Effectiveness of blended learning for an energy balance course

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Abstract – *The effectiveness of on-line modules in a fundamental chemical engineering course is examined. An undergraduate second-year course on vapour-liquid equilibrium and energy balances is augmented by six on-line modules. Each module consists of supplementary lecture material for the students in the form of screencasts and interactive simulations followed by on-line quizzing on the fundamental aspects of the content. The quizzes of three of the six modules count for a small percentage of the final course grade (2% each), whereas the quizzes of the other three are offered only for self-assessment. The primer mode of instruction is still "traditional" face-to-face.*

Access to the on-line resources is monitored and recorded. The major question that is being examined is whether students value the on-line resources and access them to enhance or clarify their learning, or simply try only the on-line "mandatory", for grade, components. Correlations between students GPA, achievement in the course, attendance to class and on-line module access and quiz achievement are also investigated. Student qualitative feedback on the effectiveness and value of the on-line material is also collected.

Students in general value on-line resources: they let students work at their own pace, on their own schedule, and provide immediate feedback. This work assesses the degree to which such resources provide added value to a course that is phenomenologically outside the core-curriculum (the course is not taught to chemical engineer students) and within a busy study term.

Keywords: blended learning, chemical engineering, energy balances, on-line quizzes

1. INTRODUCTION

Online learning is becoming increasingly popular either as a tool for reinforcing learning in traditional, synchronous face-to-face courses, or through blended-learning where online modules substitute some of the face-to-face time, or even through completely online, synchronous or asynchronous, courses. Several studies have been devoted to the efficiency of online modules [1], comparison between online and traditional teaching methods [2], and the importance of formative on-line assessments with immediate feedback [3, 4], among others. Most studies reveal certain advantages of online learning ranging from enhanced learning outcome achievement [2,3,4] to reduced student time commitment to achieve similar results to traditional face-to-face deliveries [1]. All authors, though, indicate that the design of the online resources is critical on the effectiveness of the approach. In the particular subject of mass and energy balances, a core chemical engineering course, studies have shown that active learning is beneficial [5], quizzes help student retention of knowledge [6], and that on-line problem solving with personalized homework problems promotes student achievement [7].

Encouraged by the above studies, the author augmented a face-to-face vapour-liquid equilibrium and energy balance course with a number of online quizzes. Even though the anticipated improvement of student learning was adequate reason for the endeavour, the driving force was the dwindling performance of students in the course over the five years that the author has been teaching the course: the course average as well as the final exam average dropped by 5% over 5 years. Obviously, the effectiveness of the online course material in achieving the course's learning outcomes was assessed. In addition, the usage of the online material by the students was monitored, in hope of revealing patterns of usage, student preferences, and correlations between online material and course achievement, questions that are being addressed by few other researchers [8]. To shed further light into these questions, some of the online material was part of the course grade, whereas some was not.

The paper details the structure of the online components, the data collected, and any conclusions driven through the data analysis.

2. STUDY SET-UP

2.1 The Course and the Students

The study took place in a vapour/liquid equilibrium (VLE) and energy balance course which follows a prerequisite mass balance and VLE course. The course in this study covers: multicomponent VLE; liquid/liquid and solid/liquid equilibrium; second law of thermodynamics; energy balances on open and closed systems using tables (primarily steam tables), specific heat, latent heat of phase change; and energy balances in reactive systems. Approximately four weeks are devoted to equilibrium and the remaining eight weeks to energy balances.

The course is offered in the second year, fourth semester, of a four-year bachelor of technology program in process automation technology. It is a mandatory course, but is not considered a "core" course. Graduates of the program are experts in automation, developing competencies through a series of control/automation courses, whereas this course is part of three courses on chemical engineering fundamentals, providing students with the necessary background to understand chemical processes. Besides the lecture component, which accounts for 75% of the final grade, there are eleven labs that account for the remaining 25% of the grade. The labs are unit-operation-type labs (e.g. distillation, filter press, adsorption, absorption, evaporator) with only one of them (evaporator) being closely related to the lecture material. The rest of labs provide students with hands-on skills on chemical equipment, instruments, data acquisition, data analysis, and report writing, but do not offer many opportunities to solidify the lectures.

