Research Management Review, Volume 20, Number 2 (2015)

Promoting Strategic STEM Education Outreach Programming Using a Systems-based STEM-EO Model

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Abstract

In this paper a STEM Education Outreach (STEM-EO) Model for promoting strategic university outreach programming at Penn State University to the benefit of university, school district and community stakeholders is described. The model considers STEM-EO as a complex system involving overarching learning goals addressed within four outreach domains and multiple outreach dimensions. The STEM-EO Framework provides a visual representation summarizing the complex system of interacting elements comprising STEM-EO. The STEM-EO Goals identify core aspects of STEM learning that support STEM literacy and address challenges facing the STEM pipeline. The STEM-EO Dimensions describe the context of specific projects, defining finer-grained characteristics, such as the nature of the targeted audience(s), educational setting, and methods of instructional engagement. The combination of Framework, Goals, and Dimensions provides a detailed description of projects and a multi-level grid on which to map and understand existing projects in terms of the pipeline, domains, goals, and dimensions. It allows more accurate identification of gaps in STEM-EO programming and development of projects that will help fill those gaps. This combination also emphasizes the importance of goal/assessment driven programming while recognizing the need to consider aspects of program dimensions and influence within and across domains during goal and assessment design and interpretation of assessment data.

BACKGROUND/RATIONALE

In an era of waning interest in and performance of U.S. students in science, technology, engineering and math (STEM), a number of challenges plague STEM area professionals and educators. These challenges arise from leaks and gaps in the STEM career pipeline for U.S. students due to a variety of factors, such as underrepresentation of women and minorities interested in STEM careers, lack of interest and preparedness of U.S. students entering STEM higher education programs, and declining retention of U.S. students in STEM programs (Darling-Hammond, 2011; Lowell et al., 2009; National Academy of Science & National Research Council, 2009; National Center for Education Statistics, 2012a,b). One mechanism through which higher education institutions may become more involved is STEM Education Outreach (STEM-EO) projects. These activities utilize universities' resources such as personnel, facilities, and funds to impact STEM learning outside of the institution's own particular education domain. They draw on the expertise of university STEM faculty, undergraduate and graduate students, and education outreach professionals to engage a variety of audiences in STEM-related outreach activities. Some are supported internally by the institution. Some receive support through federal, state, or private grants that specifically target STEM education. Others arise from "broader impacts" components of federally funded research grants that support scientists' and engineers' research, individually or as collaborators in interdisciplinary research centers. Taken together, these represent a large pool of funding.

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This combination of STEM expertise, facilities, and resources theoretically endows university-based STEM-EO with great promise for impacting STEM education and awareness. However, the degree to which that potential can be realized is influenced by a number of factors. For example, STEM-EO efforts are often designed within departmental silos, with little inter-project communication or collaboration. Researchers from science and engineering fields often have no training in education pedagogy or awareness of best practices associated with various educational contexts. Many view the STEM-EO component of research proposals as an afterthought, unaware of its importance and potential for enhancing STEM in the long run. Many efforts focus on only a subset of STEM learning goals, overlooking others that are also important. Project evaluation criteria and instruments are often developed independently, precluding learning from cross-project comparisons. It is paradoxical that while great efforts are made by universities, STEM colleges, and departments to plan strategically for future growth, such as where to focus resources for constructing new facilities and hiring new faculty, little if anything is done to guide development of STEM education outreach programs that use large funding resources and have the potential to address key pipeline issues impacting the U.S.'s international STEM status.

At the Center for Science and the Schools (CSATS) at Penn State, we have been wrestling with issues related to optimizing university-based STEM-EO efforts. CSATS is a university-wide center founded in 2004, whose mission is to facilitate mutually beneficial and sustainable relationships among Penn State STEM researchers and K–12 school districts to enhance STEM education locally, state-wide, and nationally. It is housed in the College of Education and works closely with Penn State education outreach professionals and researchers from the various Penn State STEM colleges to support and inform their efforts and build collaborations. CSATS also works closely with Penn State administrators, STEM researchers, and K–12 school districts to develop "broader impacts" projects that contribute to the competitiveness of proposals while addressing K–12 STEM education needs.

