A CASE-CONTROL STUDY OF STUDENT PERFORMANCE IN A BLENDED LEARNING ENVIRONMENT

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Abstract – This paper discusses student performance in a fourth-year computer-aided design course under two delivery modes: one using a blended learning format and the other based on a classical lecture style. Specifically, the final exam results following the blended learning approach (2017) are compared to those from the previous four years (2012 to 2016), where the latter delivery was based on a classical lecture style.

Course enrolment during the study period varied from a minimum of 68 students for the 2012 cohort to a maximum of 122 registrations in 2017. Meanwhile, the mean cumulative grade point average (CGPA) of each cohort varied from a minimum of 6.71 ± 1.21 (mean ± SD) in 2012 to a maximum of 7.10 ± 1.33 (mean ± SD) in 2014; the mean CGPA in 2017 was 6.87 ± 1.31 (mean ± SD).

While the class average in the final exam for each year tracked more-or-less the entrance CGPA, the distribution of grades did not. Instead, the blended learning cohort showed the lowest proportion of students achieving below 50% on the final exam.

Keywords: blended learning, hybrid learning, case-control study, engineering design course, academic performance

1. INTRODUCTION

Blended (or hybrid) learning is an instructional method that combines face-to-face and distributed deliveries of content, where the latter typically involves computer-based technologies [1]. The term was first referenced in the literature in 2000, being associated with a study examining the combination of play and work in preschool education, but soon after became synonymous with a mix of instructor-led and digitally disseminated content [2]. As technology developed, later incarnations of blended learning utilized a variety of asynchronous digital platforms such as forums, wikis, and blogs, and leveraged both computers and mobile devices in their delivery [2].

While not necessarily preferred by all students and in all situations, blended learning has been reported to enhance academic performance in some instances [3] and continues to draw interest amongst the engineering educational community (see, for example, [4] and [5]).

As Valia Spiliotopoulos points out [6], the use of technology in the course delivery is a key component to blended learning and should be linked to specific learning outcomes. The choice of technology should be such that it enhances student learning and engagement, while also providing flexibility within the learning environment. Spiliotopoulos goes on to provide concrete examples where professors have leveraged students’ proclivity towards social media such as Twitter and Facebook to exploit these platforms in assignments, discussions and peer reviews of student presentations. Meanwhile, synchronous technologies such as video conferencing and Skype have been used at times to connect classes with students abroad in order to provide a global perspective on course topics.

Despite its ability to offer creative ways to use technology to enhance and to support the classroom experience, blended learning has its challenges. Manjot Kaur [7], for example, identifies a number of obstacles to successful blended learning, such as the indiscriminate adoption of technology, the necessity for the instructor to redefine her/his role in the course, challenges related to managing student participation and activities, and the need to rethink the instructional design in order to match delivery modes to course objectives and learning outcomes.

Jennifer Hoffmann [7] seeks to address these potential obstacles in her trade article for the blended learning delivery design company, InSync Training. Regarding the temptation to employ technology for technology’s sake, Hoffmann suggests that practitioners test given technologies in smaller projects before committing them to larger ones. Presumably, professors could achieve this by introducing select technologies in standard classroom settings (such as offering in-class surveys through mobile devices) to determine how effectively they perform.

To address the potential pitfalls associated with basic course management (such as student participation) and the role of the instructor in a blended learning format, Hoffman recommends a team teaching approach or the immersing of facilitators in a blended learning program themselves. While immersion in blended learning scenarios is unlikely
to be available to most professors, many institutions have teaching support services that undoubtedly could offer professional guidance.

To deal with potential difficulties tracking student participation, Hoffman suggests foregoing “optional” online activities since these are rarely completed and instead to focus on critical, assessed activities to reduce the burden; she also recommends that instructors make clear to the students what are the course requirements and expectations.

Finally, to address instructional design challenges, Hoffman suggests substantial pre-course planning to identify activities that are best delivered face-to-face, those that require collaboration, and those that can be completed as independent activities through technology. In this she emphasizes that not all course content lends itself to a technological solution.

With both its advantages and challenges duly considered, a blended learning format was adopted in a fourth-year computer-aided design course at the University of Ottawa. The remainder of this article describes the course’s blended learning structure and the outcomes from the modified approach, wherein the results of student performance in the final exam during the 2017 academic session are compared with those from the previous four years (2012 to 2016) in the same course and offered by the same instructor but in which the delivery was based on a classical lecture style.

