Gonca Altuger-Genc, Marjaneh Issapour. (2015). Preparing STEM Teachers for Integration of NGSS: A Summer Workshop Development. *Journal of Education and Learning*. Vol. 9(4) pp. 305-313.

Preparing STEM Teachers for Integration of NGSS: A Summer Workshop Development

Gonca Altuger-Genc*
Farmingdale State College, SUNY, United States

Marjaneh Issapour**
Farmingdale State College, SUNY, United States

Abstract

The increasing emphasis on Science, Technology, Engineering and Mathematics (STEM) education in United States and across the world created the demand for STEM education to start as early as elementary school. Especially in the past decade, the demand for middle schools and high schools to increase the involvement of the STEM components in their curriculum has been on the rise. The Next Generation Science Standards (NGSS)are testimonial to this demand and need. With the fast-pace the NGSS are being adopted by different states, the expectations from science, engineering, and technology teachers to develop and design their courses to reflect the new standards and meet the updated goals increased. To support teachers with the necessary resources and training, a Summer STEM training program and a set of STEM training modules have been developed by a 4-year accredited State College. This paper provides an overview of the STEM initiatives and a step-by-step approach of the design and development of the STEM modules to train K-12 teachers.

Keywords*: STEM, NGSS, engineering education*

*Gonca Altuger-Genc, School of Engineering Technologies, Farmingdale State College, SUNY, Farmingdale, NY 11735, United States
E-mail:*gencg@farmingdale.edu*

**Marjaneh Issapour, School of Engineering Technologies, Farmingdale State College, SUNY, Farmingdale, NY 11735, United States
E-mail:*issapom@farmingdale.edu*

Received July 31, 2015; Revised October 22, 2015; Accepted November 1, 2015

Introduction

Since its formation back in 1990s (Sanders, 2009), STEM fields and the importance of STEM education gained more importance. The demands to have the STEM components to be introduced at elementary, middle and high school students are historically met by colleges and universities through their summer STEM programs and afterschool STEM workshops. Many colleges and universities across the nation offer summer programs, workshops and career exploration events to attract more students to the fields of science, engineering, technology and mathematics. These summer programs are beneficial both for the students and the universities. Students gain college experience by spending time on campus, learning about STEM programs; while universities benefit by attracting more students to their programs and departments. The recent increased interest in the STEM fields changed the demand and the expectations from K-12 science education (Issapour et.al., 2014).In an effort to meet the demands and expectations, K-12 institutions started to partner up with higher education institutions to create programs geared towards their students and teachers. These programs can be carried out in formal and informal learning environments. Formal learning environments include a set project, curriculum and a traditional learning platform. Project Lead The Way (PLTW) (https://www.pltw.org/) and Engineering by Design (EbD) (http://www.iteea.org/EbD/ebd.htm) are two examples of such efforts. Nathan et al. (2014) presented the outcomes of an integrated K-12 STEM education, where formal and informal STEM education is examined. The informal learning environments include hands-on projects, involvement of undergraduate and graduate students and families in the learning process. Schnittka et al., (2012) reviewed the informal learning environments to teach STEM to middle school students, where the middle school students work with peers and undergraduate students on engineering design and science projects. Heil et al., (2012) presented the application details of an approach named as: "*family engineering*", which is based on engaging elementary age students in exploring careers with their parents, where the outcomes showed that including families in the process increased students' willingness and participation in an engineering related field.

In addition to the learning environments, higher education faculty has employed design-based teaching. Billiar et al.,(2014) described the application and the practice of how teachers employ and utilize the "*engineering design process (EDP)*" to teach the STEM components to students. The design component plays an important role in STEM education as it develops the critical thinking skills students need for the STEM majors. Aleong et al., (2012) examined how design education is preparing engineering students to be problem solvers since the design projects are open-ended and complex. In addition to the design component, physical teaching components such as smart boards, digital whiteboards and other application systems are widely implemented and used when teaching STEM education. Tillman (2013) concluded the effectiveness of "*Do-It-Yourself (DIY)*" interactive digital whiteboards to teach mathematics to middle school students. Crittenden et al., (2013) provided a 2D paper truss project example to demonstrate the applications of the STEM principles and fundamentals; the results showed that the one-week teacher-training workshop provided a great increase in teachers' effectiveness in teaching STEM concepts.

