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Work-in-Progress: Student reactions to an Open Textbook on Mass and Energy balances

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Work-in-Progress: Student reactions to an Open Textbook on Mass and Energy balances

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Abstract

This work describes the initial stages of creating an interactive Open Educational (OER) textbook on mass and energy balances and the planned process for soliciting student feedback and making students co-creators on the textbook. The authors have taught the mass and energy balance course for several years and have been challenged by increasing numbers of students that do not purchase the recommended textbook but rely solely on posted lecture slides and relevant material, in-class notes, class recordings (lately), freely available internet videos, and possibly illegal electronic textbook copies. After obtaining some experience with PressBooks and H5P from a pandemic-induced online-lab project, and aided by an institutional OER fund, the authors decided to convert their class notes on energy and mass balances into an OER using those two tools. The aim is to provide students with a free centralized repository for course content and practice that will (1) enhance student understanding through non-text additions (quizzes, videos, and interactive activities) that meet multiple learning styles and (2) will be available to all students regardless of financial ability.

The major challenges with the ongoing content creation have been time availability for such a task and avoiding copyright infringement when creating property tables or charts, as will be discussed. Regardless of challenges, significant material has been created and the current status of this ongoing process is shared. A working version of the textbook will be used in Fall 2022 by two cohorts of 150 total students that will be questioned about their opinion on OER, in general, and the specific material through a set of primarily Likert questions and a focus group. The students' perceptions on the quality, applicability, and helpfulness of the material; the rates of material usage; and students' suggestions for improvement will be collected. In addition, methods to make students active content creators and the anticipated results of such attempts are discussed. Finally, the timeline of this work in progress, the future of OER in chemical engineering, and the possibility of contributions from a wider academic community are highlighted.

Introduction

Open Educational Resources (OER) are defined by UNESCO as "*teaching, learning and research materials in any medium – digital or otherwise – that reside in the public domain or have been released under an open license that permits no-cost access, use, adaptation and* *redistribution by others with no or limited restrictions. OER form part of 'Open Solutions', alongside Free and Open Source software (FOSS), Open Access (OA), Open Data (OD) and crowdsourcing platforms*." [1]. These works are often "*licenced in a manner that provides everyone with perpetual permission to engage in the 5R activities: Retain, Revise, Remix, Reuse, Redistribute*" [2] through a Creative Commons CC BY, CC BY-SA, or CC BY-NC licence, with the second one not allowing a change of the licence type and the latter one not allowing commercial use [3].

The concept of OER exists in higher education for approximately 20 years, since the launch of MIT's OpenCourseWare (OSW) in 2002, as detailed in "*A Brief History of Open Educational Resources"* [4]. Their adaptation, however, has not been widespread, hindered by technological challenges, lack of awareness, and confusion on the difference between OER and digital resources, as detailed in a 2016 overview [5]. This trend is slowly changing, somewhat sped-up by the necessary transition to virtual/online classrooms during the recent pandemic restrictions, but the uptake of OER must increase as they offer a plethora of advantages to students and instructors [6], [7], [8] . The most obvious one is reducing the educational cost to students and providing equal access to books for all, but OER offer, among other benefits, customizability to instructors and interactivity between students and the textbook that can lead to an enriched learning process.

Within the Canadian educational landscape and engineering in particular, the adoption of OER is limited and depends on the institution, as outlined in a 2020 review [9], where the University of British Columbia and BCcampus were identified as leaders of OER adoption through a number of initiatives for textbook and online homework, using WeBWork [10], creation. In Ontario, the hosting province of our institution, the cause is spearheaded by the eCampusOntario initiative, a non-for-profit corporation funded by the Government [11], which was created in 2016 and started funding OER in 2017, followed in recent years by institutionally-funded OER initiatives. Such a fund has assisted the current work.