2. COURSE STRUCTURE

CHG 4343 is a fourth-year chemical engineering design course in which students learn an object-oriented programming language (Java in this instance) and subsequently use this to design, validate and use a process simulator of a specific unit operation. Prior to taking the course, the vast majority of students will have had no background in Java or in object-oriented programming (OOP) in general, and so a considerable portion of the course is dedicated to teaching the fundamentals of OOP and the particulars of the Java language. Given that all students entering CHG 4343 will have completed at least two programming-related courses by the time they enter it and thereby have some programming experience, it was considered a good candidate for a blended learning approach.

2.1. Lecture Structure: Classical versus Blended

CHG 4343 is a three-credit core course, which in its classical lecture-based delivery includes two lectures per week, each of 80 minutes in length, as well as an 80-minute weekly tutorial session.

In a typical classical lecture, the professor would present a topic related to object-oriented programming and supplement this with example code. This code was later provided to the students through the course’s website hosted by the University’s learning management system (LMS). In addition, students received several optional take-home assignments that were not graded but for which solutions were provided. The course LMS site also provided discussion forums for posting questions to the professor and to the teaching assistants.

By contrast, the blended learning format replaced one lecture per week with a self-study period. In addition, students were provided with a detailed, scheduled reading list for each week. These readings were supplemented with a set of 12 videos constructed by the professor using Camtasia that provided narrated screen casts of programming topics pertinent to the first part of the course. Throughout the semester, students submitted a total of nine mandatory self-assessments in which they evaluated themselves on their level of understanding of that section’s topic and also posed questions regarding the assigned readings. The professor then customized the weekly face-to-face lecture to address recurring questions from the assessments, together with key concepts from the readings. These lectures relied on practical coding examples to illustrate these principles. The weekly lecture material, including the sample code, was provided to the class prior to the face-to-face session. In the latter stages of the course, lectures more closely approached a flipped-classroom approach in which students worked on small in-class assignments and then posted these to the course’s LMS site. Anonymous samples of these submissions were then selected for discussion in class.

Key to managing the blended learning format of CHG 4343 was the LMS, which served as the course hub. In 2017 the University of Ottawa switched its LMS to Brightspace and so this platform provided the framework for the blended learning course’s course management. The course hub provided all supporting material, including the syllabus and schedule, the detailed reading lists, the weekly lecture material, videos, additional practice problems and their solutions, and a set of optional quizzes that students could complete but that carried no graded value. The hub also provided a number of discussion forums: one designed for students to share programming tips, one for relaying questions to the teaching assistants, one pertaining to the weekly tutorials, and a fourth dedicated to questions relating to the course’s major design project.

2.2. Learning Outcomes

Table 1 lists the learning objectives for the course, both in its classical lecture delivery mode and in the revised blended learning format. Key to the blended learning approach is the addition of the two objectives referring to independent study skills and self-assessments, both of which address the CEAB’s Graduate Attribute 12: “Life-long learning: An ability to identify and to address their own educational needs in a changing world in ways sufficient to maintain their competence and to allow them to contribute to the advancement of knowledge.” It is
generally acknowledged amongst Engineering programs and Faculties that this Graduate Attribute is one of the more challenging ones to measure. However, the considerable independent study associated with the blended learning format provides an opportunity to better assess students’ readiness for a self-driven, independent learning.

**Table 1: Learning Outcomes.**

<table>
<thead>
<tr>
<th>Classical Lecture and Blended Learning Modes</th>
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<tbody>
<tr>
<td>1. will understand the fundamental principles of object-oriented programming and the difference between this approach and procedural methodologies</td>
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<tr>
<td>2. will be able to translate engineering design procedures to algorithms suitable for coding in an object-oriented language</td>
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<tr>
<td>3. will be able to analyze a software-based engineering design problem and to determine the necessary steps to complete it</td>
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<tr>
<td>4. will have gained skills in applying object-oriented programming principles to analyzing engineering problems and will also utilize standard software tools such as Excel to complement their programming work</td>
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<tr>
<td>5. will be able to complete a computer-aided design and optimization of a complex and open-ended engineering problem involving a typical chemical engineering processing unit or system</td>
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<td>6. will have assembled a design report that describes their design rationale and their optimization methodology</td>
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<tr>
<td>7. will have assembled a design report that describes their design rationale and their optimization methodology</td>
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</tbody>
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<tr>
<th>Blended Learning Mode Only</th>
</tr>
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<tbody>
<tr>
<td>8. will have further developed life-long learning and independent study skills to master the general constructs and syntax of an object-oriented programming language</td>
</tr>
<tr>
<td>9. will have honed their ability to self-assess and gauge their progress in the course’s self-study components</td>
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</tbody>
</table>

