Development of an Open Textbook for Engineering Economics

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Abstract

Knowledge of Engineering Economics is a required outcome for accreditation in most engineering colleges in Canada, the United States, and many other countries. This outcome is often fulfilled by offering a course focused on Engineering Economics.

Open textbooks are textbooks that are licensed under an open copyright license and reside in the public domain. These resources are made available for free to students, instructors, and the general public – essentially anyone can access these resources for free. Engineering Economics textbooks from major publishers typically cost between $100 and $200 USD to purchase new.

Our Engineering College had undertaken a review of their Engineering Economics course; evaluating the method of teaching, the topics covered in the course, and the education resources available. The review highlighted additional topics that should be covered in the course and corresponding gaps in available textbook resources.

An opportunity to create an open textbook for the course was pursued to provide a resource to students that was not available. This open textbook focuses on engineering problems and particularly on topics and cases relevant to Canadian Engineers, the Canadian tax system, and includes some topics not typically covered in traditional engineering economics textbooks such as budgeting, cost estimation, and the determination of product costs using principles from management accounting.

One of the most beneficial aspects of open textbooks is that others may use the book and modify it for their interest or application. This textbook contains few sections, mainly related to taxes, that would have to be adapted to a specific country to make the textbook applicable to other regions of the world.

To facilitate the development of the open textbook, funding was made available to the project that allowed the primary authors to hire two undergraduate students and one graduate student to help in the development of the textbook. The two undergraduate students had previously taken the engineering economics course while the graduate student was in a graduate program in economics. This strategy was extremely beneficial to both the instructors as primary authors and the students as contributors.

For the student contributors, their work on the open textbook allowed them to more fully understand the course concepts and apply them to examples and cases for the textbook. For the primary authors this work arrangement reduced their workload and provided feedback related to clarity of the explanations and example problems used in the textbook.

Introduction

Engineering programs in Canada and the United states have similar accreditation processes and criteria [1], [2]. ABET accredits programs in the United States while the Canadian Engineering Accreditation Board (CEAB) accredits programs in Canada. In each system, the ability of a student to consider the constraints of economics and incorporate economics into engineering

designs, projects and considerations is a requirement. As such, engineering programs must offer Engineering Economics in their programs and often fulfill this requirement with a course dedicated to this topic though it could be fulfilled in other courses such as design courses.

As part an internal improvement study, our college undertook a review[3] of the curriculum related to engineering economics to more fully understand the topics typically encompassed in the subject area of engineering economics[3]. The review consisted of an internal review of the engineering programs offered at our institution, a review of engineering textbooks commercially available, an environmental scan of the fifteen most research-intensive universities in Canada (termed the U15 universities), and survey of industry representatives. The result of this study was a list of recommended topics that should be included in an engineering economics course, including some areas where new resources would need to be developed. Some examples of materials that the improvement study recommended were related to management accounting such as budgeting and cost estimation, cost behavior, and activity-based costing.

The need for educational resources for engineering economics encompasses every university offering engineering programs and the development of open educational resources (OER) materials is an opportunity to improve the education in undergraduate programs through the adaption and modification of resources to fit a specific program and to make the basic resources to teach engineering economics freely available to anyone to use and adapt.

Open Educational Resources

Open textbooks are part of OER that have been developed with the intent to make these resources available in the public domain and have been licensed under an intellectual property license that allows for free use and the ability for others to repurpose the materials. This means that these open resources are available free to anyone in the public domain and that in many instances the materials can be modified without the need to ask permission from the original author.

Commercially available textbooks are easily available for engineering economics and typically cost between $100 and $200 USD to purchase new while electronic books and book rentals may be available at a lower cost. The content in these textbooks vary slightly to emphasize different countries or disciplines of engineering but all typically contain the same core topics.

The advantages of OER is that the resources are made freely available making them accessible to everyone regardless of economic status and that instructors may adapt the resource to their specific course. Adaptation can include the removal of materials, rewording or editing of materials, and the addition of new material. This customization can provide a custom resource for an individual course or instructor. When an adaptation is made, they should be and often are shared back to the OER community for others to use or further adapt for their purposes.

Textbook Development Strategy

Some funding was made available and administered through the teaching and learning center of our university. Approximately $40,000 CAD (approximately $32,000 USD) was made available to the primary authors and was used mainly to hire students to work on the textbook. Two

undergraduate students and one graduate level student were chosen to work on the textbook for one four-month term each.

The selection of students was through an interview process. The most important factor considered during the hiring was the student's familiarity with the subject matter, their ability to write, and their enthusiasm for developing the textbook. The undergraduate students that were hired had each completed the Engineering Economics course that this textbook would serve and had taken writing and communication courses in their undergraduate education. The graduate level student was pursuing a master's degree in economics and had interest in applying economics in the engineering context.

