The *TeachEngineering* Digital Library: Improving Access to the P-12 Engineering Conversation

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Abstract

The *TeachEngineering* digital library is a collection of searchable, standards-based, classroom-tested P-12 engineering curricula for use in science and math classrooms (Sullivan *et al.*, 2005). Its inquiry-based lessons and hands-on activities use real-life engineering as a vehicle for the integration of science and math in P-12 classrooms. Mapped to educational content standards, the activities are age-appropriate, inexpensive to conduct, and relevant to students' daily lives, helping science and math come alive. The collection is a powerful resource for those in P-12 or higher education, industry and professional communities wanting to improve STEM literacy, to engage young students in the joys and creativity of engineering and the design process, and to increase the number of students pursuing STEM careers.

TeachEngineering is based on the premise that technological literacy is an essential component of basic literacy, and that engineering and technology can assist in the instruction of STEM subjects in P-12 settings. The free-to-use materials in *TeachEngineering* incorporate current research and advances in engineering and technology for the purpose of enhancing the learning of science and mathematics fundamentals and promoting STEM education through engaging engineering exploration. This paper investigates *TeachEngineering* usage trends and curricular submission statistics. Specifically, we analyze the submission process for curriculum contributed from external authors, suggest practices for submitting new curriculum, and discuss possible support avenues for future submissions.

TeachEngineering Digital Library: A Success Story

With National Science Foundation (NSF) inspiration and funding, a multi-university team of engineering researchers embarked on creating the *TeachEngineering* digital library. Engineering educators from the University of Colorado Boulder, Duke University, Worcester Polytechnic Institute, and Colorado School of Mines, with advice from dozens of P-12 teachers, pooled the engineering curricula developed through four NSF GK-12 grants into a unified collection freely accessible via the Internet. The *TeachEngineering* digital library was launched in January 2005 as a searchable, educational standards-based repository of high-quality, classroom-tested lessons and activities for use by teachers and engineering faculty to teach engineering in P-12 settings.

> ***TeachEngineering*…recognized by the National Academy of Engineering as a model engineering education program in its <u>Guideposts to the Future, Educating the Engineer of 2020.</u>"**
> **(NRC, 2006, pg 39)**

Information systems faculty at Oregon State University (OSU) designed and developed the system infrastructure and search engine, with architecture, document collection, and metadata formulation based on established NSDL digital library protocols. Building on the NSDL-funded educational standards capabilities of JES & Co.'s Achievement Standards Network (Gateway, 2007; Sutton and Golder, 2008) and Syracuse University's Center for Natural Language Processing's CAT and SAT tools (Devaul *et al*., 2011; Diekema and Chen, 2005; Diekema *et* *al*., 2007; Diekema, 2009), in October 2008 the team issued a breakthrough release in which all curricular items were aligned to the P-12 math and science educational standards of all 50 states (as well as many national and international) STEM standards.

TeachEngineering's multi-state alignment capability enabled it to serve teachers from any state searching for P-12 engineering curricula that align to their states' standards. It also created dissemination opportunities for authors with engineering curricula who desire to meet educational standards from any state. New institutions began to contribute their original P-12 engineering lessons and activities, most from NSF-funded research grants aiming to meet outreach and dissemination requirements.

> **"…*TeachEngineering* is especially valuable for STEM education. I was able to find great information that would have helped me teach about Egyptians… weather instruments… circuits and power. Proof that engineering should not be silent in your teaching, and is actually embedded with many things you are teaching. But there was something else I found in *TeachEngineering* that caught not only my eye, but my heart. In the Able Sports lesson, students are asked to design a sport for students with disabilities, taking into account the disability. How empowering! To have a sport that YOU could play better because of what some see as a *dis*ability." —Excerpt from netTrekker blog, August 19, 2009**

Awareness of the collection accelerated as online educational websites featured, reviewed, and recommended *TeachEngineering* curriculum. Similarly, users were increasingly directed to the collection from high-caliber curriculum providers such as Lesson Planet and netTrekker, as well as NSF and NSDL itself. As a result, collection use has steadily grown.

In summer 2010, *TeachEngineering* incorporated International Technology and Engineering Educators Association (ITEEA) standards to strengthen the engineering foundation of the collection—somewhat compensating for the fact that most states do not have engineering standards. In addition, all lessons and activities already in the collection were manually aligned to the ITEEA standards and benchmarks; and all future contributions are required to be aligned with at least one ITEEA grade-specific benchmark.

