Engineering within K-12 from the Teacher's Perspective: Effectively Integrating Engineering Activities Tied to Educational Standards

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Abstract:

Reports such as the National Academies' "Engineering in K-12 Education: Understanding the Status and Improving the Prospects" describe the importance of effectively incorporating engineering concepts into the K-12 curriculum. However, as stated in "Standards for K–12 Engineering Education?" developing stand-alone engineering standards is not currently recommended for a number of reasons including "although theoretically possible to develop standards for K–12 engineering education, it would be extremely difficult to ensure their usefulness and effective implementation" at this time, in part because "there is not at present a critical mass of teachers qualified to deliver engineering instruction."

Ohio Northern University is in its second year of workshops designed to introduce hands-on engineering concepts into the classrooms primarily within grades 5-10. The series of workshops involves a detailed introduction to the revised educational standards in the state of Ohio. Hands-on activities designed to introduce engineering concepts while specifically addressing these standards are introduced to the teachers along with success stories. Free and readily accessible lesson plans are from the IEEE sponsored tryengineering.org web site, TED.com and Engineering Go For it, eGRI.com are used. The intent was to introduce and assess teacher background knowledge on topics that their students should see in the years just before and after their grade level. Unique to this workshop is the consistent attention to specific math and science standards addressed, as well as the use of an engineering design process as a problem solving tool.

The first year of the program culminated with a symposium, where teachers demonstrated the successes from their classrooms. Teachers in the second cohort were given access to web resources designed to illustrate the content from previous grades (to give an idea of realistic expectations) and following grades (to understand what is expected from their grade). Teachers were given a week-long, in-depth introduction to robotics, rocketry or Lego Mindstorm programming and their ties to their educational standards.

The paper will describe the results of the assessment from participating teachers and describe the implementation of the program for those institutions interested in building upon these efforts. Specifically of interest, establishing a concrete tie from these engineering activities to relevant educational standards, allowing teachers to actually implement these activities in their classroom.

Background:

The 2001 No Child Left Behind (NCLB) Act[1] mandated "highly qualified teachers" in every classroom by the year 2006. Professional development opportunities allow teachers to achieve and maintain high quality status, learning how to improve in content knowledge and pedagogy [2,3,4]. Ongoing professional development is an important factor in preparing and maintaining

highly effective teachers [5,6]. In most states, ongoing professional development is required for renewal of teaching certificates or licenses, since quality professional development leads to improved practice and increased student achievement [2,4].

Because of the mandates of NCLB and the desire for more teachers to stay abreast of current research and best practice, the need for professional development is expected to continue to increase[7]. According to Cocoran, one of the greatest challenges in providing professional development will be to find a variety of approaches that will be able to reach the 2.4 million teachers in 85,000 schools in the United States[8]. Business and industry are moving away from face-to-face training and moving toward electronic delivery; in fact, technology based training is expected to increase to 55% of all training[7]. Education will likely follow the influence of business and increase the amount of professional development opportunities offered electronically.

Professional development to date is often random, one-time workshops or seminars individually selected by educators or school districts to meet the requirement of continuing education hours [3,8,9]. Unfortunately, one-shot workshops fail to produce lasting results[7]. Change in professional development requires multiple exposures to innovative pedagogical techniques and opportunities to learn and practice new behaviors, which involves more than a one-shot workshop[3].

Legislation in many states requires educators to set goals and create an Individual Professional Development Plan (IPDP) that outlines the types of professional development in which the educator plans to participate during the school year to improve classroom teaching [7,10]. Professional development is needed to raise academic standards and enhance teachers' knowledge in subject matter and teaching strategies[8]. Teachers need to deepen their content knowledge and pedagogical skills in order to keep up with these new requirements[8] and well-structured professional development can provide the opportunity for this to happen.

Although numerous opportunities to attend professional development sessions are available, many barriers exist that prevent teachers from engaging in these activities. These barriers include but are not limited to:

1) fragmented and insufficient time to engage in professional development due to family, work, or social commitments [1,11],
2) the high cost of professional development to the teacher and to the school district[7],
3) distant geographical locations of course[11], and
4) frequency of course offerings[11].

