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Baby Steps toward Meeting Engineering-rich Science Standards: Approaches and Results from a Short "What is Engineering?" Course for K-5 Pre-service Teachers (Work in Progress)

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Raman enjoys teaching and has taught courses including freshmen engineering (mechanics and computer programming – to classes ranging in size from 20 to 500+), sophomore and junior level courses on mass and energy balance applications to biological systems engineering, numerical methods, electric power and electronics for technology students, senior design, as well as a long-standing residential/online graduate course on the fundamentals of biorenewable resources and technology. He has leveraged this interest into over $10M in teaching-related grant funding over his career and has contributed broadly to the literature in areas of curriculum, student risk characterization, and mentoring. He believes well trained, curious, thoughtful people are crucial to a university's research effort, and similarly to the function and survival of society. For this reason, the overarching goal of his teaching is to impart the core content needed by the students, and to do so while encouraging inquisition and higher levels of thought. He has secured competitive funds to support his teaching efforts – from university, industry, and federal sources – and for his efforts has received departmental, college, and national teaching honors including the Farrall Young Educator Award (2004) and the Massey-Ferguson Gold Medal Teaching Award (2016) given by the American Society of Agricultural Engineers. He has also been an invited participant in the National Academy of Engineering's 2013 Frontiers in Engineering Education Conference.

Raman chairs the ABE Engineering Curriculum Committee and in that role oversaw the successful 2012 ABET accreditation visit for both the Agricultural Engineering (AE) and Biological Systems Engineering (BSE) degree programs. Upon arriving at ISU in 2006, he led the development of the BSE program, and this program now enrolls over 100 students. Raman also runs multiple summer research internship programs through his roles in CBiRC and CenUSA – over 200 students have participated in summer programs he directed over the past decade. In his role as Pyrone Testbed Champion for CBiRC, Raman and his students have developed early-stage technoeconomic models of bioprocessing systems. His graduate students have gone on to faculty positions at peer institutions, and to engineering leadership positions at companies including Cargill, Nestle, and Merck.

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Kristina M. Tank is an Assistant Professor of Science Education in the School of Education at Iowa State University. She currently teaches undergraduate courses in science education for elementary education majors. As a former elementary teacher, her research and teaching interests are centered around improving elementary students' science and engineering learning and increasing teachers' use of effective STEM instruction in the elementary grades. With the increased emphasis on improved teaching and learning of STEM disciplines in K-12 classrooms, Tank examines how to better support and prepare pre-service and in-service teachers to meet the challenge of integrating STEM disciplines in a manner that supports teaching and learning across multiple disciplines. More recently, her research has focused on using literacy to support scientific inquiry, engineering design, and STEM integration.

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Baby-steps towards meeting engineering-rich science standards – approaches and results from a short "What is Engineering?" course for K-5 pre-service teachers (Work In Progress)

Abstract

Elementary teacher preparation programs are generally tightly packed, with limited room for additional coursework. As states adopt Next Generation Science Standards (NGSS[1]), the need for teacher education programs to provide meaningful exposure to engineering is growing, and a multitude of approaches can be taken to meet this need. We describe here our efforts in building a 12-contact-hour non-credit short course – based upon NGSS-aligned learning outcomes – delivered to 10 students in fall 2016.

Introduction

The recent adoption of the Next Generation Science Standards (NGSS Lead States, 2013) has added engineering content prominently to pre-college science education. The implementation details will significantly impact whether or not the new standards contribute towards increased STEM literacy among elementary and secondary education students. Optimistically, the infusion of engineering could inspire, inform, and contextualize science and math instruction, and the literature supports the idea that such context strengthens student engagement (Adams et al., 2011; Carlson & Sullivan, 2004;), problem-solving skills (Brophy et al, 2008; Crismond, 2001) and content knowledge in these topics (Kolodner et al. 2003). Pessimistically, hands-on engineering activities, devoid of appropriate math and science content, encroach on class time that would otherwise have been spent on math and science instruction. Such pessimism is not entirely unfounded – elementary teachers have existing challenges in delivering strong math and science content without the added pressures of integrating engineering (Ball, Hill, & Bass, 2005; Marx & Harris, 2006), and few elementary teachers have background knowledge or preparation in engineering (Banilower et al., 2013). Therefore, without a strong infrastructure supporting teacher professional preparation and development, simply adding new content is not likely to achieve the intended goals (Guzey et al., 2014).

