Makers on the Move: Constructing an Outreach Program with a Mobile Maker Space

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***Abstract* - This paper presents results of a pilot outreach and service-learning program, Makers on the Move, which reached 5,000+ students and community members through venues such as career expositions, Mini Maker Faire, and high schools in its first year. Makers on the Move, developed by the College of Engineering Student Success Center at Tennessee Tech, offers hands-on STEM experiences on topics ranging from electromagnetics to alternative power to middle- and high-school students. Engineering student volunteers lead the experiences, which are developed by faculty and staff in Tech's STEM Center in accordance with the Legacy Cycle and Tennessee state science standards. Most of the experiences take place on the STEMmobile, a mobile STEM education lab. This paper describes the program's first year activities; collaboration between STEM Center faculty and staff, Success Center staff, volunteers, and industry partners; and assessment of the pilot year. Overall, the assessment indicates that the program has the potential to have a large impact for participants and volunteers. This assessment is based on number of participants, volunteers, and events, as well as measurable improvements in students' understanding of STEM concepts. The authors discuss the value of the program regarding recruitment, retention, and persistence in STEM.**

Index Terms - High Impact Practices (HIP's), Maker spaces, Service-learning, STEM outreach, Student success

INTRODUCTION

While theories about recruitment, retention, and student success offer insight into best practices for faculty members and student success professionals, more evidence-based research will help these professionals better address the need for higher enrollment, retention, and persistence rates for engineers, a need outlined by several entities. For example, the U.S. Department of Labor [1] has argued that STEM training and jobs are central to the U.S. economy, and the National Science Foundation [2], which, in their 2015 report, *Revising the STEM Workforce*, determined that "the STEM workforce is extensive and critical to innovation and competitiveness" [2, p. 1]. The need exists, too, on a local level for Tennessee Tech University graduates. In their annual report, the Tennessee Higher Education Commission cited there is a high demand for and deficit in skilled engineers in Tennessee, especially in transportation, construction, and industrial engineering [3, p. 15].

Thus, to ensure that engineering programs grow enrollment and increase retention and persistence of diverse, academically talented students who can contribute immediately to the STEM workforce upon graduation, there is a need to develop, assess, and evaluate recruitment and retention practices. At Tennessee Tech, the College of Engineering's Student Success Center has developed a high-impact practice through the program Makers on the Move in collaboration with the university's Millard Oakley STEM Center. This program utilizes outreach in the form of service-learning, a well-documented recruitment and student success tool [4-8]. This paper describes, assesses, and evaluates the program's pilot year, and it discusses the future plans for the program.

Background

In September 2015, the College of Engineering Student Success Center at Tennessee Tech launched its outreach program, Makers on the Move. The program fits the Center's three-tiered approach to student success: recruitment, retention, and recognition of academically talented, diverse engineering students. The first event took place at a Mini Maker Faire in Chattanooga, TN and included student competition teams from Tech, such as Baja SAE and Formula SAE, as well as volunteers on the STEMmobile, a mobile STEM education lab. The STEMmobile was set up with stations offering hands-on STEM-related experiences, such as activities using magnets and circuits. The volunteers were trained by the Millard Oakley STEM Center faculty and staff. It is estimated that 1,500 people attended the Chattanooga Mini Maker Faire.

Both the STEM Center at Tech and the STEMmobile play a pivotal role in the Makers on the Move program. The Millard Oakley STEM Center is an educational center that opened at Tech in 2010 to offer STEM enrichment, outreach, and professional development to students and teachers in the Upper Cumberland region. The Center hosts and organizes many events and resources to achieve their mission, offering enrichment and professional development, for example, with a learning library, a math professionals

learning community, and professional development for primary and secondary educators specifically about Tennessee science standards. Moreover, the STEM Center offers outreach through free community events for children.

Regarding the STEMmobile, the STEM Center offers science, technology, engineering, and mathematics curriculum to schools in the Upper Cumberland region through this mobile STEM education laboratory. The STEMmobile is a 53-foot trailer furnished with six steel lab/work stations, six large flat screen televisions, and a classroom set of iPads. It was developed in response to a need for better STEM education in K-8, especially in the rural Upper Cumberland area. In brief, the STEMmobile is rented by an elementary or middle school and transported to that school, where the local teachers utilize the equipment to deliver lessons. In preparation, those teachers attend a professional development workshop and are supported with lesson plans and other teaching materials developed by the Millard Oakley STEM Center staff.

