Alternating Learning Methods to Construct K-12 STEM Outreach: Invention and Innovation Workshop Case Study

Ralph C. Tillinghast, COL (Ret) Edward A. Petersen, and Anthony R. Ur
ralph.c.tillinghast.civ@mail.mil, edward.a.petersen.ctr@mail.mil, anthony.r.ur.civ@mail.mil,

Abstract – Conducting STEM outreach workshops in K-12 classrooms has been found to be an effective method to inspire young minds in these critical areas. This paper looks to see how utilizing different teaching methods can be used to optimize STEM outreach workshops. This is accomplished by presenting findings based on a workshop that is actively being conducted for STEM outreach with a focus on inventing and innovating. The workshop content and key learning objectives will be outlined. Furthermore this paper will discuss the different teaching methods utilized throughout the workshop. The paper will also present survey results from participants based on key learning objectives. Lastly best practices will be presented to aid in future workshop development and optimization. Overall, the purpose of this paper is to present a detailed outline of the workshop for others to utilize and demonstrate how using alternate teaching methods can optimize the impact on students.

Index Terms – Active Learning; Classroom; Education, Engineer; Invention; Innovation; Science; STEM; STEaM; Outreach; Picatinny Arsenal; Volunteering; Workshops

INTRODUCTION

A continuing focus on STEM outreach has been seen in the K-12 educational system. This focus is to ensure we have the future Science and Engineering (S&E) professionals to take on present and future challenges. There are many methods to provide STEM outreach such as, summer camp programs, providing S&E professionals in the classroom, conducting focused Teacher training, conducting student workshops or bringing new technologies into the classrooms. [1] [2] [3] Each of these provides its own advantages and can be utilized to inspire specific demographics of students.

This paper is based on the STEM outreach programs provided by the Armament Research, Development and Engineering Center (ARDEC), located at Picatinny Arsenal in New Jersey. ARDEC currently provides a wide verity of workshops with topics focused on Engineering, Machine Design, Electricity, Sensors, Innovation and Inventing. The specific findings and information presented are based on detailed surveys and past experience taken from the ARDEC community and supported students. Further, this paper draws insight from a workshop currently being utilized focused on inventing and innovating. Part I will provide a detailed description of this workshop to act as a case study while part II of this paper will provide a review of different teaching methods adopted for the workshop. Survey findings taken from the workshop participants will be presented in Part III and finally Part IV will discuss lessons learned and best practices that could be utilized when constructing STEM outreach workshops for K-12 groups.

PART I: INVENTING & INNOVATING WORKSHOP

The outreach workshop used as a case study for this paper is focused in the areas of inventing and innovation. The workshop typically takes place over a two to three hour time span and is designed for as little as 4 students, up to 24 students. To develop this workshop, a rigorous approach is utilized to fully identify the key learning objectives, both at a high overall level and also as specific take away ideas in each of the focus areas. The overall purpose of the workshop is to ensure the students have an understanding that they can be Inventors and Innovators that can bring their ideas out into the world to make a difference.
To accomplish this task six focus areas were identified for the workshop. The following sections briefly detail each of these focus areas and provide the key learning objectives for each.

I. Inventing & Innovating
This first module focuses on the fundamentals of inventing and innovating, presenting the participants with a base understanding of the need to invent and how innovation is bringing that invention to the world. Learning objectives include being able to explain the two main types of innovation (incremental and disruptive), exploring the difference between inventors and innovators and the role of failure in the inventing and innovation process.

II. Developing the Idea
With a basic understanding of innovating and inventing established, the second module focuses on methods of developing an idea. This is accomplished through learning objectives that focus on understanding the difference between "needs" and "wants", along with content focusing on how servicing emotions with an idea can create a market for the invention. Lastly, methods to develop ideas, after a need or want is identified during the workshop, are demonstrated utilizing thought stimulating exercises.

III. Tools to Bring your Idea to the Physical World
Once an idea has been constructed and outlined, it is critical that the idea be practical and can be produced. This ensures that the invention can move on to become an innovation. The third module focuses on methods and tools to test and bring the idea into reality. Students interact with hands on technologies such as 3D printers, 3D scanners, and other tools that allow them to create inexpensive prototypes. Introducing three dimensional tools has been found to promote STEM disciplines [3]. Discussions with the students on how the invention will be manufactured or distributed to the final customer are also important to ensure that the initial design is robust and can be market ready.

IV. How to Protect Your Idea
The fourth module focuses on basic steps that can be taken to ensure that the idea or invention is protected from others. Participants are presented with the concepts of provisional, utility and design patents. How non-disclosure-agreements can play a role when communicating the idea to others is also presented. This may seem like an unneeded area to discuss with K-12 students, but during the last workshop conducted as part of the army sponsored eCybermision program, multiple 4th grade participants were in licensing discussions with large companies for their ideas. [5] The most important learning objective from this module is the concept to ask for professional council if an idea is deemed to have potential.

V. Paths to Market
The focus of this module is to convey how an idea can be transitioned to the marketplace or how one transitions an invention to an innovation. This is accomplished by presenting methods and paths to market. One method utilizes the concept of developing a sell sheet for one’s invention. The sell sheet is a one page data sheet that illustrates what the inventions purpose is and its benefit to the customer. [6] With the sell sheet completed module five focuses on possible paths to market such as crowdsourcing (example: www.kickstarter.com), licensing, cold calling and direct sales.