Educators have many responsibilities in and out of school vying for their time, and added professional development spreads the little time they have very thin. Financially, the driving expenses and childcare encumbered to attend professional development opportunities may strain an educator's budget. Spark and Hirsh[4] and others have called attention to the need for a better system of professional development, including hybrid and online delivery.

Online delivery of professional development is gaining interest among teachers, administrators, and professional development providers[12]. Teachers can participate in professional development

from the comfort of their own home at a time that is convenient to them [13,14,15]. Well-designed online professional development can be highly effective, and many administrators say that online professional development meets their needs as well[16].

Professional development has changed a great deal over the past ten years, largely because of the standards movement[6]. It is more focused on goals and standards, student learning, and an ongoing process involving more than just an individual teacher or administrator. The success of professional development is no longer judged on the number of teachers and administrators participating but whether it alters instructional behavior in ways that benefit students[9].

When one visualizes what professional development for the 21st century should look like, one does not see a program being measured for its "happiness quotient" (purely measuring success by attendee satisfaction) or educators simply receiving credit for seat time[9]. Instead, a picture of professional development certainly includes alignment with the desired results for students and time and money set aside for well-planned, team oriented, administration supported practices. Meaningful, life-long learning that will enhance teaching and improve student learning is the goal for the 21st century.

King's research[18] indicates that radical alterations of teaching perspectives and practice are possible and that professional development can be used to cultivate new views of teaching and learning. Offering various deliveries of professional development may provide more opportunities for teachers to achieve their professional development goals.

Blended or hybrid delivery of professional development includes both online and face-to-face components. A single delivery system – exclusively face-to-face or online – can limit a learning program[19]. Any combination of online and face-to-face can be used to deliver this type of program. The blended approach has significant advantages over either of the other two approaches, utilizing the best of face-to-face and online delivery[20]. Blended delivery can be completed in half the time at half the cost and is not only more efficient, but more effective[18].

King[18] conducted a qualitative case study with 15 students who participated in a "hybrid" class (six classes were held face-to face and eight were online) over a five-week period. Participants ranged from novice to experienced technology users. In-service and pre-service teachers with a mean of 5.8 years of experience participated in this case model. The purpose of the study was to explore the viability of the hybrid format. The participants provided extensive data that included 450 online discussion postings, 105 journal postings, and 12 self-reflection summaries. These data were analyzed for emergent themes and revealed "substantial dialogue and a rich learning experience can be created in online classrooms" [18, p.236]. Based on King's research, hybrid classes can offer a format that allows the technology to become almost transparent, while allowing for collaborations and rich content delivered by informed instructors and for developing communities of lifelong learners. The hybrid class provides the best practices of online and face-to-face learning environments.

SteM 2 STEM: Utilizing Science and Math Standards to Enhance Technology and Engineering, an Improving Teacher Quality grant through the Ohio Board of Regents provided the funding necessary to offer a blended professional development opportunity for 21 teachers in Northwest

Ohio during the 2012-13 school year. The teachers met twice in the spring to explore Ohio's New Learning Standards in Math and Science, two weeks in the summer in which the teachers participated in Engineering activities and an in-depth look at either classroom application of rocketry, Lego Mindstorms, or robotics using Vex Robotics. This was the second of two similar workshops hosted at Ohio Northern University.

Since time was limited, we decided to use a blended approach, incorporating significant online content and assessment. The two week workshop was face-to-face and then we were able to provide more content through electronic modules. During the summer workshop, participants engaged in a number of hands-on activities. One of the activities presented during the workshop was from tryengineering.org Teacher In Service (TISP) lesson plan, *Two Button Buzzer Circuit*. From the beginning of this activity, participants expressed their concern with working with electricity. Some content was addresses at this time but time did not allow for in-depth coverage. The participants were able to get more content through the use of an electronic module on electricity.

