AC 2008-1322: DEVELOPMENT OF AN OPEN SOURCE HIGH SCHOOL TEXT FOR ENGINEERING

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Development of an Open Source High School Text for Engineering

1 Introduction

This paper describes the development of a novel high school engineering textbook. This development is unique within engineering in several different ways. First, the text is a Flexbook – an open-source book developed with the support of and within the context of the CK12 Foundation; the Flexbook format and open-source licensing allows anyone to extend and customize the book. Second, writing the text was a collaboration between university engineering and education faculty with input from CK12 personnel; this collaboration has led to a textbook structure that supports constructivist approaches to learning. Third, the text conforms to a draft K–12 standard for engineering content.

CK12 is a non-profit foundation launched in 2007 to reduce the cost of textbooks for the K–12 market in the US and worldwide; CK12 intends to achieve this goal using an open-source, collaborative, web-based infrastructure. CK12 has developed the concept of a Flexbook as a living document that can be updated, expanded, and re-purposed to support specific standards and classroom needs. Several variants of the same text may exist at the same time, drawing on a set of common core elements; a Flexbook is stored in a digital format, and using the infrastructure provided by the CK12 Project, can be compiled and printed to meet the needs of an individual class, school, or district. Because the book content is distributed under an open-source license, anyone is free to update, expand, and customize it. The engineering text will serve as one of a number of "seed" textbooks for the CK12 Foundation; these books are intended to form the nucleus around which communities will form that use, extend, and adapt the material.

A team of university faculty was assembled to write the book. This team included faculty with expertise in K–12 STEM from the Mary Lou Fulton College of Education at Arizona State University; engineering faculty from the Engineering Department at the Polytechnic campus at ASU; and faculty from the Ira A. Fulton College of Engineering at ASU. Several members of this team had worked together previously on proposals and funded research projects; the development of a high school engineering text was a new endeavor for all involved.

This paper is a progress report on the development of the textbook; the text is not yet available to the public, and we have not had the opportunity to evaluate the text's strengths and weaknesses in a classroom setting. However, we feel that this progress report is valuable in that it identifies many of the issues arising in collaborations between engineering and education faculty, and it describes many implications for authors of materials destined for flexible open-source implementations such as the Flexbook.

2 Collaboration

This project is a collaborative effort between the engineering and education faculty and was strongly influenced by CK12 personnel. This arrangement was extremely rewarding but posed some significant conceptual challenges for the participants. These challenges included understanding and bridging the cultural differences between groups, addressing the significant tension between the desire for a traditionally structured textbook and the desire to support constructionist approaches

to learning, and providing materials that would satisfy a wide range of student users while being useful to teachers and parents.

Reconciling three cultures (the CK12 business culture, the academic engineering culture, and the science education culture) proved to be a challenge. Participants in the writing venture viewed the writing task through the lens of their own culture. Education faculty had significant experience working with educators in K–12 settings and were much more aware of the expectations of K–12 teachers and of the environment in which the material would be used. Engineering faculty started from a college perspective in which it is assumed that students will read the book fairly independently. CK12 participants had a distinctive vision of the Flexbook, which should include a system that offers flexibility in compiling the material but results in a traditionally structured textbook. Thus, shared vocabulary had to be developed, and there were compromises based on modes of working.

Initial drafts by the education faculty were teacher centric, in the sense that the text provided resources (chunks of material, activities) and relied on the teacher to provide structure to the reader. The body of the text was entirely expository material; student activities were separate from the expository material. The initial drafts by the engineering faculty were textbook centric, in the sense that the text was designed to guide the reader through the material without significant additional structure provided by a teacher; the text had embedded learning objectives for the reader, questions to be answered during the course of reading, and exercises for the reader to be done as they read through the material.

The education faculty introduced the 5E Learning Cycle [2, 3] to the engineering faculty. The learning cycle provided valuable structure for much of what was written, although the education and engineering groups interpreted it somewhat differently. The education group primarily incorporated the learning cycle into activities for which the text provided necessary factual material. The engineering group attempted to develop content modules that have a highly interactive format that supports the learning cycle. Again, this reflected the differences in culture and understanding of how textbook materials would be used. To some extent, the modular structure described in Section 4 provided a means to unify the different concepts of how the text should function. Within this structure, content modules are paired with one or more activity modules based on the learning cycle.

The education faculty also brought issues of readability and reader friendly text, new vocabulary, prior conceptions, cognitive development, and independent learning to the attention of the engineering faculty. This dramatically improved the final text.

3 CK12 Web Infrastructure

A constraint on the textbook writing process was that the text could be used as seed material for CK12. Thus, the text is licensed under a Creative Commons Attribution Share-Alike license [1] that allows the materials to be adapted and extended. This license will be used for all content included in the CK12 environment.