The authors of this work are affiliated with an NSF-funded STEM-C project STEM-C project in partnership with the Des Moines Public Schools (*Trinect*) which deploys a new model of teacher preparation through a multi-pronged, team-based approach. The project has completed three semesters of activity involving cohorts of student teachers, cooperating teachers, and engineering students. Through these efforts, we have observed several gaps in student teacher preparation, including: (1) understanding of the nature of engineering, (2) knowing the distinction and synergy between science and engineering, and (3) understanding what constitutes reasonable and relevant engineering content for grades 3 – 5. The efforts described herein are directed at improving student teacher preparation through a short, non-credit workshop.

Materials and Methods

In spring 2016, we developed an outline for a 3 credit hour course for pre-service teachers in the School of Education, entitled *Engineering Principles for Elementary Educators*. The course

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[1] NGSS is a registered trademark of Achieve. Neither Achieve nor the lead states and partners that developed the Next Generation Science Standards were involved in the production of this product, and do not endorse it.

aimed to serve as an introduction to engineering approaches to problem solving, including problem identification, criteria and constraint setting, synthesis, analysis, and iteration. We expected it to address the NGSS, and to provide exposure to the applications of fundamental engineering principles to analyze systems as part of the engineering design process. We also intended to provide students with experience using spreadsheet programs to solve engineering problems and present engineering solutions. We identified four key course outcomes, with the first three directly derived from the NGSS, as follows: (1) Define a problem; (2) Synthesize and evaluate solutions; (3) Perform tests and analyze results; and, (4) Clearly explain what engineering is and what engineers do.

As we delved into course planning, concerns about faculty and student time commitment for a full-semester course surfaced. We began to consider using a workshop (or short course) format instead, in part because in a variety of short (ca. 1 h) interactions with primary and secondary school teachers over the years, we had observed that significant progress could be made in short amounts of time. Additional potential benefits of a workshop format included enabling greater participation at lower total time investment of students and faculty, as well as providing insight into how to structure a full-semester course in the future.

Based on an informal assessment of our availability, as well as on knowledge of student availability, we constrained the short course to three half-day sessions, to be offered consecutive Saturdays prior to the midpoint of the 15-week semester. With approximately 12 contact hours available, we developed a streamlined course learning goal, articulated as follows: *Participants in this course will be able to explain the engineering design process, and in particular the role and importance of constraints, criteria, testing, analysis, iteration, and failure in the context of engineering design. They will also understand how engineering and science differ, and how they complement each other.*

We agreed to strive to employ, in each day of the workshop, several approaches that would provide coherence and continuity to the program, despite it being offered by three instructors, as follows:

- Repeatedly link to real world examples – e.g., pedestrian bridge, full-scale bakery, etc.
- Emphasize the importance of iteration and the acceptability of failure
- Ensure that there is reflection time each period to discuss how the content of the day might be incorporated into the math or science classroom.

The summary plans for each day were as follow: **Day 1:** Pre-assessment. What Do Engineers Do? Similarities, differences, and synergisms between engineering and science. Bridge Building – defining and working toward criteria, and within constraints. **Day 2:** Baking Like an Engineer. What to do when the answer's not in the book: test engineer approaches; simple experimental approaches; data presentation; data analysis. **Day 3:** That Bridge Again – returning to an engineering problem with more context. Rapid and efficient assembly lines – hands on with industrial engineering. Post-assessment.

