STUDENT AND INSTRUCTOR SATISFACTION AND ENGAGEMENT WITH BLENDED LEARNING IN CHEMICAL ENGINEERING DESIGN

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Abstract – The capstone Chemical Engineering Course was used to pilot blended learning as part of an ongoing digital learning initiative at the University of Alberta. A blended learning course structure was designed, implemented, evaluated, and redesigned using a Canadian Engineering Accreditation Board (CEAB) Graduate Attribute (GA) based continuous improvement process over a two-year pilot period. Graduate Attributes were measured using student self-assessments, instructor assessments, and through an arms length study on student engagement and satisfaction conducted with student cohorts. This contribution focuses on the results of independent interviews conducted with student cohorts during the pilot period, instructor interviews, and the data analysis of the student satisfaction and engagement surveys. Instructors were satisfied with the increased interaction with students during class time even with increased enrollment. Student satisfaction was higher for students with lower self reported GPAs, and student engagement improved in the second year of the pilot. Details of these and other outcomes are presented and discussed.

Keywords: Blended Learning, Satisfaction, Engagement, Instructor, Design, Capstone, Accreditation, Student, Self, Outcomes, Course, Assessment, Graduate Attributes

1. INTRODUCTION

The capstone design course instructional team was selected to participate in the digital learning initiative at the University of Alberta. Existing course lecture materials were redeveloped into an asynchronous online format for individual student engagement. Related in-class team-learning activities were prepared and implemented. The goals of this initiative are to increase student engagement and promote flexible, independent learning. The objectives of the instructional team were to enhance the interactions between instructors and student design teams in the face of increasing enrolment, and to align the course strategically with attributes expected for graduating engineers set out by the University of Alberta and elaborated in the Canadian Engineering Accreditation

Board (CEAB) Guidelines [8]. These goals were combined in the course redevelopment and related research studies.

This contribution is one of a series of contributions exploring aspects of blended instructional design methodology with respect to chemical engineering design. We started with “The University of Alberta Chemical Engineering Capstone Design Course Goes Flipped!” [21], outlining the design and structural changes of the Chemical Engineering Capstone course, the pre-post course CEAB GA student skill assessment tool and the preliminary results of student engagement and usage of the materials. The pre-post test and analysis is further elaborated in “Pre and Post Course Student Self Assessment of CEAB Graduate Attributes – A Tool for Outcomes Assessment, Student Skill and Course Improvement”. [19] A retrospective comparison of the performance of the initial blended cohort with previous cohorts in a historical context was completed as part of “Application of Blended and Active Learning to Chemical Engineering Design Instruction” [17]. “Online Learning Element Design - Development and Application Experiences” [19] describes the design of online learning elements connected to in-class active learning and project applications and our experiences with them over the course of a two-year pilot project. “Applying Metacognitive Strategies to Teaching Engineering Innovation, Design, and Leadership” [18] describes how reflective and metacognitive assignments can reduce team concerns. The third iteration of the blended course has been completed. This concluding paper focuses on student satisfaction and engagement with the redesigned course during the two-year pilot.

1.1. Motivation

Blended Learning is an instructional approach that fuses face-to-face instruction time and online learning [3, 12, 27]. Educators are increasingly moving toward blended learning delivery for courses because of the need to use classroom space more efficiently, the demand for greater flexibility in scheduling with changing student demographics, as well as the opportunities that the model offers with respect to increasing engagement in the

classroom [3,6,12]. Since 2014, the University of Alberta has supported pilot projects for the implementation of blended learning through a competitive awards process. Funding and support are awarded to instructors to transition undergraduate courses to a blended learning format with the aim of improving student engagement and satisfaction.

1.2. Literature Review

Student engagement is widely acknowledged as being important to their post-secondary success [1] and development of conceptual understanding [23]. In addition, the connection between student engagement and active learning is well supported in the literature [22, 38]. Numerous studies have addressed student engagement in blended learning courses [5,13,16,28,31,42]. Many of these studies focus on ways to improve student involvement [4,15,36], or to promote engagement in the online segment [9,24,29,40]. There is also a large body of research concerning student satisfaction in blended learning environments [14,25,26,33,34,41,43]. Studies contrasting traditional delivery approaches with blended learning are uncommon, and only a handful of studies have addressed elements of instructors' experiences with blended learning [2,7,35,37,39]. Instructors' overall experiences are often overlooked.

