Collaborative Community-based Research Experiences in Materials and Manufacturing (Work in Progress)

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ABSTRACT
Three regional institutions of higher learning are entering into their third year of a grant funded by the National Science Foundation (NSF) which provides authentic research experiences in materials and manufacturing for community-based teams comprised of STEM educators from urban, rural and underrepresented school districts as well as undergraduate and graduate students majoring in STEM disciplines and STEM education. The assimilated teams worked collaboratively with program principal investigators, research faculty mentors, STEM curriculum experts and evaluators to engage in real-world research activities related to the manufacturing of materials from natural products, medicinal plants as well as the scaled-up additive manufacturing of three-dimensional components for various industrial applications. This successful model of collaborative community engagement actively partners with local manufacturers involved in forging and heat treating of materials, the high-tech fields of medicinal and aerospace materials, state of the art printing of three-dimensional objects as well as conventional sheet fed print media. Essential components of engineering design from the team research experiences are incorporated into the Teach Engineering transformative STEM curriculum for implementation in the classroom to foster greater interest among students in pursuing careers in STEM disciplines, especially among female and minority learners. Multi-faceted STEM curriculum placing greater emphasis on critical thinking and engineering design skills that match current materials and manufacturing trends is a prescription essential to man (woman) power transformation. Team reflections support program revisions which include civic minded components of research ethics and engineering for the good of society, as well as the benefits of community-based learning teams for workforce development of the next generation of STEM professionals.

Introduction

Advanced manufacturing and materials science education is directly related to pre-college engineering education in that it involves the implementation and integration of new technology to improve products and/or processes, with the relevant technology described as ‘advanced,’ ‘innovative,’ or ‘cutting edge’, into innovative teaching strategies and robust learning materials.[1,2] A major constraint to the implementation and integration of new and emerging topics in manufacturing education is that in order for it to be sustainable engineers and scientists are required to develop novel materials that are compatible with these new manufacturing techniques and still be stronger, lighter, more energy-efficient, and more durable than currently available materials. In order to maintain global competitiveness, adoption of cutting-edge manufacturing technologies and advanced materials will require a workforce with advanced training in related specialized fields. Studies on the efficacy of research experiences for teachers (RET) suggest RET programs aid teachers is maintaining currency in their field as a result of participation[1] and influence their teaching style, strategies, and willingness to incorporate new open-ended curriculum in the classroom thereby exposing students to engineering while at the same time adhering to state and national education standards.[3,4]

Materials and manufacturing research and development such as that presented in this collaborative program[5,6] examines efforts to integrate that work into innovative instructional resources and tools with engineering design education. For example programmatic research at two of the three collaborating institutions examined alternative techniques such as 3D printing, which reduce part count, material waste and tooling cost, to incorporate complexity while at the same time utilizing advanced materials (i.e., composite materials, nano-materials, etc.) to obtain desired functionality (a.k.a., functional materials) for specific real-world manufacturing applications. Research efforts at the third partnering institution took advantage of material properties from natural products to investigate antimicrobial and antioxidant effects of medicinal plants with potential detection related to the development of natural electrochemical sensors and application suitable for detecting their presence in alternative energy fuels.

Program Overview

This paper builds upon prior collaborative NSF work which provides research experience for teachers. Currently in its second year, the summer program provides a rich and vibrant forum for the exchange of ideas, research, and experiences in pre-college engineering education. It is designed to promote workforce development in science, technology, engineering, and mathematics (STEM) by intentional and purposeful engagement of grade K-12 educators in both formal and informal learning environments as a means to increase reach and promote pre-college engineering education with a diverse number of students who in return are instilled with the mindset to enroll, persist and graduate college with degrees in fields of science and engineering. The three specific goals or research topics for the RET programming are (1) to equip teachers with the ability to transfer applied engineering research activities to their classrooms and develop and disseminate new curriculum associated with these activities, (2) to attain new knowledge of engineering disciplines and careers, particularly those related to advanced manufacturing and materials and gain a new appreciation for the value of team-based learning environments, and (3) to benefit professionally through development activities integrated in the RET programming. Each program goal/topic is related to one of nine objectives forming the basis for program evaluation (Table 1).