In addition to the learning environments, it is also crucial to develop good assessment tools to measure students' and teachers' responses. With the correct assessment techniques the programs can be improved. Wiebe et al., (2013) reported the use of "*S-STEM*", a new survey, as a decision-making model for both formal and informal K-12 STEM initiatives. Thomas et.al.,(2011) introduced a "*Fundamentals of Engineering for Educators*" course that was offered to K-12 teachers, the assessment designed for the course evaluated whether the student learning outcomes are achieved and what are the most effective components of the course. An implementation of robotics-based curriculum and case studies are used to teach and assess the role of mathematics as students completed the case studies (Silk et al., 2008).The development of an Energy and STEM K-12 program is presented to show the employment of STEM modules to teach the concepts of energy (Altuger-Genc et al., 2014). In addition to the college K-12 programs for STEM education, industry-college-K-12 school partnerships also provide an excellent platform to teach students about STEM and related careers (Pawlowski et.al., 2011). Tyler-Wood et al., (2010) presented two new instruments to assess perceptions of STEM related disciplines for elementary through high school students; where the surveys assess the participants' interest and attitude towards STEM education and STEM career selection.

Although the summer programs, workshops, university and industry partnerships provide a great platform to introduce K-12 students to STEM and STEM related careers; the continuous increase in demands and expectations from K-12 science and engineering education lead to the development of the Next Generation Science Standards (NGSS) (http://www.nextgenscience.org/). NGSS is developed through a state-led process and covers from K-12 physical sciences, life sciences, earth and space sciences, and engineering, technology, and applications of sciences. Since its release in April 2013, NGSS was adopted by 13 states (Heitin, 2014). The transition from the existing science standards to

NGSS requires changes at the curricular level, and in order to make the transition seamless, it is important to train elementary, middle and high school teachers. Many higher education institutions developed custom-designed training materials and workshops for STEM teachers. Bergen et al., (2014) shared an example of an engineering design module, which was designed by teachers, educators, and science and engineering professors to prepare Liberal Studies major teachers for NGSS. Passow (2013) introduced a set of lesson plans that meet NGSS on scientific ocean drilling, where the lesson plan can be used as a template for many other areas. Morrow et al., (2013) presented a web site that has more than 1200 hours of video documentation; the web site provides unique resources for teachers and educators while fulfilling the NGSS. Buhr Sullivan et al., (2013) emphasized the importance of NGSS in geosciences education and highlighted the importance of teacher education as well as curricula development. Lebofsky (2014) reviewed the instructional rock kits and materials developed by The Planetary Science Institute (PSI) to provide training and support materials to teachers to fulfill NGSS as they teach Earth and Space Science. Irwin et al., (2015) examined the use of 3D printers as a support tool to NGSS, and concluded that 3D printers improve students' understanding of the engineering concepts. In addition to the hands-on learning kits, the online learning environments are widely employed to provide training to teachers and students. Ernst et al., (2014) introduced an NSF funded project that created an online professional development system for technology, engineering and design educators for grades 6-12. Bakrania et al., (2014) provided an implementation and assessment of a workshop that is designed for 8th grade physical science standards.

In an effort to support K-12 educators and education institutions through the NGSS transition, a set of modules are developed in our institution. The modules offer a combination of applications in Physical Sciences, Life Sciences, Engineering, Technology and Applications of Science. The modules are designed to be offered through a 2-week summer workshop for high school teachers. Throughout the workshop, teachers will be introduced to the NGSS, will be provided with hands-on examples and assessment worksheets as well as curriculum development to update their courses to meet the NGSS. This paper provides an overview of the development of the training modules, the mapping of the NGSS to the modules' learning outcomes and the proposed assessment.