In the subject of mass and energy balances, which is the topic of this work, there are several online resources, but limited Open textbooks. Traditional textbooks, most notably *"Elementary Principles of Chemical Processes"* [12] and *"Basic Principles and Calculations in Chemical Engineering"* [13] lately offer online versions, in parallel to hardcopy editions, with increasing over-the-years interactive elements, but at a significant cost. More recently, Matthew Liberatore published an impressive online-only textbook on "*Material and Energy Balances"* [14] with interactivity and adaptability to the user, but not on an open licence. Regarding online resources, he most widely known is the LearnChemE repository from the University of Colorado Boulder [15] which includes numerous screencasts, simulations, and quizzes. Quite popular is also the AIChE Concept Warehouse from Oregon State University [16] which hosts a huge number of questions on fundamental concepts that can be bundled into student online quizzes. Besides these, there are also scattered online resources available through searches. In terms of Open textbooks, the authors have only been able to identify a book on *Foundations of Chemical and Biological Engineering I* [17] which includes a Chapter on Energy balances, but with only static text and no interactivities or visual aids.

Learning Challenge

The authors have been teaching mass and energy balance courses for several years in two separate cohorts that are not traditional chemical engineering programs. One cohort is a Biotechnology stream with approximately 60 students per year taking a one-term combined material and energy balance course. The other cohort is a Process Automation stream with approximately 90 students per year taking two single-term courses on materials balances, equilibrium calculations, and energy balances. The instructors had anecdotal evidence that students were not purchasing the suggested textbook [12] and that was solidified through a questionnaire run on one course for two successive years the results of which are given in Table 1. These surveys were taken during a virtual classroom environment when the need for a physical copy of the book was reduced, but they nevertheless indicate that almost 55% of the responders do not have a copy of the textbook while the majority of the others rely on electronic versions of the book. Given that this is an established textbook with older editions, our belief is that most students rely on counterfeit copies of the book, but we hesitated to make such a distinction in the questionnaire fearing it would introduce a barrier to participating. There is a slight possibility that students interpret this course as a side course instead of a core one, since they are not in a chemical engineering major; hence being less motivated to purchase a reference textbook, but similar trends are indicated with other courses with a non-mandatory textbook.

Table 1: Results of textbook ownership survey

Year	**2020**	**2021**
Students in class	93	91
Responses	49	63
Own hardcopy (new or used)	3	1
Own electronic version (legal or not)	17	31
Do not own textbook	29	31

Evidently, students rely on all the material provided through our LMS —lecture slides, lecture recordings, whiteboard notes, some screencasts of problem solutions, and textbook parts covered through a *Fair Dealing Policy*— and any material they can find on the web. Despite the lack of a textbook, students perform reasonably well in these second-year courses with average grades in the 67% to 73% range over the years. It should be noted, though, that these courses have parallel unit-operations-type lab sections that contribute to the final grade with significantly higher averages; hence the average in the theory-part of the course is slightly lower than reported above. Even though student grades and passing rates are not huge concerns, the authors believe that students will benefit from a textbook that (1) could serve as a central repository for course material, (2) could offer more rigor and depth on certain topics than what can be covered in class, (3) could incorporate all available free resources from the authors and others, (4) could enhance understanding through visual examples and (5) could provide students with interactive elements for checking their understanding.

The birth of an Open Resource

The instructors have some experience with Pressbooks, “a book authoring and editing platform” [18] available to them through eCampusOntario [11], and H5P for creating interactive HTML5 content [19] through a previous project. Aided by an OER grant through their institution, they embarked in essentially converting their class notes into an open resource, while formatting them for typesetting into Pressbooks and enhancing them with visual aids and interactive elements. An example of a visual aid are incorporated videos of the “Gimli Glider” (https://www.cbc.ca/archives/when-a-metric-mix-up-led-to-the-gimli-glider-emergency-1.4754039) and the Mars Climate Orbiter (https://www.cbc.ca/archives/when-a-metric-mix-up-led-to-the-gimli-glider-emergency-1.4754039) for emphasizing the importance of units. These videos, as shown in Figure 1, are incorporated in the text and play, in the frame or full-screen, without leaving the document, offering a modern, seamless experience.