Like many large Research I universities, Penn State has a rich tradition of STEM-EO, involving various outreach entities engaged in multiple projects from six different STEM colleges and numerous interdisciplinary centers. These projects differ in the audience(s) they target, subject matter and objectives they address, and types of engagement and instructional strategies they employ. These efforts exist within a large university STEM academic research structure housed in separate colleges and departments, and depend largely on individual project-by-project funding.

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Based on our experience working with various stakeholders, we recognized that in order to promote strategic STEM-EO programming involving more cohesive, balanced programs that optimize resources, universities might benefit from a more systematic approach to STEM-EO design and evaluation. Such an approach requires a mechanism for educating stakeholders about the complexity of STEM-EO and how STEM-EO programming influences the pipeline. To that end, CSATS has consulted with many of its stakeholders to develop a STEM-EO Model (Figure 1) to reflect the systems nature of STEM-EO and the interconnections among stakeholders, while underscoring the importance of goals, assessments, and understanding of the outreach context as drivers of project design.

STEM-EO Framework: *Visualizing the Systems Nature of STEM-EO*

The STEM-EO Framework provides a visual representation summarizing the complex system of interacting elements comprising STEM-EO. At the core of the Framework is the STEM pipeline, indicated with blue arrows. This pipeline has four main branches: a progression from pre-school to academic higher education, technical higher education, non-STEM higher education, or K–12 STEM teaching. Superimposed onto that pipeline are four major STEM-EO Domains: K–12 Student Domain, K1–2 Teacher Domain, Academic, Technical and non-STEM Higher Education Domain, and the General Community Domain. Although each Domain has an inherently different focus and scope of expertise, resources, and facilities, each has the potential for directly or indirectly influencing other domains and components of the STEM pipeline. Influences among Domains are indicated by gray arrows.

The STEM-EO Framework provides a visual representation summarizing the complex system of interacting elements comprising STEM-EO.

As its name suggests, the Framework serves as an organizing tool for the EO-Model, identifying key components that comprise it and how they are interrelated. The Framework can be used to map existing projects by domains to visualize possible interconnections and relationships to the pipeline. It also provides a systems perspective of STEM-EO and illuminates how activities targeting various domains and individuals comprising domains potentially influence players within other domains to support STEM literacy and the pipeline. This perspective can help STEM-EO developers identify gaps in programming across the pipeline and within domains that influence the pipeline.

