learning structure in primary education. This has been made apparent by recent research showing that students learn science best by doing science [2]. In response to these findings the following module based curriculum was designed to be cross-disciplinary with integrative learning strategies developed accordance with the *Next Generation Science Standards* (NGSS) using the *three dimensional learning* framework [3]. The NGSS breaks the 3D learning model into three overarching components [1]:

- <u>Dimension 1 (Practices):</u> Describes the problem solving processes taken by scientist and engineers, such as the scientific method.
- <u>Dimension 2 (Crosscutting Concepts):</u> Outline how different domains of science are interlinked in an effort to enable students to organize interrelated knowledge from various fields of science and engineering.
- <u>Dimension 3 (Disciplinary Core Ideas):</u> Dimension three requires that a curriculum be teachable and learnable to students across multiple grades, have a broad importance across multiple scientific or engineering disciplines, and provide key tools to investigate and solve more complex problems.

The modules we developed during this project supplement the 3D Learning framework by separating various disciplines of science and engineering into well defined, yet interlinking components. Therefore, our strategy makes integrative learning strategies such as the 3D Learning framework more accessible to a broad range of educators who can mix and match modules to suit the needs of their students and capabilities of their schools.

III. Participants

We use the before mentioned strategy to solve real world medical challenge problems in the prehospital care environment. The study consisted of eight teaching assistants (TA's) from Texas Tech University (TTU), four chaperones and 40 students from Bean Elementary School (Bean). The TA's from TTU made up a cross-disciplinary team of Biologist, Biochemist, Engineers, and Computer Scientists. In order to maintain uniformity of teaching methods, all TA's were given identical training and direction in how to teach

Grant 110637-A-17-0126-001 Civil Military Prehospital Care Innovation Curriculum: A Scalable Pilot Program

each module and what integrative pedagogies to follow. Insuring that all students received information in accordance with our strategy was important for assessing the effectiveness of our teaching modules. In order to insure the effectiveness of our modules across varying grade levels the 40 students from Bean were between second and fifth grade. The study took place over a two week time period with 20 students undergoing the course during the first week, and a separate 20 students undergoing the course in a following week (Fig. 1).

IV. LAYOUT

Each week students were randomly split into four teams of five students each and given two TA's. Each team of students was paired with the same group of TA's throughout all modules and the challenge problem. Over the course of two days teams rotated through four learning modules. Once each team had completed all of the learning modules they were given a presentation outlining a specific prehospital care challenge problem. Each team was given two and a half days to complete the challenge problem. Upon completion of the challenge problem a series of students were randomly selected and interviewed to assess the effectiveness of the overall course, as well as each module.

TABLE I. WEEKLY AGENDA

	Activity
Monday	• Module 1: 9:00AM -11:00AM • Module 2: 11:00 AM -11:50AM
Tuesday	• Module 3: 9:00AM -10:00AM • Module 4: 10:00AM -11:50AM
Wednesday	• Present challenge problem 9:00AM – 9:30AM • Begin Challenge Problem 9:30AM -11:50AM
Thursday	• Continue Challenge Problem 9:00 -11:50AM
Friday	• Complete Challenge Problem 9:00AM - 10:00AM • Interview and asses students 10:00AM - 11:00AM • Showcase student creations 11:00AM – 11:50AM

V. MODULES

In addition to following the guidelines laid out by the 3D Learning Framework we designed the modules in the study to be thematic and integrative [1]. Over the course of one week students learned how to design and prototype ideas for solving real world problems in the prehospital care environment (Table 1). These modules include 3D printing, 3D scanning, alginate life-casting, computer automated design (CAD), and a challenge problem that thematically brings all of the aforementioned modules together.

Fig. 1. Week one Bean Elementary students.

Module 1: LifeCasting

In the first module students learned how to create replica models of body parts and real world objects using alginate and plaster. Students also learned how these techniques can be applied to the prehospital care environment in conjunction with 3D scanning, 3D printing, and CAD software to design custom medical devices such as prosthetics, and splints (Table 2).