More recently, NAE-tested engineering messages and taglines were added to the introductory pages of all *TeachEngineering* lessons and activities, and the text and imagery in the most highly used curriculum is being enhanced to reflect the National Academy of Engineering's *Changing the Conversation* research (NRC, 2008). Recasting P-12 engineering teaching materials using updated messaging that have proven appeal to girls and minority youth has the power to widen teachers' perspective about who belongs in engineering.

Improving the Publishing Experience for *TeachEngineering* Contributors

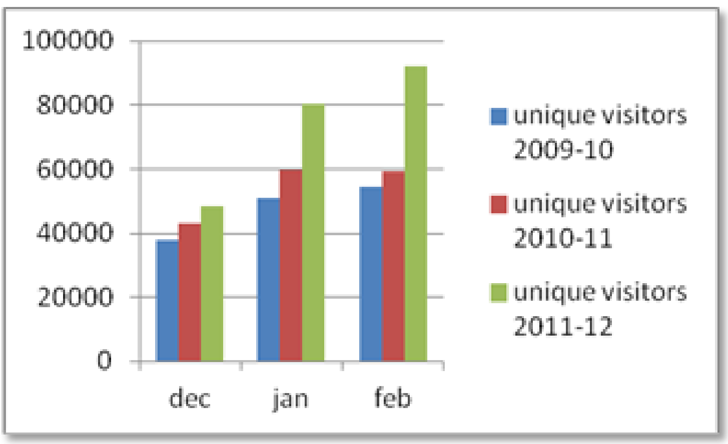
As the *TeachEngineering* digital library continues to grow to meet the needs of teachers and colleges engaged in P-12 engineering, assessment of its uses and its submission and publishing process becomes increasingly necessary. The goal of this paper is to look at the usage and publishing statistics for *TeachEngineering* and determine some best practices for authors who plan to publish their innovative engineering curricula in the collection. *How is the TeachEngineering digital library growing? How much support and/or training do contributors need to successfully publish in TeachEngineering? What are best practices for authors who wish to submit their original engineering curricula to the collection?*

Expanded Opportunities for Impact

To welcome authors to publish their classroom-tested curricula in *TeachEngineering,* in January 2009, the team hosted an NSF workshop in Boulder, CO for the 26 then current and past NSF-funded engineering GK-12 grantees. Forty-two people from 25 higher education institutions (of which 22 were NSF GK-12 projects) attended and indicated an intent to publish in *TeachEngineering*. Not counting contributions from the four founding programs, nearly 900 lesson and activity submissions have been received from 40 different universities or programs to date. This significant influx of curricular submissions, mainly from NSF GK-12 and RET grantees, led to the implementation of a professional and peer review-based publishing process engaging more than 50 volunteer teacher and engineer reviewers from 24 states.

Starting with a rapid upswing in usage since the 2008 alignment of TE curricula with standards for all 50 states, the collection's user base has steadily grown. Comparing the unique visitors count from February 2011 (59,162) to February 2012 (92,018) shows a 56% year-over-year (Figure 1). Further evidence of real use by teachers is that *TeachEngineering* usage numbers closely track the academic year.

***Figure 1*. Three-year trend of *TeachEngineering* monthly users during the Dec-Feb period, as of February 29, 2012 (robots & internal request activity removed).**



The surges in both curriculum contributions and system usage affirm that *TeachEngineering* fills niches for engineering colleges engaged in P-12 work who seek long-term, stable and highly visible dissemination venues for their P-12 engineering curricula, as well as for teachers seeking high-quality P-12 STEM resources.