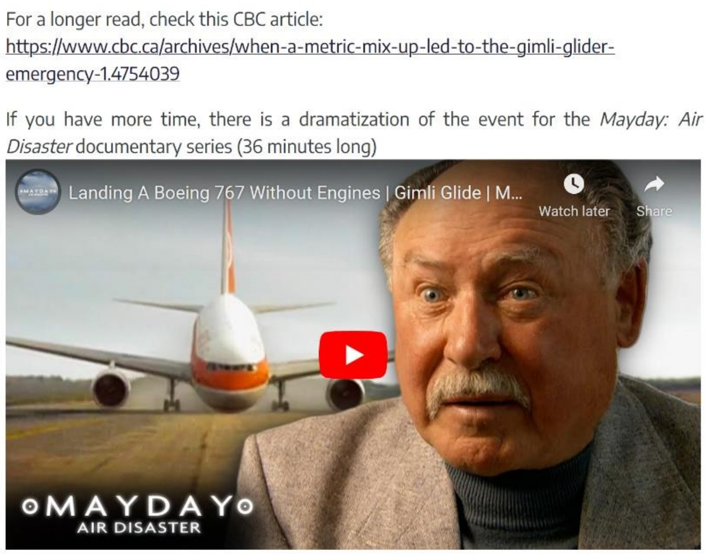


Figure 1: Example of a video incorporated into the text.

An example of an interactive element is a series of 5 questions for checking the understanding on significant figures, as seen on Figure 2.

These quizzes, built through H5P, contain a pool of static questions (i.e. questions numbers do not change, but the order of the possible answers does) a number of which are included in a quiz. A student can move through the questions, check their answers, and see, after selecting their answer, the correct answer for each question. Obviously, these questions are not marked for grade, but certainly help in understanding and clarifying possibly misconceptions. Some of these questions used in the text are, though, among questions used for graded quizzes distributed through our LMS, possibly with different constant values; hence, students that will read the text and attempt the interactive elements might find the graded quizzes slightly easier.

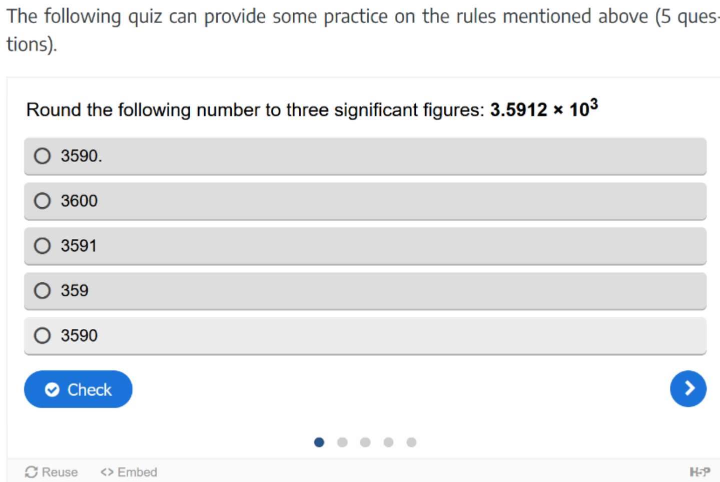


Figure 2: Example of interactive element: 5 question quiz on significant figures

The design includes expandable sections, as shown in Figure 3 to enable focused reading by having only a small part of the text open/available at any instant. This feature, combined with the ability of Pressbooks to adjust the typeset based on the used device, helps primarily when viewing it on small screens (e.g. cellphones). It is also essential as the text is continuous without page numbers and readers might it find difficult to locate certain parts within a document that runs several screens long.

