Stormwater Management Research Team - SMART Supports Success of Students

Program Impact since 2014

University of Maine "Engineering Innovative Solutions to Stormwater Problems through Diverse Community Participation" NSF Award # 1348266; \$735,315; 10/1/2013-9/30/2016, PI: M. Musavi, Co-PIs: A. Abedi, C. James, J. Vetelino, J. Peckenham.

- Trained over 200 students from 20 different schools in science and engineering of stormwater
- Trained 25 teachers in science and engineering of stormwater providing 3 CEU credits/year
- Supported 4-5 day overnight experience for 200 high school students at UMaine campus
- Provided 250 total annual stipends to both teachers and students for completing training and yearlong research projects on local stormwater issues
- Engaged a diverse population in a low-diversity state: annually 75-84 % of SMART student participants have self-identified as either female or a racial minority
- **41% SMART students now accepted or enrolled in a STEM degree program** of approximately 125 currently college-eligible former and current SMART students
 - Declared majors 20% in engineering, including chemical engineering, electrical engineering; also biology, computer science, marine biology, physics
 - o 84% of these STEM students are either female or URM (underrepresented minority)
- Supplied Maine high school labs with water testing equipment including 5 Quanti-tray sealers, 5 incubators, 5 spectrophotometers, 5 UV lights, 12 LabQuest data collection units, 20 macroinvertebrate bug nets, 5 dissolved oxygen meters
- Analyzed 131 water samples taken by SMART students for total phosphorus via resources of UMaine Climate Change laboratory
- Measured by students: over 4000 water parameters at over 30 sites statewide and entered data points (e.g., temperature, conductivity, pH) into common online database
- Employed 4 graduate students and 3 undergraduate students from UMaine engineering programs
- Developed new intellectual property for remote water data collection *Wireless Stormwater Research Box at right*
 - SMART-supported graduate student developed remote data acquisition device for continual collection of water data
 - Specs: Solar panel used to power system and charge battery, Internal battery allows continuous power even while not sunny, sensors include: (1) EZO pH sensor, (1) EZO Conductivity sensor (conductivity, salinity, specific gravity, dissolved solvents), (1) Temperature sensor; SD card for storing data



(backup); XBee for wireless communication for real time readout, or remote data access, Real time clock IC used to keep track of date/time and collect data at equal intervals

- Programmable to collect data on intervals from as small as 15 seconds per data collection to as large as desired with a 1 second incremental resolution
- System sleeps between taking data points to decrease power consumption and increase runtime between charges
- Designed to allow for easily adding additional EZO sensors (standard box and PCB would need to be modified/added)
- Entered science competitions in Maine and nationally: 36 SMART Students presented their projects on stormwater and other topics 3 stormwater projects awarded first or second place
- Gained national recognition for stormwater research: SMART student Paige Brown (center in photo below) awarded first place in Global Good category at the national Intel Science Talent Search for her project on mitigation of phosphorus in stormwater



- Attracted additional funding from community: IDEXX Corporation, Emera Maine (electric power utility), Maine Community Foundation, Bangor Savings Bank, and other individual donors provided substantial donations
- Administered total of 11 surveys over 3 years to both students and teacher-mentors resulting in these emerging *trends*:
 - URM Females: 100 percent of URM Females said it was very important to help make a difference in their community (2016 cohort)
 - Their relationship with mentors, meeting with stormwater group, an awareness of how stormwater affects the community, and brainstorming solutions to stormwater problems increased Female and URM interest in pursuing a STEM major or career
 - Females express a lower level of confidence in performing science- and engineering-

related tasks than males

- Participating in SMART increased URM student confidence in taking STEM courses
- Most mentors agree/strongly agree the SMART program helped students gain confidence in STEM skills
- More than half of teachers believe they have little access to opportunities to work with other teachers and time available to plan and prepare lessons. Almost half have Little Access to opportunities for teacher PD
- More than half of teachers are not at all or only slightly confident teaching Engineering. All now have at least some knowledge of stormwater and its impact on our environment.
- More than half of teachers (June 2016) are in schools that do not offer a program to mentor underserved students to engage in science and engineering

Project Evaluation Results - July 2016 report

The UMaine SMART Program has demonstrated that it can provide students and teachers with valuable and interactive educational opportunities that use science and engineering to solve local problems. For example, prior to the 2015 SMART Summer Institute, nearly 60% (58.3%) of participating students reported that they had never used a wireless sensor network and nearly half (47.2%) had never collected water data via probes. This fell to just 7.7% and 6.2%, respectively, post-institute – with further opportunities to engage in hands-on research using emerging technology throughout the school year.

