STEM Outreach: A Stakeholder Analysis

Mr. Daniel C. Appel, Mr. Ralph C. Tillinghast, Ms. Carla Winsor & Dr. Mo Mansouri
daniel.appel.4.ctr@us.af.mil, ralph.c.tillinghast.civ@mail.mil, cwinsor@wisc.edu & mo.mansouri@stevens.edu

***Abstract* – The evolving challenges facing our society will increase the demand for Science, Technology, Engineering and Math (STEM) professionals. Educational outreach in STEM areas can supplement current educational systems to promote interest, increase understanding, and encourage students to pursue careers involving STEM fields. In order to maximize benefits from STEM educational outreach opportunities, developing a better understanding of stakeholders involved, and their needs, goals, and objectives across the educational ecosystem, is required. This work presents a stakeholder analysis for the STEM outreach system intended to enhance understanding of how each stakeholder in the STEM educational outreach system of systems contributes towards unique goals of improving student understanding and success in pursuing educational and career goals within STEM fields. Understanding the dependencies and relationships between stakeholder entities enables further research and future improvements for STEM outreach initiatives. Ultimately, these efforts aim to provide key contributions to building the next generation of science and engineering professionals.**

Index Terms – Education; Engineering; Mathematics; Outreach; Science; Stakeholder, STEM; STEAM; STEM-H; Systems; Technology

INTRODUCTION

With an ever-increasing need for Science, Technology, Engineering and Math (STEM) professionals to address increasingly demanding and complex problems, the educational pipeline for training such professionals continues to be pivotal within the education system, the political arena and the research community. Understanding the stakeholders provides critical insight into target audiences within the STEM domain space, and how to best maximize beneficial results from the myriad of outreach activities. This stakeholder analysis was a result of a broader STEM outreach literature review conducted to document the STEM outreach system. Including stakeholders, teaching methods, assessment tools, curriculum developments, and other STEM outreach programs and has been published separately under the title: "STEM Outreach: A Literature Review and Definition". [1] Within the scope of relevant outreach activities established, the different needs, goals, and objectives of various stakeholders involved in each type of outreach activity emerged as a means to better understand the STEM educational outreach ecosystem and how to improve it from the perspectives of key stakeholders.

Identifying the stakeholders involved and determining interactions with one another is critical to understanding how STEM outreach programs and research efforts impact the overall goal of improving STEM understanding. Better understanding of the network of interdependent and mutually reinforcing relationships between key stakeholders can improve resource allocation for outreach programs and better target underserved student demographics. Through classifying and analyzing stakeholders and their relationships, it is possible to identify instances where enabling factors and force multiplying tools can expand the reach and improve the lasting beneficial impacts of outreach activities. Therefore, this work aims to provide a robust review of STEM outreach research specific to stakeholders.

PART I: METHODOLOGY

The selected approach for identifying and classifying stakeholders is conducting an extensive literature survey of STEM outreach activities where active and passive stakeholders were identified. Collecting and reviewing sources from IEEE, ASEE, the Journal of Education, the International Journal of STEM Education, the Journal of Research in STEM Education, Journal of Engineering Education, and other literature yielded large numbers of works. Constraining the scope of literature reviews to outreach activities within STEM fields with a focus on developing student interest and motivating students to pursue goals within STEM careers allowed for a relevant stakeholder analysis. During the previously referenced literature review a literature classification system was established. This included a detailed stakeholder structure which has been utilized in this work.

PART II: LITERATURE REVIEW

The principal means of identifying the stakeholders involved in STEM education outreach activities is through literature review. The initial aim of this literature review effort involves defining STEM Stakeholders, identifying active and passive stakeholders within the scope of STEM outreach activities, and classifying these stakeholders through analysis of the needs, goals, and objectives. Relevant literature is presented in a series of sub-categories based on classification heuristics, including students,

student peers, mentors and role models, teachers, parents/guardians, administrators, outreach providers and organizations, and other stakeholders. The interactions and dependencies between the stakeholders will be discussed in brief. The goal is to provide high level trends and insights within each section and provide contextual information to support a systematic understanding of how stakeholder objectives and activities support the overarching goals of STEM outreach within the greater education and outreach system.

STEM outreach is a complex system with many different stakeholders and a network of interactions involved. As demonstrated through the literature review, many of the relationships established between stakeholders are requisite or beneficial enablers for achieving successful outreach activities.