As mentioned above, the course has been taught by the author for five consecutive years with dropping student performance. The student final grades as well as the final exam grade have fallen by 5% in the past five years. This drop cannot be attributed to the students' interest in the course or the nature of the labs described in the previous paragraph, as these parameters have not changed in that time period. An increased student cohort, from twenty two to sixty five students, might provide some explanation. Nevertheless, an intervention was implemented in Winter 2015 in a cohort of seventy three students to improve student learning and achievement.

2.2 Online Quizzes Description

The course assessment prior to 2015 was based on two term tests, one final exam, and the lab component. Assignments were also used in earlier deliveries of the course, but were abandoned in 2012 to prevent mass plagiarism of solved solutions; practice problems with posted solutions have ever since taken the place of assignments. One challenge with this assessment pattern was that students had long periods, approximately four weeks, with no assessment. During that hiatus most students put little effort in the course and, despite all the active learning initiatives during class time, retained little knowledge. To address this, it was decided to introduce five online quizzes, spread-out during the duration of the course, to assess basic knowledge in the following subjects:

- Quiz 1: Vapour pressure calculation and two-component VLE.
- Quiz 2: Liquid/Liquid equilibrium and ternary diagrams.
- Quiz 3: Steam tables.
- Quiz 4: Specific heat and latent heat of phase change.
- Quiz 5: Reaction stoichiometry.

All quizzes consisted of approximately 8 questions. In each quiz, a couple of questions were true/false, some questions were multiple-choice, multi-select, or matching, and at least two questions were arithmetic calculations (e.g. calculate the specific heat of a component at a given temperature). For all questions, a pool with at least three choices was created, while arithmetic calculation questions were with random number generation within given ranges. Students were given three attempts to each quiz, with the best grade counting towards their mark. After each attempt, they saw their total score and the correct answer to the arithmetic questions, if their answer in that question was wrong. Correct answers to the non-arithmetic questions were not shown to somewhat prevent the integrity of the test, whereas the correct answers to the arithmetic questions were provided to allow students to reverse-engineer the correct solution process and identify their mistake(s). The quizzes were administered through the university's online learning management system (D2L) and all user attempts were recorded in detail including time and duration of attempt, questions asked and given answers.

Out of the five quizzes, quiz 1, 3, and 4 counted for a total of 9% of the course grade, whereas quiz 2 and 5 were optional. The optional quizzes were, however, followed by related in-class quizzes, worth 3% each, that were announced to the students (no surprise quizzing took place). These online quizzes were offered as practice for the corresponding in-class assessments. This differentiation between the quizzes was made in order to examine the access patterns of students to the provided resources. Questions that were pondered were: whether students value the on-line resources, whether they will attempt the optional resources, whether the multiple attempts improve their learning and achievement level, and whether their perceptions on the value of optional resources will change through the term.

3. RESULTS

The data of all seventy three students were recorded and used in this study. Results indicate different patterns for mandatory (i.e. for grade) and optional quizzes; hence they are reported separately.

3.1 Mandatory Quizzes

The completion rate of mandatory quizzes was, as expected, high: 92% of the available quizzes were completed. The distribution of student grades is provided in Figure 1. The average for each quiz was: 73% for quiz 1, 91% for quiz 3 and 75% for quiz 4. Clearly, quiz 3 was relatively easy to the students, whereas the distribution of grades is wider for quiz 1 and quiz 4.

