Developing a Toolkit and Online Community of Practice to Support Implementation of Engineering in PreK-12 Education (Other)

Dr. Elizabeth Cady, National Academy of Engineering

Dr. Elizabeth Cady is a Program Officer at the National Academy of Engineering (NAE) working on engineering education topics such as building skills in project management and change leadership, diversity, and developing communities of practice. She also staffs the Frontiers of Engineering Education symposium, which recognizes and supports innovative engineering faculty members. She co-edited a resource collection translating research on women in science and engineering into practical tips for faculty members. She earned M.S. and Ph.D. degrees in Cognitive and Human Factors Psychology from Kansas State University and a B.A. in psychobiology and political science from Wheaton College in Massachusetts.

Greg Pearson, National Academy of Engineering

Greg Pearson is a Senior Program Officer with the National Academy of Engineering (NAE) in Washington, D.C. Greg currently serves as the responsible staff officer for the NSF-funded project "The Status, Role, and Needs of Engineering Technology Education in the United States." He is also study director for the Chevron-funded project, Guiding Implementation of K-12 Engineering in the United States. He was the study director for the NAE and National Research Council project that resulted in the 2014 report, STEM Integration in K-12 Education: Status, Prospects, and an Agenda for Research. He was the study director for the project that resulted in publication of Standards for K-12 Engineering Education? (2010) and Engineering in K-12 Education: Understanding the Status and Improving the Prospects (2009), an analysis of efforts to teach engineering to U.S. school children. He oversaw the NSF-funded project that resulted in the 2013 publication of Messaging for Engineering: From Research to Action and the 2008 publication of Changing the Conversation: Messages for Improving Public Understanding of Engineering and was co-editor of the reports Tech Tally: Approaches to Assessing Technological Literacy (2006) and Technically Speaking: Why All Americans Need to Know More About Technology (2002). In the late 1990s, Greg oversaw NAE and National Research Council reviews of technology education content standards developed by the International Technology Education Association. He has degrees in biology and journalism.

Mr. David R. Heil, David Heil & Associates, Inc.

DAVID R. HEIL, President of David Heil & Associates, Inc. (DHA), and founder of the Foundation for Family Science & Engineering, is well known as an innovative educator, author, and host of the Emmy Award winning PBS family science program Newton's Apple. Active in promoting public understanding of science and engineering for over 35 years, he was the lead Editor of the popular book Family Science (1999) and a Co-Author of the recently published Family Engineering: An Activity & Event Planning Guide (2011). DHA provides the STEM education and science center fields with Research & Evaluation, Strategic Planning, and Materials Development and Implementation services. David Heil is a sought after national and international presenter on STEM education, is a past Director of Informal Science Education for the National Science Teachers Association, and served 2 years on the ASEE K-12 & Pre-College Division Board of Directors.

Mr. Derek W Rector, Diamax Information Systems

Derek is President & Principal Consultant of Diamax, a Washington DC based interactive design consultancy and software engineering company that specializes in the implementation of digital exchanges for leading organizations throughout the United States, Canada, and Europe. A digital producer with more than 18 years of Internet and information systems experience, Derek founded Diamax in 1998 and has designed many interactive solutions for organizations such as the World Bank, the National Academy of Engineering, the Institute of Medicine, the National Academy of Sciences, the InterAcademy Council, West Point, and the United Nations. As a digital strategy consultant, Derek has helped many associations, think tanks, and non-profits innovate and succeed through a stakeholder centered, design-based approach.

Derek's productions for the NAE include Engineering Grand Challenges, Engineer Girl, Engineering Messages, Frontiers of Engineering, Greatest Engineering Achievements of the 20th Century, Engineer Your Life, and Frontiers of Engineering Education. Between 2002 and 2011 Derek led the development of Diamax CMS, a structured content management system, and in 2013 he created Miliu, a digital exchange platform. Prior to Diamax, Derek worked as a computer systems analyst, business analyst, and technology manager for the World Bank, Lockheed Martin, and Atlantic Duncans International. He was responsible for assignments involving manufacturing plant closures, global connectivity for mobile staff, executive information access, knowledge management, and business process automation. The overall objective of Derek's work is to create technologies that help people make better decisions and solve problems faster, by connecting them with knowledgeable professionals through relevant content. Derek completed his B.Sc.(Agr.) in Environmental Biology at McGill University.

