WeBWorK as an Open Online Homework System in Material and Energy Balances

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Abstract—Many studies have shown the advantages of dynamic homework tools for student learning. Material and energy balances is a common foundational course in chemical engineering and related disciplines. There are a number of open educational resources that have been developed around material and energy balances such as screencasts, interactive simulations and conceptual multiple choice tests. In order to build upon these resources, we sought to create online homework assignments on an easily accessible platform, with instant feedback and dynamic questions with individual numbers and unique solutions. We selected WeBWorK as a tool for this due to its common use, open and editable nature and the ease to which problems can be shared between authors through the Open Problem Library system built into the software. WeBWorK problem sets were easy to use for students and well received. The switch from pencil and paper to WeBWorK showed no significant effect on student grades or participation in homework assignments. On the Instructors’ side, WeBWorK saved time overall by reducing grading significantly. This allowed greater time for student interaction with instructors. However certain problem types, notably creating diagrams or explaining problem solving methodology could not be accomplished with WeBWorK. A hybrid of pencil and paper homework as well as WeBWorK is recommended for material and energy balances due to the course material and objectives.

Keywords: Online Homework: WeBWorK: Open Educational Resources: Material and Energy Balances: Chemical Engineering

1. INTRODUCTION

1.1 Online homework

There are a variety of online homework platforms which are available for instructors to use in their courses. These can personalize questions for students, giving each student individual numbers for their homework set problems. One such platform is WeBWorK, an open-source platform developed in the mid 1990’s focused on mathematics [1]. Other popular platforms include Mastering Engineering [2], the Learning-Online Network with Computer-Assisted Personalized Approach (LON-CAPA) [3], those associated with learning management systems, as well as many others [4].

Studies have shown these online homework systems can have a significant impact on courses. Advantages noted in literature with these online homework platforms include faster feedback to student, positive student perceptions and reduced time for assignment marking [5], [6]. Studies have also shown no significant gains or losses in student performance when switching from pencil and paper homework assignments to WeBWorK [7].

Within the context of chemical engineering, material and energy balances (MEB) is a course that is common and fundamental to many chemical engineering programs around the world. Online homework in Material and Energy Balances has been developed previously and written on in a number of studies. A study done by Matthew Liberatore using the Sapling Learning online homework system found a statistically significant difference between a set of students completing online homework and another set completing multiple choice reading quizzes [8]. Liberatore then went on to design interactive textbooks using the same principles around personalized interactive homework. His textbook on Material and Energy Balances, published under the Zybooks platform, provides a dynamic textbook with questions and interactive activities students can work through as they go through the material. The Zybooks interactive textbook has been shown to be effective at enhancing student understanding of course materials and encouraging students to complete readings [9]. However, systems such as Sapling and Zybooks can be difficult to adapted and manipulate since they rely on the companies that operate these platforms to support and update them and come with costs directly borne by students.

Open and free platforms such as WeBWorK present advantages since individual course instructors can edit and adapt these materials for their courses as well as correct issues directly, although this has disadvantages in terms of requiring instructors to have knowledge of these platforms [5]. Thus far a variety of openly licensed tools have been created for material and energy balances courses [10]. One example are screencasts, interactive simulations and course
notes from the LearnChemE.com site created through a partnership between the National Science Foundation, the University of Colorado Boulder and Shell [11]. Multiple-choice ConcepTests, which are conceptual questions have been curated by the American Institute of Chemical Engineering (AIChE) Concept Warehouse which is hosted at Oregon State University [12].

In order to build upon these existing resources, we have created questions that give students practice with longer-form problems similar to those they would find at the end of textbook chapters. The advantage of coding these questions with the WeBWorK platform is that the problems are dynamic, with changing numerical values. These problems can also be shared openly with other institutions through the WeBWorK Open Problem Library. The open problem library is a repository of over 33,000 problems available to all WeBWorK users to freely use in their courses [1]. WeBWorK is also used in a variety of other disciplines and courses, notably those in mathematics departments, meaning students may have already encountered and used this system.