During the initial year, this program placed twelve G6-12 teachers and five pre-service teachers with research mentors at one of the three regional universities to work on projects that connected with regional strengths in materials and advanced manufacturing.[5,6] The second summer cohort introduced 6 college students to the teaming of 6 new pre-service and an additional 12 in-service teachers majoring or teaching in STEM disciplines, respectively, in the Dayton, Ohio area providing 6 weeks of manufacturing and materials science experiences. This teaming of six groups included two in-service teachers, one pre-service teacher, one college student mentor and one faculty mentor. Field trips, guest speakers and team building activities were interspersed with group work that produced K-12 engineering curriculum and documented research experiences in materials and manufacturing. Industry tours provided participants with first-hand experience in materials and manufacturing in industrial settings. Second year programming focused on facilitating unified professional development activities to be experienced by all participants and included added components on historical and social implications of engineering as well as poignant seminars on talking to underrepresented students (i.e. women, minority) about engineering.

Pre-College Engineering Curriculum Development and Pedagogy

Since one of the main objectives of this program was to facilitate the transfer of the engineering research activities into the teacher participants' classrooms, a significant component of the experience was dedicated to curriculum development. As such, the in-service and pre-service teachers participated in a one week ASM materials “boot camp”, facilitated workshops and activities that focused on curriculum development and inquiry-based learning. Detailed emphasis on the pre-college engineering curriculum developed by the pre-service and in-service teachers was accomplished through an ideation session designed to stimulate creative curriculum development, on which the participants were provided training, coaching and mentoring. Additional exposure participants received, which informed their curriculum development, were on alternative ways to change the topic of discussion about engineering and bring non-traditional groups into the conversation, the concept of service-learning and other pedagogical strategies (such as team-based, real-world) to demonstrate the breadth of opportunities in the field of engineering. RET participants were engaged in a process-oriented engineering design model[7-9] as a way of solving problems and formatted their curricula using the TeachEngineering template[10] located at (https://www.teachengineering.org/).

Formative and summative pre- and post-assessments were included in the curriculum units developed. The teachers and pre-service teachers, with input from their research mentors, the project PI’s and a curriculum development coordinator, developed and wrote STEM curriculum that incorporated some of the concepts that they had learned from either the ASM Materials Camp or from their research experience. Additionally, all of the curricula were designed to align with the state and national curriculum standards. During a Curriculum Sharing Day, each team had the opportunity to share the curriculum they developed with the rest of the participants and invited guests. Each team was required to provide an overview of their lesson and then facilitate a short sample hands-on activity. A question and answer period was facilitated at the end of each teams’ presentations which provided the audience with an opportunity to provide feedback and give ideas to the presenting team. The curriculum developed through this experience is currently being subjected to a vetting, editing and piloting process and will eventually be published on the at www.teachengineering.org website, where it can be widely accessed and used by teachers across the nation. Table 2 presents a summary of the 5 curricula developed by cohort 2 as a result of the summer experience.

Data Collection and Program Evaluation

As this program is a work in progress, only preliminary data from the first two cohorts are available for program evaluation. Current evaluation efforts were based on participant reflections, pre- and post-program Local Systemic Change (LSC)[11] surveys, participation in academic year follow-up activities, as well as data collection and reflection during the follow-up academic year. These sources were aggregated to describe the impact of the participants’ summer experiences for primary investigators leading the program, materials and manufacturing researchers, in addition to the NSF funding agency. The evidence collected regarding the nine objectives based on the three research topics are listed in Table 1 including progress and recommendations for the follow-up year two activities and for implementation in year three of this program. Full evaluation results collected and analyzed for the entire three year collaborative program are anticipated to be available beginning in 2018. To date, qualitative and quantitative data were used to capture evidence of participants’ self-perceived growth for many of the stated objectives and provided evidence regarding the impact of these professional development opportunities on the teachers’ attitudes, beliefs and practices.[12] Evaluation of these nine objectives indicated that all were met. There were two statistically significant findings. (1)

Participants' LSC pre/post responses showed statistically significant improved attitudes (p = 0.10) towards teaching after the professional development. (2) Within the LSC composite regarding attitudes towards teaching, participants' reflected statistically significant improvement (p = 0.01) regarding their being able to engage students in inquiry oriented activities. Thus, participants' comfort in planning activities that involved inquiry based learning received the largest improvement at a p level of 0.01.

Thus, preliminary assessment results noted above suggest the leveraging of existing academic, professional and social support services for teachers via experiential learning about the capabilities available in the Dayton region in materials and manufacturing related fields promote student success by the improvement of engineering design instructional materials delivered by the program participants to their STEM students. Also of interest is that participants represented Grade K-12 schools with 9 from Dayton, OH; 1 from Columbus, OH and 1 from Charlotte, NC. The majority of schools participating in cohort 2 had 14% or fewer nonwhites and less than 40% considered to be from economically disadvantaged districts (excluding participant from Charlotte, NC). Increased diversity of school districts, in-service and pre-service teachers participating in cohort 2 is a very noteworthy accomplishment for the program during year 2 as it impacts the potential to reach and engage a greater number of diverse student populations experiencing pre-college engineering education.