Development of the STEM Summer Workshop

The workshop for teachers designed to provide a vast array of modules that cover sciences, technology and engineering concepts as well as integration of mathematics into these concepts. High school NGSS cover three Physical Sciences components: HS – PS1 – Matter and Its Interactions, HS – PS2 – Motion and Stability: Forces and Interactions, and HS – PS3 – Energy, respectively (http://www.nextgenscience.org/). This paper focuses on the modules developed for the HS – PS3 – Energy component.

The summer workshop for high school teachers has 2 components: theoretical and practical. The theoretical component is designed to provide students the overview of the concepts of energy, applications of energy, current energy challenges, and conservation of energy, and energy in everyday life. The practical component is designed to provide hands-on project and problem-based teamwork experience along with curriculum and course material design for teachers. The assessment of the summer workshop will be carried out in two levels: the first level will be completed by surveys prior to the workshop, the second level will be completed in two phases: surveys immediately after the workshop and surveys 6 months after the workshop. The immediate assessment aims to measure teachers' experience in the workshop, whereas the second level aims to measure the long-term outcomes of the workshop as well as teachers' experience in implementing modules and materials into their courses. The assessment outcomes will be used to monitor and continuously improve the modules as well as in creating new modules for HS – PS1 – Matter and Its Interactions and HS – PS2 – Motions and Stability: Forces and Interactions.

Development of the STEM Modules

The STEM modules for the HS - PS3 - Energy component are designed to cover various areas in Energy while meeting the NGSS. A total of 7 modules have been developed for the summer workshop: Introduction to Energy, Energy and Engineering, Energy Sustainability, Solar Energy, Wind Energy, and Electrical Energy, respectively. A brief description of the modules are listed below:

Introduction to Energy Module: In this module, high school teachers will be provided with information on definitions of energy, sources of renewable energy, as well as qualitative and quantitative methods to measure energy, as well as kinetic and potential energy. This module aims to provide an introductory knowledge and material for teachers to introduce their students to the concept and components of energy. Teachers will be provided with information sheets to be used in the classroom, along with worksheets to be distributed to students for assessment.

Energy and Engineering Module: This module will cover the important role energy plays in engineering applications as well as design of engineering systems for energy related applications. A review of working principles of wind turbines, solar energy ovens and energy generation will be discussed. In addition to the information sheets, teachers will be provided with worksheets to assess their students' learning.

Energy Sustainability Module: This module provides an overview of the concept of sustainability. Evidence-based energy sustainability evaluation will be covered and mathematical analysis of the outcomes will be examined. This module will also provide real-life examples of energy sustainability and will strengthen critical thinking skills of the students. The energy sustainability module includes information sheets and worksheets for teachers to share with their students; teachers will also have the flexibility to customize their worksheets to measure their students' understanding of the concepts.

Solar Energy Module: This module provides a review of the renewable energy sources and focuses on solar energy as a renewable energy source. Solar energy devices as well as photovoltaic cells will be reviewed within this module. Examples related to solar modules, as well as, hands-on study material will be provided to teachers. Like the previous modules, teachers will be provided with information sheets and worksheets to implement into their courses.

Wind Energy Module: This module continues with the review of the renewable energy sources and focuses on the wind energy as a renewable energy source. Wind energy generation and distribution are reviewed. Teachers are provided with information sheets and worksheets to use in their classrooms. The wind energy module also covers the working principles of wind turbines such as; how are they built, where they should be located, and how blade angles are chosen.

Electrical Energy Module: The electrical energy module provides an in depth overview of the concepts of electrical energy while focusing on electric and magnetic fields, energy storage, and how generators work. These concepts will be supported with qualitative and quantitative examples that promote critical thinking. Teachers will be provided with information sheets and worksheets.