2. METHODOLOGY

2.1 Course context

A material and energy balances course (course code: CHBE 241) is offered to second year students at the University of British Columbia (UBC). In the Fall 2017 offering, CHBE 241 has an enrollment of 190 students with 127 students (67%) majoring in Chemical Engineering or Chemical and Biological Engineering, 60 students (31%) majoring in Integrated Engineering and 3 students (2%) in other engineering disciplines. Homework was moved from five pencil and paper assignments in the Fall 2016 offering to six online WeBWorK assignments in the Fall 2017 offering.

2.2 WeBWorK Problem Development and Deployment

Forty WeBWorK problems were developed corresponding to course learning objectives. The majority of these problems were numerical answer problems where students were required to set up and solve algebraic expressions corresponding to a given system. An example of a WeBWorK problem text is shown below.

“Butane is burned with air in a furnace to provide heat for a facility. 10.0 m³/hr of butane is fed with 735.0 m³/hr of air (79% Nitrogen and 21% oxygen by mole with an average molecular weight (MW) of 29 g/mol, these are common assumptions for air used in this class). The butane has a density of 2.48 kg/m³ and the air has a density of 1.23 kg/m³. One reactant (butane or oxygen) is provided in excess. By how many moles in excess is this reactant provided and what is the percentage excess (note that this percentage may be more than 100%)?”

Each of these problems took on average two hours to develop. This included initially finding a suitable question, creating a generalized solution equation, adding graphics (if any), coding the question, text and solution into WeBWorK and testing the problem to ensure it functioned properly.

At the beginning of the semester students were told that the WeBWorK platform would be used for homework problems and a link to the system was made available on the course homepage. Through a poll taken at the start of the semester over 90% of students indicated that they were familiar with the WeBWorK platform, likely having encountered it in previous math courses. No training was given to students in using WeBWorK. Students were allowed to work with others on WeBWorK assignment questions, however they were also warned that they should ensure that they understood the solution methodology. Each student had different numerical values for the same question, which avoided directly copying answer numbers from other students. Students were initially given ten attempts for each question for the first three assignment sets. Following that students were given unlimited attempts for the last three assignment sets.

3. RESULTS AND DISCUSSION

3.1 Student Performance and Perspective

Student performance was assessed through assignment and final course grades to attempt to identify any impact of changing the assignment to WeBWorK. Grades on assignments for the five paper assignments in fall 2016 and the six webwork assignments in fall 2017 are shown in figure 1. Students performed significantly better on the first two WeBWorK assignments but following these first two, the averages appear to be similar. We postulate that the attempts and instant feedback on WeBWorK allowed students to adapt to the style of the assignments faster in the fall 2017 class, and thus achieve higher grades on earlier assignments. This difference however did not have a significant impact on final course grades as shown in table 1. There were a variety of other changes associated with the course, as well as a change in student cohort. These other changing factors present difficulty in evaluating the effect of the change in assignment submission method only. The results of this study are similar to those of previous studies showing that WeBWorK does not have a significant positive or negative impact on grades [7]. The submission rates of assignments were also recorded. As can be seen in figure 2, no
significant difference is apparent between the years studied. Student submissions were within the range of 80% to 100% in both years, with submissions generally dropping lower as the semester has gone on. The similarity between the two years studied indicates no significant change in student participation when shifting to the WeBWorK system.