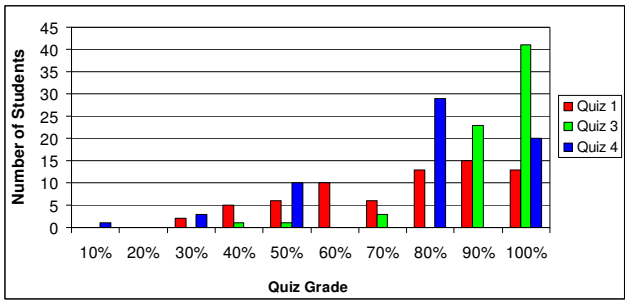

Fig. 1. Grade Distribution for mandatory quizzes.

Three attempts were allowed for each quiz and Figure 2 illustrates the average student grade at each attempt. This is the average of the students that took the attempt, as several students only used one or two attempts at a specific quiz. Overall, on average 2.17 attempts were used in each quiz. In general, the performance of students improved with each attempt. The only exception is quiz 3, where there is a dip in the average grade from the second to the third attempt. This was a quiz with a couple of challenging questions and a closer look at the data revealed that many students abandoned their third attempt because they got different versions of the two difficult questions and did not want to invest time to solve them and improve their grade which, by their judgement, was acceptable.

The timing of the students' attempts on the quizzes is presented in Figure 3. Since the three mandatory quizzes were due at different times, the days before the due date is used as the x-axis variable to normalize the data.

Clearly, the majority of students leave the quiz attempt(s) to the last day/minute. The due day also plays a major role on the attempt distribution. Quiz 1 was due on a Friday, while quiz 3 and 4 were due on a Monday. There was limited activity over the weekend (days 2-3 for quiz 1 and days 5-6 for quizzes 3 and 4) and there was activity on a Friday only when the quiz was due on that day (quiz 3 and 4). The attempts in quizzes 3 and 4 appear more uniformly distributed than that of quiz 1. This might be just a matter of the due day or a function of students realizing that they should not leave everything to the last minute.

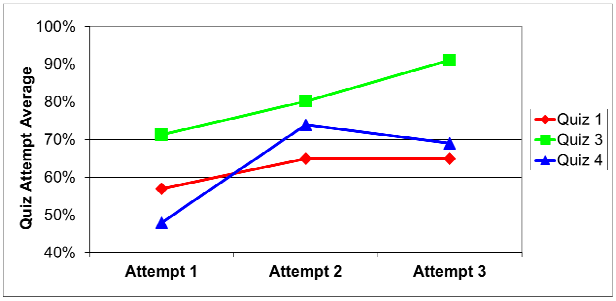

Fig. 2. Average quiz grade in each of three attempts.

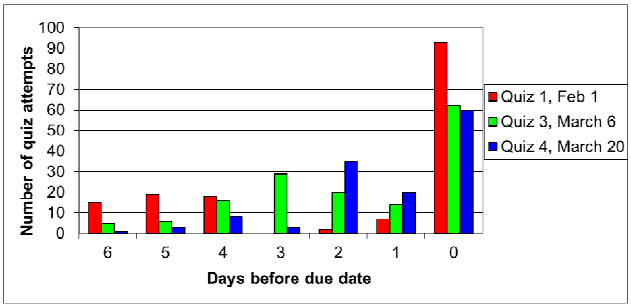

Fig. 3. Timing of mandatory quiz attempts.

3.2 Optional Quizzes

The two optional quizzes were not as popular as the mandatory ones. Quiz 2 was attempted by fifty students (68% of the class) who had 1.2 attempts on average. Quiz 5 was visited by only sixteen students (22% of the class) with 1.7 attempts on average. Both quizzes were visited by fewer students than the mandatory quizzes and had fewer attempts by the visiting students. Considering that there were in-class paper quizzes associated with the material covered in the optional online quizzes, the number of attempts is concerning. Apparently, students opted for other material, primarily solved practice problems, that they felt was more relevant to what they expected in the in-class quiz. This student perception was true, as online quizzes cover fundamental knowledge, whereas the in-class quiz required higher problem-solving skills. Still, though, they would have gained a lot by trying the online quizzes, as some students make mistakes when applying basic fundamental principles.