Ms. Jana Jurukovska, Diamax Information Systems

Jana Jurukovska is a digital strategy consultant and interactive producer at Diamax Information Systems Corporation, a software company and interactive agency based in Washington DC. Jana focuses primarily on digital media projects related to STEM education and has full lifecycle (idea to impact) strategy and production experience through her work with organizations such as the National Academy of Engineering, International Technology and Engineering Educators Association, InterAcademy Panel, the Interstate Natural Gas Association of America, and the World Bank. Jana's STEM projects include the NAE's Engineer Girl, Frontiers of Engineering Education, Grand Challenges for Engineering, and LinkEngineering websites. As a strategist Jana applies design thinking, business process analysis and a strong visual communications skill set to characterize opportunities and conceptualize innovative solutions. As a producer Jana leverages her training in art direction and project management to lead technology and creative teams through iterative human-centered digital implementations. Jana holds a BBA in Marketing with a Minor in Fine Arts from George Washington University School of Business.

Developing a Toolkit and Online Community of Practice to Support Implementation of Engineering in PreK-12 Education (Other)

This paper presents results of front-end research conducted to inform development of a resource website, LinkEngineering, containing materials relevant to teaching and learning engineering at the PreK-12 level as well as a platform for developing a community of practice. The research effort was coordinated by David Heil & Associates, Inc., a contractor to the National Academy of Engineering (NAE). The planned website is the main product of a project at NAE funded by Chevron. Part of the motivation for the project is the recent publication of the *Next Generation Science Standards*, which include concepts and practices related to engineering as well as science. The goal of the website is to provide guidance to in- and out-of-school educators, teacher educators, professional development providers, and building, district, and state administrators regarding implementation of PreK-12 engineering education in the United States.

The site is being developed in an iterative fashion based on the front-end research and input from early users of the site. A committee of 20 people at the NAE oversees the project; five committee members represent partner organizations in the project: National Science Teachers Association, Council of State Science Supervisors, International Technology and Engineering Educators Association, Achieve, Inc., and American Society for Engineering Education. Front-end research included input at three regional workshops, focus groups, and a national online survey.

In addition to supporting development of the resource website, results of the research may be of broad interest to individuals and organizations engaged in or thinking of becoming engaged in PreK-12 engineering education.

Stakeholder Workshops

Three regional stakeholder workshops were held in Washington, DC, (June 2014), St. Paul, MN (August 2014), and Pasadena, CA (November 2014). These workshops served to provide input from representative samples of educational leaders and potential users of a new online resource for engineering education from across the country. Collectively, these workshops hosted over 200 stakeholders across a broad cross-section of formal and informal education as well as levels of experience with engineering education and online resource access and use. A pre-workshop survey completed by 97 of the 219 total attendees indicated a range of experience in both education and engineering education as well as a mix of grade levels taught. The format for all three stakeholder workshops combined short presentations about PreK-12 engineering (*What Does Engineering Education Look Like When Done by K--12 Students? What Does the Preparation of K--12 Educators to Teach Engineering Look Like?* and *The Role of Digital Design in the Project*) followed by committee-moderated small-group discussions focused on specific questions related to those presentations. Reporting from the small groups was in the form of notes posted on large poster-sized sheets of paper. Sufficient time was provided between topical sessions for attendees to read and vote (using colored dots) for the ideas that most appealed to them.

The dots at the last two workshops corresponded to the stakeholder group (e.g., all middle school teachers had orange, all pre-service teacher educators had green). However, analysis of the dot counts indicated that individuals with different roles in PreK-12 education did not select different top ideas. In fact, for those ideas that had large numbers of dots placed next to them, there was broad representation of the different types of attendees at each workshop, suggesting that the most highly ranked ideas will potentially serve the needs of a broad spectrum of users. Tables 1 and 2 show the ideas with the most votes across the three workshops.