I. STEM Outreach Stakeholders

Developing a better understanding of the active and passive stakeholders involved in the comprehensive STEM education and outreach system supports research goals as well as improving outreach programs and initiatives. Determining which entities are relevant stakeholders requires identifying involved parties, classifying organizations and groups of stakeholders, and evaluating the objectives and roles each plays. Through the literature survey focused on defining STEM outreach activities and the scope of activities that directly support "delivering STEM content outside of the traditional student/teacher pedagogical relationship" [1] the scope of activities leads to clearly delineated groups which justifiably meet the definition of key stakeholders. Leveraging a selection of formal definitions of stakeholders is the first step in this process, which include the following:

> *1) A stakeholder in an organisation is (by definition) any group or individual who can affect or is affected by the achievement of the organisation's objectives.* [2]
>
> *2) An individual, team, or organization (or classes thereof) with interests in, or concerns relative to, a system.* [3]
>
> *3) N.B. Stakeholders include, but are not limited to end users, end user organizations, supporters, developers, producers, trainers, maintainers, disposers, acquirers, customers, operators, supplier organizations and regulatory bodies.* [4]
>
> *4) Individual or organization having a right, share, claim, or interest in a system or in its possession of characteristics that meet their needs and expectations.* [5]
>
> *5) Any individual, group or organization that will have a significant impact on or will be significantly impacted by the quality of a specific product or service.* [6]

Given the pervasive nature of education methodologies supporting cognitive development of students affecting the success of society as a whole, there are numerous classes of stakeholders which could logically be considered. [7], [8] The far-reaching economic and social effects of preparing K-12 students for college, careers, and life will play an increasingly substantial role in society [9], [10], which expands the number of passive stakeholders that should be considered for large scale initiatives. For the intended scope of this effort, it is logical to limit the stakeholders considered for this work to those individuals and representative organizations who directly affect and are affected by STEM outreach activities. When considered as a system of systems, this includes the active parties in pedagogy: students, teachers, and outreach providers. [11] Additionally, parents, guardians, and school administrators must be considered given the roles they play as key enablers in the education process. Additional stakeholders in the form of organizations, including professional associations, academic event coordinators, and organizations such as outreach non-profits are relevant to the outreach field.

Further subdivision of students is also warranted by the various aims of STEM outreach to reach diverse student audiences, particularly groups underrepresented in STEM fields in both post-secondary education and career professional groups.

II. Students

For students targeted by STEM Outreach activities, literature analysis allowed for subdivision into specific groups. The initial classification heuristic focused on demographic differentiation, such as female and male students, or under-privileged and minority students currently under-represented within STEM career fields. [12], [13] Analysis of literature reviewed also suggested other designations, including gifted and talented students, second-language learners, online and hybrid education students, and home-schooled students. Examples of outreach programs that support students by specific grade are documented in the previously referenced literature review. [1]

Identifying students as key stakeholders in STEM outreach and in broader terms educational outreach activities indicated the need to address both the active and passive stakeholder interactions required from students. Structurally, the active roles students take within STEM outreach activities are inherited from the roles students play throughout pedagogical literature. Within the system of systems context of STEM outreach, students are the primary

recipients of outreach content and the ultimate goal of outreach activities is improving achievement of each student's personal goals that can benefit from outreach activities in STEM domains.

Viewing them as stakeholders requires an understanding of what global benefits are possible for students experiencing STEM outreach activities, and how they might benefit across a time span including studies of K-12 that result in career outcomes for students. The goals and objectives that can be attributed to students are therefore viewable as a time-invariant problem, where benefits and outcomes of former students who are reaching milestones in post-secondary education and career attainment can be considered simultaneously with any stated goals and objectives of student cohorts currently in K-12 pedagogy. This methodology of treating students as a broader stakeholder superclass with subdivisions for students by age, gender, minority status, or other differentiators can be logically extended in order to provide a valid surrogate for better understanding the various demographic and environmental effects across the educational and STEM outreach system.

Many of the STEM domain focused needs and goals present for students revolve around achieving mastery of fundamentals in each domain. [14]. Pedagogy methods focus on capturing the requisite facts, relationships, and context to achieve an actionable understanding of concepts accumulating into understanding of a field. The baseline scholastic achievement for students is supported by this methodology, but does not necessarily meet the needs of students and other stakeholders to improve understanding of challenging topics, or creating interest to seek out pathways to careers in STEM fields. [15]

Among the most significant actionable lessons learned from studying K-12 STEM Outreach is that within student cohorts, those who perceive themselves as able to become future researchers, engineers, and technicians are much more likely to continue academic pursuits in those fields. [16], [17] The correlation between the self-confidence students express in their abilities and the self-perception of capability for mastering fundamentals in each subject is incredibly significant across all literature surveyed. The means of achieving and reinforcing student buy-in to this key aspect of the education process can become a seminal focus of outreach activities tied to STEM domains. Across all of the various outreach delivery methodologies, programmatic scopes, and target audiences, this is where outreach activities as a whole demonstrably led to the greatest net improvement in creating and maintaining student engagement. [18] The biggest enabling tools are those that support self-agency of students and teach the basics of metacognition - making these accessible to all students through whatever delivery method is best to prepare students for futures beyond K-12 education. [19]

The measurable phenomena which lead to students losing interest in technical fields presents the greatest opportunity for outreach efforts to reduce net losses of potential scientists, mathematicians, and engineers. [20] Maintaining retention of students pursuing STEM degrees remains a tremendously important effort. [21] However many career STEM professionals cite participating in various outreach programs as a major contributor to their decision to continue pursuing relevant degree programs. The other most significant opportunity for improvement is increasing preparedness of college-bound students with aspirations in STEM and healthcare fields, again with the aim of reducing the number of college entrants who are unable to graduate within STEM-H fields in six years or less.

