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Creation of Open-Source Course Materials for Engineering Economics Course with Help from a Team of Students—Lessons Learned

Dr. Tamara R. Etmannski, University of British Columbia

Tamara Etmannski is an Assistant Professor of Teaching in the Department of Civil Engineering at the University of British Columbia (UBC) in Canada. Her position is focused on teaching content and various curricula and teaching and learning initiatives connected to 'impacts in engineering' (sustainability, leadership, economics, entrepreneurship). Her pedagogical interests include high-impact practices like active and experiential learning, team-projects and writing-based assignments, with special focus on learning through real-world applications

Creation of Open-Source Course Materials for Engineering Economics Course with Help from a Team of Students - Lessons Learned

Tamara R. Etmannski
Assistant Professor of Teaching, Department of Civil Engineering,
The University of British Columbia, Vancouver, BC, Canada
tamara.etmannski@ubc.ca

1. Introduction

In accordance with program accreditation prerequisites [1], engineering students across Canada are mandated to undertake an Engineering Economics course. The primary focus of these courses is on the evaluation of monetary profits and direct financial costs incurred throughout the design, operation, and decommissioning phases of projects. Typically, instructors rely on textbooks as the primary instructional tool, and students are commonly expected to buy these materials at a cost ranging from $99 to $200 each, depending upon the publisher and the format (hardcopy versus online access only) [2][3]. Given the relatively static nature of core materials in engineering courses such as this, numerous students choose to forego purchasing the required textbooks. Instead, they resort to free online resources, older editions of textbooks, or course notes. Some instructors, aware of the financial burden on students, opt not to require a textbook, and instead curate a blend of available online content and generating their own instructional material. In any case, the patchwork of sources creates problems in this course in particular, because of the variation of notation used across sources, which can easily cause confusion. It was this problem that inspired the creation of a set of open-source materials, referred to in this paper as Open-Educational Resources (OER), that students and instructors can use for free, enabling the instructor to have control over notation while saving the students money. This paper is an overview of that project, including the methodology employed in the materials' creation, the processes of materials review, utilization, and discussion connected to feedback from student surveys.

2. Methodology

2.1 Pedagogical Context

The University of British Columbia (UBC) located in Vancouver, Canada, is a very large university (equivalent in size to many state universities in the US) with an annual student enrollment of approximately 60,000 [4]. The Vancouver campus has seven distinct engineering departments, each offering its own engineering economics course, collectively catering to approximately 1,000 students annually. CIVL 403, the course where the OER materials were piloted during the 2024 winter term is a 3-credit core course offered by the Department of Civil Engineering. The total enrollment was 197 students, which are primarily fourth-year students in their final term. This course comprised two 1.5-hour lectures per week. While it is part of the Civil Engineering curriculum, the fundamental concepts covered are consistent across all engineering economics courses at UBC and national-wide as mandated through the accreditation

process. The course emphasizes topics such as cost estimation, the time value of money, economic and engineering decision-making, risk and sensitivity analysis, and basics of engineering accounting. Students are evaluated through two midterms, and a term-long business case project, where they must develop a proposal for a new business supported by a thorough economic analysis.

2.2 Content Development

In an effort to enhance educational accessibility, an "Open Educational Resources Implementation Grant" of $25,000 (CAD) was secured to develop open-source materials accessible to instructors and students across these departments. To fulfill the stipulations of the grant, student participation was mandated, leading to the formation of a dedicated team of four undergraduates, entrusted with crafting the initial draft of the materials. This team comprised two full-time, fourth-year commerce students with expertise in finance and accounting, alongside two part-time, fourth-year engineering students, both of whom had successfully completed the course previously. The engineering students, having earned the highest grades in the course the preceding year, demonstrated a solid level of understanding of core engineering economics concepts.