Table 1. Top Online Resource Ideas To Address Needs of PreK-12 Educators in Engineering Education from Workshop Attendees

Online Resource Idea (PreK-12 Educators)	Count
Teacher clearinghouse	41
Multi-tier PreK-12 teacher activities that take content deeper or scale down according to need	33
Ask the engineer	30
Teach the teacher about engineering (videos of students working, teachers discussing lessons, way to understand how to incorporate engineering practices as a way of teaching and learning).	30
Robust search filter	28
Helping users of site address issues of equity and diversity	27
Videos of classroom models and real world connections	24
Engineering education lessons	24
A resource that defines: What is engineering? What does it look like in PreK-12 classrooms?	23
STEM resources from businesses and universities	20
Practical and intuitive navigation	20
Online community space	19
Connections beyond the classroom	18
Space for user interaction and networking	18
Resources for curriculum	18
Standards-based engineering projects	17
Learning progressions for engineering education	17
Basic engineering background, professional development resources	16
Links to local as well as global communities of practice	16
Expert and user interface exchange of ideas, best practices, resources, and opportunities in engineering	16
Resources such as “tangible” lesson plans, affordable curriculum, time estimates, and formal assessments	16
Understanding engineering careers	15
Expected outcomes by grade or grade level bands w/sample rubrics	15

Online Resource Idea (PreK-12 Educators)	Count
Lesson plan ideas (e.g., Written plans that are budget conscious, videos and student samples, single vs. long term plans, and the engineering process)	15
Professional Development resources, pedagogy	14
Access to community of engineers, experts, and educators	14
Curriculum resources, videos, sorted by state	13
What does a STEM classroom look like physically, emotionally, and pedagogically?	13
Online professional development (e.g., Webinars, and blogs)	12
Lesson plans that are grade appropriate, easily implementable, with clearly defined outcomes and available resources	12
Networking opportunities by grade levels such as chat rooms on each grade/project and the ability to upload (resources)	12

Table 2. Top Online Resource Ideas To Address Needs of PreK-12 Pre-Service Teacher Educators and Professional Development Providers

Online Resource Idea (Teacher Educators/ Professional Development Providers)	Count
Exemplar videos “real time as needed”	34
Assessment tools, strategies	33
Cross curricular connections	29
Real world examples of engineering, classroom examples of engineering education	29
Easy to navigate	27
Embedding engineering education into other content areas	23
Content for specific audiences (e.g., Elementary, Middle School, High School, or Administration)	22
Tools to promote effective classroom ecology for engineering educ.	21
Professional development resources	20
Dynamic, timely, interactive	20
Authentic engineering experiences for teachers	19
Virtual community for sharing best practices	19
Hands-on engineering activities that work with students but create paradigm shifts for teachers	17
Community-based resources and authentic partnerships beyond classroom	16
Outline of questions for teachers to pose during lesson	16
Videos that spotlights the engineering process	16
Teacher toolkit for administrator buy-in	15
Professional Development tools, online courses	15
Networking with other professionals	15

Online Resource Idea (Teacher Educators/ Professional Development Providers)	Count
Zip Code PD: local trainings in area; full and ½ day district training opportunities so all teachers see how engineering applies everyday	15
Clarifying real world engineering and classroom version (engineering education)	14
Industry recognized credentials/certifications – ASEE, ITEEA, etc.	13
Cross-curricular/disciplines seeing STEM as a thread to future careers	13
Online learning module	11
Engineering across the curriculum	11
Emphasis on process using videos to demonstrate lessons being presented	11
Cross-curriculum PD designed around standards that promote engineering	11
Creating a professional development community	11
Archival database of PD training materials (PowerPoint, charts, webinars)	11

The session on the site design included a mock-up of the new site shared by the digital design contractor, Diamax. Between the first workshop in June and the third workshop in November, the site mock-ups became more detailed and responsive to suggestions made in prior workshops. In all three regional workshop locations, this session allowed attendees to get a firsthand look at possible approaches and visuals associated with a new online resource to support PreK-12 engineering education and discuss ideas for website attributes, functions, and features that would maximize use. Table 3 lists the features receiving the most dots during the first two workshops.