Figure 1 provides an overview of the mapping between each module and the NGSS disciplinary core ideas.

Proposed Implementation Procedure of the STEM Modules

The proposed implementation procedure for the STEM modules for high school teachers includes a series of steps to be followed. The summer workshop is designed to start with an overview of the NGSS and review of the standards, outcomes and the core areas. Upon completion of the introduction, the six modules will be covered in the same order presented in Figure 1. Within each module teachers are provided with information sheets and worksheets. The information sheets have two versions: the teachers' version and the students' version. The students' version provides students information on the concept covered in that particular module along with discussion questions, examples and in-class problems. Teachers' version has the same components as the students' version with the addition of follow-up questions to discussion questions, answers and solutions to examples and in-class problems. The worksheets also have teachers' and students' versions. The students' version has activities, questions, and problems with empty spaces for students to fill out the information. The students' worksheets are designed so that if the teacher chooses to collect, grade and provide feedback they can use the worksheets to assess students' learning. The teachers' versions of the worksheets have the answers, solutions and recommendations for teachers to provide to their students. The training overview along with the mapping of the STEM modules and NGSS are provided in Figure 2.

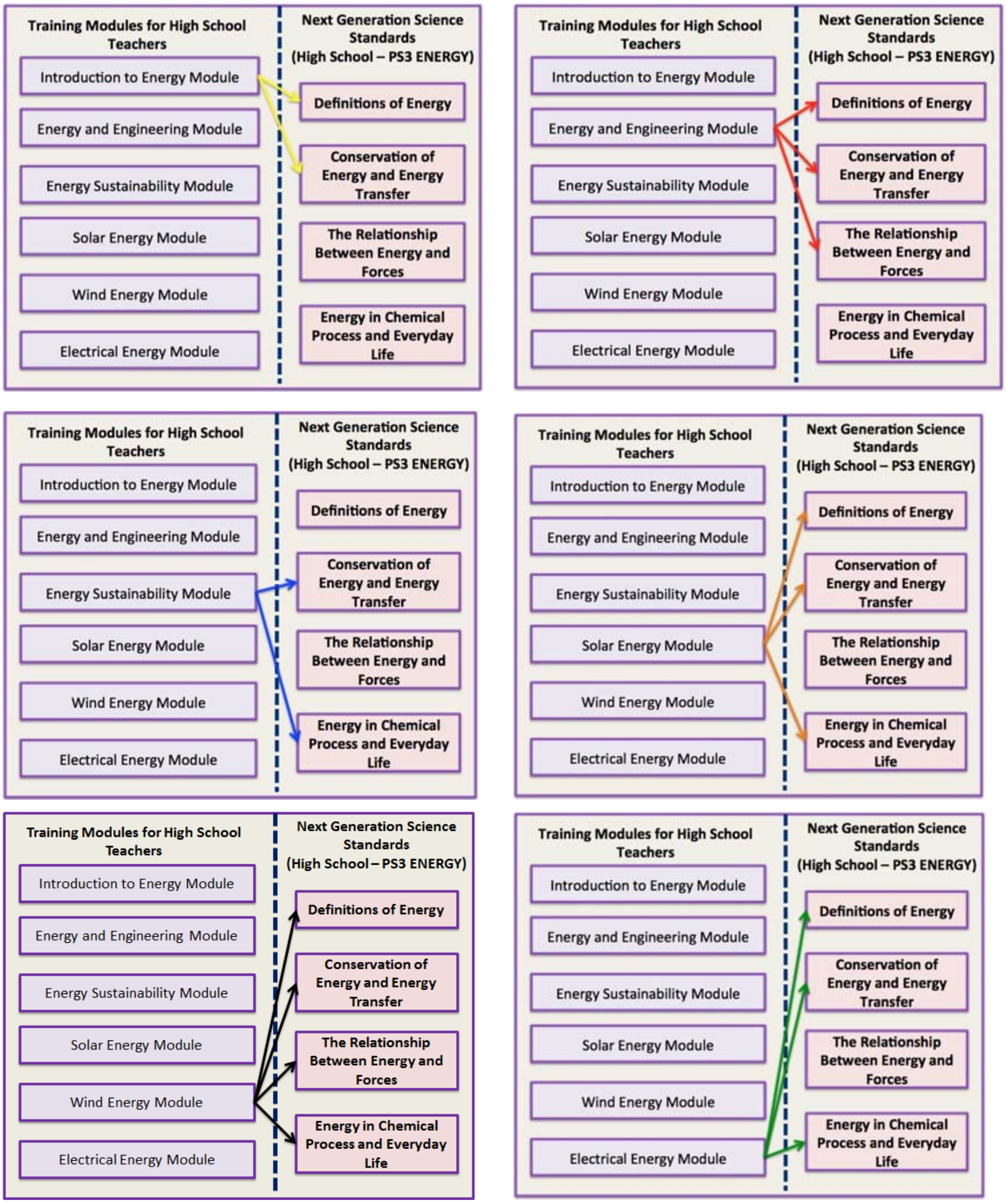


Figure 1. Mapping of the STEM Training Modules and NGSS Disciplinary Core Ideas

Assessment of the Summer Workshop

The assessment of the summer workshop will be completed in two levels. In the first level teachers will be provided a questionnaire prior to the start of the summer workshop. This initial questionnaire aims to measure teachers' initial knowledge of the NGSS as well as their expectations from the summer program. A portion of the initial questionnaire (pre-workshop questionnaire) is provided in Figure 3. The second questionnaire has 2 phases: in the first phase, a questionnaire is provided right after the completion of the summer camp to measure teachers' immediate response (post-workshop questionnaire 1), the second phase, a second questionnaire, is provided 6 months after the completion of the summer program (post-workshop questionnaire 2) to measure teachers' long term response as well as their experience implementing the modules into their courses. A portion of the post-workshop questionnaire 1 and 2 are shared in Figures 4 and 5, respectively. The assessment results will be used to improve the modules, and make necessary and recommended updates to meet the needs of the teachers.

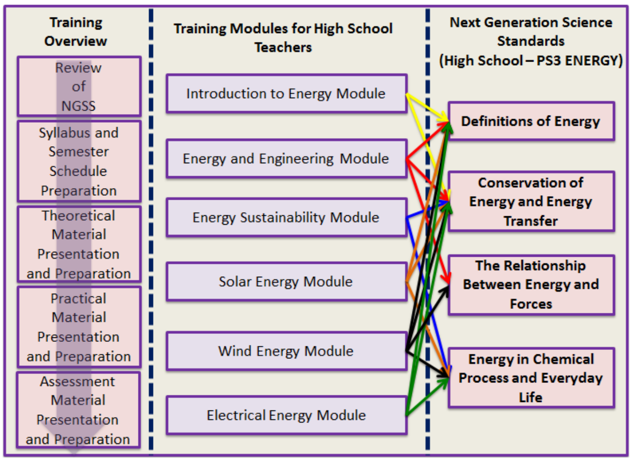
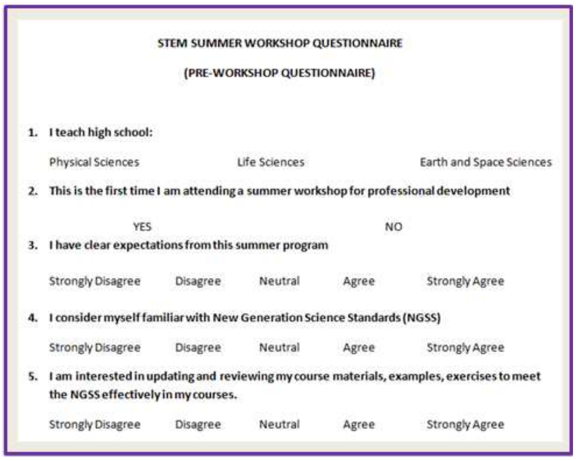