As expected, project data suggest that these experiences are effective in promoting interest in STEM education and careers among participants. Students in the 2015 cohort reported that numerous key components of the summer institute made them "somewhat" or "to a great extent" more likely to apply to a STEM program in college. These included participating in real-world, community-based research opportunities (83.1%), and then using these experiences to research real issues facing their community (93.7%), helping to solve these local problems (95.3%).

These data highlight the importance students place on finding solutions and feeling empowered to address these problems by connecting with their community. However, without projects such as SMART, few students have such opportunities. Prior to participation, nearly half of students (48.6%) indicated that they had never used data to help solve a local environmental problem, and three-fourths (74.3%) indicated that they had never worked with environmental officials. SMART provides students with repeated such opportunities across the academic year.

Not surprisingly, SMART has further demonstrated that it can use these experiences to promote interest in STEM and careers specifically for females and minorities. As shown in Table 3 below, the majority of participants and nearly one third of students are from ethnic minority groups; Maine's population of minorities is under 4%. Participation by these groups does indeed translate to greater interest in STEM, with female participants reporting significantly greater levels of knowledge in Engineering (t(33)=4.146, p<.001), Chemistry (t(33)=3.016, p=.005), and Biological science disciplines (t(33)=2.431, p=.021) two months after the summer institute. Table 4 below shows the change in students' interest in STEM after participants—the greatest reported by males, the change among female and minorities is considerable.

Ultimately, the goal is to improve enrollment, especially among female and minority students, in postsecondary STEM fields. While documenting such impacts will take time, results based on the 2014 cohort of students are promising. Nineteen of 20 graduating high school students who completed post-

program surveys reported that they had applied to college – and the remaining student indicated that they planned to apply. This far exceeds the statewide average of 62% of seniors attending college in the following year. Of those who had applied to college, most anticipated majoring in a STEM field, including 84% of females. Half of the male participants (50%) indicated that they planned to major in Engineering, and almost half of female respondents (46%) planned to major in Biology. Forty-seven percent (47%) were planning to enroll at the University of Maine.

Students	2014 (61)	2015 (78)	2016 (81)
Male	34%	36%	42%
Female	66%	64%	58%
Caucasian	43%	59%	54%
Black	26%	10%	15%
Hispanic	8%	3%	6%
Native	160/	100/	10%
American	1070	1070	1070
Others	5%	6%	15%

Table 3: SMART Student Participation

Table 4:	Change in	level of interes	st in a STEM	college or care	er after o	completing SMART
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How has your level of interest in choosing a STEM major/career changed since June, prior to the SMART Summer Institute	Male (<i>n</i> = 20)		Female $(n = 37)$		White (<i>n</i> = 39)		URM (n = 18)		All Students $(n = 57)$	
	N	Pct.	N	Pct.	N	Pct.	Ν	Pct.	N	Pct.
I am less interested	0	0.0%	1	2.7%	1	2.6%	0	0.0%	1	1.8%
My interest has not changed	9	45.0 %	20	54.1 %	18	46.2 %	11	61.1%	29	50.9 %
I am more interested	11	55.0 %	16	43.2 %	20	51.3 %	7	38.9%	27	47.4 %

Related Publications to date

James, C. J. Isherwood, M. Musavi. (2017). Changing the Face of STEM with Stormwater Research: University of Maine's SMART Program. Submitted to IEEE Frontiers in Education 47th Annual Conference, Indianapolis, October 2017.

