



# Educational materials on sustainable engineering: Do we need a repository?

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## NSF workshop: Sustainability in engineering courses and curricula, August 2014

In August 2014, the U.S. National Science Foundation Workshop on Sustainable Engineering (SE) brought together some 50 individuals to address a serious problem: virtually all young professionals graduating with at least a bachelor's degree in engineering anywhere in the world are by and large not prepared for the challenges of the 21<sup>st</sup> century. Although standards of living are improving in many regions globally, the total number of people who lack basic human needs like sanitation, clean air, clean water, and sufficient nutrition is still unacceptably high (United Nations, 2015). Furthermore, efforts to improve living conditions for the world's poor are hampered by shortages of water, energy, and land, with many of these shortages related to climate change which is likely to intensify. Problems of sustainability are also serious in the developed world, where per capita use of scarce resources is unacceptably high. Rapid progress in new fields such as nanotechnology, synthetic biology, information technology, and applied cognitive science create previously unknown materials and new forms of life with unknown consequences for human civilization.

A key problem with SE education in the U.S. as well as elsewhere is the lack of high quality educational materials like textbooks and other course readings covering current challenges. This problem is reflected by the lack of a Body of Knowledge in SE, although such compendiums have been completed in other fields such as Environmental Engineering (AAEE, 2008) and Civil Engineering (ASCE, 2008). Hundreds of engineering programs are simultaneously attempting to develop SE educational materials, but are doing so in relative isolation. Significant gains could be made if the SE education community came together to develop shared educational resources that could be posted on a website. The overall goal of the workshop was to make progress in this direction through three distinct objectives: (1) to expose members of the community to the benefits of a repository such as a web platform for educational materials which could improve teaching efficiency, (2) to illustrate state-of-the-art online educational resources as well as instructional design and assessment methods to improve teaching effectiveness, and (3) to solicit and assess the SE education community's preferences for such a repository and identify barriers to adoption. Objectives 1 and 2 were mainly met through regular plenary presentations at the workshop, while Objective 3 was achieved through open discussions in smaller breakout groups and also through an on-line survey administered to the broad SE education community across the U.S. a few weeks prior to the workshop. In this article, we focus on Objective 3. We present a summary of the breakout group discussions as well as the results of the last section of the survey. Both the breakout groups and the last section of the survey asked individuals to consider two activities, namely *creating modules* and *using modules*, where a module is a unit of educational material ranging from a homework problem or lecture outline to a large group project or even a full course. We will consider both of these activities in turn.

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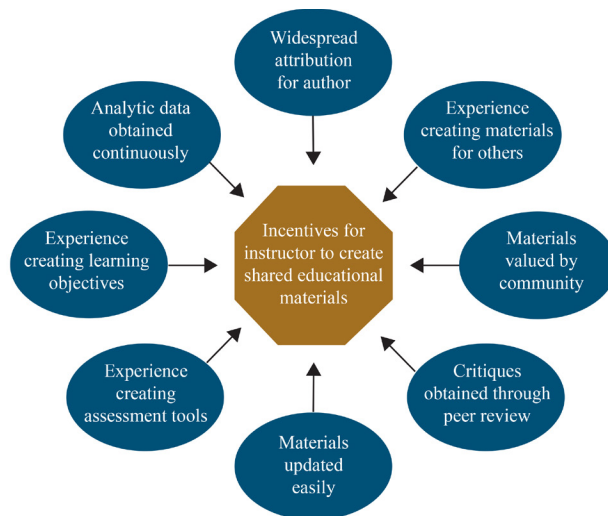
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**Figure 1**  
Breakout group discussion for question 1.

Categories of answers expressed in the breakout group discussions to the question “What incentives would entice you to create shared educational resources for posting in an open repository on the web?”

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## Creating modules

For the discussion of preferences, workshop attendees were divided into three similarly sized breakout groups. Each group first discussed the following question:

- What incentives would entice you to create shared educational resources for posting in an open repository on the web?

Figure 1 highlights what might make it attractive for instructors to create and submit educational modules according to the breakout group discussions. Starting at the top of the figure and proceeding clockwise, the groups thought that each author must be given attribution for submitting a module – the author’s name must be clearly associated with a module and should stand out on the website. Furthermore, users of a module must cite the author in a way consistent with citations of journal papers, which gives credit to the authors.