The timing of the attempts for these two quizzes is presented in Figure 4. Because there was no set deadline

for the quiz, the timing was associated with the term tests and the final exam of the course. Similar to the mandatory quizzes, some interest was generated right after the quizzes were posted. Then, as the quizzes were left active for the duration of the course, students visited the material before term tests and the final, or deferred final, exam.

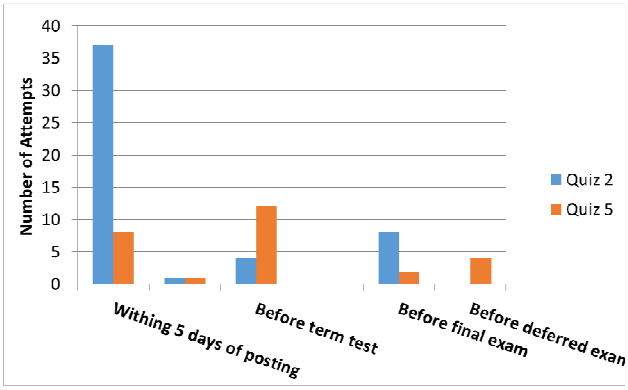

Fig. 4. Timing of optional quiz attempts.

5. CONCLUSION AND FUTURE WORK

The motivation behind the whole undertaking was the dropping student performance in the past five deliveries of the course. Figure 5 shows the average of the final course grade and the average in the final exam for the last 6 iterations of the course, including 2015 when this study took place.

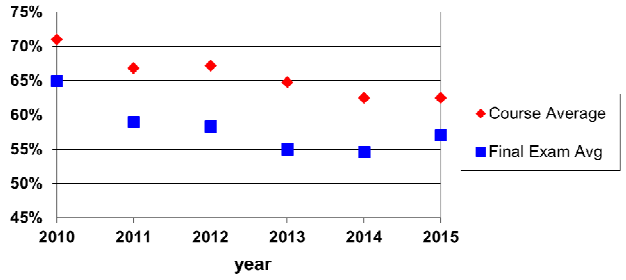

Fig. 5. Course and final exam average.

While the overall course average did not change from the previous course delivery, the final exam average increased by about 3%. This observation by itself is not a confirmation of better student learning, but an closer view of students' performance makes the author believe that the learning outcomes were satisfactory reached by a higher percentage of students.

In retrospect, the online quizzes helped because they forced students to keep in touch with the learning material at shorter intervals than with only term tests in the course. They also took away no class time. On the contrary, since the fundamentals were tested, and hopefully reached, through online testing, there was more time to devote on active learning in class. The timing of the quizzes was also important; having them due on Friday night seemed to be the best option. Students seem reluctant to work on them over the weekend and will primarily work on the last minute. A Friday deadline helps as the instructor can remind them during the week and (s)he is available for clarifications during the final minute/day rush. Coordination of this out-of-class workload with the demands of other courses would be ideal, if possible.

The optional quizzes were of little value, as students did not try them as enthusiastically as the mandatory ones. The one lesson learned from them is that students will go back to the quizzes during their studying for the final exam; so, all quizzes should be made available for ungraded tries even after their due date.

Students, based on their responses on the student evaluation forms, seemed to appreciate the opportunity to test their learning through on-line testing with multiple tries. They also liked the quizzes as a grade buffer: getting a high mark on them is easier than achieving high grades in written tests. From the instructor's perspective, this approach is not optimal, but is acceptable if it helps students solidify their fundamentals.

Moving forward, it is planned to expand the number of quizzes in the next delivery of the course, connect quiz attempts and achievement to overall class grade and specific test problem grade, and interview students about their approach to and preferences towards online quizzes. A comparison of this cohort's quiz use patterns to a cohort of chemical engineers, where this subject is a fundamental core one, is also sought.

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