The STEMmobile has proven to be a remarkably valuable asset to the region. The lessons developed for the lab are based on the Legacy Cycle, a curriculum developed in response to the findings presented in *How People Learn* [9], findings suggesting that, for optimal learning to take place, the learning environment must meet the following criteria: knowledge-centered, student-centered, assessment-centered, and community-centered [10]. Thus, lessons on the STEMmobile have been developed as project-based learning experiences, and those lessons are assessed through pre- and post-tests. Moreover, the curriculum has been developed to support Tennessee State standards. Regarding the success of the STEMmobile, it reached 6000+ students in the 2013-2014 school year, and assessments showed on average a 34% increase in correct answers from pre- to post-tests [11].

While the STEMmobile's primary purposes are to offer elementary- and middle-school teachers professional development in STEM education and to provide elementary- and middle-school students innovative and valuable educational experiences, the Makers on the Move program was developed with different but complementary goals and objectives: 1.) To recruit students into STEM; 2.) To offer high school students valuable STEM enrichment experiences; and, 3.) To offer a high-impact practice (HIP), as defined by the National Survey of Student Success, to current engineering students.

In order to meet these goals and objectives, the Makers on the Move program has been developed as follows. The program team establishes contacts with industry partners, teachers, and school board representatives who then "book" the STEMmobile for the Makers on the Move program, at no cost. Tech's College of Engineering Student Success Center covers the cost for the STEMmobile, costs which range from $2,000-$3,000, depending on travel distance. In addition, the Makers on the Move program team seeks out venues where there can be a large community impact, such as the Chattanooga Mini Maker Faire mentioned above. Once venues are set, the stakeholders (teachers, industry partners) communicate with the team and decide what activities or experiences to include in the program at the venue. For more community-based venues, short experiences are prepared, while for school-based venues, lengthier, more in-depth experiences are prepared. An example of a short experience is using magnets, while an example of a more in-depth experience is understanding alternative energy technologies. Finally, the team recruits engineering students to volunteer for the upcoming venues. The STEM Center staff offers these volunteers professional development training on the venue's experience/activities.

The program predominantly utilizes the STEMmobile as a makerspace where these near-peers (college students) who participate in the professional development training lead the lessons for middle and high school students. By tapping into the concepts of makerspace, outreach, and service learning, the team hopes to increase recruitment and retention in STEM, especially engineering. The makerspace is conceived as a place where students engage in active learning in a collaborative atmosphere and reflects the growing trend across the U.S., where libraries, museums, and educational institutions, including Tennessee Tech, are constructing spaces where people from all backgrounds can learn and experiment with science and technology [12]. As a description of how the STEMmobile experiences act as a makerspace, take the short experience mentioned above: magnets. One station on the STEMmobile is set up with a bowl full of water and a ping-pong ball attached to a magnet, floating in the water. All around the bowl are pegs on which participants can place magnets. To demonstrate attraction and repulsion, students can move the ping-pong ball by placing magnets on different pegs. Other short experiences include creating a motor with a battery, paper clips, magnets, and a wire; or, creating simple or complex circuits.

A more in-depth experience in the makerspace is, for example, a lesson on windmills. In brief, students are shown a short PPT, created by the STEM Center faculty/staff, which asks students, "How do we capture energy from the wind?" [14]. After offering some background information on the mechanics of a windmill and on the process by which windmills generate energy, the lesson continues by encouraging students to build their own windmill for optimal energy generation. In groups, they formulate hypotheses: how many windmill blades are optimal? What blade shape(s) are optimal? Blade thickness? Pitch? Then, they test out the hypothesis by putting together a windmill (parts provided by a kit) and, using a fan and a multi-meter, determining what combination of blades and pitch generate the most energy. At the end of the allotted time, students gather to discuss their findings and to consider why, for example, a windmill with three blades works better than one with six blades.