TABLE II. MODULE 1 FOCUS AND PEDAGOGY CHECKLIST

1 hour 45 minutes	**Focus Checklist**	**Pedagogy**
Introduction	What is LifeCasting? How does LifeCasting work?	Keep students engaged by asking questions. Provide visual and tangible examples. Use short and simple sentences.
Safety	Explain safety procedures and potential hazards. Explain what kind of PPE is required and why.	Provide examples and images of potential injury. Ask students questions to keep them engaged. Adhere to curriculum.
Primary Instruction	What materials are needed? Walk students through a casting exercise. Discuss common problems and how to troubleshoot (Basics).	Hands-on Interactive Ask students questions to keep them engaged. Holistic Adapt curriculum to maintain interest.
Discussion	Briefly provide examples and pictures of potential applications Discuss what applications the students are most interested in. Brainstorm ideas.	Interactively engage with the students. Provide thematic examples and images. Discuss Interdisciplinary uses with other modules.

Module 2: 3D Scanning

Module two taught students how to use Einscan-S 3D scanners to create 3D digital images of real world objects, body parts, and plaster casts (Fig. 2). In addition to learning how to use the scanners students learned how to apply 3D scanning techniques to real world problems in the prehospital care environment, and how to upload 3D scans to CAD software for modification (Table 3).

TABLE III. MODULE 2 FOCUS AND PEDAGOGY CHECKLIST

50 minutes	Focus Checklist	Pedagogy
Introduction	What is 3D scanning? How does 3D scanning work? Explain differences between photogrammetry and traditional scanning.	Keep students engaged by frequently asking questions. Provide visual examples of 3D scans. Use short sentences and simple explanations.
Safety	N/A	N/A
Primary Instruction	What software do you use? How do you use it? How to manipulate settings (Basics). Provide teams with applicable objects to scan. Discuss common issues and how to troubleshoot (Basics).	Hands-on Interactive Ask students questions to keep students engaged. Holistic Adapt approach to maintain interest.
Discussion	Briefly provide examples or pictures of potential applications Discuss what applications the students are most interested in.	Interactively engage with the students. Provide thematic examples and images. Discuss Interdisciplinary uses with other modules.

Fig. 2. Einscan-S 3D scanner.

Module 3: Computer Automated Design

In module three, students learned basic CAD processes using an open source, browser-based CAD software (Table 4). Specifically, students learned how to use a variety of tools, manipulate shapes, and import/export files for 3D printing.

TABLE IV. MODULE 3 FOCUS AND PEDAGOGY CHECKLIST

50 minutes	Focus Checklist	Pedagogy
Introduction	• What is TinkerCAD? • What do people use TinkerCAD for?	• Use thematic examples. • Ask students questions after each section to keep them engaged. • Use short sentences and simple explanations.
Safety	N/A	N/A
Primary Instruction	• How to manipulate Settings (Basics). • Challenge individuals to create simple objects. • Discuss common issues and how to troubleshoot (Basics).	• Hands-on • Interactive • Ask students questions to keep them engaged. • Holistic • Adapt curriculum to maintain interest. • Short sentences and simple explanations. • Problem based.
Discussion	• Briefly provide examples and pictures of potential applications • Discuss what applications the students are most interested in.	• Interactively engage with the students. • Provide thematic examples and images. • Discuss Interdisciplinary uses with other modules.

Module 4: 3D Printing

In module four students learned how to safely and properly operate dual extrusion fused deposition modeling 3D printers (Fig. 3). A study on the effectiveness of using 3D printers as a tool for increasing K-12 understanding of engineering principles found that 3D printers significantly increase student's ability to grasp engineering principles with the main barrier being lack of knowledge and meaningful lesson plans [4]. Module four surpasses these barriers by teaching students how to use 3D printers intuitively. Students also learned how to manipulate important printer settings in order to optimize success of challenging prints (Table 5).