Figure 2. Training Overview - STEM Modules – NGSS Mapping



STEM SUMMER WORKSHOP QUESTIONNAIRE

(PRE-WORKSHOP QUESTIONNAIRE)

1. I teach high school:

Physical Sciences Life Sciences Earth and Space Sciences

2. This is the first time I am attending a summer workshop for professional development

YES NO

3. I have clear expectations from this summer program

Strongly Disagree Disagree Neutral Agree Strongly Agree

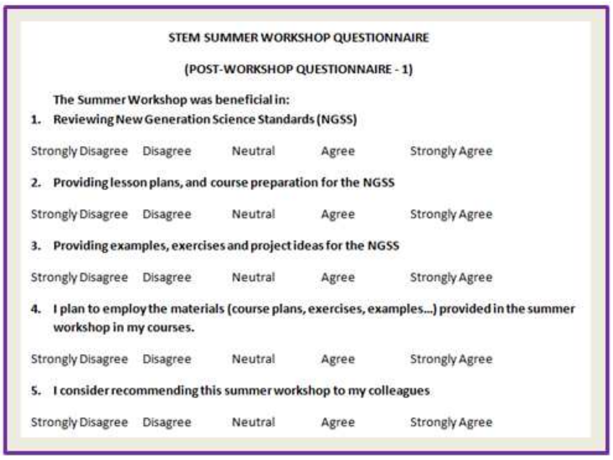
4. I consider myself familiar with New Generation Science Standards (NGSS)

Strongly Disagree Disagree Neutral Agree Strongly Agree

5. I am interested in updating and reviewing my course materials, examples, exercises to meet the NGSS effectively in my courses.

Strongly Disagree Disagree Neutral Agree Strongly Agree

Figure 3. Pre-Workshop Assessment Questionnaire



STEM SUMMER WORKSHOP QUESTIONNAIRE

(POST-WORKSHOP QUESTIONNAIRE - 1)

The Summer Workshop was beneficial in:

1. Reviewing New Generation Science Standards (NGSS)

Strongly Disagree Disagree Neutral Agree Strongly Agree

2. Providing lesson plans, and course preparation for the NGSS

Strongly Disagree Disagree Neutral Agree Strongly Agree

3. Providing examples, exercises and project ideas for the NGSS

Strongly Disagree Disagree Neutral Agree Strongly Agree

4. I plan to employ the materials (course plans, exercises, examples...) provided in the summer workshop in my courses.

Strongly Disagree Disagree Neutral Agree Strongly Agree

5. I consider recommending this summer workshop to my colleagues

Strongly Disagree Disagree Neutral Agree Strongly Agree

Figure 4. Post-Workshop Assessment Questionnaire -1

STEM SUMMER WORKSHOP QUESTIONNAIRE

(POST-WORKSHOP QUESTIONNAIRE - 2)

1. **Since the Summer Workshop, I taught a high school level Sciences Course**

   YES NO

2. **I employed the materials (course plans, exercises, examples...) provided in the summer workshop.**

   Strongly Disagree Disagree Neutral Agree Strongly Agree

3. **Summer workshop was beneficial in preparing me for the NGSS.**

   Strongly Disagree Disagree Neutral Agree Strongly Agree

4. **I plan to continue to employ the materials provided in the summer workshop in the future.**

   Strongly Disagree Disagree Neutral Agree Strongly Agree

5. **I consider attending future summer workshops for professional development.**