The workflow of the interdisciplinary team unfolded in a systematic manner. The student development team all worked from home from May to August 2023. There were weekly team check-in meetings with the instructor and daily, real-time discussions over zoom between the students. The commerce students took the lead in developing the slides, simplifying concepts and ensuring clarity of explanation in a logical sequence. The two commerce students were each assigned different engineering economics foundational topics, with a logical grouping of concepts, as presented in Table 1. The commerce students designed a PowerPoint template to ensure consistency in formatting and structure across all decks, and were trained on how to ensure the materials were fully accessible (could be used by text to voice software). The sequencing of the concepts was decided by the instructor. Simultaneously, the engineering students were responsible for creating the problem sets. They worked through each chapter systematically, with one student creating the problems and solutions and the other solving them blindly (without solutions) to provide feedback on wording, difficulty, and to flag any possible errors in logic or typos. Also, following the completion of the initial draft of slides for each chapter, the engineering team provided valuable input for refinement. Subsequently, the materials underwent a comprehensive review by the engineering professor, who conducted detailed assessments and implemented necessary edits or corrections.

Table 1: List of Topics per Chapter and Distribution of Work between Commerce Students

Chapter	Topic	Student
1	Time Value of Money	A
2	Interest	A
3	Cash Flow Diagrams & Depreciation Methods	B
4	Uniform Payment Series	B
5	Project Comparisons Part I	B

6	Project Comparisons Part II	B
7	Replacement Decisions	B
8	Inflation	B
9	Uncertainty & Sensitivity Analysis	A
10	Public Projects & Market Failures	A
11	Taxes	A
12	Financial Accounting	A

2.3 Material Use

The materials were distributed to the class as accessible PDFs through the course website. As part of an incentive structure, the class was invited to report any errors found in the materials through a brief survey that remained active until the end of the course. Students were rewarded for every error found in the "debugging process" with an amazon gift card. The value of the reward depended on the type of error discovered, with typos, spelling mistakes and grammatical errors earning $2, quantitative errors worth $5 and conceptual errors worth $10. After all of the OER material was presented in class, a QR code linking to an online survey was displayed, the instructor left the room, and students were asked to use remaining class time to complete it. Participation in the survey was entirely voluntary, and responses were completely anonymous.

2.4 Survey Structure

The survey consisted of three parts. The first part explored the students' textbook buying behaviour in the past and their anticipated behaviour for this course (hypothetically). With the possible responses being Normally/Probably Yes, Normally/Probably No, and Unknown. The two questions asked were as follows:

- "When a textbook has been required in past courses you've taken, did you buy the textbook?"
- "Normally a textbook is required for CIVL 403 ($100). Would you have bought it?"

The second part of the survey consisted of the three statements listed in Table 2, for which students had to indicate their level of agreement on a 5-point scale (1 – Strongly Disagree, 2 – Disagree, 3 – Neither Agree nor Disagree, 4 – Agree, 5 – Strongly Agree). Statements focused on the replaceability of the textbook as well as the perceived satisfaction and effectiveness of materials used.

Table 2: Quantitative Survey Questions

For each statement, please select the response that best represents your opinion, as it connects to the PowerPoint slides, the practice questions and solutions from Chapters 1-12…
1 – The materials used in CIVL 403 adequately replaced a textbook
2 – I was happy with the materials used in CIVL 403
3 – The materials used in CIVL 403 were effective

The final part of the survey consisted of the following open-ended text-entry prompt, with no length constraints:

- "Share any thoughts you have on the materials used in CIVL 403 or any thoughts on the debugging process."

2.5 Survey Data Analysis

The responses for part 1 of the survey were counted, the scores of the responses for part 2 were aggregated, and the average score and standard deviation for each prompt are presented. Open-ended responses to part 3 of the survey were thematically analyzed, for each module [3]. Results were first reviewed to identify major emerging themes or recurring comments, and then more strictly coded during a second pass-through, using an open coding approach. The result of this analysis is presented here along with representative student comments, and discussed. The full list of survey responses and coding notes can be made available to any interested party.