The environments and demographic backgrounds of students are also tremendously significant across literature surveyed regarding attaining and retaining student interest in STEM fields. There is a multitude of outreach programs and educational initiatives that focus on girls. [22]–[34] Programs for minorities are also well documented. [12], [28], [30], [35]–[40] This is also expanded into other underrepresented groups in STEM. [27], [32], [41]–[43] All of these works elucidate the challenges faced by students with career aspirations in STEM fields. These provide encouraging directions in how to overcome existing biases and structural limitations which can be addressed through outreach activities in coordination with improvements of existing traditional education activities.

While STEM outreach activities in isolation are unlikely to provide comprehensive solutions to affect positive changes within this problem space, the unique architecture of outreach-driven programs to provide diverse inputs into the education process creates unique opportunities to advance the state of the art. Developing strategies to positively affect the environment surrounding students does require a deeper understanding of the broader system context and identifying key functional relationships present in the system of systems architecture. The diversity in ways to improve STEM education through strategy, architecture, and program-specific options is considerable across the scope of literature analyzed.

III. Student Peers

Student peer groups emerged during the research process as a critical enabler in maintaining student interest in STEM fields, and that outreach activities can influence the perception of entire peer groups of students. Through analysis of outreach delivery methodologies, the positive impacts of student group project-based learning, workshop, and camp/club activities became evident. [44] Palmer

observed this effect to be particularly relevant when focusing on retention of minority student interest. [39] While the impact of peer groups on student interest within STEM domains has been identified, grouping student peer groups with the student key stakeholder group will be pursued for future efforts. [24], [45], [46]

IV. Mentors and Role Models

Mentorship and role modeling activities across literature surveyed directly contributes to the success of students, as well as providing substantial benefits for those serving in mentoring roles. [47] Practically, the outsized impact for individual students that mentoring can provide is substantial and measurable, although there exist inherent difficulties with widespread application of this methodology. [48], [49] Matching students with mentors and maintaining consistent interaction intervals within the schedules of professional mentors and K-12 mentee commitments is effort-intensive. Providing adequate supporting resources for specific outreach content areas can be challenging; however, the value of K-12 student mentorship in STEM fields remains substantial enough to justify such efforts. [41] Nelsen's team in their work documenting the positive results of having undergraduate students mentor K-8 youth in STEM programs, finding ~94% reflected on the positive impact on their education. [50] Many formal mentoring programs exist and some are established specifically for underrepresented groups. One example of this is the document by Pluth and his team for a middle school and high school based program that utilizes University of Oregon students to conduct outreach and act as mentors. [51] Mentoring also aids in putting a face to STEM, which will build a positive link to who Scientists and Engineers are. [42] Positive impacts have been found for females and other minority groups. [25], [26], [40]

V. Teachers

Teachers represent one of the stakeholders who have the most interaction time with students. This places teachers in a central role in enabling student achievement in STEM domains. Content delivery and outreach activities, often serving to either amplify and support curriculum centered around traditional student-teacher pedagogy, have been documented. [52], [53] As core stakeholders in the education process, STEM outreach targeted towards teachers can carry unique benefits in helping current and future students reach academic and career goals. Further, having teachers providing outreach outside of the classroom is beneficial to both students and the teachers themselves. [54] The Picatinny STEM Outreach program specifically highlights the importance of this with the statement *"Win the teachers, win the war. Lose the teachers, lose the war."* [55] Indicating how outreach targeted towards teachers has the potential to reach more students than just student based outreach.

A common theme found is "teach the teachers" thus ensuring that teachers are maintaining and growing their STEM understanding. [56] The efforts to teach the teachers allow for teachers to engage in lifelong learning opportunities, participate in cutting edge research, and improve pedagogy-specific skillsets and tool proficiencies. [57] Outreach directly provided to teachers can be found to ensure that they have the tools needed to stimulate the students they interact with. [58] Constantly being able to impact teachers through outreach has been found to be difficult. Yamuna in her research found that the outreach they conducted had minimal impact on knowledge, confidence, or pedagogical approaches due to lack of involvement and pre-existing beliefs of teachers. [59] This illustrates that just presenting STEM based information to teachers may be insufficient to make a measurable impact.