The CK12 Foundation is developing a web-based infrastructure to implement the Flexbook concept. This infrastructure provides the capability to author material, import material from other sources,

compile material into books, and produce text and/or online versions of the book from compiled material. The CK12 environment is currently in beta test.

A nominal workflow for the creation of a Flexbook using this infrastructure is:

1. Draft new materials or adapt existing materials to be included in the book. This can be done (for example) in the CK12 environment (supported by collaborative editing tools), in a traditional word processor, or using a Wiki environment.
2. Organize new and previously existing content into the desired book structure.
3. Produce the textbook in the desired medium: print, online, etc.

The fact that this workflow is implemented online and the content is licensed to promote reuse and adaptation provides both opportunities and challenges to the content authors. The content can be continually updated, which implies that many different versions of the text may coexist at a given time. Indeed, it may be difficult to declare that a book is ever finished; on the other hand, the textbook can be easily upgraded to reflect new understanding of students' learning of the material. A design challenge is to create a text that is a unified whole but can still be readily adapted and modified as necessary. Clearly, format must be consistent, especially in light of the need to mix and match selected content. Beyond format, the structure applied to the material must anticipate the various uses and combinations in which the material will be configured. This required the authors of the engineering text to identify different potential audiences and their needs.

4 Text Structure and Content

The ultimate goal of the project is a text that introduces high school students to the fundamental components of engineering. Thus, the text has been drafted to conform to the ASEE Corporate Members Council Draft Engineering Standards; these draft standards will serve as input to the National Academy of Engineering process of considering engineering standards for K–12 education. This process is still in an early stage, and it is not clear that the process will result in the adoption of standards; if it does, there may be significant evolution of the proposed standards before the process is complete. Nevertheless, we believe that the draft standards represent a reasonable level of consensus within industry and academia about the aspects of engineering that are considered important for students in a high school engineering curriculum, and thus form a reasonable framework for the text. The draft standard includes the following aspects of engineering:

- Engineering Design
- Connecting Engineering to Science, Technology, and Mathematics
- The Nature of Engineering
- Communication and Teamwork
- Engineering and Society