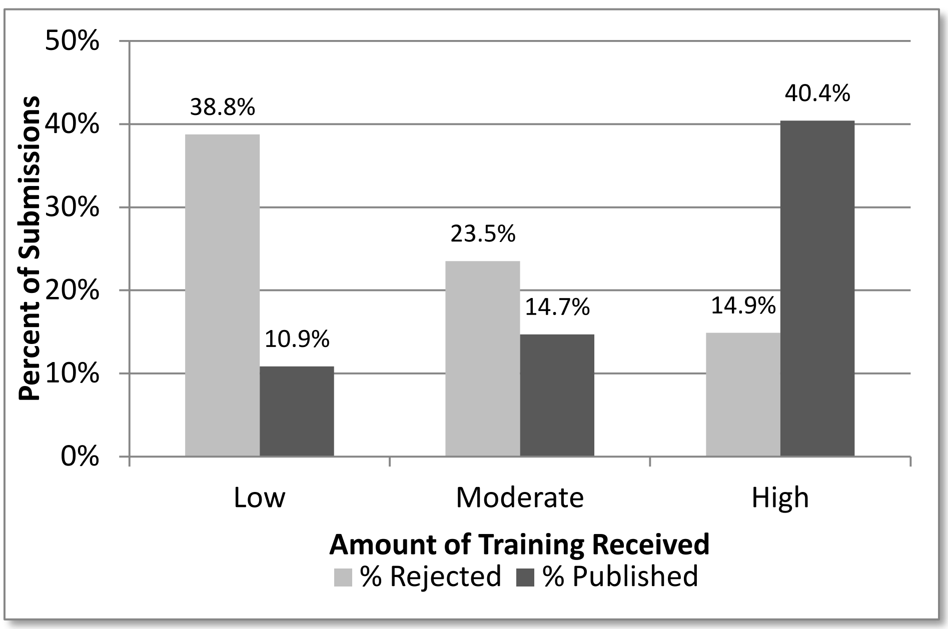
External Curricula Publishing Process

TeachEngineering has streamlined its publishing process to increase access for potential authors. To support the publishing work flow, the project adopted the Open Journal System publishing application (Edgar and Wilinsky, forthcoming). Since 2010, additional editorial resources provided through the Duke and Colorado project partners enabled increased throughput of the backlog of curricula submitted for review and publication. From the *TeachEngineering* website, authors are instructed on how to best format submissions and can access the submission portal. The steps to publishing curriculum on *TeachEngineering* begin with the creation or adaptation of original curricular materials within several flexible Microsoft Word templates. Next, authors upload their submissions to the submissions portal. At this point, *TeachEngineering* editors review submissions for completeness and potential duplication within the existing collection. If a submission is deemed ready for review, it moves to the peer-review stage. Each submission receives at least two reviews—one from a P-12 teacher and one from an engineer. Currently, 53 reviewers volunteer to review for *TeachEngineering*. Teacher and engineer reviewers use different rubrics for content and context evaluation of the submissions (available to authors on the website). Submissions must pass both of these reviews for consideration, and, similar to standard academic journals, can be accepted unconditionally, accepted pending changes, or rejected.

In Support of Successful Contributions

The surge in curriculum submissions prompted us to take a closer look at contributors and their publishing success rates, relative to the amount of training received from the *TeachEngineering* team. For example, many contributors rely solely on the information presented to authors on the website. Program managers from institutions who attended the 2009 Boulder workshop received a moderate level of guidance and support to adapt their curricula to the collection. They learned about the publishing templates and were able to ask in-person questions of the team. Some contributors who did not attend this workshop have requested a greater amount of support from the team, including email communication as they converted their curricula into the template formats. This also included over-the-phone training with program managers and authors prior to submission.

***Figure 2*. Submission publishing percentages (rejected *vs*. published) compared to amounts of training received.**



We compared the success rates for publishing with the amount of training received to determine how much support is needed for success. As shown in Figure 2, "low training" corresponds to contributors who relied exclusively on website information (n=129, ~50% still in process), "moderate training" corresponds to program manager engagement in single workshops (n=136, ~62% still in process), and "high training" indicates more extensive communication between authors and editors prior to submission (n=47, ~45% still in process). We observe that the success rate for *TeachEngineering* publication corresponds to the amount of communication prior to external review, suggesting that the likelihood of publication success for authors could be increased by providing more training opportunities. The relationship is statistically significant (chi-squared=20.77, DF=2, $p<0.001$).

Best Practices for Submitting to *TeachEngineering*

As indicated by Figure 2, the publishing success rate increases with more editor communication prior to submission. Although submission instructions are provided through online documentation, it helps editors and authors alike to highlight particularly difficult sticking points prior to submission. Also, some ideas are simply easier to communicate through discussion rather than through online templates, especially since, by their very nature, submissions are unique and widely variable in their development and quality. With this in mind, the team is currently investigating avenues for online training webinars to facilitate the submission process. In order to address this gap and share lessons learned with potential future contributors, the editors collaborated to develop the following best practices for submitting to *TeachEngineering*.

- *In advance, discuss with TE editors a program's plans to submit.* A few clarifications at the beginning of the publication process save time for authors and editors. For example, if 10 *teachers* are submitting work from an RET program, and all 10 of them make the same mistakes, editors need to explain the error 10 times. Processing a small sample of work initially minimizes this exchange.

- *Provide training to student and teacher authors on using TeachEngineering.* It is useful to hold a workshop for teachers on the publication process. What teachers submit to *TeachEngineering* should be quality products worthy of publication. Some programs require teachers to submit curriculum to *TeachEngineering* as part of participation. This is encouraged, but it sometimes causes teachers to quickly submit something that is not finished at the end of the semester, which reflects poorly on the program. It is helpful when program managers provide feedback on curricula prior to submission to *TeachEngineering*. Another method for learning about *TeachEngineering* is to ask teachers and students to volunteer to review for *TeachEngineering*. This helps them understand what is required by the submission process, and they learn about the different templates used in the collection.