VI. Parents/Guardians

Parents and guardians play critical roles throughout the education process, and make tremendous impacts on the success of preschool-12 student success and later career goals. [60]–[63] The specific role of parents and guardians is further highlighted by Albers and his team including comprehensive family inclusion in STEM activities, with promising results. [64] Additionally, the collaborative role of individual mentorship with parental engagement is also evident across the literature surveyed. Alternate venues such as libraries have the advantage of reaching parents during student based outreach programs. [47] Focused programs for parents can be found in the form of parent conferences or informational events, with the hope to increase STEM understanding and awareness. [65] Further, Moakler and Kim found students are more likely to choose a STEM field if they have a parent with a STEM occupation. [66]

VII. Administrators

School administrators continue to play key roles as enablers and indirect support of teachers, as well as interface with outreach organizations and providers to aid in tailoring outreach efforts for the student population. Additional roles exist in program assessment and in supporting project-based learning activities at school-wide levels and supporting workshop and club events. Administrative support staff, including guidance counselors and other non-faculty roles, also play key roles in supporting students. [14], [67], [68] Students pursuing goals in STEM fields can benefit from outreach efforts that actively involve administrators and related stakeholders, though this interaction is typically indirect throughout the literature surveyed.

VIII. Outreach Providers & Organizations

The individuals providing STEM Outreach content to student groups are key stakeholders in the process, and are a necessity across the entire outreach system. Stakeholder analysis for the needs, goals, objectives, and opportunities of outreach providers is not as developed as the authors would hope: however this presents a valuable opportunity for continued research. Within the literature surveyed, although motivations of individual outreach providers varies widely, the outreach process still results in remarkable unity in the shared purpose of helping students develop academically, and more favorably view STEM professions as a whole.

Perhaps the most appealing aspect of STEM Outreach opportunities from the perspective of the outreach providers is summed up extremely eloquently in Eby, that 'One engineer can make a difference'. [48] While fundamental motivations for STEM Outreach providers are inevitably variable, surveys have identified three positive metrics for the outreach providers, 1st the feeling that a positive impact has been made, 2nd an increase in motivation from stepping away from daily routine and 3rd it reminds them of why they became an STEM professional in the first place. [69]

The organizations which exist to facilitate, organize, and support STEM Outreach also emerged as key stakeholders. They have the ability to facilitate existing outreach activities, expand upon outreach opportunities to increase reach, improve content and curriculum, and create new venues for outreach delivery. Importantly, analysis reinforced the observation that all of these organizations share a common reliance on volunteers to serve as educators, mentors, role models, and supporters to perform outreach functions. A surprising observation made previously is that in balancing the needs, goals, and objectives of stakeholders for larger STEM outreach efforts, the inherent flexibility of Outreach as a delivery mechanism can better support teachers and outreach providers, as well as continue providing reward opportunities for career professionals to justify continued contributions of time, effort, and materials at no cost to teachers, parents, and schools. [70]

IX. Other Stakeholders

Beyond the previously identified active stakeholders, other stakeholders and influencing roles can be identified. While this is by no means an exhaustive list of additional stakeholders, this highlights some key roles identified throughout the literature surveyed that should be considered when formulating research plans or specific outreach initiatives.

Policy Makers: This group includes politicians and government policy makers, government entities involved in education and STEM fields, commercial and industry organizations with interests in STEM education policy, and professional organizations including technical professional organizations and professional societies with interests in STEM education. [71] Despite the varied individual goals and interests of these stakeholders, within the scope of STEM outreach activities these groups share common purpose in seeking ways to improve scholastic achievement of K-12 students in STEM domains and improve the numbers and quality of college students completing degrees and entering STEM fields as skilled professionals. [72]–[74]

Organizations: This can include groups with a focus on STEM, professional organizations that exist within STEM domains, and even organizations with other outreach focuses that can be involved in STEM outreach. Organizations that promote STEM and outreach specifically function in organizing, event-hosting, and recruiting roles for outreach activities. [75] Professional organizations typically support outreach activities through sponsoring, organizing, and recruiting volunteers and mentors. [76] Prime examples of the latter groups include YWCA, Scouts and professional societies such as IEEE and ASEE, who use outreach activities that include STEM content to promote achievement and self-confidence for girls to pursue career goals in fields including STEM areas.

Museums, MakerSpaces, and STEM Camp Venues: This group includes organizations and institutions which directly or indirectly support enrichment and outreach activities for the public in fields which can include STEM domains. While the fundamental needs, goals, and objectives for this class of stakeholders has a broader public focus on results, the significant intersection in supporting and enabling capabilities to improve the reach of adjacent STEM outreach activities, coupled with the ability to host events and camps for students makes these important stakeholders to consider across the outreach ecosystem. [77], [78]

Academia and Researchers: Academia and researchers within both educational and commercial organizations are a unique class of stakeholders, with the ability to directly support STEM outreach activities, conduct evaluation of outreach programs and efforts, and leverage research efforts to recruit individuals from outside existing STEM outreach activities to contribute to those efforts. [79] This group also conducts research on methods to understand and optimize the STEM Outreach system.