The makerspace offers a shift from a teacher-led space to a student-led space where college students can serve as role models. Recruitment literature tells us that student-led

outreach can be a very effective tool [14], especially for students who are under-represented in the field and thus may be unaware of what it means, for example, to do engineering [15, p. 20]-[16, p. 31]. Furthermore, research suggests that outreach programs involving undergraduates offer valuable learning experiences for high school students [17]. Finally, the program offers engineering students the opportunity to participate in a high-impact practice. Participation in high-impact practices, especially when fostered by a student's institution, can play an important role in students' engagement and, thus, in their success [18-20]. Several researchers have pointed out that the networks and skills built by these types of co-curricular activities help improve under-represented students' chances for success [21-24]. In this paper, the authors will describe the program's activities during 2015-2016, its pilot year.

ANALYSIS

What we will report in this paper is the impact of the program that we can measure thus far. First, we provide a description of the program's activities and volunteers. Second, we summarize the impact in terms of how many people interacted with the Makers on the Move volunteers. Third, we offer statistics about the effectiveness of the activities.

TABLE I
OVERVIEW OF MAKERS ON THE MOVE ACTIVITIES

Date	Event	# of Participants	Lessons offered
Sept. 2015	Mini Maker Faire Chattanooga	1,500 community members	Electric motors
Nov. 2015	Eastman Chemical Co., 11th Grade Career Expo	12 schools 1,049 students	Electric motors
March 2015	Eastman Chemical 8th Grade Career Expo	12 schools, 1,609 students	Electric motors Circuits
March 2015	DENSO-Athens Career Expo	6 schools, 248 students	Electric motors Circuits
March 2015	Grundy County High School	200 students	Robotics and programming Wind Power
March 2015	Coffee County High School	200 students	Wind Power
March 2015	STEM Camp (through the University of Tennessee Extension Office in Murfreesboro, TN)	2 schools, 25 students	Simple engine and circuits Wind power Hydro power Finch robots Density Rockets Solar power
April 2015	Stone Memorial High School, Cumberland County High School, and Phoenix High School (all at Stone Memorial)	3 schools, 400 students	Wind power Finch robots
April 2015	Baja Competition	20 community members	Magnets Circuits

Table 1 describes the different events Makers on the Move participated in during the 2015-2016 academic year. The events range from the public events, such as the Chattanooga Mini-Maker Faire and the Baja Competition, to company-sponsored events, such as the Eastman Career Expos, to events where the program traveled to specific schools, such as Coffee County High School. Table 1 also indicates what types of lessons stakeholders asked the program's team to prepare. These lessons, prepared by STEM Center staff, ranged from short experiences of 5-10 minutes in length for public events to longer experiences of 20-45 minutes for school-based events. Thus, during the program's pilot year, Makers on the Move provided outreach in a variety of venues and with a variety of lessons.

TABLE 2
DESCRIPTION OF STUDENT VOLUNTEERS

Average GPA	**Breakdown by Class**		**Breakdown by Academic Department**		**Breakdown by Gender and Ethnicity**	
3.08	Freshman	20.83%	CEE	12.5%	Male	75%
	Sophomore	12.5%	CHE	33.33%	Female	25%
	Junior	20.83%	CSC	12.5%	White	79%
	Senior	37.5%	ME	33.33%	African American	21%
	Grad student	8.33%	MET	8.33%		

Table 2 describes the student volunteers who were trained for Makers on the Move by the STEM Center faculty and staff, showing a diverse set of students interested in the program. Each class was represented, with slightly more seniors than other groups participating. Six out of eight academic departments in the College of Engineering were represented, with Chemical Engineering and Mechanical Engineering having the largest numbers of participants. Finally, a quarter of the volunteers were female, while the rest were male. While women only made up 25% of the volunteers, this percentage is slightly higher than the percentage of women currently enrolled in engineering at the university (11%), according to the Office of Institutional Research at Tennessee Tech [25]. Similarly, volunteers represented a higher percentage of under-represented minorities (21%) than are currently enrolled in the College of Engineering (6%). Thus, this description of the student volunteers provides a picture of a diverse group of students actively engaged in the Makers on the Move outreach.