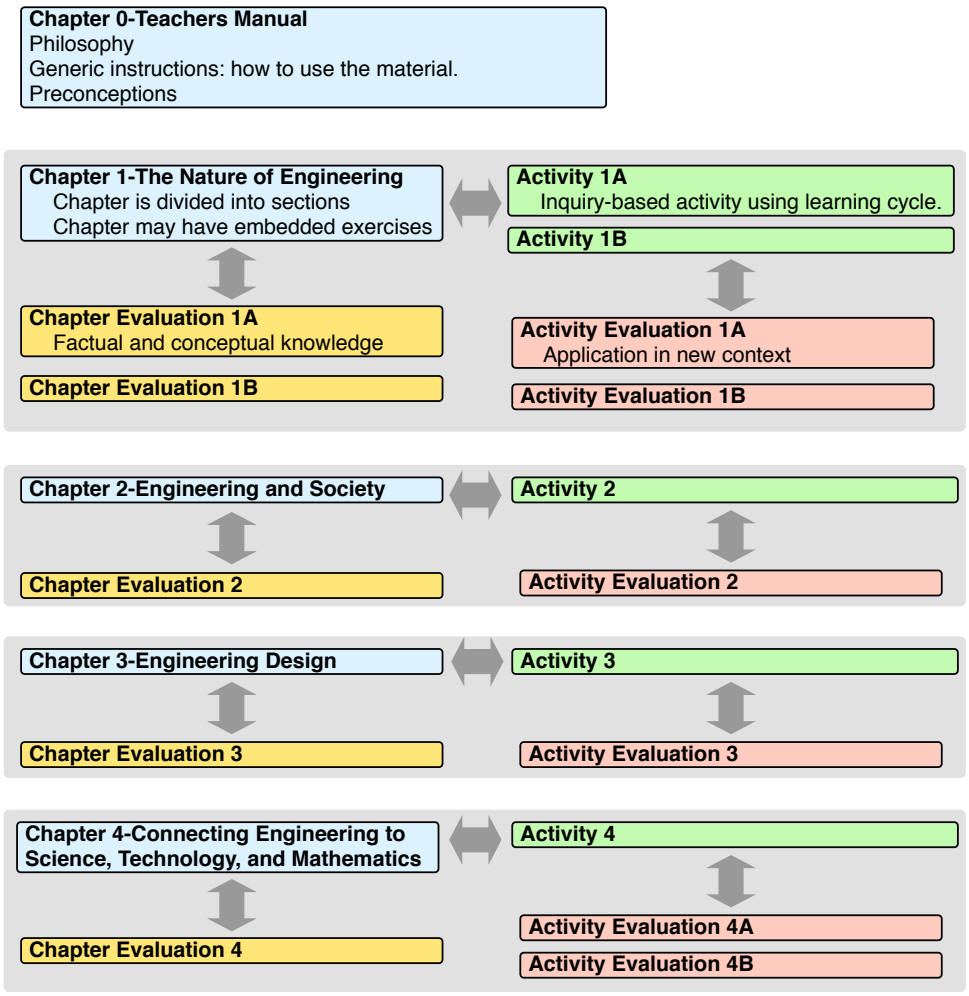

Figure 1: Modules from which the Flexbook can be assembled.

The book currently has four chapters that cover the nature of engineering, engineering and society, engineering design, and the connection between engineering, science, and mathematics; these chapters correspond to outcomes in the draft engineering standards. An additional chapter on the history of engineering is currently being written. In addition to these content chapters, the text also includes a Chapter 0 that serves as a teacher's manual and summarizes the book's philosophy and common student preconceptions.

Each chapter is structured as a collection of modules as illustrated in Figure 1. We developed four types of modules:

Content: Content modules contain the subject matter information. In addition, they may include student learning objectives, common student preconceptions, a glossary, and an annotated bibliography.

Chapter Evaluation: Chapter evaluation modules include assessment instruments and rubrics.

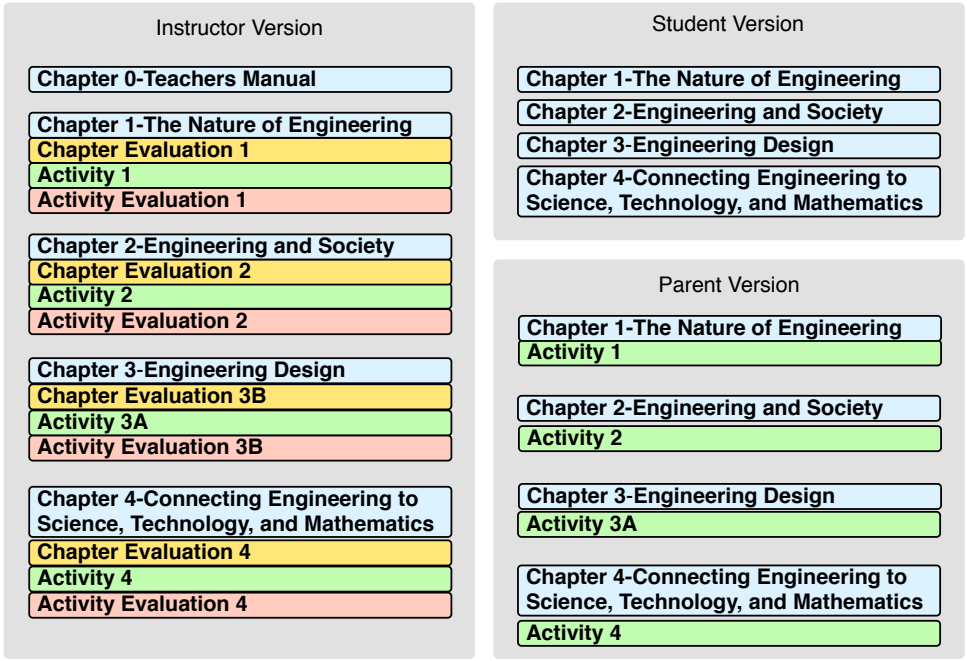

Figure 2: Different versions of the book could be assembled to serve different audiences.

Activity: Activity modules including inquiry-based activities structured around the learning cycle.

Activity Evaluation: Activity evaluation modules provide assessments of activities by requiring students to apply knowledge in a new context.

The modular designed resolves many of the tensions that surfaced in our writing process; for example, the tension between the requirement for a traditional textbook and the need to support constructivist classroom approaches was resolved by the addition of the activity and activity evaluation modules.

Using the CK12 infrastructure, modules are chosen and combined to customize the book for a given audience as illustrated in Figure 2; for example, activity and assessment modules might be included in a teacher edition but not a student edition.

5 Summary and Lessons Learned

This paper has described the overall goals and objectives of the engineering Flexbook authoring effort. The collaborative effort between the engineering and education faculty and CK12 personnel revealed some significant cultural differences that manifested themselves as differences in expectations about what the project outcomes should be. The flexibility of the Flexbook structure provided a mechanism whereby the book could be structured to address the different expectations on the team.

References

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