VI. Changing the World
The last module focuses on showing how all of the steps can be utilized to take an idea and bring it to the world to make a difference. Due to the age range of participants, it is stressed that inventing and innovating can be used to take on major social issues such as world hunger and over population, or just to make someone’s day a little better. The idea promoted is making small improvements to each other’s lives may result in a large change. This view also takes some of the pressure off the young inventors, as they understand they do not have to come up with major innovations.

PART II: TEACHING METHODS
To ensure engagement in the classroom during STEM outreach, many different teaching methods can be utilized. [7] [8] It should be noted that based on the work of Felder and Silverman it is not needed to utilize every method of teaching, but a test and drop method is appropriate, when constructing material to see what students respond to. [9] Methods were alternated during the workshop in an attempt to fully engage the students and optimize learning. The following sections will detail some of the different learning methods adopted along with giving some specific examples that were utilized in the workshop.

I. Traditional
The traditional lecture method continues to have its place to introduce students to base concepts. When utilizing this method, the instructors tried to incorporate many pictures and graphics to illustrate the concepts, ensuring multiple learning styles of students are reached. [10] Figure 2, illustrates a slide discussing different types of innovation as an example.
II. Active Learning

Active learning has the advantage of putting stress on the participants by making them think and come up with their own understanding of a topic [11]. This type of learning was utilized to make the students think about the content in a different way and be forced to respond. For example this was achieved by simply asking the participant if Thomas Edison was an inventor or an innovator. Participants then need to discuss this with one another and come to a conclusion.

III. Inductive Learning

Inductive learning is another method to engage the students by presenting them with specifics on a topic and steering the discussion to better understand the overall concept. [12] In the workshop students were asked to take off one shoe and pass it forward. Each shoe was reviewed and common features were identified to show the base design of the shoe. Then unique features were identified to show how the shoe was innovative and unique. This is one example of focusing on the specifics of the shoe and working it back to the overall design.

IV. Problem Based Learning

Problem based learning has been found to be a very effective method of teaching. [13] To adopt this for the workshop an exercise was developed to force the participant to try to invent an object. This was achieved by giving each participant a block of clay and other supplies before asking one question: “What can you invent to make your day at school better?” This question allowed the student to work through the content presented and use hands on materials to develop a concept.

PART III: CASE STUDY FINDINGS

In an attempt to better understand if conducting workshops in the manner previously described had a positive impact, workshop participants were surveyed before and after the workshop event. The 6th through 9th grade participants from multiple states in this case study were evenly distributed, both in ethnicity and gender. This data was collected to see if the critical learning objectives outlined in Part I did in fact have an impact on the students. The questions also assessed the mindset of the students. Such as 100% of the students stating that they liked to solve problems and 89% indicating they feel it is OK to be wrong. 78% of participants felt they were inventors before the workshop followed by 89% after the workshop. 100% of participants stated they feel they can make a difference in the world, showing a positive optimistic/growth mindset. As illustrated in Figure 2, participants were able to define disruptive innovation after the workshop.

This indicates that the students did absorb some of the key learning objectives during the workshop. Access to the students after the workshop was desired to evaluate long term retention. This was not granted due to student privacy considerations.

PART IV: LESSONS LEARNED

Based on the authors experiences in conducting STEM outreach and various workshops, a culmination of the best practices and lessons learned have been identified. The following sections will further detail these lessons learned.

I. Meet the Teachers Needs

The teacher is the gate keeper to the students. It is important to understand and match the outreach support to the teacher’s needs.

II. Learning Objectives

Taking the time to layout the learning objectives for the outreach workshop ensures that the time spent with the students is organized and focused on the core learning goals. Further, it allows the instructor to identify and capitalize on teachable moments. This allows the instructor to create a more holistic workshop, where each module can feed into one another and support past materials.
III. Switch between Teaching Methods

The authors have found it very effective to switch from one teaching method to another during the workshop. This aids in maintaining the momentum and focus of the students. It also allows for the students different learning styles [8] to be satisfied by alternating the delivery.

IV. Provide Physical Examples

As referenced above alternating deliveries is critical. This can also be accomplished by providing physical examples for student interaction. This can include actual tools or technologies, such as 3D printers. It can also act as a level of ‘shock and awe’ that has a way of boosting focus and excitement. Bringing in examples that can relate to toys or current trends can increase interest.

V. Grab Attention Early

During the first few minutes of the workshop, the authors have found it important to grab the student’s attention with something unexpected. It tends to increase their focus and ensure they do not see this activity as just another day in the classroom. This can be achieved just by using simple power point slides as illustrated in Figure 3, showing how the inventing can be taking an everyday object and modifying it to make it better.

![Figure 3](example.png)

**FIGURE 3**
EXAMPLE SLIDE TO GRAB PARTICIPANTS ATTENTION

CONCLUSIONS

Conducting outreach is a critical tool that should be utilized to inspire young minds to pursue STEM careers. The workshop presented is only an example of possible STEM based workshops. Based on the survey results and students engagement during the workshops the approach utilized by the authors has been found to be effective. Further the lessons learned about different teaching methods can be applied universally when STEM professionals augment regular classroom discussions.

REFERENCES


AUTHOR INFORMATION

Ralph C. Tillinghast, Lab Director, Collaboration Innovation Lab, Armament Research Development Engineering Center (ARDEC), U.S. Army, Picatinny Arsenal, N.J.

COL Edward A. Petersen (Ret), Program Manager, ARDEC STEM Office, ARDEC, U.S. Army, Picatinny Arsenal, N.J.

Anthony Ur, Lead Visual Information Specialist, ARDEC, U.S. Army, Picatinny Arsenal, N.J.