Brown, P., C. James, M. Musavi. (2016). Engineering and Science Practices of Stormwater Problems for High School STEM Education. Paper ID #16649. American Society of Engineering Educators Annual Conference and Exposition: K-12 & Pre-College Engineering Division: Fundamental & Research-to-Practice: K-12 Engineering Resources: Best Practices in Curriculum Design, New Orleans, June 2016: ASEE.

Musavi, M., C. James. (2015). Transformative Apprentice Research STEM Program, Paper ID #14070A. 122nd American Society of Engineering Educators Annual Conference and Exposition, Seattle, WA, June 2015: ASEE.

Musavi, M. A., Abedi, J. Vetelino, J. Peckenham, J. Isherwood. (2015). Attracting High School Female and Underrepresented Minorities to STEM, Institute of Electrical and Electronics Engineers Integrated STEM Education Conference (ISEC '15), March 2015: IEEE.

Next phase: NSF INCLUDES

Technical Abstract for NSF INCLUDES Collaborative: Creating a Diverse STEM Pathway with Community Water Research, NSF Award #1649346;: \$299,451

This INCLUDES collaborative will not simply replicate the SMART program, which has been implemented and adapted to a variety of local Maine communities, but will specifically address the water, demographic and cultural needs of each location. It will address the global challenge of water quality and availability with an immediate communal and local benefit [Ball 2011; Grosman & Parker 2012; Dyer-Barr 2013a, 2013b; Salto et al. 2014). Using a global challenge to meet local needs and the effect of invested mentors accompanying the students in their discovery, has been shown to be a principal driver in attracting URM and females to STEM [Atman et al. 2010; National Academy of Sciences 2011).

Through a recent broadening participation project called SMART (Stormwater Research Management Team; NSF-EPSCoR award #1348266) based at the University of Maine, the research team found that there is a crucial need for more engaging and continuous educational opportunities that are active and relevant to students, which build confidence and connect knowledge and skills directly to solving problems in their communities and to their own cultural identities. There is also a need for long-term invested mentors that guide underrepresented students through crucial transitions periods from middle to high school and from high school to college.

The long-term vision of this effort is to broaden the impact of a successful model that uses the topic of stormwater science and engineering solutions to engage and build confidence of underrepresented minorities (URM) and female students in STEM fields. Long term success will be measured by a significant increase in the number of URM-in-STEM students who succeed throughout school and into STEM careers. Toward that vision, the goal of this project is to identify and engage an effective system of partners in offering and improving opportunities for women and URM students into STEM using stormwater as a topic.

This pilot project will form an INCLUDES Alliance and define a strategic plan for scale-up to a national alliance resulting in a coordinated effort to increase the long-term success rate of URM-in-STEM K-12 students into the STEM workforce and higher education. The collaborative of multiple and varied organizations will align to collectively contribute time and resources to a pre-college educational pathway. There are countless isolated STEM programs that offer short-term interventions for URM students; however, there is lack of organizational coordination for aligning current program offerings, sharing best practices, research results or program outcomes along the education to workforce pathway. The Alliance activities will emphasize relationships among skills, confidence, culture and future careers.

Alliance partners will define and establish a centralized infrastructure in each location to coordinate recruiting of invested community leaders, educators, and parents, around a common agenda by designing, deploying and continually assessing a stormwater themed project that addresses their location and demographic specific needs. The INCLUDES Alliance community will consist of higher education faculty and students, K-12 students, their caregivers, mentors, educators, stormwater districts, state and national environmental protection agencies, departments of education, and other for-profit and non-profit organizations. The Alliance will address the need for research on mechanisms for change, collaboration, and negotiation regarding the greater participation of under-represented groups in the STEM workforce.

References

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Dyer-Barr, R. 2013a. What Works in STEM Intervention Programs (SIPs) for URM Undergraduates: Perspectives from SIP Administrators, ASQ Advancing the STEM Agenda Conference Session 2-4 Grand Valley State University- Grand Rapids, Michigan - June 3-4, 2013.

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