These knowledge gaps related to key institutional decision variables are addressed through data collection and analysis for all of the pilot projects funded at the University of Alberta. The research questions guiding the arms length studies are: What is students' engagement and satisfaction in blended learning? What is the instructors' experience in developing and implementing blended learning? Here we focus on student engagement and satisfaction in the flipped and blended chemical engineering capstone design course. We also address the instructors' key objective in undertaking the blended learning project: to enhance the interactions between instructors and student design teams [21] increasing enrolment.

1.3. Problem Definition

The chemical engineering capstone design course is a project course where approximately 25 teams comprising 5 or 6 students complete unique industry sponsored design projects. Students must research their project, identify and compare competing options using sustainable design criteria, develop a team structure, a project plan and schedule, and then complete their design project. Currently five capstone design instructors teach as a team in one section. [17]

Students and instructors are typically faced with a heavy workload to complete the course successfully and to support successful completion by teams respectively.

The direction of engineering education has been moving toward demonstrating performance attributes like the CEAB GA [8] and an experiential instructional approach supported by open-ended problems and inductive teaching methods [17].

The blended learning course format was designed and implemented using the successive approximation method for instructional design and improvements were implemented between year one and two of the pilot. More learning elements were created, some were improved, activities were adapted and a writing seminar [17] was added to further engage students.

1.4. Solutions Considered

Students agreeing to participate in the case study were interviewed, after they had completed the course, and were asked to complete a survey. Instructors were also interviewed following iterations of the course. The data were collected and analyzed independently, by the University of Alberta Centre for Teaching and Learning and made available to the authors. The arms length data acquisition and analysis provided measures of student engagement and satisfaction with the blended course structure and course design as it developed over the pilot period and ensured that the cognitive and emotional engagement of the instructors did not introduce bias.

1.5. Significance

Student satisfaction and engagement are associated with higher level cognitive and affective domain task competency, especially when students have skills appropriate to a task level [17]. Satisfaction and enjoyment with learning and the work reinforce continued learning and commitment. Student satisfaction with the course format and the course experience are critical to learning. Satisfaction and engagement are related to a combination of the students' skills, expected tasks, and scaffolding provided by the instructors for students to accomplish tasks [10,17]. Student engagement was a primary motivator for the implementation of the flipped and blended course structure [21] and was modeled on Csikszentmihalyi's concept of flow [10, 30], wherein an individual is engaged when: they are intensely focused on their current activity, feel intrinsically rewarded and in-control, feel that the task is neither too difficult nor too easy, and may lose track of time [21]. The learning activities and scaffolding leveraged ideas from the work of Vygotsky, Perry, Csikszentmihalyi and Bloom with respect to creating an enjoyable course experience and focusing on higher cognitive task learning opportunities [21,17,19,20]. Arms length measurement of engagement and satisfaction are an important validation of the instructors' observations and perceived success of implementing a blended learning structure.

2. STUDENT ENGAGEMENT AND SATISFACTION

The arms length study of *student engagement* distinguished three levels: behavioral, emotional, and cognitive [11]. Behavioral engagement refers to course participation, and includes all academic, social, and extracurricular activities that are considered critical for achieving positive academic outcomes, and includes being able to ask clarifying questions about the materials, being able to consistently pay attention, following the course schedule, and complete the assignments. Emotional engagement concerns reactions to instructors, classmates, and the institution that can influence willingness to complete activities and may include perceptions of whether the amount and quality of interaction with both instructors and classmates is appropriate, the value the relationships built with peers, and whether they enjoyed taking the course. Cognitive engagement refers to investment and readiness to put in the work necessary to understand complex ideas and master skills that are being taught, and may include going back to the course materials to review, asking themselves questions to make sure they understood, reading extra materials to learn more about concepts in the course, and their perception that the course helped improve their understanding of key concepts and skills.