Electronic Modules:

The online component of the grant was designed to provide participants a chance to review concepts in math and science which they might not use on a daily basis but are important when integrating engineering activities into the math and science curriculum. This was an important component of the grant since there was a mixture of math and science teachers at the middle level and high school level, and due to the intent to introduce teachers to content in the grades beyond the grade in which they currently teach. Several of the teachers remarked that they had forgotten some of the concepts in math and science which were addressed in the TISP activities and the second week activities of robotics, Lego Mindstorms, and rocketry. Using the online modules as a refresher and a guided source for further exploration of content for the participants was one goal. A second goal was to introduce participants to a web-based platform which provides content in math and science as well as other content areas, Sophia.org[21]. Links to relevant Sophia tutorials were embedded in the modules not only to provide assistance for the participants but also to provide them with another tool to use with their own students.

Five modules were developed based on educational standards for the grades represented by the workshop participants. These included: Sound, Electricity, Measurements, Physics (Force and Motion), and Mathematics. Following the development of the modules, participants completed a pre-assessment on four of the five modules: Sound, Electricity, Measurement, and Mathematics. The participants were given a link and completed the pre-workshop assessment online. This assessment was designed in a multiple choice format. Table 1 includes an example from each module.

Table 1: Sample questions from workshop participant content assessment

Module	Question
Sound	A wave has a wavelength of 50 m and is traveling at 2500 m/s. What is its frequency? a. 250 Hz b. 50 Hz c. 2550 Hz d. 125,000 Hz
Electricity	Which property concerning electric flow is true? a. Electrons move toward the positive terminal of the circuit b. Electricity flows fast if the circuit is an open loop, not a closed one. c. The electrons come from the power source and move through the circuit, and once the circuit is interrupted, the conductor has no electrons in it anymore d. Electrons move very slowly through the circuit, averaging one meter per hour
Measurement	What is Mass? a. The amount of matter within an object b. Amount of force on an object due to gravity c. SI definition of weight d. The amount of matter inside a set volume
Mathematics	What shape will the following line equation make? $3x^2 + 2x + 1$ a. Parabola b. Hyperbola c. Line d. Circle

During the summer months, the participants were required to complete at least two of the modules, but they were encouraged to complete as many as possible. In the fall semester, the participants were sent a link via email to complete an identical post assessment.

The online math and science content modules were made on a Google based web page. Access to the modules was restricted to teachers participating in Ohio Northern University SteM2STEM workshops, and pages were keyed to attempt to prevent access from search engines. The science portion of the site focused on modules in sound, electricity, measurements, and physics (force and motion). A main Table of Contents page served to direct teachers to one of the appropriate five modules; from the main page of each of the overall topics, pages were further broken down into smaller sections with links to separate modules. An example of one of the pages of one of the science modules is shown in Figure 1.