TABLE V. MODULE 4 FOCUS AND PEDAGOGY CHECKLIST

1 hour 45 minutes	Focus Checklist	Pedagogy
Introduction	What is 3D printing? How does 3D printing work? Explain differences between FDM and SLA 3D printing.	Provide pictures, videos, or GIF's. Keep students engaged by frequently asking questions. Provide tangible examples. Use short and simple explanations.
Safety	Printer Anatomy: What are the most important components of a 3D printer? How can these components be dangerous? Explain safety procedures.	Be hands on with a real printer. Ask students questions to keep them engaged. Adhere to curriculum.
Primary Instruction	What is slicer software? How do you use it? What settings can you manipulate (Basics). Provide teams with objects to print. They must be quickly and easily printed. Discuss common issues and how to troubleshoot (Basics).	Hands-on Interactive Ask students questions to keep them engaged. Holistic Adapt curriculum to maintain interest.
Discussion	Briefly provide examples/pictures of potential applications Discuss what applications the students are most interested in. Brainstorm ideas.	Interactively engage with the students. Provide thematic examples and images. Discuss Interdisciplinary uses with other modules.

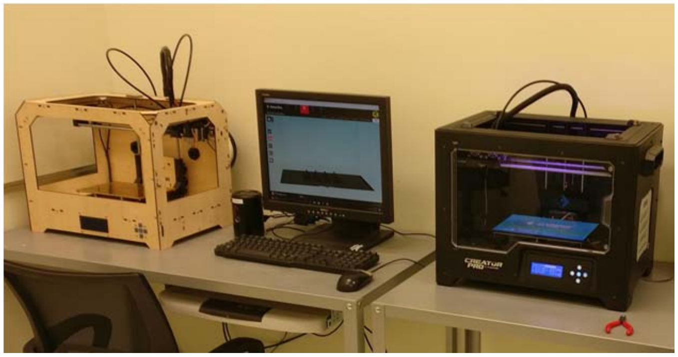

Fig. 3. 3D printing workstation with Flashforge 3D printers.

Challenge Problem:

For the challenge problem, teams of students were presented with a pre-hospital care challenge that required them to utilize the techniques they learned in modules one through four. The students were challenged to design and create an oropharyngeal airway (OPA) with a modified mouthpiece that allowed for the quick attachment of healthcare tools. In this case, students designed a filter attachment for the OPA in order to decrease the potential for contaminants to enter a patient's airway while it is being held open (Fig. 4). Over a two and a half day period student teams worked independently to develop their own design and solution for the oropharyngeal challenge problem.

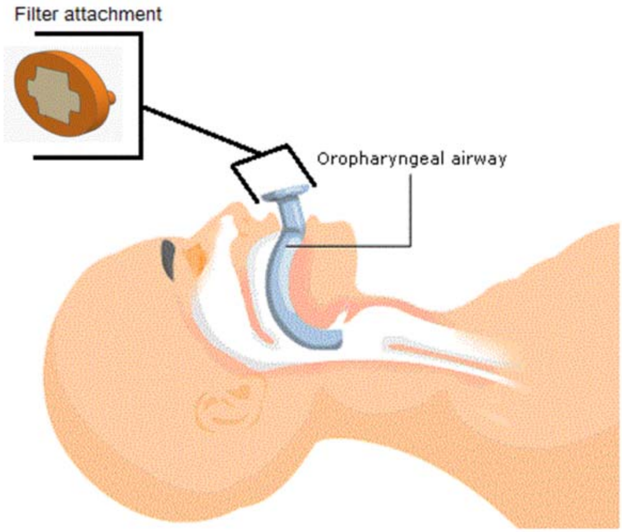

Fig. 4. A diagram depicting the mode of action of an OPA and modular air filtration device.