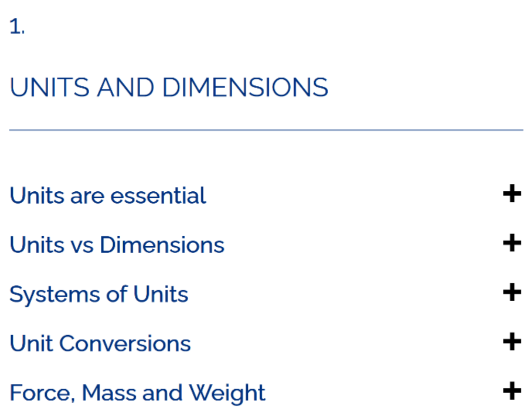
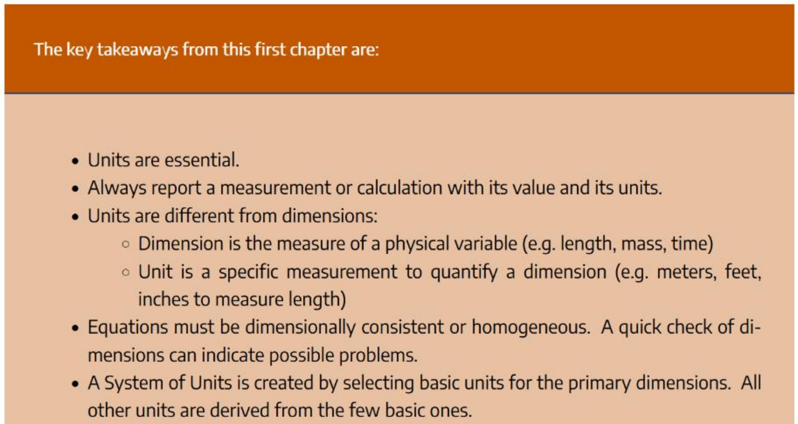


Figure 3: Example of expandable text menus. Clicking on the + sign expands the section

Finally, each chapter is closed with a summary that highlights the key takeaways from it, as shown in Figure 4. In addition, end-of-chapter and whole-textbook glossaries with links to corresponding places in the textbook are also included to enable easy location of specific theory components and terms.



The key takeaways from this first chapter are:

- Units are essential.
- Always report a measurement or calculation with its value and its units.
- Units are different from dimensions:
  - Dimension is the measure of a physical variable (e.g. length, mass, time)
  - Unit is a specific measurement to quantify a dimension (e.g. meters, feet, inches to measure length)
- Equations must be dimensionally consistent or homogeneous. A quick check of dimensions can indicate possible problems.
- A System of Units is created by selecting basic units for the primary dimensions. All other units are derived from the few basic ones.

Figure 4: Example of end-of-chapter summary with key takeaways.

Current status and Future Steps

Because of a late start of the project (end of Summer 2021) and some unforeseen obstacles, the textbook development has been lagging compared to the course content coverage. Besides time-availability constraints, a major challenge that has now been somewhat overcome was how to incorporate into the text the necessary volume of physical data without infringing copyright of published commercial textbooks. Because of these delays, the work has not been yet shared with students for feedback, comments, or their assistant in content creation. It is anticipated that a working version of the OER will be ready by the end of summer 2022 for use in our Fall 2022 courses with two cohorts of approximately 150 students in total.

At that point, pending clearance by our institution's Research Ethics Board, students will be asked to report on the usability and effectiveness of the OER through Likert questions and a roundtable run by a student researcher. To investigate if their perceptions towards Open Education Resources in general changes through the textbook's use, certain questions will be asked both at the beginning and the end of the semester. Towards the end of the term, students will also be challenged to contribute to the Open textbook through an assignment on creating an interactive textbook element (e.g., a drag-and-drop task, a matching task, or a quiz). Selected student works, as voted by the students themselves, will then be incorporated to the text. We are really excited about this upcoming collaboration with students in content creation, as it pushes them to get creative and essentially comprehend content through its application on problem creation, triggering and requiring a higher level of cognitive function. It also demonstrates to them the power of OER, where users are allowed to revise and reuse, becoming creators in the process. We hope that this involvement with OER will turn some students to advocates of the cause to their classmates and instructors.

At the end of the summer of 2022, the textbook will also be shared with the broader academic community for feedback, and possible adaptation or modifications. We recognize that a textbook creation is a dynamic, ongoing process and we are committed to revisiting the material, expanding it, enhancing it with newer examples, updating it to current technological tools, and adapting it to the needs of our students. We are also looking forward to contributions from other authors that will certainly enhance the content through alternative viewpoints, different content explanation, and problems from specific disciplines. This ability to collectively create content is, we feel, one of the benefits of Open resources which is then reflected on enhanced student learning.