TABLE 3
SUMMARY OF MAKERS ON THE MOVE IMPACT

Total # of events	**9**
Total # of days	29
Total # of student volunteers	24
Total # of people impacted (students and community members)	5,000+
Total # of participating schools (middle and high schools)	35

Table 3 offers a snapshot into the impact that the Makers on the Move program had, especially regarding how many

students and community members were exposed to the program. For example, at the Eastman Career Expositions in fall and spring, 1,049 11th graders and 1,609 8th graders rotated on and off the STEMmobile. Approximately 5,000+ community members and students were reached via this program, and 35 middle and high schools participated.

Data was also collected on three of the activities: Wind, Hydro, and Density, through pre- and post-tests. While other activities and experiences were offered, as shown in Table 1, these three activities were the focus of educational assessment, adding to the database of assessments the STEM Center staff has already collected in the preceding three years of operations. The following tables show the results from the data analysis:

TABLE 4
DESCRIPTIVE STATISTICS OF PRE- AND POST- TESTS

	Mean	SD	Min	Max	N
Density					
Pre-test	4.26	1.46	0	6	415
Post-test	5.30	1.06	0	6	415
Hydro					
Pre-test	2.54	1.30	0	5	184
Post-test	3.42	1.12	0	5	184
Wind					
Pre-test	4.62	1.48	0	6	333
Post-test	5.27	1.00	0	6	333

Table 4 shows that students' correct answers on the post-test exceeded correct answers on the pre-test, for each of the three activities. For example, before the density, hydro, and wind activities, students were asked simple questions pertaining to the activity, such as "Volume is how much space an object takes up" with the following options available, *true, false, I don't know*, with the density test consisting of six questions, the hydro test consisting of five questions, and the wind test consisting of six questions. After taking the pre-test, students were asked to set these aside, and the lesson proceeded. At the end of the lesson, they took the post-test (exactly like the pre-test), before commencing with a discussion of what was learned. The data in Table 4 suggest that the activity was successful in raising students' knowledge on the various topics of density, hydro power, and wind power.

TABLE 5
PAIR-SAMPLE T-TESTS FOR MEAN-DIFFERENCE BETWEEN PRE-TESTS AND POST-TESTS

	Density	Hydro	Wind
Pre-test	4.26	2.54	4.62
	(1.46)	(1.30)	(1.48)
Post-test	5.30	3.42	5.27
	(1.06)	(1.12)	(1.00)
Mean diff.	1.04	.89	.65
t	14.06***	8.56***	7.77***
Pr-Pst % Increase	17.3%	17.6%	10.8%

Note: Standard deviation in parentheses.
* p<.05; ** p<.01; *** p<.001

Tables 4 and 5 show that, based upon paired-sample t-tests, the post-test scores for density were, on average, just over one point higher (mean diff.=1.04), which is a 17 percent increase from the pre-test scores (t=14.06; p<.001). Similarly, the post-test scores for hydro were over 17 percent than the pre-test score; that it, the were almost a point higher than the pre-test scores (mean diff.=.89; t=8.56; p<.001). Finally, although the post-test scores for wind were higher than the pre-test (mean diff.=.65; t=7.77; p<.001), they had the smallest increase of the tests with just over a 10 percent increase. Thus, these data suggest that the Makers on the Move program offers a valuable learning environment for middle- and high-school students.

DISCUSSION

It was found that the Makers on the Move program showed overall success in its pilot year. For example, the program showed positive growth from two events in fall 2015 to seven events in spring 2016. Regarding recruitment of diverse students, we have a diverse set of student volunteers, with the theory that they will inspire a wide range of middle- and high-school students to enroll in a STEM program. In terms of student persistence and retention, though correlations between student success and the Makers on the Move program cannot be made, each one of the volunteers for the program has either graduated May 2016 or is persisting towards their degree (i.e., is enrolled in engineering for fall 2016). Furthermore, the program's educational value has shown success, with an increase in the percentage of correct answers from pre- to post-tests on three assessed activities. Finally, as a marker of the program's success, the Makers team was recently awarded funding from two sources: a grant from the Tennessee Board of Regents, Tennessee's state university governing board, and additional funding from the Advisory Council for Engineering's non-profit foundation.

Next steps in developing the program are based on a reflection of what worked and what challenges we encountered during the early stages. In addition to asking ourselves to reflect, we solicited feedback from our volunteers—following are some of the responses to the question, what did you like best about volunteering for Makers on the Move?