VI. RESULTS

As a result of the modular program described, 40 ELPN elementary students successfully completed summer camp, at the nonprofit makerspace U(biquitous) Labs®, and participated in a Showcase Competition for family and friends. Several students designed very accurate devices in response to the OPA challenge problem, such as the air filter OPA shown below (Fig. 5).

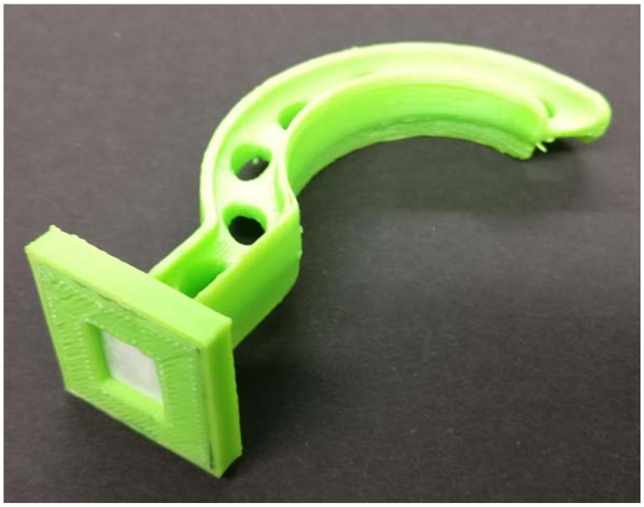

Fig. 5. A student designed OPA with a built in air filter.

We saw that some students found the OPA concept difficult to grasp. This observation typically correlated with age and attentiveness. As a result, many of the younger students who did not understand the functional importance of OPA's decided to build similar but different devices, such as gas masks (Fig. 6). In the future, we will better tailor the challenge problem to the perspective age groups that are participating.

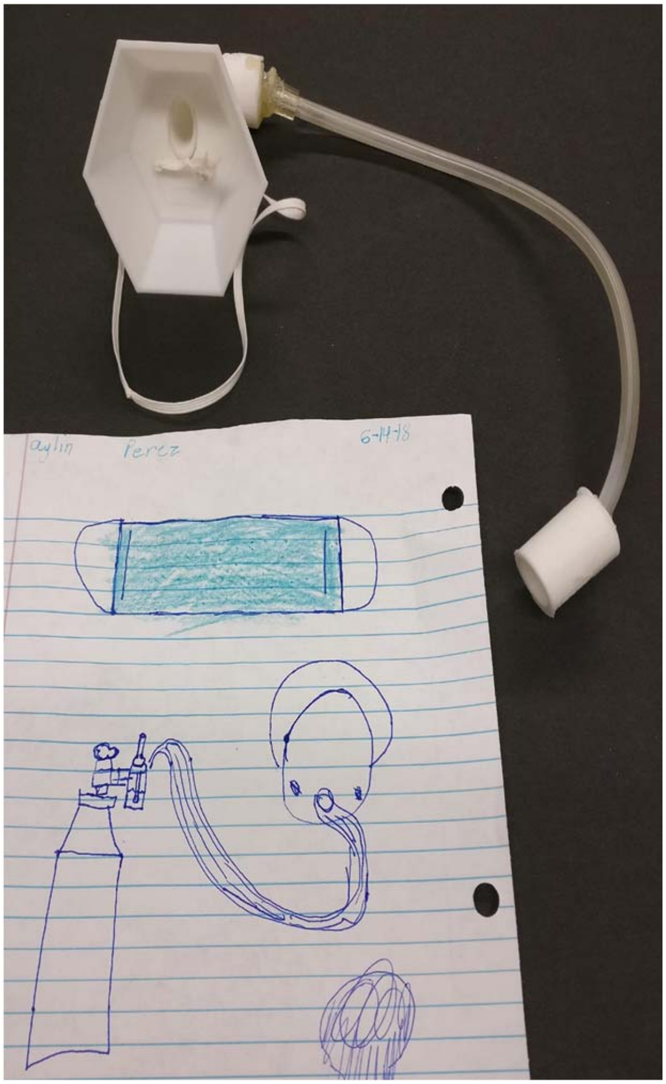

Fig. 6. A student designed gas mask and schematic.