Aknowledgements

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References

[1] UNESCO, "Open Educational Resources (OER)," [Online]. Available: https://en.unesco.org/themes/building-knowledge-societies/oer. [Accessed 2022].

[2] D. Wiley, "Defining the "Open" in Open Content and Open Educational Resources," [Online]. Available: http://opencontent.org/definition/.. [Accessed 2022].

[3] Creative Commons, "About the Licenses," [Online]. Available: https://creativecommons.org/licenses/. [Accessed 2022].

[4] T. J. Bliss and M. Smith, "A Brief History of Open Educational Resources," in *Open: The Philosophy and Practices that are Revolutionizing Education and Science*, R. S. Jhangiani and R. Biswas-Diener, Eds., London, Ubiquity Press, 2017, pp. 9-27.

[5] O. M. Belikov and R. Bodily, "Incentives and barriers to OER adoption:," *Open Praxis,,* vol. 8, no. 3, pp. 235-246, 2016.

[6] M. T. Martin, O. M. Belikov, J. Hilton III, D. Wiley and L. Fisher, "Analysis of Student and Faculty Perceptions of Textbook Costs," *Open Praxis,* vol. 9, no. 1, pp. 79-91, 2017.

[7] R. DeRosa and S. Robison, "From OER to Open Pedagogy: Harnessing the Power of Open," in *Open: The Philosophy and Practices that are Revolutionizing Education and Science*, R. S. Jhangiani, and R. Biswas-Diener, Eds., London, Ubiquity Press, 2017, pp. 115-124.

[8] R. S. Jhangiani, F. N. Dastur, R. Le Grand and K. Penner, "As Good or Better than Commercial Textbooks: Students’ Perceptions and Outcomes from Using Open Digital and Open Pring Textbooks," *The Canadian Journal for the Scholarship of Teaching and Learning,* vol. 9, no. 1, 2018.

[9] G. McSorley, A. d'Entremont, J. Verrett, N. Ibrahim, J. Dickinson, R. Sellens and D. A. Salem, "Open Educational Resources in Undergraduate Engineering Education: Opportunities and Challenges," in *Proceedings 2020 Canadian Engineering Education Association (CEEA-ACEG20) Conference*, Concordia and McGill Universities, June 18 – 21, 2020.

[10] J. S. Lee and J. Verrett, "WeBWorK as an Open Online Homework Systems in Material and Energy Balances," in *Proc. 2018 Canadian Engineering Education Association (CEEA18) Conf.*, University of British Columbia, June 3 – 6, 2017.

[11] "eCampusOntario," [Online]. Available: https://www.ecampusontario.ca/. [Accessed 2022].

[12] R. M. Felder, R. W. Rousseau and L. G. Bullard, Elementary Principles of Chemical Processes, 4th ed., John Wiley & Sons, 2018.

[13] D. M. Himmelblau and J. B. Riggs, Basic Principles and Calculations in Chemical Engineering, 9th ed., Pearson, 2022.

[14] M. Liberatore, Material and Energy Balances, https://www.zybooks.com/catalog/material-and-energy-balances/#toggle-id-1: zyBooks, 2018.

[15] "LearnChemE," [Online]. Available: https://learncheme.com/. [Accessed 2022].

[16] "AIChE Concept Warehouse," [Online]. Available: https://newjimi.cce.oregonstate.edu/concept_warehouse/CW.php.

[17] J. Verrett, R. Qiao and R. a. Barghout, "Foundations of Chemical and Biological Engineering I," [Online]. Available: https://www.oercommons.org/courses/foundations-of-chemical-and-biological-engineering-i/view.

[18] "Pressbooks," [Online]. Available: https://pressbooks.com/.

[19] "H5P - About the Project," [Online]. Available: https://h5p.org/about-the-project.