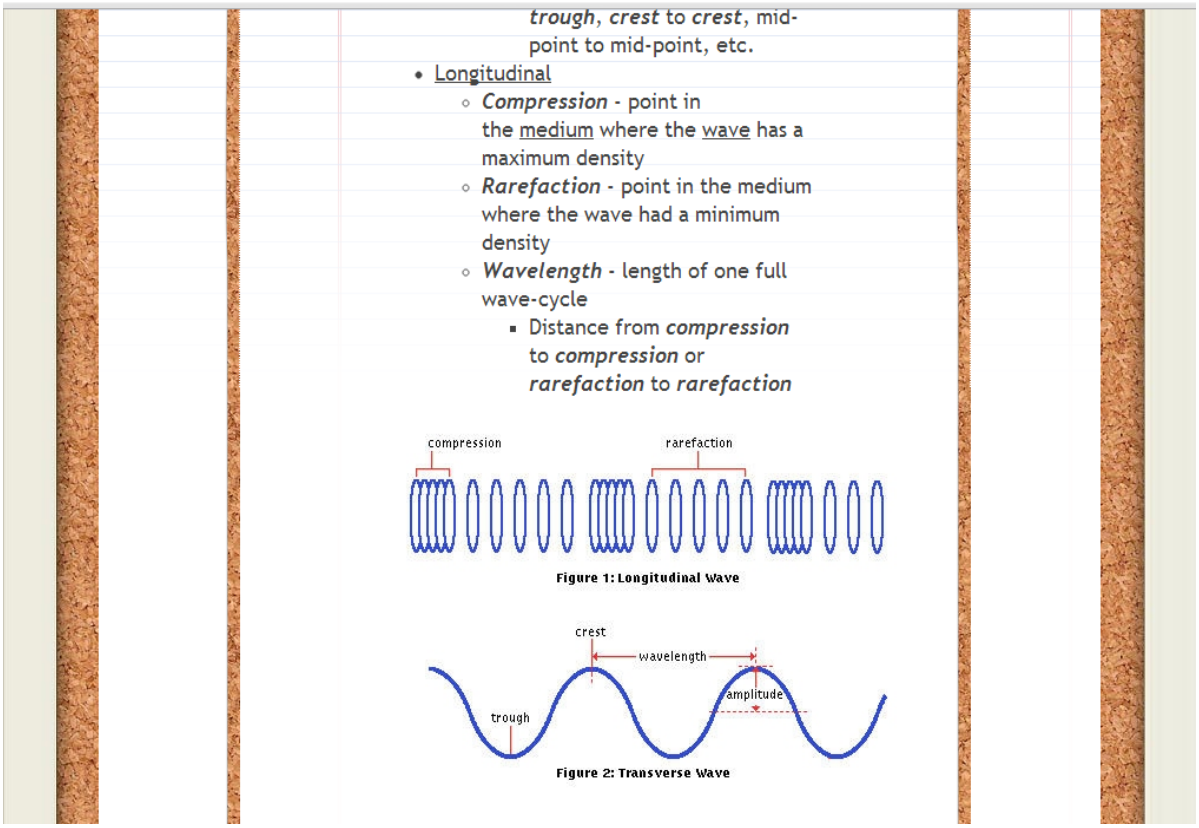

Figure 1: Sample page showing longitudinal wave content

The mathematics portion of the site focused on modules in order of operations, terms, basic algebra, multiplying parentheses, and simplifying quadratic equations. An example of one of the pages of one of the mathematics modules is shown in Figure 2.

Each module has embedded practice problems and solutions, static and animated diagrams and external links to embellish the material presented. Simple navigation was added to every page to help the site be as user-friendly as possible. Before the site was distributed to workshop participants, volunteers in different disciplines reviewed the modules for content and to ensure ease of navigation, to ensure they were applicable to a wide audience.