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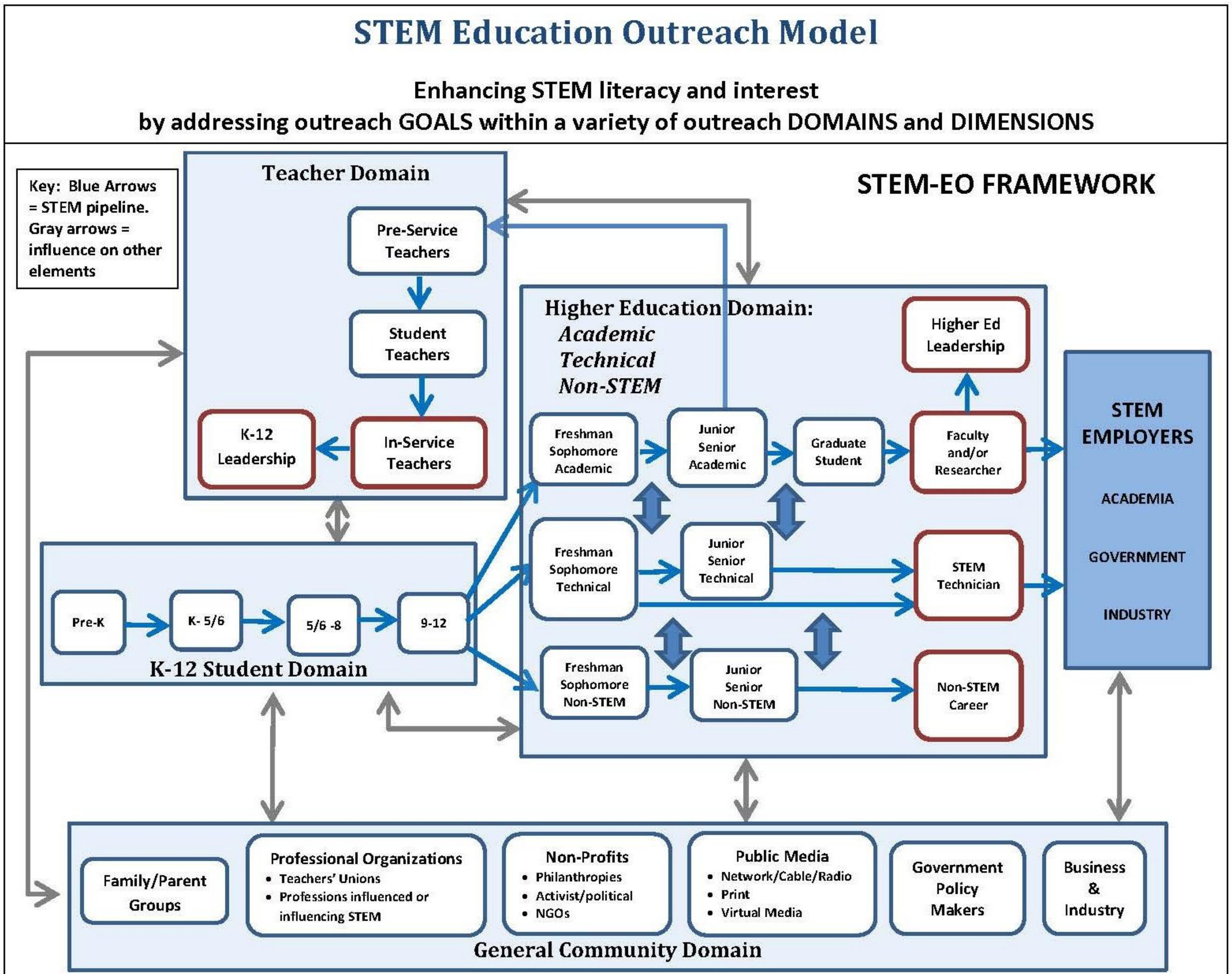

GOALS

- STEM Content Learning
- General Science Teaching Strategies
- Topic Specific Representations & Strategies
- STEM Career Awareness
- Nature of Science and Role in Society
- Global Awareness/Perspective
- Motivate/ Interest/ Excite in STEM
- Methods of Science/Engineering
- Discourse and Practices of Science
- Scientific Thinking: Creativity, Critical Thinking, Problem Solving
- Recruit and Retain Interest in STEM
- Diversity Awareness/Perspective
- Cross-Domain Communication Skills

DIMENSIONS

- Formal/ Informal Education (curricular, co-curricular, extra-curricular)
- Equity: Diversity/Underrepresented groups/Special Needs/ELL
- Urban, suburban, rural
- Discipline Areas: Individual STEM/ Interdisciplinary STEM/ Integrated STEM + non-STEM)
- Access: Face to face/ Distance Learning/Blended
- Instructional Styles: Didactic/ Demonstrations/ Active engagement/ Inquiry-based

Figure 1. STEM Education Outreach Model

STEM-EO Learning Goals: *Addressing Key Aspects of STEM Literacy and Pipeline Improvement*

The STEM-EO Goals identify core aspects of STEM learning that support STEM literacy and address challenges facing the STEM pipeline. These general EO Goals were derived from work sessions involving Penn State STEM faculty, outreach providers, science education faculty, and school district administrators and teachers. They were framed to be applicable across multiple domains and dimensions.

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The Goals provide focus for outreach projects and link directly to expected project outcomes. They are important guides for designing and implementing specific project activities. They promote the examination of projects in terms of the likelihood that proposed activities will lead to the achievement of the goals. They help identify evaluation criteria and instruments that can be applied across projects, allowing greater depth of understanding of their effectiveness. Characterizing projects in terms of goals also provides another layer of insight into how various projects intersect. Understanding this type of overlap and using it in longitudinal planning can provide a mechanism for sustainability. As funding for one project draws to an end, a project developed as a broader impacts component of another grant can take over the same core goal(s).