   Strongly Disagree Disagree Neutral Agree Strongly Agree

Figure 5. Post-Workshop Assessment Questionnaire -2

Conclusions and Future Work

This paper provided an overview of the design and development of a summer workshop to prepare high school teachers for the NGSS in the area of Energy. The mapping between each training module and the NGSS is provided along with the proposed 2-level assessment. The developed modules are expected to provide benefits for the teachers and for the college. One important expected outcome is for teachers to gain familiarity with the NGSS related to their area of expertise. Throughout the summer workshop, teachers will be provided with hands-on project material, worksheets, and support materials. These resources are expected to help teachers as they transition from the existing science standards to NGSS. The two level assessment processes is expected to provide feedback to improve the summer workshop for future years. The expected outcomes for the college are to build stronger relationships with the local high schools and continuously offer additional modules over the summer training.As future work, it is recommended to use the feedback to improve the existing modules as well as to develop new modules. The new modules can be developed in other areas of STEM to meet the NGSS.

Acknowledgements

Authors of this paper would like to extend their gratitude to the support they received from the FSC School of Engineering Technology Dean Dr. Kamal Shahrabi and RESC faculty and staff. The equipment and supplies purchased for these workshops were funded by the "Department of Energy's Smart Grid Demonstration Grant" and "Empire State Development Cooperation Grant"

References

Aleong, R.J. and Strong, D.S. (2012). "Student Perspectives of Engineering Design Education", *Proceedings of the ASEE 2012 Annual Conference*, June 10-13, 2012, San Antonio, TX.

Altuger-Genc, G. and Issapour, M. (2014). "Introducing the Design and Development of Energy and K-12 Program", IEEE Explore, *Proceedings of the 2014 International Energy and Sustainability Conference*, October 24, 2014, Farmingdale, NY.

Bakrania, S., Bhatia, K.K., and Jahan, K. (2014). "A standards-based tool for middle school teachers to engage students in STEM fields", *Proceedings of the 2014 ASEE Annual Conference*, June 15-18, 2014, Indianapolis, IN.

Bergen, A.M. and Chen, K.C. (2014). "Designing Engineering Curriculum for Pre-Service Teachers in Preparation for NGSS: Medical Mission Drop (Curriculum Exchange), *Proceedings of the 2014 ASEE Annual Conference*, June 15-18, 2014 Indianapolis, IN.

Billiar, K., Hubelbank, J., Oliva, T. and Camesano, T. (2014). "Teaching STEM by Design", *Advances in Engineering Education*, Volume 4, Number 1 – Winter 2014, pp: 1-21.

Buhr Sullivan, S.M., Awad, A.A., and Manduca, C.A. (2013). “National Association of Geoscience Teachers (NAGT) support for the Next Generation Science Standards”. Proceedings of the American Geophysical Union, Fall Meeting 2013, Abstract # ED53C-0646

Crittenden, K.B., Tims, H. and Hall, D.E. (2013). “2D Paper Trusses for K12 STEM Education”, *Proceedings of the 2013 ASEE Conference*, June 23-26, 2013 Atlanta, GA.

Ernst, J.V., Segedin, L.J., Clark, A.C. and De Luca, V.W. (2014). “Technology, Engineering, and Design Educator Professional Development System Implementation: Initial Pilot Results”, *Proceedings of the 2014 ASEE Annual Conference*, June 15-18, 2014, Indianapolis, IN.

Heil, D.R., Hutzler, N., Cunningham, C.M., Jackson, M., and Chadde, J.F. (2012). “Family Engineering: Exploring Engineering with Elementary-Age Children and Their Parents”, *Proceedings of 2012 ASEE Annual Conference*, June 10-13, 2012, San Antonio, TX..

Heitin, L. (2014). “Next Generation Science Standards: Which States Adopted and When?”, Education Week http://blogs.edweek.org/edweek/curriculum/2014/08/next_generation_science_standa.html Accessed on 7/28/2015.