### 2.3. Assessment Tools: Classical versus Blended

In its classical lecture format, CHG 4343 included three formal assessment tools: one or more midterm tests (20% of the final grade in total), a group design project (20% of the final grade), and a final exam (60% of the final grade). As mentioned earlier, the course also included a weekly tutorial, during which students completed an assigned problem that was discussed near the end of the session by the teaching assistant facilitating the tutorial.

The graded assessments used in the blended learning format were essentially the same: a single midterm test (25%), a group design project (20%) and a final exam (55%). However, while the self-assessments were an ungraded component of the blended learning structure, they were none-the-less mandatory: three or more missed assessments could lead to a failure in the course.

In both the classical lecture delivery and the blended learning format, the evaluation of the group project was based on a detailed rubric that was made available to the students at the beginning of the semester. The rubric included evaluations of various aspects of a final design report submitted by each team, along with assessments of each team’s group work based on task allocation sheets and one to two meetings during the semester with the supervising teaching assistants. In the classical delivery mode, these latter appraisals were also combined with peer evaluations of each group member to determine individual contributions to the teamwork and that had a modest affect a student’s final project grade.

Two modifications were made to the overall project evaluation process in the blended learning structure. First, the final project mark was based on a three-tiered structure [9] that considered (i) the quality of the final report using the standard rubric, (ii) a component separately evaluating the technical sophistication and complexity of the team’s submission and (iii) a more substantial assessment of each team member’s contribution to the project.

The second change to the project evaluation process involved the peer evaluations, which now played a more significant role in the final project grade. In this case the peer assessments were outsourced to the Canadian research group, ITP Metrics (www.itpmetrics.com), which provides a free service that includes detailed diagnostic reports of the team dynamics and peer feedback for both the instructor and the team members. The instructor’s report also includes an assessment of the relative contributions of each team member that was used to assign the weighting factor for individual performance in the tiered rubric.

### 3. RESULTS AND DISCUSSION

Year by year total registrations in CHG 4343 are provided in Table 2, while the remainder of this section presents historical data for the course, including student performance measures extending from 2012 through to the introduction of the blended learning format in 2017.

**Table 2: Enrolment in CHG 4343 by year.**

<table>
<thead>
<tr>
<th>Year</th>
<th>Enrolment</th>
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<tbody>
<tr>
<td>2012</td>
<td>68</td>
</tr>
<tr>
<td>2013</td>
<td>90</td>
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<tr>
<td>2014</td>
<td>73</td>
</tr>
<tr>
<td>2015</td>
<td>87</td>
</tr>
<tr>
<td>2016</td>
<td>99</td>
</tr>
<tr>
<td>2017</td>
<td>124</td>
</tr>
</tbody>
</table>
3.1. Student Academic Profile: 2012 to 2017

As a core component of the undergraduate chemical engineering program at the University of Ottawa, all students are required to complete CHG 4343 to graduate and as such, each group of students analyzed here is representative of that year’s entire cohort.

Figure 1 provides a histogram of the mean cumulative grade point averages (CGPA) of the classes entering CHG 4343 for the years covered in this study. The error bars represent one standard deviation from the mean. As the graph shows, the academic performance of the various cohorts closely matches one another; specifically, these range from a minimum of 6.71 ± 1.21 (mean ± SD) in 2012 to a high of 7.10 ± 1.33 in 2014. The class of 2017 undergoing the blended learning format, meanwhile, had an average CGPA of 6.87 ± 1.31, which also matched closely the CGPA of 2015 (6.84 ± 1.36). All else being equal, one would therefore not expect the performance of any particular group to differ substantially from that of the others.