Table 1. *Program Objectives, Outcomes and Recommendations*

Objectives	Evidence	Progress of Objectives and Recommendations
A. Teach engineering concepts to over 1,000 PK-12 students over the project period, including students from schools with a significant minority population (Goal 1).	Annual demographics from participating schools.	Objective met. No recommendations
B. Develop inquiry- and team-based STEM curriculum and innovative pedagogy to encourage interest in STEM and, in particular, engineering (Goal 1).	All participants collaborated in group development of STEM Curriculum Design during the summer program.	Objective met. Consider curriculum development feedback regarding more clear requirements for the project and regarding group membership.
C. Disseminate curriculum deliverables through the Teach Engineering digital library, and professional development workshops such as the STEM Think Tank (Goal 1).	The curriculum will be available through the Teach Engineering digital library and through professional development workshops such as the STEM Think Tank for Dayton area teachers.	Objective met. Continue to keep statistics regarding piloting and usage of curriculum deliverables.
D. Have their STEM interest sparked by using modern engineering tools and gaining new knowledge of engineering careers (Goal 2).	Participants named new knowledge and STEM interest regarding 3D printing, measuring the wavelength of light, learning about specific properties of materials and other STEM topics	Objective met. No recommendations
E. Understand the social relevance and ethical implications of engineering activities related to manufacturing (human rights, environmental impact, etc.) (Goal 2).	The social relevance and ethical implications of manufacturing as a sociological phenomenon was presented and discussed.	Objective met. No recommendations
F. Share knowledge, ideas and concepts working on teams with professional and pre-service teachers, research mentors and industry partners (Goal 2).	Participants worked as teams within the university hosting sites during which the teams developed research related to the PIs expertise. Participants reported successful team work.	Objective met. Consider suggestion regarding grouping participants by background
G. Acquire collaboration and networking possibilities through interaction with real-world engineering industry and government mentors and partners (Goal 3).	Participants reported plans to use the laboratory experiences and industry tours for collaboration and networking in the upcoming year.	Objective met. No recommendations
H. Attain leadership roles in K-12 setting through the RET program's professional development component (Goal 3).	Participants will collaboratively work with team members and RET PIs in publishing their research findings and distributing curriculum developed in the program.	Objective met.
I. Achieve long-term collaborative partnerships with the regional university research community and engineering professionals during substantial follow-up activities (Goal 3).	Relationships were developed. Follow-up activities will be documented.	Objective met.

Summary

This paper describes a regional collaborative program for STEM educators at all levels by which engineering research in advanced manufacturing and materials development is transferred into pre-college curriculum using the engineering design process and piloted in the classroom. This approach is a successful strategy for disseminating STEM education that meets quality standards.[9] Follow-up activities, post-program reflections, and LSC composite surveys[11] suggest equipping teacher participants with the tools, knowledge, and relevant curriculum concerning the engineering profession in advanced manufacturing and materials described herein enables them to encourage and inspire their students to pursue careers in STEM areas with the intent to contribute to workforce development in these fields.

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Table 2. *Pre-College Engineering Curriculum Development*