Student satisfaction encompasses both satisfaction with the course format and their preferences related to blended learning, upon completion of the course [32]. Other measures of student satisfaction included whether or not students believe online and face-to-face course components enhance one another, if the web resources were helpful, if they would take another blended learning course in the future, given the opportunity. These measures are based on established precedents. In blended courses, students may experience enhanced time and spatial flexibility, wider and easier access to the learning resources, as well as increased autonomy over regulating their own learning [32]. There is some evidence that having both face-to-face and online components allows students to communicate directly with instructors, receive immediate faculty guidance and support if needed, and get involved with other students in the class [32].

2.1. Student Study Participants

There were 90 student participants (49 for Winter 2015 and 41 for Winter 2016). A member of the arms length research team visited the class each term to explain the purpose of the study and to invite students to complete the survey. A link to the survey was provided in the learning management system (LMS), and the response rate exceeded 20%. The student participants were 60% male, 33% female, 6% preferred not to respond, and 2% identified as other. Students reported having an average

GPA of 3.24 ($SD = 0.38$), taking an average of 5.57 ($SD = 0.85$) courses, as well as working an average of 5.13 ($SD = 11$ hours a week during the term they took the course. 54% of the students were enrolled in the co-operative program and 46% in the traditional program. Most of the students (87%) were in the chemical engineering subprogram; 8% were in oil sands, 5% in the computer process control subprogram. The student participants reported feeling motivated to succeed (34% agree, 61% strongly agree), and having strong time management skills (61% agree, 26% strongly agree) (Figure 1).

Figure 1. Student Motivation and Time Management

2.2. The Study Setting

Oil Sands Engineering Design and Chemical Engineering Design II (CH E 435 & CH E 465) are two fourth-year courses taught as a combined section as part of the Chemical and Materials Engineering program at the University of Alberta. The rationale for transforming this course into a flipped and blended format was to address student learning depth, heterogeneity and engagement, and to enhance the quality of student-instructor interactions. Instruction was moved online to open up in-class time for application of concepts, for teams to meet and work together, and for both formal and informal questions/discussions with instructors ahead of planned enrollment increases. Classes and student teams comprise students from co-operative and traditional programs, as well as from chemical engineering, oil sands, and computer process control subprograms. Students had ongoing access to instructional resources (highly produced videos and quick reference text summaries), direct communication with instructors (which favored immediate support), and they were encouraged to engage with classmates during lectures.

3. METHOD

The arms length study used a concurrent embedded mixed methods strategy: a one-shot case study design for the quantitative portion, and then a case study design for the qualitative portion. Student participants responded to a 10-minute post-course online survey with questions targeting constructs of student engagement and satisfaction. Two subscales were adapted for this study: (1) student engagement [11] had a total of 15 items divided into behavioural, emotional and cognitive

dimensions, which had an internal consistency reliability of .85; and (2) student satisfaction [32] had a total of 6 items divided in course format and preference of blended learning, which had an internal consistency reliability of .75. At the end of the survey students were given the option to volunteer for a 40-minute semi-structured interview with questions also targeting the two main constructs. Instructor participants volunteered for a 60-minute semi-structured interview with questions regarding their experience developing and implementing blended learning in the course.

4. RESULTS AND DISCUSSION

Students agreed the online tutorials combined with the in-class related activities helped them develop skills related to all CEAB graduate attributes as shown in Figure 2. Design, problem analysis, engineering tools, teamwork, and communication skills scored the highest - 94% agree or strongly agree.

Figure 2. Skill Development in CEAB GA Results Arising from the Blended Capstone Design Course

4.1. Student Satisfaction

The difference in scores between students who took the course in Winter 2015 and Winter 2016 was statistically significant for satisfaction ($p = 0.002$), satisfaction with course format ($p = 0.006$) and preference for blended learning ($p = 0.001$). Students in the Winter 2016 term were more satisfied with the course, had more positive opinions about its format, and generally preferred blended learning (Table 1). A second independent samples t test showed that the difference in student satisfaction scores ($p = 0.004$), satisfaction with course format ($p = 0.006$), and preference for blended learning ($p = 0.004$) between students above and below the average GPA was statistically significant. Students below the average GPA reported being more satisfied with the course in all three dimensions than students above the average GPA (Table 2).