Irwin, J.L., Opplinger, D.E., Pearce, J.M., and Anzalone, G. (2015). “Evaluation of RepRap 3D Printer Workshops in K-12 STEM”, *Proceedings of 2015 ASEE Annual Conference*, June 14-17, Seattle, WA.

Issapour, M. and Altuger-Genc, G. (2014). “Forming a Leadership Bridge Between High School and College: The Energy and STEM Leadership Program”, *Proceedings of the 2014 ASEE International Forum*, June 14, 2014, Indianapolis, IN.

Issapour, M. and Sheppard, K., (2014). “In Search of “ET”: K-12 Engineering and Technology Education in the New York State”, *Proceedings of the 2014 Conference for Industry and Education Collaboration*, February 5-7, 2014, Savannah, GA.

Lebofsky, L.A., Canizo, T.L., and Buxner, S. (2014). “Using the Planetary Science Institute’s Meteorite Mini-Kits to Address the Nature of Science”, *American Astronomical Society*, DPS Meeting # 46.

Morrow, C.A, Katzenberger, J., Osenga, E.C., and Arnott, J.C. (2013). “From the Horse’s Mouth: A Unique Resource for Bringing NGSS Standards on the Nature and Process Science to Life via Educational Access to Videos of Scientists Communicating with Each Other”, *Proceedings of the American Geophysical Union,* Fall Meeting 2013, Abstract # ED12A-02

Nathan, M. and Pearson, G. (2014). “Integrating in K-12 STEM Education: Status, Prospects, and an Agenda for Research”, *Proceedings of 2014 ASEE Annual Conference*, June 15-18, Indianapolis, IN.

Passow, M.J. (2013). “Designing Innovative Lesson Plans to Support the Next Generation Science Standards”, *Proceedings of the American Geophysical Union*, Fall Meeting 2013, Abstract#ED23A-0720

Pawlowski, J.S., Standridge, C.R., and Plotkowski, P.D. (2011). “Stimulating K-12 Student Interest Through Industry, Engineering College, and K-12 School Partnerships, Proceedings of the 2011 ASEE Annual Conference, June 26-29, 2011, Vancouver, BC, Canada.

Sanders, M. (2009). “STEM, STEM Education, STEMmania”, *The Technology Teacher*, December/January 2009, pp: 20-26

Schnittka, C.G., Brandt, C.B., Jones, B. D. and Evans, M.A. (2012). “Informal Engineering Education After School: Employing the Studio Model for Motivation and Identification in STEM Domains”, *Advances in Engineering Education*, Summer 2012, Vol.3, Issue 2, pp: 1-31.

Silk, E., and Schunn, C. (2008). “Using robotics to teach mathematics: Analysis of a Curriculum Designed and Implemented”, *Proceedings of the 2008 ASEE Annual Conference and Exposition*, June 26-29, 2008, New Orleans, LA.

Thomas, A., Hansen, Jan B., Cohn, Sarah H., Jensen and Brian Phillip. (2011). “Development and Assessment of an Engineering Course for In-Service and Pre-Service K12 Teachers”, *Proceedings of the 2011 ASEE Annual Conference*, June 26-29, 2011, Vancouver, BC, Canada

Tillman, D. (2013). "Supporting K12 Teachers that want to build their own Do-It-Yourself (DIY) Interactive Digital Whiteboards, *Proceedings of 2013 ASEE Annual Conference*, June 23-26, 2013, Atlanta, GA.

Tyler-Wood, T., Knezek, G., and Christensen, R. (2010). "Instruments for Assessing Interest in STEM Content and Careers", *Journal of Technology and Teacher Education*, 18(2), pp: 341-363.

Wiebe, E.N., Faber, M., Corn, J., Collins, T. L., Unfried, A., and Townsend, L., (2013). "A Large Scale Survey of K-12 Students about STEM: Implications for Engineering Curriculum Development and Outreach Efforts (Research to Practice)", *Proceedings of 2013 ASEE Annual Conference*, June 23-26, 2013, Atlanta, GA.