STEM-EO Dimensions: *Considering the STEM-EO Audience and Learning Context*

The STEM-EO Dimensions describe the context of specific projects, defining finer-grained characteristics such as the nature of the targeted audience(s), educational setting, subject matter areas addressed, and methods of instructional engagement. These dimensions were identified based on audiences often targeted by granting agencies, as well as the variety of settings and subject matter, and instructional methods included in Penn State STEM-EO projects.

The STEM-EO Dimensions describe the context of specific projects, defining finer-grained characteristics, such as the nature of the targeted audience(s), the educational setting, the subject matter areas addressed, and methods of instructional engagement.

The Dimensions promote awareness of differences and similarities in approach needed when working within different contexts. An understanding of how the various STEM-EO dimensions interact will promote development of activities based on knowledge of the learners and the educational setting, rather than “feel good” activities that relate to a particular topic but are only marginally useful for attaining the selected learning goal with the targeted audience. Also, an understanding of how the various STEM-EO projects intersect in terms of these dimensions will inform collaborations among outreach developers as they seek advice from those who have expertise working within other dimensions.

The Integrated STEM-EO Model

Although each element has its own value, the full potential of the model depends on integration of the three elements as a cohesive whole. The combination of Framework, Goals, and Dimensions provides a detailed description of projects and a multi-level grid on which to map and understand existing projects in terms of the pipeline, domains, goals, and dimensions. It helps us more accurately identify gaps in STEM-EO programming and plan projects that will help fill those gaps. It also helps us understand how existing projects overlap in terms of goals and dimensions within and across domains, leading to broader impacts projects that link higher education, pre-college, and community activities into cohesive, interrelated programs. It also fosters collaborations and possibilities for the longitudinal sustainability of projects by drawing on components that have proven to be successful, refashioning them for use in new projects.

Model Implementation at Penn State

Preliminary introduction of the model has been met enthusiastically by Penn State administrators, STEM researchers, STEM-EO professionals, and local school districts. We are now in the process of implementing the first iteration of the model at Penn State. Outreach professionals are “mapping” their STEM-EO projects and their goals onto the Framework to understand how they relate to the overall STEM-EO system and how they potentially impact the various domains. They are also examining their projects in terms of learning goals and dimensions to thoughtfully consider how activities could be modified and how including expertise from other STEM-EO groups might better address stated goals. Once the various outreach groups have “mapped” and characterized their projects, we will look across projects to find overlaps and gaps in goals, domains, and dimensions. In the long term, we hope to quantitatively monitor the “balance” within the model of dollar investments in projects of different kinds university-wide.

In addition, we are also using the model in our discussions with STEM researchers while developing broader impacts components of their research proposals, helping researchers better understand ways their STEM-EO projects can impact the STEM pipeline and value of cohesive, multi-domain, or multi-dimensional STEM-EO projects that contribute to STEM education and their own research agendas and careers. In addition, we are using it to stimulate discussion among researchers and STEM-EO professionals about best practices for delivering STEM-EO to address their chosen learning goals within the particular outreach dimensions. In order to provide wider access to the model, we are developing an education plan for introducing the various STEM-EO stakeholders to the theory, processes, and potential impacts associated with the model, and supporting their use of the model within their various contexts.

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All of these efforts form the basis for a collaborative research agenda investigating impacts and challenges of a STEM-EO Model-mediated approach to programming for various stakeholders. Our initial research will examine effects on stakeholders' perceptions of STEM-EO programming and their approach to STEM-EO project design and strategic planning. We consider the model to be dynamic in nature and expect it to evolve and expand as it is used and as various aspects are examined through research. For instance, some key issues may entail its use in identifying and developing common evaluation criteria, identifying which key areas of research and gaps in goals and domains are important to pursue, and designing more cohesive STEM-EO programs that integrate domains, goals, and dimensions. We are also interested to learn what aspects of the model are applicable in different contexts, and welcome discussion of how it might be adapted for different institutions. We also hope to examine its potential for developing descriptive and predictive statistical models of how different components contribute to the retention of students in the pipeline.