Students indicated that the web resources in this course were helpful (58% agree, 5% strongly agree), that the online and face-to-face course components enhanced each other (47% agree, 3% strongly agree) and about 40% indicated they rarely had technical problems associated with accessing the materials (26% rarely, 16% never). Students also indicated that the eClass page was not easy to navigate (26% agree, 37% strongly agree). The tutorials students found the most useful were PFD and P&ID drawings (88%), plot plans and safety (69%),

Table 1. Independent Samples t Test for Student Satisfaction Categories Between Cohort Terms

Cohort	Student satisfaction	Satisfaction with course format	Preference for blended learning
Winter 2015	•N=47 •M=15.66 •SD=5.79	•N=47 •M=10.43 •SD=3.51	•N=49 •M=5.24 •SD=2.45
Winter 2016	•N=35 •M=19.37 •SD=4.39	•N=38 •M=12.39 •SD=2.78	•N=35 •M=7.00 •SD=1.81
t	(80) = -3.17	(83) = -2.82	(82) = -3.59
p	0.002	0.006	0.001
95% CI	[-6.04, -1.38]	[-3.36, 0.58]	[-2.73, 0.78]
Cohen's d	0.72	0.62	0.81

capital cost estimation (50%), heat exchanger design (47%), risk analysis and economic evaluation (both 41%), separation equipment (34%) and team development (31%). For the 2016 cohort, a writing seminar was added to assist students with developing their report during the term. More than half indicated attending the writing seminars during the first month of the course (66% yes, 34% no). Approximately half of the students found the writing seminars useful (46% agree) or the notes for these

Table 2. Independent Samples t Test for Student Satisfaction Between Above and Below Average Self Reported GPA

Cohort	Student Satisfaction	Satisfaction with course format	Preference for Blended learning
Above Average	•N=43 •M=15.60 •SD=5.52	•N=44 •M=10.36 •SD=3.30	•N=43 •M=5.26 •SD=2.40
Below Average	•N=39 •M=19.0 •SD=4.99	•N=41 •M=12.32 •SD=3.10	•N=41 •M=6.73 •SD=2.10
t	(80) = -2.97	(83) = -2.81	(82) = -2.99
p	0.004	0.006	0.004
95% CI	[-5.76, -1.13]	[-3.33, 0.57]	[-2.46, 0.49]
Cohen's d	0.65	0.61	0.65

writing seminars helpful (54% agree). Students also indicated that writing assistance would be particularly helpful as feedback on their writing (35%), and if it occurred prior to this course (26%). Students reported being overwhelmed with information and resources (47% agree, 13% strongly agree). Students were satisfied with the course overall (57% agree, 11% strongly agree), and they would probably take another course that had both

online and face-to-face components if given the opportunity (51% agree, 5% strongly agree).

4.2. Student Engagement

Student survey data demonstrated a statistically significant difference in student engagement scores between Winter 2015 and Winter 2016. Students taking the course during Winter 2016 were more engaged ($p = 0.001$), held better opinions about their affective relations and belonging in the course (emotional engagement) ($p = 0.004$), scored higher in investment in their learning and self-regulation (cognitive engagement) ($p = 0.001$), and had a more positive conduct and academic involvement score (behavioral engagement) ($p = 0.037$) than students taking the course during Winter 2015 (Table 3).

Cohort	Emotional Dimension	Cognitive Dimension	Behavioral Dimension
Winter 2015	•N=48 •M=19.31 •SD=4.65	•N=48 •M=20.89 •SD=4.27	•N=49 •M=10.12 •SD=2.12
Winter 2016	•N=37 •M=22.27 •SD=4.41	•N=35 •M=23.71 •SD=2.58	•N=35 •M=11.11 •SD=2.10
t	(78.1) = -3.79	(79.4) = -2.99	(78.8) = -2.13
p	0.004	0.001	0.037
95% CI	[-4.92, -0.99]	[-4.44, -1.20]	[-1.92, -0.06]
Cohen's d	0.65	0.80	0.47

Students indicated they liked taking this course (49% agree, 16% strongly agree). Students valued the relationships they built with their peers (65% agree, 19% strongly agree), and they felt that the amount (65% agree, 16% strongly agree) and quality (57% agree, 8% strongly agree) of their interactions with other students was appropriate. Students also reported that the amount (62% agree, 14% strongly agree) and quality (70% agree, 8% strongly agree) of their interactions with course instructors was appropriate (Figure 3).