- *Clearly indicate the engineering context.* Central to the success of authors submitting curriculum to *TeachEngineering* is the ability to demonstrate that the scientific and mathematical concepts studied and experienced through the lessons and/or activities pertain to real-world engineering. This distinguishes the *TeachEngineering* content from the myriad science/math-only resources available. To be published in the *TeachEngineering* digital library, curriculum must fit into one of three categories that aim to describe the amount or depth of engineering content: 1. *relating science and/or math concept(s) to engineering*; 2. *engineering analysis or partial design*, and 3. *the engineering design process*.

  A frequent issue that arises with unsuccessful submissions is an insufficiently developed connection that fits into one of these three categories. Most often, this issue comes up in submissions aiming to fit into categories #1 or #3. In attempting to submit curriculum that fits into category #1, authors commonly create innovative and engaging science activities, with well-stated engineering connections described in the "Engineering Connection" section of the templates. However, even though the preliminary connection to engineering is made in the appropriate template section, activities like these often present themselves as scientific labs or investigations, rather than activities that relate science and/or math concepts to engineering. In other words, the engineering connection needs to be manifest in the body of the activity (procedure, and/or assessment) so that students are experiencing engineering during the activity.

When submitting as category #3—engineering design process—curriculum, the tendency is to leave parts of the design process incomplete. To meet this category, four of the following six steps identified on the TE review rubric as important to the engineering design process must be met by students: 1. identify the need or problem, 2. research the need or problem, 3. select the best possible solution(s) from a number of options, 4. construct and test a prototype(s), 5. revise and improve the design, 6. communicate the solutions. It is generally important that the steps followed be contiguous, and it is important to remember that students must actually do these steps. Even if the activity defines the problem for the students and then they conduct four of the other steps, the important engineering design practice of iteration is frequently left out of the experience. At the very least, it is important for students to consider how to improve on initial engineering designs.

- *Attachments add fullness and usability to curriculum.* Published curricula generally include attachments and add-ons that make them desirable and user-friendly for teachers. (Reitsma *et al*., 2010). Though not required, a published lesson might include a student worksheet, worksheet answers, and perhaps a supplementary PowerPoint presentation enabling teachers to simply print or download the provided materials to complement a lecture. Similarly, a successful activity might include a handout with instructions, a worksheet with a data table, and/or a homework assignment or quiz with investigative and reflective questions. Sample answer keys for any assessments and attachments are also necessary.
- *Ask TE editors other questions that arise.* To date, 245 lessons and activities from 24 different (non-founding) universities or programs have been successfully published in the *TeachEngineering* collection, so the editors have experience working through all sorts of questions from new contributors. Hence, please ask the TE editors about required *vs*. optional fields, the use of images, linking learning objectives with assessments, how to utilize the standardized templates to present a program's unique materials, *etc*. The editors can most likely answer questions and often point authors to already-created helpful resources.

***TeachEngineering*: On the Horizon**

In many ways, the current *TeachEngineering* challenges are what we hoped would happen: the creation of a relevant collection of free, standards-based K-12 engineering curricula that teachers and engineering faculty alike trust *and use*. The demand from the NSF-funded community to publish their work continues to be significant. The core *TeachEngineering* team continues to apply and improve the standards to the publishing process, while strengthening backbone system infrastructure and dynamically aligning all curricula in the collection to changing K-12 STEM educational standards.

The data presented above indicate that that increased contact with authors and program managers is associated with higher publication rates. For that reason, we have begun including PIs and/or program managers in some author communications so they can help us disseminate best practices. We also are exploring webinars as a training avenue for current and future submitters. Using webinars has the potential to simultaneously reach both authors and program managers.

The *TeachEngineering* collection contains 1,033 hands-on engineering lessons and activities designed for K-12 youth, with 404 additional lessons and activities in the review process (as of February 29, 2012). Curricula created by individual authors across the nation continue to be added to the collection after meeting standardized components, engineering content requirements and quality-control criteria.

TeachEngineering serves as a dissemination website for the curricula created from numerous NSF-funded grants to US engineering colleges in partnership with P-12 teachers. Through the *TeachEngineering* digital library, that curriculum can be used by tens of thousands of teachers monthly—nationwide and beyond. In order to sustain this infrastructure, the *TeachEngineering* team welcomes continued dialogue about lessons learned with regard to training tools and best practices.

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