3. Results

3.1 Material Development

The early planning stages of the project included rethinking the traditional textbook format, and opting instead to produce annotated and comprehensive slides designed to function as both study aids for students and instructional tools for educators. The foundational concepts of engineering economics were systematically organized into twelve distinct chapters, each represented by a PowerPoint slide deck. The size of these decks varied, spanning from 20 to 40 slides, with an average of 30 slides and a median of 29. Each deck included a title page and a table of contents slide (for organizational purposes), with the remaining slides relatively content heavy. While prioritizing accessibility through readable formatting (able to be read by software for those who are visually impaired), minimal emphasis was placed on a particular presentation style. This straightforward format intentionally allows instructors flexibility to tailor the material to their preferences. Instructors are afforded the latitude to infuse their distinctive approach, incorporating personal touches, stylistic elements, anecdotes, pertinent visuals, or discipline-specific case studies as deemed appropriate. The intent was to empower instructors with a malleable framework that accommodates diverse teaching styles and facilitates the integration of contextually relevant content. Additionally, a set of practice problems (including solutions), were created for every chapter for self-paced student engagement. The formulation of questions, encompassing both in-class examples and practice problems, adhered to a gender-neutral phrasing approach to ensure inclusivity. Additionally, all questions were designed to be discipline-neutral, accommodating diverse engineering departments and enhancing the materials' applicability for dissemination purposes. To ensure uniformity of notation across the slides and practice problems during development, a list of variables and a formula sheet were also created and included as integral components of the materials package.

The engineering students produced high quality problems within the budgeted time frames given, which was approximately one hour per problem-solution. However, the proficiency of the commerce students was underestimated. Despite a rigorous vetting process at the time of hiring,

the commerce students were not as confident in the concepts of the material as expected, resulting in them having to spend significant amounts of time (re)learning the material. During the planning stage of the project, it was estimated that it would take the students approximately 20 hours to create each slide deck, however in reality it took 80 hours to complete each slide deck. As a result, the initial scope of the project was reduced. The team had initially considered creating supplementary handouts for each chapter, which would have complimented the slides, however due to time constraints were not able to. Despite reducing the scope in this way, the project still exceeded its budget by $6,000 CAD.

3.2 Material Use & Debugging

Prior to presenting the material to the class each week, the instructor would review each deck again in detail. After a few weeks of use the instructor noticed that the slide decks were similar to existing engineering economics slides that were available online (and owned by a well-known publisher). The instructor had in fact used that material in previous iterations of the course, though that material had not been given to the student team as one of the resources to refer to in supporting the creation of the new material. Upon further investigation, it was determined that when asking ChatGPT some specific questions, the responses are also very similar to that material, suggesting its use of the publisher's material in its training, and perhaps use of either the materials directly or of ChatGPT by the student development team. In any case, the material development phase of the project ended in September, four months before this discovery (in February 2024) so the student development team was unable to support in any corrections that were required. The instructor then rewrote and/or restructured many slides prior to use, to ensure the was no question of copyright infringement.

The debugging process proceeded seamlessly, with students in the course finding 29 typos/grammatical errors, 12 quantitative errors, and no conceptual errors. This led to a final pay out of $118 in gift cards. All of the errors were corrected in real-time and the materials for student-use immediately replaced with corrected versions.

3.3 Quantitative Survey Results

The response rate for the feedback survey was 27% with 53 students competing the survey out of the 197 students registered in the course. For question 1, 76% of respondents answered "normally no" indicating that in past courses, they normally do not purchase a required textbook. And based on the responses from question 2, 89% of the respondents answered "probably no" to a statement about spending approximately $100 on buying a textbook for this particular course. No respondent answered "unknown" to these two questions. Responses to these questions suggest the need to provide comprehensive open-source materials to students, as even deeming a textbook "required" for a particular course does not mean that students actually buy it. The average and standard deviation of the scores for each question in Part 2 of the survey are shown in Table 3.

Table 3: Survey Results

Question	Average Scores	Standard Deviation
1	4.45	0.50
2	4.37	0.49
3	4.35	0.48

Results indicate that as a whole, students found the OER materials used in this course as an adequate replacement for a textbook, they were happy with the materials, and found them to be effective.