X. Stakeholder interactions and dependencies

Understanding the interactions and dependencies between each of the stakeholders to one another allows for a larger systemic view of the STEM outreach system. Figure II,

illustrates a high level stakeholder diagram based on the previous sections described.

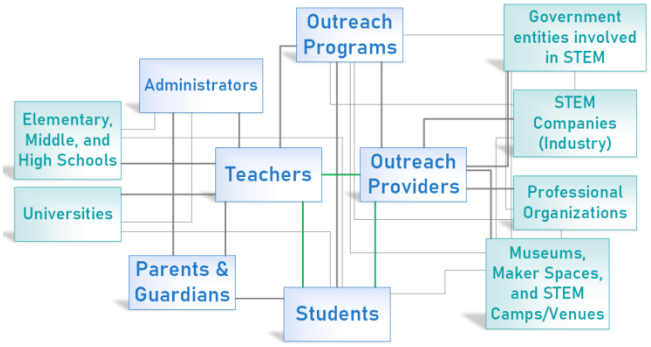

Figure II, STEM Outreach Stakeholder Diagram

This figure is presented as an overview and starting point for discussion. Some of these interactions have been discussed in the previous sections and other works. [70], [80] A deeper narrative and analysis of the stakeholder interactions and dependencies was beyond the scope of this work but is planned as a follow on effort. Further, systemic forces that may impact the stakeholders needs to be considered, such as environmental, economic, political and even distance from STEM focused commercial companies that have S&E personnel available to support STEM outreach.

The relationships between STEM outreach stakeholders demonstrate that the STEM outreach enterprise is a complex system of systems, as demonstrated by the literature. This analysis should help ensure that all stakeholders are addressed within the proposed definition of STEM outreach [1], and can be appropriately considered for any future research or novel outreach initiatives within STEM education domains.

Conclusions

Through leveraging literature reviews focused on STEM education and outreach activities that directly support STEM education for K-12 students, an analysis of involved stakeholders supports ongoing research to continue enhancing student achievement across STEM domains through outreach methodologies has been developed. A more detailed analysis using system dynamics modeling of stakeholder interactions remains desired to further understand the holistic interactions within the STEM outreach system and between stakeholders. Additional work can be conducted to build more detailed literature reviews within each of the sections discussed. From these efforts, further improvements for STEM outreach initiatives can be achieved

Author Information

Mr. Daniel C. Appel, Systems Engineer and Analyst, AEgis Technologies Group Inc., supporting U.S. Air Force Research Laboratory, Directed Energy, Kirtland AFB, N.M.

Mr. Ralph C. Tillinghast, Science and Technology Advisor for Fire Control, US Army, CCDC Armament Center, Picatinny Arsenal NJ

Ms. Carla J. Winsor, PhD Dissertator, Mechanical Engineering Department, University of Wisconsin-Madison.

Dr. Mo Mansouri, Associate Professor, School of Systems and Enterprises, Stevens Institute of Technology, Hoboken N.J. acknowledgments

References

[1] R. Tillinghast; D. Appel; C. Winsor; M. Mansouri, "STEM Outreach: A Literature Review and Definition," *IEEE Integr. STEM Educ. Conf.*, 2020.

[2] R. E. Freeman, "Strategic Management: A stakeholder approach," *Boston, MA, Pitman*, vol. 1984.

[3] IEEE, "ISO/IEC/IEEE 26702," 2007.

[4] IEEE, "ISO/IEC/IEEE 29148," 2011.

[5] IEEE, "ISO/IEC/IEEE 15288," 2015.

[6] ASQ, "Stakeholder Management 101," 2016.

[7] E. S. Peisner, *The children of the Cost, Quality, and Outcomes Study go to school*. DIANE Publishing, 2000.

[8] N. Lopez, S. Patrick, and C. Sturgis, *Quality and equity by design: Charting the course for the next phase of competency-based education*. Washington, DC: CompetencyWorks and iNACOL, 2017.

[9] M. Barry and M. Dannenberg, *Out of pocket: The high cost of inadequate high schools and high school student achievement on college affordability*. Education Reform Now, 2016.

[10] S. D. Spence, G. Autin, and S. Clausen, "Reducing the cost of remediation: A partnership with high schools," *Res Teach. Dev. Educ*, pp. 5–23, 2000.

[11] R J Cloutier (Editor in Chief), "SEBoK.. 'Stakeholder (Glossary).' in SEBoK Editorial Board," *Guid. to Syst. Eng. Body Knowl. (SEBoK), v.*, vol. 2.1, 2019.

[12] L. Tsui, "Effective Strategies to Increase Diversity in STEM Fields: A Review of the Research Literature," *J. Negro Educ*, vol. 76, no. 4, pp. 555–581, 2007.

[13] S. M. McBay and L. Davidson, "Achieving Quality Education for Minorities in Mathematics, Science, and Engineering," *J. Sci. Educ Tech*, vol. 2, no. 3, pp. 487–496, 1993.