The content of the open textbook was not driven by what was available in commercial textbooks but rather what we wanted in our textbook for our course. To start the process of defining the content, a brainstorming session was held resulting a long list of topics which was subsequently condensed into chapters for development. The topics initially identified for inclusion in the textbook are summarized in Table 1 below.

Table 1 Main topics included in the Engineering Economics open textbook.

Chapter Name	**Main Topics Included**	
Business and Accounting	Financial Statements	Financial Ratios
	Proforma Statements	Taxes and Depreciation
Time Value of Money	Inflation	Simple and Compound Interest
	Economic Equivalence	
	Equations of Economic Equivalence	
Financing: Borrowing and Debt	Loan Conditions and Terminology	
	Amortized Loans	Mortgages
	Interest-only Loans	Leases
	Effective Interest Rates	
	Tabular and Remaining Balance Methods	
Evaluation Methods	Rate of Return	Conventional Payback Period
	Discounted Payback Period	
	Net Present Value or Present Worth	
	Annual Equivalent Value or Annual Worth	
	Capital Recovery Costs	
	Internal Rate of Return	Modified Internal Rate of Return
	Analysis Period and Project Lives	
	Risk: Sensitivity, Scenario, and Break-even Analyses	
Project Evaluations	Replacement Analysis	Life Cycle Cost Analysis
	Benefit-Cost Analysis	Feasibility Studies
	Service Projects vs Revenue Projects	

The student employees were then assigned chapters to develop based on their interest and background. The first step was to review all other open resources that were available because there is no point in recreating materials that had already been created and are available. This involved looking at OER materials in the areas of engineering, business, and economics. These resources were kept for potential inclusion in our chapters. Our search did uncover some resources related to economics and business that would help in the development of our book.

Once writing was underway, weekly writing reviews were held with the students to improve how the writing was being completed, clarify muddy points, and provide direction for the students to continue their work. These, typically four-hour, sessions were conducted in a meeting room with the document displayed on a projector and edits were made in real time. These sessions proved to be much more effective and productive than individually reviewing documents and submitting suggested changes. This process allowed for real time coaching for the students in the development of the textbook.

One of the aspects we did focus on in the writing of the book was the language used. We wanted this book to be accessible to as many people as possible. We consciously wrote the materials a level that we thought could be understood by readers with a junior high school reading level.

For each section of the open textbook, example problems are given with solutions to help demonstrate methods of solving problems in each section.

Future Work and Adaptability

The first step in making this OER product was to develop the essential materials in an open textbook. There are two subsequent steps that can be taken to advance this resource: the development of complimentary resources, and the adaptation of this open textbook for other countries, states, or universities.

To further build the educational resource it is desirable to develop additional materials such as case studies, spreadsheet templates and examples, question banks of example problems, and a set of presentation slides that provide some the basic materials that course instructors can use a starting point for their own slides.

To make the open textbook applicable to other countries, the main changes that are suggested is to replace the section on taxes with a section representative of the tax regime in the country or state of instruction and to develop some examples with local context. The open textbook discusses the Canadian tax system but modifying this section to reflect the U.S. tax system (or any country's system) should not be an onerous endeavor for a course instructor familiar with their local tax structure. Many of the examples used in the textbook relate to Canadian industries and businesses. While there is nothing wrong with keeping these Canadian examples, it may engage students more if the examples reflect the important industries or businesses of their geographic region.

The authors of this current version of the open textbook would like to encourage others to adopt the textbook and may provide some assistance with modifications to help suit the needs of other instructors.

Future work also includes studies to determine the effectiveness of this open textbook. A meta-analysis [4] was undertaken to evaluate postsecondary student's learning performance and course withdrawal rates between open and commercially available textbooks. This study found that there were no differences in learning efficacy between the open textbooks and traditional textbooks but that the withdrawal rate was significantly lower for courses with open textbooks. These factors, among others, will be considered in future work.

References

[1] ABET, "ABET engineering accreditation commission: criteria for accrediting engineering programs," 2017.

[2] Canadian Engineering Accreditation Board, "Canadian Engineering Accreditation Board Bureau canadien d ' agrément des programmes de génie," 2017.

[3] C. Hoessler, C. Martin, and S. Vanderby, "ENGINEERING ECONOMICS TASK FORCE - FINAL REPORT," 2015.

[4] V. Clinton and S. Khan, "Efficacy of Open Textbook Adoption on Learning Performance and Course Withdrawal Rates: A Meta-Analysis," *AERA Open*, vol. 5, no. 3, pp. 1–20, 2019.