3.4 Open-ended Survey Results

There were only fourteen comments to review out of the 53 completed surveys. Despite the small sample size, three themes were identified: 7/14 comments appreciated the clarity and simplicity of the materials as a whole; 4/14 comments expressed support for the financial incentive of the debugging process; and finally, 4/14 expressed specific satisfaction connected to the practice problems. Below are some representative quotes:

"I thought it was effective and I liked that we didn't have to read through a bunch of extra material. We were just given what we needed to succeed in the course."

"Incentives for finding bugs made me look carefully at each question and it actually made me report the issues rather than just flag it down. Also, the reporting site for the bug was easy and conducive for reporting it quickly."

"The practice questions are very effective as practice for the midterms. I like that there are a variety of questions and a clear solution."

4. Discussion

There are many lessons to be learned and shared about the experience of developing materials with students, for students. Firstly, despite the temptation to align the core concepts of engineering economics with business, it became apparent that students in the commerce program at UBC might not possess a deep enough understanding to seamlessly apply them within an engineering project context. Given the struggles the commerce students had with the material, having only engineering undergraduate students on the team, especially students who recently completed the course, might have shortened the amount of time needed to develop each PowerPoint slide deck. Alternatively, hiring graduate students, though more expensive on an hourly basis, may have also resulted in greater productivity. Since graduate students have more expertise, this likely would have resulted in less time spent on learning concepts and likely not having to rely on generative AI tools.

The approach taken by the two engineering students when developing practice problems proved effective and as such is strongly recommended. During the development the system of one student being blind and having to solve problems first and compare to the given solution resulted in many productive conversations about wording of the question as well as possible alternative

solutions. In the student feedback survey, there were only positive comments about the utility, clarity and thoughtfulness of the practice problems, which further demonstrates how useful it is having students build that aspect of the materials.

As the students in this project all worked from home during the summer months, it is likely the instructor would have been able to prevent as much use of generative AI tools if the students had received more constant, in-person supervision from the instructor. So, there is a lesson-learned regarding work-flow and the importance of working arrangements, especially when dealing with a junior team.

During the materials development phase, consideration was given to the creation of supplementary handouts for each chapter, to expand on the theory of the concepts covered in lecture. However, when the scope of the project needed reducing, it was decided to include all the relevant material into the slides, even if that meant a few text-heavy slides. Despite the potential benefits of additional information, the team prioritized simplicity and directness in the materials, assuming that a limited percentage of students would delve into supplementary material, compared to likely all the students reading the slides. Given the positive feedback from the class regarding the slides, it seems this supplementary material may not have been necessary for a student's success in the course.

The debugging process aligned with expectations, affirming the efficiency of using the student body as a means to crowd-source editing. This collaborative editing approach not only improved the overall quality of the materials, but also served as a valuable learning opportunity, demanding a deep understanding of the material to identify errors. All detected errors were promptly corrected in real-time, ensuring that the materials in-use were as correct as possible and ready for dissemination more widely.

The student survey conducted after the materials were used in the classroom resulted in a small data set, in a specific curriculum context (civil engineering, and mostly 4th-year students), however, the data seems to indicate that as a first step, students believe the materials produced were an acceptable replacement for a textbook. Anecdotally, it also meant less student confusion about notation that the instructor had faced in previous years.

Moving forward, it is the intention of the author to apply a Creative Commons license and to make the material available to interested parties. However, there are anticipated challenges in the dissemination of the materials because of a potential lack of awareness among other engineering economics instructors and limitations in the current distribution methods. Presently, knowledge of the existence of these materials relies on word-of-mouth or direct contact from the creator to other instructors. This distribution model places an undue burden on the creator and is inherently inefficient. Consideration needs to be given to more effective dissemination strategies, along with the selection of a platform for posting the open-source materials. This platform should be accessible to instructors internationally, while also fostering a collaborative environment where instructors can comment, edit, and contribute to the continuous improvement of the materials.

5. Acknowledgements

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As confirmed by the UBC Behavioural Research Ethics Board (BREB) office, the work is considered “Quality Improvement and Assurance and Program Evaluation”, which under Article 2.5 of the Tri Council Policy Statement is exempt from institutional ethics review requirements. This work therefore does not require ethics review for its performance or dissemination.

6. References

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