Implications

There has never been greater need for universities to support STEM education through their STEM-EO efforts and for those efforts to be designed strategically, capitalizing on the complexities of STEM-EO and potential synergies inherent within that complexity. The STEM-EO Model presented here, along with dissemination plans and research, will help us move toward that goal. The combination of Domains, Goals, and Dimensions superimposed upon the STEM pipeline allows appreciation of the complex and interdependent nature of STEM-EO, and the important roles and responsibilities each stakeholder has in promoting effective STEM-EO efforts. This combination also emphasizes the importance of goal/assessment-driven programming, while recognizing the need to consider aspects of program dimensions and influence within and across domains during goal and assessment design and interpretation of assessment data. In addition the combination of more concrete aspects, such as the STEM-EO Domains and the STEM pipeline, with pedagogically oriented aspects, such as learning goals and learning contexts, provides valuable links for educating the range of stakeholders about the complex systems nature of STEM-EO. Also, the systems nature of the model promotes investigation of interrelationships among components, leading to the development of predictive models for informing strategic planning. This dynamic model can guide the growth and evolution of STEM-EO programming to the benefit of all stakeholders.

The combination of Domains, Goals, and Dimensions superimposed upon the STEM pipeline allows appreciation of the complex and interdependent nature of STEM-EO, and the important roles and responsibilities each stakeholder has in promoting effective STEM-EO efforts.

ACKNOWLEDGMENTS

The author thanks the Penn State Center for Science and the Schools staff—L. Bug, J. Howe, M. Johnson, and R. Osborn; Penn State outreach and engagement professionals—C. Anderson, C. Bartely, B. Bengtson, J. Bortiatynski, L. Brown, E. Bryzicki, K. Dreyer, R. Ehrmann, H. Nelson, C. Palma, S. Palma, L. van der Sluys, J. Snider, and M. Zeman; Penn State education faculty—L. Boggess, S. McDonald, and D. Smith; and PA STEM Alliance school district administrators and teachers—M. Sackash, K. Gee, and S. Morgan. Special thanks to G. Kelly, Associate Dean for Research, Outreach and Technology; W. Carlsen, science education faculty and former director of CSATS; and K. Dressler and L. Mulfinger, Strategic Proposal Development, Penn State Strategic Interdisciplinary Research Office.

LITERATURE CITED

Darling-Hammond, L. (2011). *The flat world and education*. New York: Teachers College Press.

Lowell, B. L., Salzman, H., Bernstein, H., & Henderson, E. (2009). *Steady as she goes? Three generations of students through the science and engineering pipeline*. John J. Heldrich Center for Workforce Development, Rutgers University, and Institute for the Study of International Migration, Georgetown University. *http://policy.rutgers.edu/faculty/salzman/steadyasshegoes.pdf*).

National Academy of Sciences & National Research Council. (2009). *Engineering in K-12 education*. Washington, DC: National Academies Press.

National Center for Education Statistics. (2012a). *The nation's report card: Mathematics 2011*. Washington, DC: U.S. Department of Education, Institute of Education Sciences. *http://nces.ed.gov/nationsreportcard/pdf/main2011/2012458.pdf*).

National Center for Education Statistics. (2012b).*The nation's report card: Science 2011.* Washington, DC: U.S. Department of Education, Institute of Education Sciences. *http://nces.ed.gov/nationsreportcard/pdf/main2011/2012465.pdf*).

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Annmarie Ward is the Director of the Center for Science and the Schools and Assistant Professor of Education (Science Education) at Penn State. In these roles, Dr. Ward works with Penn State scientists and engineers, as well as school districts across Pennsylvania to design and implement broader impacts components of STEM researcher grant proposals that build capacity for K-12 teachers to teach science using methods that incorporate the discourse and practices of science and engineering. She also engages other Penn State STEM outreach groups in activities designed to promote collaboration and enhance understanding of current STEM education issues. Her research interests include 1) developing strategies for enhancing K-12 teachers', and STEM undergraduate and graduate students' understanding of how scientists and engineers do research and how to translate that knowledge into their teaching; and 2) optimizing universities' STEM outreach efforts, allowing them to more strategically and meaningfully address the science education needs of students, K-12 teachers, higher education, and the community.