- *I enjoy being able to get children interested in engineering.*
- *Learning, teaching others, and sharing my experiences to help others in their future life.*
- *I love helping younger students succeed.*
- *By volunteering with makers on the move, I got the chance to work with kids so that they can learn the same things that I know. And also it was a chance for me to learn about things that I didn't know about it.*

Volunteers were also asked to respond to the question, where do you see the need for improvement for the Makers on the Move program?

- *There were too many events during the school week, and the program could've been much more in depth or enriching*

- *Times*
- *More advertisement! STEM is awesome!*
- *Makers on the Move could create a series of programs to help students gain real world experience.*
- *More word of mouth advertising*

The first set of responses indicate an enthusiasm for engaging in a meaningful activity exists, reflecting the idea that service-learning programs like Makers on the Move have the potential to be a high-impact practice, with significant impact on student retention and success [26]-[6]-[7].

The second set of responses reflect also what we learned through the pilot year, as well as our recommendations for moving forward:

TABLE 6
REFLECTION AND RECOMMENDATIONS

Lessons	Recommendations
Volunteers' academic schedules were challenging to work around.	Schedule events during college students' breaks, such as fall break, winter break, and spring break. Schedule more weekend events.
Student volunteer buy-in to the program needs to be increased.	Offer enrichment opportunities, such as developing their own lesson plans and assessment tools. Offer plant tours and networking opportunities when volunteering at a company. Offer professional development, such as communication skills training, to volunteers.
Engineering faculty were, in general, lacking in awareness about the program.	Increase faculty knowledge by promoting the program as well as by registering the program with the Office of Service Learning on campus.
Aside from a small cohort of volunteers, it was challenging to recruit for the program.	Increase student awareness of the program through informational meetings as well as by registering with the Office of Service Learning.
Costs for the program (STEMmobile operating costs, mileage and lodging for volunteers, and advertisement costs).	Offer company advertisement for help with costs. Apply for grant monies to offset costs.

Table 6 details the team's assessment of the program from an administrative standpoint. As with any newly developed program, the team encountered challenges. In the case of Makers on the Move, the largest challenges were in two categories: general knowledge about the program on campus and student schedules. Despite advertisement on the College of Engineering website and through brief informational presentations to student groups, engineering faculty members and engineering students, in general, lacked a thorough understanding of Makers on the Move's goals, objectives, and activities. Moreover, while the program did attract a small cohort of volunteers (24), it was difficult to staff the program for events taking place during the week, as those events interfered with students' course schedules. In response to these problems, the team plans to hold an informational meeting about Makers on the Move at the start of fall 2016 semester, register the program with the university's Service-Learning Center, and schedule events as much as possible during the students' school breaks (such as fall break, winter break, and spring break). By increasing awareness of the program, as well as opportunities to earn service credit, the team hopes that a larger cohort will be built, resolving staffing issues.

In addition to resolving these logistical issues, the team also hopes to increase professional development and enrichment for the volunteers. In order to do so, students will be asked to collaborate with the STEM Center staff to create their own curriculum. For example, students belonging to competition teams, such as Concrete Canoe or Steel Bridge, or students belonging to organizations such as Autonomous Robotics Club, will develop lessons based on the Legacy Cycle, working with the STEM Center staff to ensure the curriculum meets the criteria for optimal learning and reflects Tennessee State standards. The rationale behind this approach is that it is student-centered, will build a learning community (another high-impact practice), and will increase volunteers' ownership and motivation in regard to the Makers on the Move program.

Finally, the team has developed a set of research questions, based on the pilot year, which they will pursue. The team has obtained IRB approval to distribute a survey in the next year, addressing the following questions about student retention:

1. What motivates students to volunteer for the program?
2. Did student volunteers feel that the program built a learning community?
3. What level of confidence do student volunteers have in their STEM and communication skills?

In addition to collecting and analyzing data pertaining to student retention, the team has plans to collect contact cards from middle- and high-school students participating in the program and analyze enrollment databases to explore the impact of the program on recruitment, looking not only at general enrollment, but also exploring impact on recruitment of diverse students.

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