![Figure 1: Average grades for assignments in fall 2016 and 2017 courses with 95% confidence intervals.](image)

**Table 1: Average final course grades from fall 2016 and 2017 classes with 95% confidence interval.**

<table>
<thead>
<tr>
<th></th>
<th>Fall 2016</th>
<th>Fall 2017</th>
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<tbody>
<tr>
<td><strong>Average</strong></td>
<td>71.79 +/- 1.88</td>
<td>70.56 +/- 1.95</td>
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</table>

![Figure 2: Percentage of class submitting assignments in fall 2016 and 2017 courses.](image)

A student survey was developed to assess student attitudes on WeBWorK along with other course resources. Students were asked to complete the survey in the last third of the class semester. Students were encouraged to participate by indicating that their feedback was valuable to course instructors in order to further improve the course. No other incentives were given to participate. Responses were received from 40 students representing 21% of the class. Survey questions relating to WeBWorK were as follows:

a) "I would prefer written assignment that take 1 week to grade and return over the current WeBWorK assignments"

b) "I prefer unlimited attempts over 10 attempts in WeBWorK assignments"

![Figure 3: Student responses to class survey questions focusing on WeBWorK.](image)

Based on these responses, shown in figure 3, students indicated they strongly preferred WeBWorK homework to written assignments. Students also indicated they preferred having unlimited attempts on problems. These results indicate similar student attitudes to those found in other studies where WeBWorK is used to replace homework alternatives [6].

In the open-ended section of the survey, student reported using WeBWorK both as an assignment and study tool. Student report referring back and re-attempt problem sets following the assignment due date if they wished to practice solving questions.

### 3.2 Instructor perspective

The six new WeBWorK assignments replaced five previous written assignments. The instructor hours spent developing and grading each of these are listed in table 2 below. Assignment preparation took half the time for written assignments due to no need for coding, variable selection and testing. However, assignment grading or debugging the assignment took significantly longer for written assignments as each student’s work needed to be graded individually. As can be seen in table 2, there was a significant time savings associated with WeBWorK assignments. This allowed teaching assistants to redistribute hours from marking assignments to other duties. Teaching assistants were present in class to answer student questions as well as more actively involved in online discussion boards than in the previous course iteration. Teaching assistants also had time to organize a review session for student prior to the course midterm. This redistribution in teaching assistant hours allowed for greater contact time with students.
Table 2: Instructor time associated with assignments in Fall 2016 (written assignments) and Fall 2017 (WeBWorK) assignments.

<table>
<thead>
<tr>
<th></th>
<th>Fall 2016</th>
<th>Fall 2017</th>
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<tbody>
<tr>
<td>Number of Assignments</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Assignment Preparation (h)</td>
<td>6</td>
<td>12</td>
</tr>
<tr>
<td>Assignment grading or debugging (h)</td>
<td>20</td>
<td>4</td>
</tr>
<tr>
<td>Total (h)</td>
<td>130</td>
<td>96</td>
</tr>
</tbody>
</table>

Hours invested in developing and debugging WeBWorK questions will be useful in future course iterations as these questions will be re-used. Written assignments were previously rewritten each year, meaning time invested into them was useful only for the course iteration that year. However, both of these resources could be given to students as problem solving practice.

3.3 Future work and improvements

Though online homework provides instant feedback to students it is not as flexible in terms of questions that can be asked and assessed as written assignments. Tasks such as drawing diagrams or explaining solution logic are very difficult to assess automatically and it is difficult to implement these types of question with WeBWorK. As such, the instructional team will be moving towards a combination of both WeBWorK and pencil and paper homework, taking advantage of the strengths of each.

Future development of WeBWorK questions may also include hints to guide students as they solve problems. Practice sets will be implemented which would be copies of problem sets available to students following assignment submission with the same problems but different sets of numbers that could be further used for practice purposes. WeBWorK questions developed in this course will be made available on the Open Problem Library in summer 2018. Additional problems will be developed for the next course iteration.

4. CONCLUSION

There is currently a variety of open educational resources useful in supplementing material and energy balances courses. However, there are few resources for numerical homework. WeBWorK is a reliable open-source software used by many institutions each year for implementing individualized online homework sets for students. WeBWorK was used to replace handwritten assignment problem sets in a material and energy balances course. Student feedback on this change was overall positive and teaching assistant time was shifted from marking written assignments to student interaction. In future iterations a combination of both online and written assignments will be used to leverage the advantages of each medium.

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References