While Fig. 2 appears unremarkable, an examination of the grade distributions provides a more interesting result. Figure 3 compares the normalized distribution (basis: 100 students) for the combined years of 2012 through to 2016 with the normalized distribution for 2017. The distribution associated with the classic lecture delivery appears “flat”, whereas for the blended class grades are closer to a normal distribution. Most striking is the substantial decrease in the percentage of students scoring “F” (i.e. a grade below 40%) on the final exam.

3.2. Final Exam Performance: 2012 to 2017

Perhaps the best comparison of relative academic performance of the cohorts is offered by considering the scores on the final exams in each year that provide a summative, student-by-student assessment. In all cases the final exam was three hours in length and covered the entire syllabus.

The final exams for years 2012 through to 2016 consisted of two parts: a major programming assignment (Part A), followed by second question consisting of a series of smaller programming tasks and short answer problems (Part B). The final exam of 2017 included both of these, but also expanded the short answer component as a separate section (Part C), the problems of which were selected from the questions comprising the optional quizzes mentioned in Section 2.1.

Figure 2 shows the class average in the final exam of CHG 4343 versus academic year. These averages are bounded between a low of 63.6% (2013) and a high of 73.1% (2014) and more-or-less track the CGPA distribution shown in Fig. 1.

Comparing grade distributions from individual years further delineates the differences in performance. Three such comparisons are provided in Figs. 4, 5 and 6, respectively: 2012 (with the lowest entering CGPA) to 2017, 2014 (with the highest entering CGPA) to 2017, and 2015 to 2017 (with the closest matching CGPA).

Turning first to the side-by-side distributions for 2012 versus 2017, one notes that a greater portion of the class of 2012 scored in the lower spectrum of marks (“F” to “D+”) when compared to the students of 2017. One might argue
this to be a result of the lower entering CGPA for the class of 2012, though the difference is not pronounced (6.71 for 2012 versus 6.87 for 2017). Alternatively, the variation may have been due simply to differences in the specific exam questions. However, as the figures that follow demonstrate, the 2017 cohort typically performs better at the lowest end of the grade spectrum relative to the others.

Recalling that the cohort of 2014 had the highest CGPA of the years considered, it is not surprising that the percentage of students achieving “A+” outstrips the number for 2017. However, once again the class of 2017 performs better at the bottom end of the scale: in this case, with the portion of students receiving “F”. The same pattern is observed when comparing the data from 2015, with its closely matching CGPA, to that of 2017.

These observations are summarized in Fig. 7, which compares the combined percentage of grades below 50% (i.e. “E” and “F”) for each of the years in the study. Nine percent (9%) of the registrants in 2017 score below 50% in the final exam, compared to 19.1% achieving below 50% for the pooled registrants from the other five years.

Finally, a few words regarding the final exam of 2017 are in order. As mentioned earlier, this exam expanded upon the short answer section of previous years and based these upon questions appearing in the optional online quizzes. The question then arises as to whether these changes, and in particular the addition of the quiz questions, somehow influenced for the better students’ performance in the exam.

Figure 8 presents the exam grade distribution for the 2017 cohort according to the three exam sections: the major programming assignment (Part A), the smaller programming tasks (Part B), and the expanded short answer component (Part C).
As the graph shows, the class performance in Part C centered around a letter grade of “B” with significant falloff towards the extreme ends of the plot. By contrast, the distributions for the other two parts showed a significantly larger portion in the upper range of the grades spectrum. Meanwhile, the averages for each part were as follows: 74% for Part A, 71% for Part B, and 64% for Part C, indicating that in fact performance on the last part was in general the poorest of the lot. It is worth noting here that while the majority of students attempted the first two out of five optional quizzes, engagement rapidly dropped in the latter ones, with less than 30% participation rate for the final quiz. This also lends further credence to Hoffman’s [8] general remarks concerning students’ lack of participation in optional work.

4. CONCLUSIONS

Blended learning offers unique opportunities to leverage technology in course delivery at the university level, thereby leading to greater flexibility in student learning. As well, in some instances it has been reported to enhance student engagement through creative use of social media platforms.

In the case of CHG 4343, data suggests that a blended learning approach, while not necessarily yielding higher averages in summative assessments such as the final exam, may improve the distribution of grades by reducing the number of catastrophic failures.

Clearly insufficient data has been gathered with respect to CHG 4343 to confirm this as an expected outcome for this course in general. However, the results presented here are encouraging enough to warrant further study.

Acknowledgements

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References


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