Table 3. Top Ideas For Website Features/Functionality in the First Two Workshops

Website Features/Functionality	Count
Highly credible, professional development hub	36
Materials and resources vetted by experts	27
Sophisticated filtering and sorting system	23
Content must be kept current, easily searched	19
Lesson plans with various filters – standards, grade levels, careers, etc.	19
Add connections to state standards, local events/grants clearinghouse	17
Website Quality Control	17
Clear, multiple pathways for different users	16
Feature local Resources	16
Making site unique, stand out in crowded web landscape	15
Process for making contributions to the site	15
Access to local and regional resources	14
Needs to be culturally responsive and have an equity presence	14
Many different searchable filters	13
Differentiated login for teachers, PD providers, administrators, etc.	13
Customized pathways for formal, informal (out-of-school), administrators, etc.	13

Website Features/Functionality	Count
Finding balance - social media site vs. reliable professional site	13
Opportunity to personalize content at the district/state level	13
Videos with different user voice-overs, perspectives	12

The third workshop's mock-up was a functional alpha 1 site, allowing attendees to try some simple navigation and resource selections. As a consequence, the small group discussion and reporting task for this session was changed slightly from the previous workshops. Table 4 lists the top features that CA workshop attendees "liked" about the alpha site they previewed, while Table 5 lists features the attendees felt were missing. It is important to notice that reflected in this list are some of the same attributes identified as priorities in the previous two workshops.

Table 4. Alpha Site Features/Functionality "Liked" by CA Workshop Participants

Alpha Site Feature/Functionality Liked	Count
Explaining what engineering is and outlining specific fields of engineering	7
Keeping it simple and user friendly	5
Making sure we can communicate with mentors	4
Opportunity to showcase educator materials	3
Ability to filter searches for lesson plans and materials	3
The three main tabs – Discover, Connect, and Teach	3
Vetted resources	3
Embedded videos that are easy to access	3
Interactive networking capability	2
Featuring local schools	1

Table 5. Alpha Site Features/Functionality Identified As "Missing" or "Needing Improvement" by CA Workshop Participants

Alpha Site Feature/Functionality Missing/Needs Improvement	Count
Connections to actual engineers and engineering companies	17
Separate lesson plans by NGSS standards, grade levels, resource type	17
Grab and go lesson plans	15
Ties into Common Core and NGSS, as well as state---level standards	15
Professional development page with short tutorial videos, mentor interviews	11
Site is not visual or stimulating enough	10
Needs a quick look drop down menu for standards, specific content	9
Differentiation for different students (e.g., gifted, special needs, etc.)	8
Lesson plans that are complete	8
Navigation is difficult	5

In all three workshops, attendees were asked at the end of each small group discussion session to write down at least one barrier or challenge that related to the topic at hand (i.e., implementing engineering in PreK-12 education, professional development, accessing and using a website). Analysis showed that many attendees listed similar barriers. During the workshop, the barriers were reviewed and one barrier was distributed to each table for the last small group discussion to identify possible solutions or "work-arounds" for their assigned barrier. At the end of the session, tables posted their solutions on the wall but attendees were not asked to prioritize them using their colored dots. Barriers focused on the accessibility of both technology and content, motivating and welcoming users, recruiting and retaining experts, creating awareness of the site, and keeping the content on the site current and vetted for high quality. In addition, attendees mentioned copyright and security issues and lack of time and resources to use the site or buy supplies for activities.