We used a multi-pronged recruitment approach for pre-service students. We advertised via an email list-serve which we created of all students accepted into the educator preparation program, omitting those who were already at the student teaching phase. We distributed similar information to educator preparation instructors and asked that they discuss it with their students. In all cases, interested participants responded to an online poll.

To assess the workshop effectiveness, we administered the design, engineering, and technology (DET) survey (Hong, Purzer, & Cardella, 2011) to all workshop participants on the first and last day. The DET survey includes 40 items that are rated on a five point Likert scale, and is designed to assess teachers' perceptions of engineering and familiarity with teaching engineering, engineering design, and technology. One additional open ended question, as well as four 5-point Likert scale questions asking students about the four course outcomes, with the prompt, "to what extent do you feel able to..." were included in the survey.

The survey data contained both quantitative and qualitative data that were analyzed separately and merged to provide an overall interpretation (Creswell & Plano Clark, 2011) of the extent to which this workshop addressed the identified needs of the pre-service teachers. The DET survey questions were analyzed individually as well as according to the four subscales: Importance of DET, familiarity with DET, stereotypical characteristics of engineers and characteristics of engineering. Data analysis is still ongoing, but the preliminary results presented below looked at pre/post changes in participant's survey responses.

Results and Discussion

The program started with 10 students enrolled. One dropped due to illness, so on the second and third days, attendance was 9. The students were highly engaged both during the lecture and design / experimental phases of the class. The overall structure of lesson – hands-on – reflection seemed to work well, as did the low student-to-faculty ratio.

Because one student dropped while another lost their ID, it was not possible to do anonymous matching of pre-post responses. Instead, we took the group average responses on each of the pre- and post- questions, as shown below in Table 1, (which is not inclusive of all questions, for space reasons).

As seen in Table 1, students indicated a 0.9 (2.5 → 3.4) increase in their familiarity with design, engineering, and technology; a 1.7 (2.1 → 3.8) increase in confidence in incorporating design, engineering, and technology in their classrooms; and a 0.9 (2.1 → 3.0) increase in their knowledge and familiarity with NGSS. When asked about the qualities of a typical engineer, notable increases (>0.5 Likert points) were seen in categories of (a) works well with people, (b) has good verbal skills (0.87), and (c) has good writing skills (tabulated data not shown). We believe these collectively reflect our repeatedly discussing the breadth of types of work in which engineers engage.

As shown in Table 2, the course appeared to have succeeded in meeting its key learning outcomes. Participants reported large increases in their ability to define an engineering problem, synthesize and evaluate solutions, and explain what engineering is and what engineers do. We are cognizant of the small *n* associated with this work, and would caution against drawing any overarching conclusions from these preliminary results.

Table 1: Excerpted results from pre/post surveys, and comparison to published means (PM) from Hong, Purzer, & Cardella, 2011. Gain = Prog. Post – Prog. Pre.; PPo = Prog. Post

Background/Comfort with Engineering	Published Mean	Prog. Post Mean	Program Gain	PPo – PM
How familiar are you with Design, Engineering, and Technology	2.0	3.4	0.9	1.4
Have you had any specific courses in Design, Engineering, Technology?	1.3	2.3	0.3	1.1
How confident do you feel about integrating more Design, Engineering,…	2.5	3.8	1.7	1.3
How important should preservice education be for teaching Design, Engineering,....	3.3	4.3	-0.1	1.1
Do you believe Design, Engineering, Technology should be integrated into...	3.5	4.7	0.1	1.2
How much do you know about the national science standards related to Design...	2.0	3.0	0.9	1.0
I would like to be able to teach my students to understand the...				
Design process.	3.53	5.0	0.6	1.5
Use and impact of Design, Engineering and Technology	3.51	5.0	0.7	1.5
Science underlying Design, Engineering and Technology.	3.46	4.9	0.4	1.4
Types of problems to which Design, Engineering, and Technology should be…	3.54	5.0	0.6	1.5
Process of communicating technical information.	3.38	4.9	0.4	1.5

Table 2: Excerpted results from pre/post surveys on key learning outcomes for the course.