[14] L. Weis *et al.*, "In the Guise of STEM Education

Reform: Opportunity Structures and Outcomes in Inclusive STEM-Focused High Schools," *Am. Educ. Res. J.*, 2015, doi: 10.3102/0002831215604045.
[15] Y. Chan *et al.*, "Engineering outreach: A successful initiative with gifted students in science and technology in Hong Kong," *IEEE Trans. Educ*, vol. 53, no. 1, pp. 158–171, 2009.
[16] R. D. Robnett and C. Leaper, "Friendship Groups, Personal Motivation, and Gender in Relation to High School Students' STEM Career Interest," *J. Res. Adolesc.*, vol. 23, no. 4, pp. 652–664, Dec. 2013, doi: 10.1111/jora.12013.
[17] T. Perez, J. Cromley, A. K.-J. of educational, and undefined 2014, "The role of identity development, values, and costs in college STEM retention.," *psycnet.apa.org*.
[18] T. J. Kennedy and M. R. L. Odell, "Engaging Students In STEM Education," 2014.
[19] K. Tanner, "Promoting student metacognition," *CBE Life Sci Educ.*, vol. 11, pp. 113–120, 2012, doi: 10.1187/cbe.12-03-0033.
[20] National Science Board, *Science & Engineering Indicators*. 2018.
[21] M. R. Anderson-Rowland, "Understanding engineering students for better recruitment strategies: a four-year study," in *Proc. 30th Ann*, 2000.
[22] G. Todeschini and C. Demetry, *Longitudinal studies of an outreach program for seventh grade girls: Evidence of long-term impact.*, vol. 2017 IEEE. Forum USA East, 2017.
[23] T. A. Dubetz and J. A. Wilson, "Girls in Engineering, Mathematics and Science, GEMS: A science outreach program for middle-school female students," *J. STEM Educ*, vol. 14, p. 3, 2013.
[24] C. Demetry and S. Sontgerath, "A middle school engineering outreach program for girls yields STEM undergraduates," 2017.
[25] K. Weber, "Role models and informal STEM-related activities positively impact female interest in STEM," *Tech. Eng Teach.*, vol. 71, no. 3, p. 18, 2011.
[26] T. C. Dennehy and N. Dasgupta, "Female peer mentors early in college increase women's positive academic experiences and retention in engineering," in *Proc. Nat*, 2017, pp. 5964–5969.
[27] E. Matson, S. DeLoach, and R. Pauly, "Building interest in math and science for rural and underserved elementary school children using robots," *J. STEM Educ*, vol. 5, p. 3, 2004.
[28] N. Ambady, M. Shih, A. Kim, and T. L. Pittinsky, "Stereotype Susceptibility in Children: Effects of Identity Activation on Quantitative Performance," *Psychol. Sci.*, vol. 12, no. 5, pp. 385–390, Sep. 2001, doi: 10.1111/1467-9280.00371.
[29] C. Stein, *Botball Robotics And Gender Differences In Middle School Teams.* Salt Lake City, Utah: ASEE 2004 Ann Conf., 2004.
[30] T. Fredericks, S. Butt, and J. Rodriguez, "The Impact Of A Summer Institute On High School Students, Perceptions Of Engineering And Technology," *ASEE Ann. Conf., Salt Lake City, Utah*, vol. 2004, Jun. 2004.
[31] E. A. Holden and K. M. Fields, ?"Physics on the Ropes Course," *Proc., Amer Soc. Eng. Educ, Ann. Conf.*, 2013.
[32] C. R. Chambers, M. Walpole, and N. Outlaw, "The influence of math self-efficacy on the college enrollments of young Black women," *J. Negro Educ*, vol. 85, no. 3, pp. 302–315, 2016.
[33] R. D. Goldman and B. N. Hewitt, "The Scholastic Aptitude Test explains why college men major in science more often than college women," *J. Couns. Psychol.*, vol. 23, no. 1, p. 50, 1976.
[34] C. Leaper, "Do I belong? Gender, peer groups and STEM achievement," *Int. J. Gender, Sci. Tech*, vol. 2, Jul. 2014.
[35] J. F. Drazan, H. Danielsen, M. Vercelletto, A. Loya, J. Davis, and R. Eglash, "A case study for integrated STEM outreach in an urban setting using a do-it-yourself vertical jump measurement platform," in *Proceedings of the Annual International Conference of the IEEE Engineering in Medicine and Biology Society, EMBS*, 2016, doi: 10.1109/EMBC.2016.7591367.
[36] M. Moakler-Jr; and M. Kim, "College major choice in STEM: Revisiting confidence and demographic factors," *Career Dev. Q.*, vol. 62, no. 2, pp. 128–142, 2014.
[37] O. M. Nche, M. Sitaraman, E. L. Colbert-Busch, and V. Zordan, "Presenting CS Concepts through Multiple Representations to Engage African-American Elementary School Children Paper," *CoNECD Collab. Netw. Eng. Comput. Divers. Cryst. City, Virginia, April*, 2019.
[38] N. Haynes, S. K. Jacobson, and D. M. Wald, "A life-cycle analysis of minority underrepresentation in natural resource fields," *Wildl. Soc. Bull.*, vol. 39, no. 2, pp. 228–238, 2015.
[39] R. T. Palmer, D. C. Maramba, and T. E. Dancy, "A qualitative investigation of factors promoting the retention and persistence of students of color in STEM," *J. Negro Educ*, pp. 491–504, 2011.
[40] K. Kendricks, K. V Nedunuri, and A. R. Arment, "Minority student perceptions of the impact of mentoring to enhance academic performance in STEM disciplines," *J. STEM Educ Innov. Res.*, vol. 14, p. 2, 2013.
[41] S. Stevens, R. Andrade, and M. Page, "Motivating young native American students to pursue STEM learning through a culturally relevant science program," *J. Sci Educ. Tech*, vol. 25, no. 6, pp. 947–