The aforementioned skill set developed through the course of this program is vital to the production of new products based on the creativity of the youth. An example of the implementation of these skills by one of the collaborators is the "3-Dimensional kinetic generator" a device designed and created with CAD software and printed with 3d printing (Fig. 7). The "3-Dimensional kinetic generator" is a generator that converts energy from a weighted gyroscope into electricity and has the potential to provide sustainable personalized portable power to the masses. With knowledge of objects physical properties and the skillset developed through these modules this product and others like it can be imagined and developed for the benefit of society.

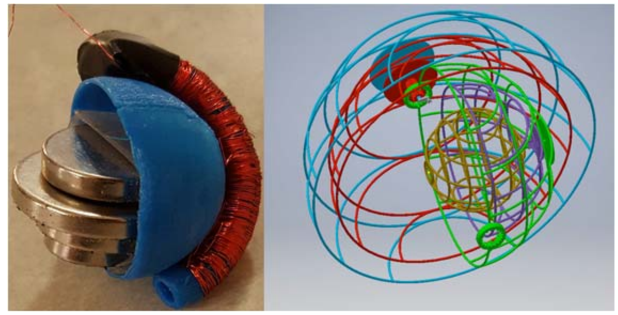

Fig. 7. Prototype/ CAD 3-Dimensional kinetic generator.

VII. Discussion

Experiential learning is a key aspect of engineering and science education and transition to applied engineering. This route and perspective on education and training provides a pragmatic approach to these disciplines that will catalyze the pipeline of new scientists and engineers. The point is to not only encourage one breed of engineers but those who pursue all engineering disciplines and interdisciplinary fields.

Our prototype camp employs modular training and recognizes the need to educate in small teams within distributed learning environments focused on various engineering tasks and relevant skills development. Our approach develops coursework that applies State of Texas educational standards and performance metrics.

The motivational factor for students in this program is excitement centered around innovation, problem-solving and product. Students see their ideas transform into engineering solutions and working prototypes that solve real world problems.

The initial challenge problem centered around personal protection measures during a disaster. The students were given a hypothetical challenge problem that addressed environmental and respiratory challenges and had multiple 3-D printing solutions. We found that this approach to engineering solutions and basic understanding of both anatomical models and engineered respiratory devices was best for attention retention and cognitive challenge. The contextual environment for learning also is ideal for team problem solving, interdependent thought, and skills development.

The uniqueness of our program is two-fold: undergraduate student educators that relate well to an elementary school population; and interdisciplinary professors serving as overall program developers, and innovators with operational focus. For example, the disaster engineering challenge is developed by a former Homeland Security Director with extensive operational experience. The planned microgrid and renewal energy camp will be led by a mechanical engineering though leader and graduate students in engineering, with complementary skills activities in 3-D printing.

Performance metrics for this educational platform are straightforward and consist of the following:

- Utility across disciplines.
- Human factors and usability.

- Interoperability with other modules/platforms.
- Ease of adaptability to the operational setting.
- Successful completion of challenge problem criteria.
- Student information retention.

VIII. Summary

Immersive, problem focused approaches to STEM education hold great promise to retain kids in the STEM pipeline. Education data indicates early intervention is the key to successful outcome metrics to include graduation from high school and continuation into higher education [5]. In addition, additive manufacturing using COTS 3-D printers provides a unique platform for modular education with embedded medical information and understanding of human physiology, biomechanics, and translational science. Ultimately, involvement of the family unit is important to ensuring student involvement, engagement, and information retention, and cultural acceptance. We believe this approach is part of a more comprehensive process to enhance our knowledge-based economy [6].

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