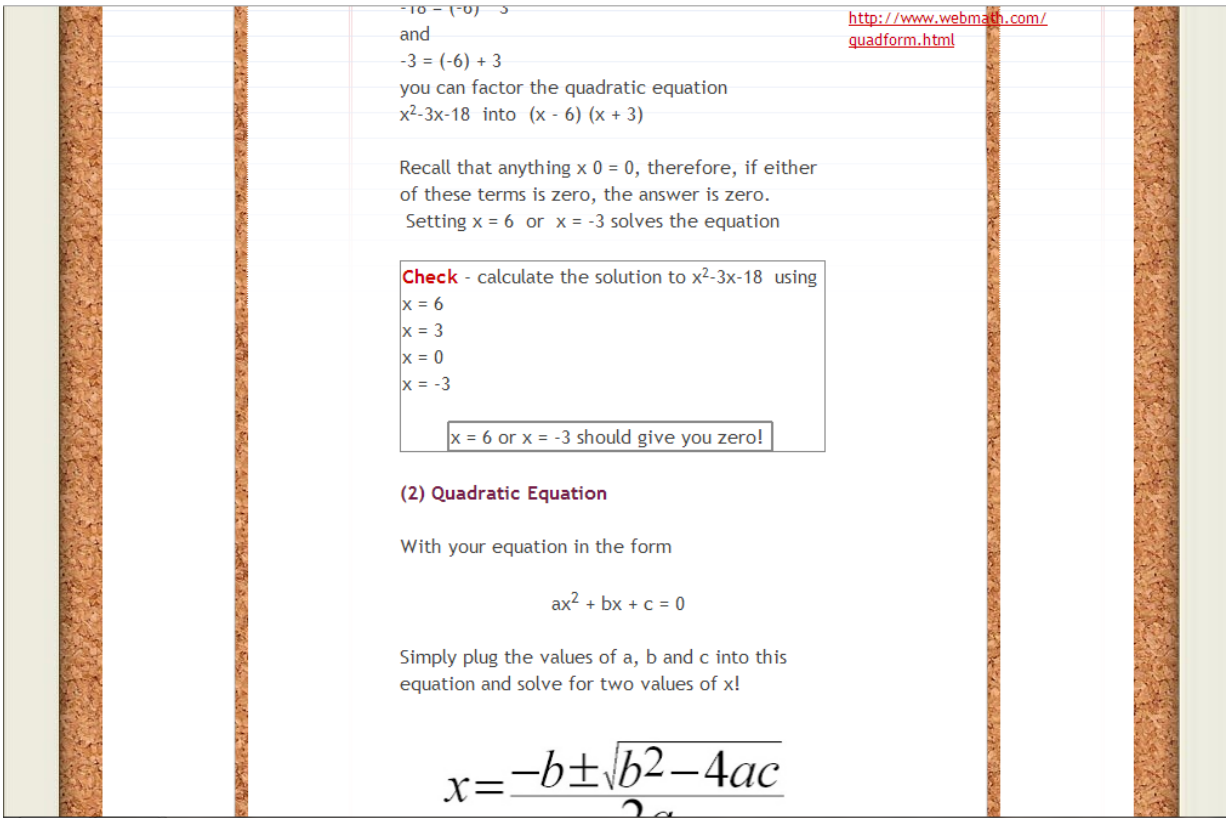

Figure 2: Sample from module showing the solution of a quadratic equation

Assessment Results:

Data from the pre and post assessments were analyzed using SPSS. A Paired Samples Test showed statistically significant improvement between the mean scores on the pre-assessment and the post-assessment specifically on only one of the modules: the Electricity module (0.01, $p<.05$) for those teachers who had completed both pre- and post-assessments (N=13).

The other individual modules did not show a significant change between pre and post assessment scores. When comparing overall scores, however, a significant improvement in the post-assessment over the pre-assessment on the total score was found (0.013, $p<.05$).

There is a possible confound introduced as the teachers were able to take the pre-assessment in a computer lab with their peers, while the environment for their post-assessment was not controlled. The fear is that teachers may have squeezed the post-assessment into their busy schedule, since this was taken after classes started. Unfortunately, individual differences or differences for specific grade levels or teachers of similar subjects could not be identified because participants did not use the same identification code on the pre and post assessments.

Teachers remarked that they were very satisfied with the content and format of the workshop in a variety of qualitative assessments during the workshop. Further assessment at the end of the program is planned to see which activities or techniques were implemented and whether they felt

the program improved their understanding of concepts in their grade or grades beyond the grade they teach.

Conclusion / Further Research:

SteM 2 STEM: Utilizing Science and Math Standards to Enhance Technology and Engineering was a program made possible through a grant from the Ohio Board of Regents. The program consisted of a workshop and associated content developed for and offered to a cohort of middle school and high school math and science teachers. Teachers participated in a pre-workshop assessment of math and science concepts from the educational standards for grades 5 – 10 which represented the range of teachers participating in the workshop. Following the pre-assessment, teachers attended a two-week workshop with general, widely-applicable activities for their classroom and specialized week-long, in depth workshops. Online modules were created to offer teachers in-depth content in math and science, specifically developed to re-introduce teachers to content prior to and just beyond the grades in which they teach.

Significant improvements in scores were found in the teachers' total score, combining all modules, and in the individual module on electricity. Drawing a general conclusion is difficult based on confounds in data collection and the relatively small number of teachers participating in both pre-assessment and post-assessment. Although significant differences were was not found in the pre and the post assessments of the other individual modules, they were still useful for the purpose of allowing participants to refresh their content knowledge. The modules also linked to a source with a variety of multimedia-based support, Sophia.org, which gives teachers a resource to use with the students in their own classes which should assist in increasing student learning.

The modules developed for this workshop should be widely applicable to other teachers in grades 5 – 10. A website is being developed which will provide access to the modules for all K-12 teachers. Additional modules may be developed in the future as needed.

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