The second oval in Figure 1 emphasizes the opportunity of an author to gain experience in structuring SE content and taking the time to exploit learning design methods that could improve teaching. The process of creating materials for use by others requires the author to describe the purpose of the module, the background and context of the material, and anything else needed to make the module self-sufficient. This information can help instructors know when and how to use the module, and can help students overcome unstated assumptions and implicit information that can hamper learning.

The third oval highlights the satisfaction that comes with creating a product of broad interest to the community at large. An outstanding module can have a long lifespan, and make its way into courses across the country and overseas.

The fourth oval mentions a benefit usually associated with research papers but rarely with educational materials, namely the opportunity for peer review of the modules. This can markedly help improve the materials.

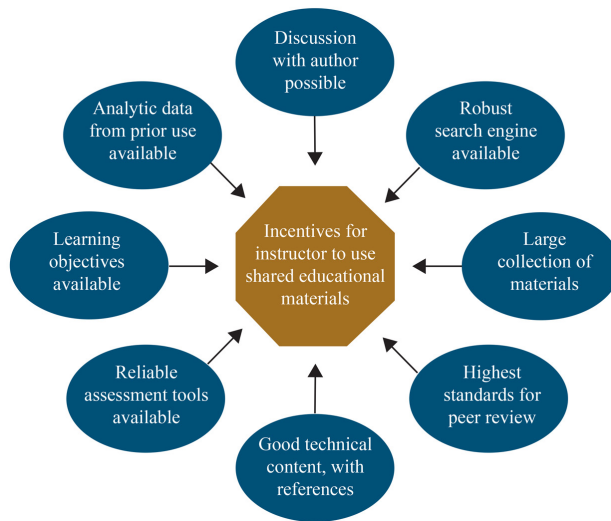
The fifth oval states an advantage of an active website over textbooks and other printed education materials: an electronic file typically can be easily updated, in a more timely fashion for lower cost. This enables the materials to be designed in a different way than a textbook, for example, with some sections that can be replaced or updated as new information becomes available.

The sixth and seventh ovals highlight an important problem. Too many engineering courses are taught without clear and well-designed learning objectives and assessment tools to enable quantified information on whether the course objectives have been achieved. The combination of these two ovals allows the instructor to engage in a process of continual assessment, revision, and re-assessment to improve the course and keep it updated. This is also part of the ABET strategy for accreditation of engineering programs.

Finally, the eighth oval refers to the availability of analytic data about who is using the module and how students are reacting to it. Such information can help the author update the materials and track their success. It can also enable the website to be of value in tenure and promotion cases by providing evaluations of an instructor’s written educational contributions.

In contrast to the breakout group discussions, the last section of the on-line survey posed the following two questions:

- What is the most important obstacle preventing you from contributing material to a shared resource repository?
- How could this obstacle be overcome?



**Figure 2**  
Breakout group discussion for question 2.

Categories of answers expressed in the breakout group discussions to the question “What incentives would entice you to use shared educational resources posted on the web by others?”

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Of the 140 completed surveys representing 108 academic institutions, 36% of the respondents indicated lack of time as the most important obstacle. Many of these individuals argued that to overcome this challenge, modules would need to be considered important for promotion and tenure; others explained they would need to receive compensation (e.g., monetary, or release from teaching), assistance from others (e.g., experts in educational design), or guidance in preparing the materials to contribute modules to the website. A total of 25% of the respondents were concerned that the preparing and posting of their module would not be easy, their module would not be easy to use, or the website would not be easy to navigate. Overcoming these obstacles would require clear guidelines for contributors as well as changes in promotion and tenure criteria, and compensation as discussed previously to provide more time for contributors. Roughly 16% voiced concern about whether their module would be widely used after going through the effort of creating it. Overcoming this problem would require a well-advertised and well-designed website with a lot of high quality useful content to attract users. Note that these are not mutually exclusive categories; some respondents indicated concern over time as well as concern about minimal use of their module. Numerous other concerns were reported in the survey results, although the aforementioned were by far the largest three clusters.

## Using modules

The breakout groups also considered the following question:

- What incentives would entice you to use shared educational resources posted on the web by others?

Figure 2 highlights what might make it attractive for instructors to use a web platform repository of educational materials, according to the breakout group discussions. Just as providing credit to the author is a key point in Figure 1, a key point at the top of Figure 2 is that the author must be available to answer questions about the module and clarify concepts for the user. Creating good educational materials takes a lot of time, and if the author is to see the benefit of that time investment through widespread use of the materials created, it is necessary to be accessible to answer questions by users.