To what extent do you feel able to…	Pre (avg)	Post (avg)	Gain (avg)
Define an engineering problem.	2.40	4.11	1.71
Synthesize and evaluate solutions.	2.70	4.33	1.63
Perform tests and analyze results.	3.40	4.22	0.82
Clearly explain what engineering is and what engineers do.	2.70	4.44	1.74

Conclusions

This short-course approach to provide pre-service educators with a grounding in engineering appears to have succeeded in its baseline goals of helping pre-service teachers with no background in engineering develop a better understanding of the nature of engineering, appreciate the distinction and synergy between science and engineering, and improve their preparedness for including engineering, engineering design and technology in their future classrooms. These preliminary results suggest the engineering workshop model, like the one highlighted in this work, may be a time-effective mechanism for providing teacher-education program graduates with basic engineering content knowledge. Future research is needed to assess how well the workshop models prepares them for classroom teaching and to document if workshop participants are inspired to partake in deeper professional development opportunities centered around engineering education.

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References
1. Adams, R., Evangelou, D., English, L., Figueiredo, A. D., Mousoulides, N., Pawley, A. L., ... & Wilson, D. M. (2011). Multiple perspectives on engaging future engineers. *Journal of Engineering Education*, *100*(1), 48-88.
2. Ball, D. L., Hill, H.C, & Bass, H. (2005). Knowing mathematics for teaching: Who knows mathematics well enough to teach third grade, and how can we decide? American Educator, 29(1), pp. 14-17, 20-22, 43-46.
3. Banilower, E. R., Smith, P. S., Weiss, I. R., Malzahn, K. A., Campbell, K. M., & Weis, A. M. (2013). Report of the 2012 National Survey of Science and Mathematics Education. *Horizon Research, Inc.*
4. Brophy, S., Klein, S., Portsmore, M., & Rodgers, C. (2008). Advancing Engineering Education in P-12 Classrooms. *Journal of Engineering Education*, *97*(3), 369 – 387. doi:10.1002/j.2168-9830.2008.tb00985.x
5. Carlson, L., & Sullivan, J. (2004). Exploiting design to inspire interest in engineering across the K-16 engineering curriculum. *International Journal of Engineering Education, 20*(30), 372- 380.
6. Creswell, J. W & Plano Clark, V. L. (2011). Designing and Conducting Mixed Methods Research (2nd ed.). Thousand Oaks, CA: Sage.
7. Crismond, D. (2001). Learning and using science ideas when doing investigate and redesign tasks: A student of naive, novice and expert designers doing constrained and scaffolded design work. *Journal of Research in Science Teaching*, *38*(7), 791-820.
8. Guzey, S. S., Tank, K., Wang, H.-H., Roehrig, G. and Moore, T. (2014), A high-quality professional development for teachers of grades 3–6 for implementing engineering into classrooms. *School Science and Mathematics*, 114(3),139–149. doi: 10.1111/ssm.12061
9. Hong, T., Purzer, Ş., & Cardella, M. E. (2011). A psychometric re-evaluation of the Design, Engineering and Technology (DET) survey. *Journal of Engineering Education, 100*(4), 800-818.
10. Kolodner, J. L., Camp, P.J., Crismond,D., Fasse, B. B., Gray, J. T., Holbrook, J., Ryan, M., & Puntambekar, S. (2003). Problem-based learning meets case- based reasoning in the middle- school science classroom: Putting a learning-by-design curriculum into practice. *Journal of the Learning Sciences*, *12*(4), 495–548. doi: 10.1207/S15327809JLS1204_2
11. Marx, R. W., & Harris, C. J. (2006). No Child Left Behind and science education: Opportunities, challenges, and risks. *The Elementary School Journal*, *106*(5), 467-478.
12. NGSS Lead States. 2013. *Next Generation Science Standards: For States, By States*. Washington, DC: The National Academies Press