960, 2016.
[42] S. E. Graham and L. E. Provost, *Mathematics Achievement Gaps between Suburban Students and Their Rural and Urban Peers Increase over Time. Issue Brief No. 52*. Carsey Institute, 2012.
[43] G. Ragusa, M. Khoo, E. Meng, and J. Cocozza, "Engineering Outreach: Connecting Biomimetic Research To Urban K 12 Classrooms," *ASEE Ann. Conf. Expo.*, pp. 13–517, 2008.
[44] C. Lang, A. Craig, and G. Casey, "A pedagogy for outreach activities in ICT: Promoting peer to peer learning, creativity and experimentation," *Brit. J. Educ Tech.*, vol. 48, no. 6, pp. 1491–1501, 2017, doi: 48 10.1111/bjet.12501.
[45] C. Leaper, "Do I belong? Gender, peer groups and STEM achievement," *Int. J. Gender, Sci. Tech*, vol. 2, Jul. 2014.
[46] S. Sontgerath and R. Meadows, "A Comparison of Changes in Science Interest and Identity and 21st Century Learning Skills in a Mixed-gender and Single-gender Robotics Program for Elementary/Middle School Youth," *CoNECD Collab. Netw. Eng. Comput. Divers. Conf., Cryst. City, Virginia*, Apr. 2018.
[47] R. C. Tillinghast, E. A. Petersen, G. L. Fischer, D. Sebastian, L. Sadowski, and M. Mansouri, "Expanding STEM outreach through multi-generational reach: Establishing library based STEM programs," in *ISEC 2017 - Proceedings of the 7th IEEE Integrated STEM Education Conference*, 2017, doi: 10.1109/ISECon.2017.7910236.
[48] M. Eby, "One Engineer Can Make a Difference.," *Elect Constr. Maint.*, vol. 102, Jan. 2003.
[49] E. B. Brown, R. L. Stiegler, P. N. Squire, J. J. Matkins, G. Hardinge, and J. A. McLaughlin., *VDP: A Mentor Focused Middle School Outreach Program*. Chicago: ASEE Ann. Conf. & Expo., , Illinois, 2006.
[50] K. Nelson, J. Sabel, C. Forbes, N. Grandgenett, W. Tapprich, and C. Cutucache, "How do undergraduate STEM mentors reflect upon their mentoring experiences in an outreach program engaging K-8 youth?," *Int. J. STEM Educ*, vol. 4, no. 1, p. 3, 2017.
[51] M. D. Pluth, S. W. Boettcher, G. V Nazin, A. L. Greenaway, and M. D. Hartle, "Collaboration and near-peer mentoring as a platform for sustainable science education outreach," *J. Chem Educ*, vol. 92, no. 4, pp. 625–630, 2015.
[52] G. Bracey, M. Brooks, S. Marlette, and S. Locke, *Teachers in training: Building formal STEM teaching efficacy through informal science teaching experience*. Grand Valley State University, Michigan: ASQ Advancing STEM Agenda Conf, 2013.
[53] M. Iskander, V. Kapila, and N. Kriftcher, "Outreach to K-12 teachers: Workshop in instrumentation, sensors, and engineering," *J. Prof. Issues Eng Educ. Pr.*, vol. 136, no. 2, pp. 102–111, 2010.
[54] J. Chin, A. Zeid, C. Duggan, and S. Kamarthi, "A Unique Methodology For Implementing High School Capstone Experiences Through Teacher Professional Development," *Amer J. Eng. Educ*, vol. 2, no. 2, pp. 17–30, 2011.
[55] E. A. Petersen, R. C. Tillinghast, C. Mainiero, and S. Dabiri, "A STEM Outreach Program Model: Case Study of a US Army Based STEM Program," *ASEE Southeast. Sect. Conf*, 2018.
[56] L. Moyo and L. Hadebe, *The role of teacher education in the sustainability of STEM*. Eur. J. Educ. Stud, 2018.
[57] G. Ragusa, M. Khoo, E. Meng, and J. Cocozza, "Engineering Outreach: Connecting Biomimetic Research To Urban K 12 Classrooms," *ASEE Ann. Conf. Expo.*, pp. 13–517, 2008.
[58] F. Aslam, A. Adefila, and Y. Bagiya, "STEM outreach activities: an approach to teachers professional development," *J. Educ Teach.*, vol. 44, no. 1, pp. 58–70, 2018.
[59] P. I. Myszkal, "The Impact of STEM Outreach Programs in Addressing Teacher Efficacy and Broader Issues in STEM Education," *(Unpublished master's thesis). Ontario Inst. Stud. Educ. Univ. Toronto Libr.*, vol. 1807, 2016.
[60] D. C. Pena, "Parent involvement: Influencing factors and implications," *J. Educ Res*, vol. 94, no. 1, pp. 42–54, 2000.
[61] K. J. Anderson and K. M. Minke, "Parent involvement in education: Toward an understanding of parents' decision making," *J. Educ Res*, vol. 100, no. 5, pp. 311–323, 2007.
[62] H. Dempsey, V. Kathleen, and M. S. Howard, *Parental involvement in children's education: Why does it make a difference?* Teachers College Record, 1995.
[63] E. A. Gunderson, G. Ramirez, S. C. Levine, and S. L. Beilock, "The role of parents and teachers in the development of gender-related math attitudes," *Sex Roles*, vol. 66, no. 3–4, pp. 153–166, 2012.
[64] L. Albers, L. Bottomley, and E. A. Parry., *Assessing the Impact of Active Learning on Students in Grades 3-8 during GK-12 Outreach Program Administered Family STEM Nights*. ASEE AnnConf. & Expo., Vancouver, BC, 2011.
[65] A. K. Lawrey, S. B. Heyman, and R. H. Rockland, "Engineering a Difference: Outreach Component," 2004.
[66] M. W. M. Jr and M. M. Kim, "College major choice in STEM: Revisiting confidence and demographic factors," *Career Dev. Q.*, vol. 62, no. 2, pp. 128–142, 2014.

