A STUDY OF BLENDED LEARNING IN A FIRST-YEAR CHEMISTRY FOR ENGINEERS COURSE

Jason Grove and Eline Boghaert
Department of Chemical Engineering, University of Waterloo
jason.grove@uwaterloo.ca; eline.boghaert@uwaterloo.ca

Abstract – Chemistry for Engineers is an introductory chemistry course taken by most engineering students at Waterloo during their first term. Over the past two years online content was developed to facilitate the implementation of blended learning. The motivation for this was: i) to create time for more valuable instructor–student interactions, allowing the instructor to reinforce challenging concepts, focus on problem-solving strategies and lead experiential learning activities, and, ii) to allow students to explore content at their own pace, thereby accommodating the diversity of students’ high-school chemistry preparation. Our study aims to compare and contrast student experience, satisfaction and performance between a blended learning and traditional lecture model of instruction through data from surveys and grades.

Keywords: blended learning; online modules; general chemistry; experiential learning.

1. INTRODUCTION

Chemistry for Engineers is a large (enrolment over 1400) general chemistry course taken by the majority of engineering students at the University of Waterloo. This paper describes aspects of instructor and student experience in redeveloping the course to be offered in a blended learning format. The course redesign was intended to make the best use of limited student–instructor class time by focusing on i) conceptual understanding, and, ii) problem-solving skills; this decision was based on the instructors extensive previous experience of the course. The existing course was delivered in a traditional lecture format, with three hour-long lectures delivered by the instructor, two hours of problem-solving-focused tutorials in smaller groups with a grad student teaching assistant (TA), and adaptive online assignments delivered through MapleTA. This design led to the focus of lectures on delivery of theoretical content and relatively simple example problems. However, this use of class time is misaligned with areas of student challenge in the course, which relate primarily to problem-solving.

In the blended format, online modules were developed to facilitate the delivery of theoretical content and simple examples previously developed in lectures, with the class-time instead focusing on clarifying more conceptually challenging areas and developing problem-solving skills. Problem-solving skills are then further developed, as in the traditional lectures, in small groups during TA-led tutorials and individually through MapleTA assignments. The changes were designed to be time-neutral overall for the students, with class time reducing to two hours from three. Overall instructor contact hours are maintained by the instructor facilitating two (eventually to be three) hand-on learning activities, developed through the Engineering IDEAS Clinic initiative at Waterloo (https://uwaterloo.ca/engineering-ideas-clinic/).

A research study was undertaken to assess the outcome of these changes in terms of student experience, satisfaction and performance. This paper describes the instructor experience with the course together with some high-level findings from the research.

2. METHODS

2.1. Course Implementation

The blended mode of instruction was first trialed in the course during Fall 2016, see [1]. Significant changes were made for Fall 2017, notably the creation of all supporting online content (versus half that was available in 2016) and changes to the instructional strategy informed by the 2016 experience, in particular stronger articulation of goals and expectations, more explicit study guidance, and the implementation of pre-class quizzes.

Students in the blended course were introduced to the format during the first lecture. This included a clear articulation of the reasons for the selected instruction and expectations for the course, in alignment with the suggestions for achieving student buy-in by Smith [2]. Course material was divided into six online modules, usually of two weeks duration. Every two weeks, a new module was delivered through the Learning Management System (LMS), with students given explicit instructions on which sections to address for each week together with guiding questions for their study. A weekly quiz was given, due the night before class, with one questions asking for a brief summary of major concepts (a small credit was
associated with this) and a second no-credit question asking about difficulties and challenges with the online material. Class time was divided into a short conceptual session, with iClicker “concept check” integrated with instructor explanation of the challenging concepts, followed by a longer guided problem-solving session. Classes were intended to be of 2 hour duration, but were scheduled for 1.5 due to logistical constraints. Students in the traditional classes received three hours per week of lectures. Tutorials and assignments for the blended and traditional modes were identical with the exception of the IDEAS Clinic activities. During two-hour tutorials led by grad student TAs, students practiced problem solving in small groups. Individual assignments were delivered through MapleTA. For the blended groups only, two of the tutorials were devoted to hands-on IDEAS Clinic activities run by course instructors with half-size classes. These activities explored the operation of a drinking bird and a fuel cell car. Previous experience has shown the presence of the instructor to be important for these to be successful.

2.2. Study Design

In Fall 2017 the course was offered to approximately 1400 students in twelve sections of 80-150 students, including eleven first-year and one second-year cohort. Each section represents a cohort from a particular engineering program (some programs are represented by multiple sections). Ten sections participated in the study (the instructor of the other two sections opted out). Instructors were given a free choice of teaching in the blended or traditional modes. In the results, blended and traditional groups are indicated by B and T. The second-year cohort is B5. Four instructors, including the authors, chose to deliver the course in blended mode to a total of five sections, including the second-year section (B5). One of the instructors delivered the course to two sections being cohorts from the same program (therefore having similar characteristics), one in each mode (B3 and T5).