Solutions were offered for all barriers, although some were viewed as more difficult to overcome. For example, attendees suggested overcoming technology barriers by having materials available on a low bandwidth platform, enabling resources to be downloaded and saved for later use, and providing advance notice of the site to school districts to allow access to the site from behind a school firewall. Suggestions for the accessibility of the content included providing a glossary of terms and simple ideas that teachers could use without too much background knowledge of engineering. Solutions for motivating users and experts included both updated and quality content and creating a shared experience for the users. Suggestions for the currency and quality of the website included having multiple and clear measures of assessment and peer review, archiving outdated materials, and using a combination of expert and crowd-sourced vetting of resources.

National Survey

In an effort to reach out to the broadest spectrum of stakeholders and potential users of the website, a national survey was posted online for two weeks in October 2014. The partner organizations, especially ASEE, ITEEA, and NSTA, sent emails to their membership and thus were instrumental in recruiting respondents for the survey. An estimated 80,000 individuals received an email invitation to complete the survey, and the response rate of 1,850 respondents provides a 99% confidence level with a 3% margin of error. Survey respondents were well dispersed across the U.S and work in a variety of community settings.

The majority of survey respondents are currently working in formal education roles as PreK-12 classroom teachers or as PreK-12 school or district level specialists (60%), but a substantial number of other educational professionals including college and university faculty and students, professional development providers, out-of-school and after school educators, independent education consultants and curriculum developers, and professional scientists and engineers also responded. Of those selecting from the provided list of roles, high school teachers made up the largest sub-category, with middle school and elementary school next in rank order. Survey respondents also had a wide range of experience in education, with 33% engaged for more than 20 years, 7% engaged for less than 2 years, and the remaining 60% engaged between 3 and 20 years.

One key objective of the survey was to capture input from a broad representative sample of stakeholders and potential users of the new online resource including individuals with a range of prior experience in engineering education, from no experience and novice to advanced and expert levels. Most of the respondents considered themselves Basic (37%) or Advanced (28%), with smaller groups indicating they were Beginner (21%) or had No Experience (10%). Another 5% of respondents considered themselves to be Experts in engineering education. In addition, 60% of respondents had taught engineering to PreK-12 students and had received at least minimal training (e.g., a 1-2 hour workshop) before teaching. The demographic information gathered from the national survey indicates that the project is receiving input from the target audiences of the website.

Respondents were asked about individual and system-wide awareness, confidence and readiness for PreK-12 engineering education. Table 6 summarizes the responses to this set of questions, highlighting the percentages of respondents indicating they either agreed or strongly agreed with each statement. The findings suggest a high level of need to better prepare both formal and informal educators for effectively implementing PreK-12 engineering education. For example, only 20% of respondents agreed that there is an adequate supply of well-designed, quality online resources for engineering education. In addition, 15% of respondents felt that colleges and universities are effectively preparing education graduates to teach engineering, and very few felt that there were adequate opportunities for professional development in engineering education in their community.

Table 6. Percentages of Survey Respondents Who Indicated they “Agree” or “Strongly Agree” With the Following Statements (n= 1,638)

Statement	% Agree
PreK-12 schools in my community will need help implementing engineering education in their classrooms	90.2%
Out-of-school and after school programs in my community will need help implementing engineering education into their programs	81.6%
I am very familiar with the Next Generation Science Standards (NGSS)	67.5%
I am very familiar with the engineering standards in the NGSS	53.7%
I feel I need a better understanding of what engineering is before I can teach it at the PreK-12 level	37.3%
I am very familiar with ITEEA's Standards for Technological Literacy (STL)	21.2%
I am very familiar with the engineering standards in the STL	20.1%
There are plenty of well-designed online resources on engineering education	19.9%
I have high confidence in the quality of existing online resources in engineering education	19.4%
Colleges/universities in my area are effectively preparing their education graduates to teach engineering	15.3%
There are plenty of professional development opportunities in engineering education	9.5%

in my community	

The survey also asked stakeholders about their interests, needs, motivations, and expectations from a new online resource in engineering education. Respondents indicated their level of interest in a range of online content or topical features and how important certain attributes of an online site were. Table 7 provides the percentages of respondents that indicated modest or high levels of interest in each type of online content or topical feature. Although all features were viewed with interest by a majority of respondents, the top items correlate closely with top priorities of the stakeholders attending the workshops. Examples of real-world engineering, cross- curricular connections, and PreK-12 engineering lesson plans rated by experts are the highest ranked features, although stakeholders are also interested in local resources and professional development opportunities, peer reviews of lesson plans, assessment tools, and video examples of engineering education in both PreK-12 classroom and informal settings.