[67] M. F. Bugallo and A. M. Kelly, “Engineering Outreach: Yesterday, Today, and Tomorrow,” *IEEE Signal Process. Mag*, vol. 34, no. 3, pp. 69–100, 2017.

[68] J. L. Epstein and F. L. Van Voorhis, “School Counselors’ Roles in Developing Partnerships with Families and Communities for Student Success.,” *Prof. Sch. Couns.*, vol. 14, no. 1, 2010.

[69] R. C. Tillinghast, E. A. Petersen, S. Rizzuto, S. Dabiri, and M. C. Gonzalez, “Utilizing science and engineering professionals in the classroom: How your workforce can positively impact STEM and your company’s bottom line,” in *ISEC 2015 - 5th IEEE Integrated STEM Education Conference*, 2015, doi: 10.1109/ISECon.2015.7119918.

[70] R. Tillinghast and M. Mansouri, “Influencing factors in identifying the optimal age for conducting STEM outreach,” in *ISEC 2016 - Proceedings of the 6th IEEE Integrated STEM Education Conference*, 2016, pp. 128–131, doi: 10.1109/ISECon.2016.7457517.

[71] P. Winograd, “New Mexico’s STEM-H Ecosystem: A working paper,” 2018.

[72] National Science Board, *Science & Engineering Indicators*. 2018.

[73] National Research Council, *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. The National Academies Press: Washington, DC, 2012.

[74] New Mexico First, *STEM Network models and their implications for New Mexico*. Retrieved from, 2016.

[75] R. C. Tillinghast and E. Petersen, “Establishing a Balanced Organizational Structure for Large STEM Outreach Programs: Adopting the 10, 20, 30, 40 Rule,” *Spring Mid-Atlantic ASEE Conf*, 2016.

[76] S. Cook and G. Muller-Parker, “Professional Societies Begin Ocean Science K-12 Education Collaboration,” *Oceanography*, vol. 22, no. 3, pp. 262–267, 2009.

[77] L. Lyons and Z. Pasek, “Enhancing engineering outreach with interactive game assessment,” *113th Ann. ASEE Conf. Expo Available*, 2006.

[78] A. Genau, *Materials Camp at UAB, Launching Technology to New Heights*. Amer. Soc. Eng. Educ, 2012.

[79] B. Bogue, *Assessment Driven Change: How Systemic Evaluation Can Lead To More Productive Outreach*. ASEE Ann Conf. & Expo., Portland, Oregon, 2005.

[80] Y. Bagiya, “A Study of Evaluation Methodologies and Impact of STEM (Science, Technology, Engineering and Mathematics) Outreach Activities,” PhD. dissertation, Coventry University, 2016.