Curriculum Title	Grade Band	Engineering Design Challenge
A. ***Shanty Town Design***	*High school physics, social studies, chemistry, and art lesson with engineering design challenge on shanty town building improvements.*	*After being introduced to the problem of the living conditions of homes in shanty towns, students will investigate the chemical and physical properties of cement based composites to improve the shanties found in many less-developed nations. Their goal is to find a material that is more resistant to chemical degradation, weather and natural disasters (rain, hail, earthquakes, etc.), and man-made disasters (bombs, pollution, etc.). Students will experiment with materials to create an overall pleasing surface design to improve quality of life in the shanty town. The replacement shanty materials should be inexpensive and/or readily available so that they are a viable alternative to the economically disadvantaged.*
B. ***Doghouse Design***	*Grades 4 – 5 lesson with engineering design challenge on light, energy, and heat.*	*Students will explore light energy and how it does or doesn't travel through various materials as well as explore how color affects the absorption or reflection of light. Students will complete a series of simple light/heat experiments to explore light/heat transfer. Students will use this knowledge of light, energy transfer, absorption, insulation, and materials to design a doghouse that will protect the dog from heat.*
C. ***Fruit Circuitry Design***	*High school math and science lesson with engineering design challenge on manipulating equations to solve for variables and applying concepts to electric formulae.*	*Students will create a circuit out of fruit and different household metals in order to determine which metals and fruit will create the strongest current in order to power their cell phones, which will be displayed by a lightbulb during the experiment. They may also design different circuits with the combinations of fruit with in the entire class.*
D. ***Cell Phone Packaging Design***	*High school math and physical science lesson with engineering design challenge where students will be able to use their knowledge of linear regression.*	*Students design and solve a real world challenge about creating a better packing solution for cell phones using a composition of a variety of materials. Students will determine the specific properties of different materials and then determine how they can be combined to meet specifications set by the company.*
E. ***Lift Hook Design***	*Middle school math, science, and social studies lesson with engineering design challenge about properties of metals.*	*The three heat treatments we will be focusing on are annealing, quenching, and tempering. Students will build, test, analyze and compare heat treated and non-heat treated paper clips that represent a hook for a lift. Lifts have a variety of uses and applications but all lifting hooks must not fail for their applied uses. Lifts can range from wheelchair lifts to extreme uses such as ship or building construction. Students will learn about heat treating and how engineers develop their products.*

References

1. Salzman, N., Nadelson, L., Ubic, R. (2016). “Implementing and Assessing a Joint REU/RET Program in Materials Science,” 2016 ASEE 123rd Annual Conference and Exposition. New Orleans, Louisiana. June 2016. Paper ID #16370.
2. Ragusa, G., Mataric, M. (2016). “Research Experiences For Teachers: Linking Research to Teacher Practice and Student Achievement in Engineering and Computer Science,” 2016 ASEE 123rd Annual Conference and Exposition. New Orleans, Louisiana. June 2016. Paper ID #17351.
3. Trenor, J., Yu, S., Grant, D., Salem, H. (2009). “Participation in a Research Experience for Teachers Program: Impact on Perceptions and Efficacy to Teach Engineering,” 2009 ASEE 116th Annual Conference and Exposition. Austin, Texas. June 2009. Paper ID #AC 2009-786.
4. Klein-Gardner, S., Johnston, M., Benson, L. (2012) “Impact of RET Teacher-Developed Curriculum Units on Classroom Experiences for Teachers and Students,” *Journal of Pre-College Engineering Education Research (J-PEER)* 2:2, Article 4 pp. 21-35.
5. Mian, A., Pinnell, M., Petry, L., Srinivasan, R., Franco, S., Taylor, M. (2016) “Summer Research and Collaborative Professional Development Experience for NSF RET Teachers in Advanced Manufacturing and Materials,” 2016 ASME International Mechanical Engineering Congress and Exposition. Phoenix, Arizona. November 2016. Paper ID #IMECE2016-66141.
6. Pinnell, M, Franco, S., Preiss, S., Petry, L., Mian, A., Taylor, M. (2016). “Assessment of a Collaborative NSF RET Program Focused on Advanced Manufacturing and Materials,” 2016 ASEE 123rd Annual Conference and Exposition. New Orleans, Louisiana. June 2016. Paper ID #15987.
7. Rowley, J., Preiss, S., Pinnell, M., Franco, S., (2012). “Engineering Innovation and Design for STEM Teachers and the STEM Quality Framework,” Conference Proceedings, Published, P-12 Engineering and Design Summit, Washington DC, April 2012.
8. Pinnell, M., et. al, (2013). “Bridging the Gap between Engineering Design and PK-12 Curriculum Development Through the use the STEM Education Quality Framework,” *Journal of STEM Education* 14:4 available at http://ojs.jstem.org/index.php?journal=JSTEM&page=article&op=view&path%5B%5D=1804.
9. STEM Education Quality Framework website, http://stemframework.washingtonstem.org/, Accessed Sept. 2013.
10. TeachEngineering https://www.teachengineering.org/.
11. Horizon, Inc. (1996). “Local Systemic Change Teacher Survey for Math and for Science Teachers. Retrieved from http://www.horizon-research.com/instruments/hri_instrument.php?inst_id=10.
12. Desimone, L., Porter, A. C., Garet, M. S., Yoon, K. S., Birman, B. F. (2002) “Effects of Professional Development on Teachers’ Instruction: Results from a Three-Year Longitudinal Study,” *Educational Evaluation and Policy Analysis* 24:2 pp. 81–112.