Table 7. Percentages of Survey Respondents That Indicated "Modest" or "High Interest" In Each Type of Online Content or Topical Feature Listed Below (n=1,628)

Statement	% Agree
Examples of real-world engineering problems/solutions	89.6%
Cross-curricular connections between engineering and other content areas	87.3%
PreK-12 engineering education lesson plans and projects reviewed/rated by experts (Expert Rating)	86.3%
Local resources/professional development opportunities in engineering education	82.1%
PreK-12 engineering education lesson plans and projects reviewed/rated by educators (Yahoo-style user rating)	81.7%
Assessment tools/strategies for PreK-12 engineering education	80.0%
Video examples of engineering education in PreK-12 classrooms	76.1%
National resources/professional development opportunities in engineering education	75.6%
Student enrichment opportunities and competitions related to engineering education	73.6%
Clarifications of engineering standards in the NGSS or STL	67.9%
Video examples of engineering education in informal learning settings	66.4%
Definition/description of the engineering design process	65.4%
Engineering education resources from business and industry	64.3%
An "Ask the Engineer" feature connecting to professional engineer mentors	63.6%
Information on engineering careers	59.6%
Video interviews/profiles of professional engineers	54.9%
Definition/description of what engineering is	54.8%

Finally, respondents indicated which barriers (drawn from those suggested at the workshops) would be "essential" or "very important" to address. Ensuring the quality and currency of the content was viewed as most important, although several other barriers were also viewed as important to address. The results are shown in Table 8.

Table 8. Percentages of Respondents Who Indicated the Following Potential Challenges/Barriers Will Be "Essential" or "Very Important" to Address for the New Online Resource (n=1,560)

Barrier to Address	% Agree
Ensuring quality of educator-posted resources	77.4%
Keeping the site's content current	76.8%
Recruiting/retaining experts and mentors to contribute to the site	63.3%
Making the site too complex, difficult to navigate	63.1%
Keeping up with new/changing technologies and online delivery vehicles	60.3%
Making target audiences aware of website and/or related social media	56.8%
Differentiating the site so it stands out in a crowded online landscape	50.8%
Accessing videos at schools with low bandwidth	49.1%
Getting through school firewalls with social network features	48.1%
Addressing issues of copyright/ownership of posted resources	46.3%
Motivating users to return to site and/or related social media	43.3%
Monitoring online community networking and interaction	33.3%

Discussion

The results described here are potentially useful to a wide range of audiences. First, together with some more qualitative information from focus groups and interviews with the developers of other websites that include both educational materials and a community of practice, the research described has informed the design of the LinkEngineering website to date and will continue to do so. For example, the site contains resources that define engineering and show what it looks like in a PreK-12 classroom, both elements that were requested by stakeholders. The site allows users to follow their own pathway through the site to find resources and connect to other educators. The site also includes resources that address issues of equity and diversity, and there is a mix of expert-vetted and community-sourced resources with a clear distinction between the two. The community section of the website allows users to connect with peers, ask identified experts for help finding or using a resource, and find events and colleagues in their immediate area. Schools and districts can also create profile pages for their teachers to use as collaboration sites. As the site continues to evolve, both web analytics and a beta-user survey will be used to identify areas for further improvements.

In addition, the research results could inform other PreK-12 engineering education efforts. Professional development and teacher education programs could use these results to develop courses or other resources for educators. School and informal education administrators could use these results to develop support systems for educators as they begin to teach engineering, and district or state administrators could also use these results to develop systems to support educators and schools. Finally, these results could be used to inform policy change around PreK-12 engineering education.