Students were given three surveys, in the first week of class, near the middle (prior to midterm examinations) and during the last week of class. Survey questions were intended to assess: i) student reaction and experience in the course, ii) confidence and self-efficacy; iii) perceived effectiveness of content delivery; and, iv) perceived relevance and value of the course. Survey responses were combined with course grade data to examine differences in learning and understanding. Survey participation was voluntary with students opting-in by providing research consent on the first survey. This research study has received ethics clearance through a University of Waterloo research ethics committee.

2.3. Instructor Experience

Instructor experience is based on i) the reflections of the authors as instructors of the course, and, ii) a semi-structured focus group conducted by the authors with the other two instructors using the blended approach.

3. RESULTS AND DISCUSSION

3.1. Student Performance

There was no statistically significant difference in student performance between the blended and traditional sections. Based on the authors’ experience with the course, differences usually exist in the performance of different instructors and courses taught by the same instructor; therefore the blended and traditional sections from the same program taught by the same instructor were examined (coded as B3 and T5 in figures) and no statistically significant difference in performance was found between these groups.

3.2. Student Experience

Several deviations from the intended course design should be noted. First, it became apparent to the instructors that many students were unable to study the online material effectively with the guidance provided (which comprised some advice on overall approach together with a set of guiding questions for each module). For the second half of the course, more explicit study guides were provided with specific questions and instructions to assist in studying and taking notes of the material. These were generally very well received. Second, challenges were encountered by the instructors in completing classes during the available 1.5 hour periods, leading to a number of additional “make-up” hours being scheduled, with different instructors handling this in different ways. Third, one instructor (section B4) deviated significantly from the course design by reverting to traditional lecturing for three hours per week.

As shown in Fig. 1, different sections indicated very different opinions regarding the relevance of the course to their engineering education. Note that B1 is chemical engineering, who might be expected to recognize greater relevance of a chemistry course, and B5 are the second-year group and may not be directly comparable to other sections. Section B3 and T5 (same instructor, same engineering program, different instruction modes) show no significant difference in response.

![Fig. 1. Response to the end-of-term survey question, “This course is relevant to my engineering education.”](image-url)
Students were also asked about whether the course met their expectations (Fig. 2), which mode of instruction should be implemented in the future (Fig. 3), and the effectiveness of various course components (data not shown except related to the online content, Fig. 4). The data show the considerable dissatisfaction of section B4, who also reported spending a great deal longer on the course than all other sections (data not shown), consistent with the instructional changes noted above.

![Fig. 2. Response to the end-of-term survey question, “The delivery of this course, through online material, in-class activities and tutorials, met my expectations of a university course.”](image)

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![Fig. 3. Response to the end-of-term survey question, “Based on your experience which of the following modes of instruction should we implement for future offerings of the course.”](image)

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![Fig. 4. Response to the survey question, “To what extent were the following course activities effective in helping you learn? –Online material.”](image)

Fig. 4. Response to the survey question, “To what extent were the following course activities effective in helping you learn? –Online material.”

The data show mixed results across all sections (both blended and traditional). The data may reflect comments from the students relating to their capacity for online self-study, both relayed informally to the instructors and provided on surveys. A significant number of students feel that they are unable to study independently and need to “be taught”. Interestingly, they rarely appear to appreciate that such an ability may be developed, instead regarding their need to be taught as an immutable fact. That the second-year group of software engineering students (B5) are the most strongly in favour may be a reflection of their improved maturity in terms of study skills, perhaps in combination with a greater affinity towards the online world suggested by their selection of software engineering.

### 3.3. Instructor Experience

All instructors indicated that they enjoyed teaching the course in blended mode and would do so again if given the opportunity. There was also general agreement that the amount of the online material was too great in some areas and that the shortened classes of 1.5 hours were problematic. All instructors found the turnaround of conceptual challenges articulated by students in the quizzes prior to class the following day to be challenging. Prior experience with the course was an asset in this regard, since it enabled an ability to anticipate some (though not all) challenges and also provided a greater bank of material such as appropriate examples to draw upon. One instructor attempted to respond to student challenges individually via the LMS but found the interface to be inadequate and slow, instead (with one other instructor) posting a document responding to all questions. A third instructor responded in class to the most common questions, while the fourth reverted to traditional lecturing and did not address the questions explicitly. All instructors enjoyed facilitating the IDEAS Clinic activities and found this to be a useful interaction with the students. This appeared to be reflected in informal discussions with students and post-activity polls of the class; however, students did not indicate that the activities were effective in helping them learn on the end-of-term survey (data not shown); the reason for this is unclear and will be examined in the future.

### 4. CONCLUSIONS AND FUTURE WORK

A large first-year class has been redeveloped in order to be offered in a blended learning mode. No difference in performance was observed for the blended versus traditional modes. Significant variation is seen in student experience of the course. Future work will focus on incorporating explicit “learning-to-learn” objectives into the course design.

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Note that a closely related paper, including the same graphs, has been published as a work-in-progress paper in ASEE [3].

References