The second oval indicates the need for all materials to be easily searchable – by engineering subdiscipline, topic area, keywords, intended audience, and other attributes. But a good search engine is useful only if the total collection holdings are large enough so a user is likely to find what he or she is looking for. So the third oval emphasizes the size of the collection. To influence SE education nationally and globally, the repository must have large numbers of contributors and large numbers of users. Knowing what will attract contributors and users is a key to the success of this endeavor.

The fourth oval relates to the need for peer review – just as the author can benefit from reviewer comments, as pointed out in Figure 1, users will want assurance that the material is accurate, clear, and useful for class. There is no substitute for a rigorous peer review. This is linked to the fifth oval, which emphasizes high quality content and also lists the need for references so the user can track down any of the material in greater depth.

The sixth and seventh ovals highlight what the module is supposed to accomplish in terms of learning objectives, and how to measure the success of achieving those objectives with an assessment tool. Users are much more likely to adopt a module that has clearly defined objectives and ways to assess student learning.

Finally, the eighth oval refers to data provided by the web platform analytics. The user as well as the author can benefit by knowing how the module has been used and received at other schools. This suggests

the possibility of a recommendation system where users could rate a module, e.g., on a 1 to 5 scale on the basis of its technical content, understanding by the students, ease of instructor use, and other parameters.

Several other themes came out in the breakout sessions. For example, the benefits of a well-organized web platform repository were recognized by most workshop participants. However, a less certain issue is whether such a project would attract a critical mass of contributors and users. Related to this issue is whether a web platform is the most desirable method of gaining widespread use of educational materials; some attendees noted that there are already many individual websites with SE educational materials, and there are some SE materials available in print form. Thus a proposed web platform would have competition. Alternatively, a new web platform could be designed to incorporate links to these other resources, enabling a one-stop shop to bring the community together.

The last section of the survey also included the following two questions:

- What is the most important obstacle preventing you from using material from a shared resource repository?
- How could this obstacle be overcome?

Roughly 45% of the 140 survey respondents mentioned that using a module in their own courses is not likely to be easy or straightforward for various reasons. Some cited the low probability of finding content that matches their course goals, along with the need to read through a large number of modules to see whether there is a match. Others pointed out that they are not likely to find modules that align well with the needs of their students. For example, a few respondents mentioned the lack of sufficiently advanced material for their courses. Other respondents commented on the lack of background in existing modules that would help them understand the context of the material. Suggestions for overcoming these challenges included the need for a large collection of modules with a good search engine to enable rapid identification of candidate modules. The search engine could include advanced features such as search history and use history. Having the modules in a common format would make it easier to determine if there is a good match to a particular course. Several respondents commented on the importance of a repository organized by several criteria, such as topic area, intended use, and learning objectives.

A total of 24% of the respondents noted the challenge of making the repository highly visible for potential users. Several respondents indicated that they were unaware of such repositories, and they would like to be informed when such resources are created. Some complained that existing repositories are not easily findable on the web. A number of ideas were suggested on overcoming the challenge of visibility of a repository. Widespread advertising through professional societies such as ASCE and ASEE was mentioned, along with occasional email alerts about updating the repository. Sessions on conferences could highlight which modules were of greatest interest by users.

Around 10% of the respondents mentioned that the time needed to search for and adapt modules from a repository for their courses was a major obstacle. Although it might be more time to create a module from scratch, at least the certainty of having a module that is a close fit to the course is an advantage. The uncertainty of knowing whether a module can be adapted to fit is a key problem.

As stated before, these are not mutually exclusive categories. Although there were a number of additional obstacles cited for using a repository, these three categories were the largest. More detailed findings from this survey will be reported in a separate paper.

In closing, the lists of items in Figures 1 and 2 and the suggestions from the survey respondents are merely a starting point for discussions on how a web platform might be designed as a repository for SE education materials. While showing a high level of interest, the small sizes of the breakout groups and the limited time available for discussion make it difficult to know whether these ideas would be embraced by the broader SE community. Similarly, a set of 140 survey respondents cannot be taken as fully representative of the community. However, we plan to continue these discussions and identify steps that could be taken to enable SE education to continue to grow, both within the U.S. and internationally. Details on all aspects of the NSF workshop can be found in <http://www.nsf.gov>.

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## Contributions

- The authors of this manuscript were the organizers of the NSF workshop on Sustainability in Engineering Courses and Curricula in August 2014. All authors contributed to the workshop and to this summary paper.

Educational materials on sustainable engineering

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#### **Competing interests**

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