Figure 3. Emotional Dimension of Engagement Results

Overall, student self-responses provided evidence of their investment in learning and self-regulation. In particular, if students did not understand a concept in the course they did something to figure it out (77% agree, 23% strongly agree), and went back and reviewed the course materials (71% agree, 17% strongly agree). Students also reported that they were engaged in the course (68% agree, 14% strongly agree), read extra material to learn more about the concepts covered (54% agree, 23% strongly agree), and asked themselves questions to make sure they understood course materials (66% agree, 6% strongly agree). They also thought the course improved their understanding of key concepts and skills (51% agree, 24% strongly agree) (Figure 4).

Figure 4. Cognitive Dimension of Engagement Results

Student self-reports of their behavior provided evidence of positive conduct and academic involvement. For example, students mentioned being likely to ask questions (60% agree, 23% strongly agree), and being able to consistently pay attention in the course (57% agree, 9% strongly agree). The majority of students also reported, contrary to the interviews, that they followed the course schedule and completed the non-graded activities (54% agree, 9% strongly agree) (Figure 5).

Figure 5. Behavioral Dimension of Engagement Results

4.2. Student and Instructor Anecdotes

Students and Instructors were interviewed and both groups recognized the significant emotional, cognitive, and behavioral demands placed on students during the capstone design course. Some of their observations are noted below.

4.2.1 Perspectives about student investment in learning and self-regulation

"There were some students that probably did not wind up getting their pre-lecture reading done. But if they were forced to come to class and forced to sit and listen to you talk, technically they're forced to receive the information. Whether they pay attention that entire time or not, I don't know, but without that the onus really was put on the students" (Instructor).

"For the most part, we would just complete the post-tutorial side of it, because not a lot of people paid attention to the rest of items just because they're not for marks or anything" (Student).

"The execution could be better done, because I found a lot of my class didn't pick up on the point of each portion, and so there were a few people that I know that didn't even participate [in...]the pre-tutorial portion" (Student).

"The benefit of this course was that you always had the resources online, so you could always do it whenever you wanted, and then you could always go back to it. Whereas for my other courses they were mostly written by hand. And so, it was either you went to the lecture, or you missed out of the lecture. I thought it was helpful to go back to this" (Student).

4.2.2 Perspectives about positive conduct and academic involvement

"Having tracking was really helpful, because you held everybody accountable. If they saw that the other group members were working way more hours than they were, and accomplishing way more tasks, then that was kind of self-motivating. And so, that was really good" (Student).

"...I think most of the value comes from having the course material online, but also being able to go and talk to the professor about specific things" (Student)

"Student workload is honestly similar to what it has been in the past, but the difference is that now that we've added some scaffolding to help them, that could end up increasing their workload" (Instructor).

"What the students learned, generally speaking, didn't change. With a few exceptions all the materials are similar. They're learning the same thing, but perhaps not in the same way. In some cases, it's in a deeper way, a flexible way, and I think they appreciate that" (Instructor)

4.2.3 Perspectives on affective relations and belonging in the course

"I learned a lot from this course, and especially from the advisor asking you to think by yourself, because it used to be: 'I'll tell you this, and you'll tell me that', but

this time it was: 'you tell me what you think, or what's the option you have to accomplish this design' And that made me very motivated" (Student).

"Learning in that environment was actually really interesting, because some of the other students could have an insight that another may not, and a lot of the co-op students have worked in different areas, and when we talked about pumps or heat exchangers, they knew about them more than some of the traditional students. So, it was really nice to share the experiences and to start learning from other people, and start collaborating with them" (Student)

"For students that actually took it seriously and did all the work, it was really useful and you could see the benefit they got out of it" (Instructor).

"The real win was the opportunity for students to ask questions based on what they had read or what they had seen or what was provided to them. That's what worked well and what really maximized our benefit for time spent" (Instructor)

5. CONCLUSIONS

The change in course delivery format shifted the responsibility for preparation and learning to the students as the instructors took on more of a guiding and mentoring role. There is a learning curve for instructors as they shift to a blended and active learning format. The transition impacts student satisfaction and engagement as instructors develop skill and improve materials. Students were significantly more engaged and satisfied with the second iteration of the blended learning delivery format than the first. Iterative and ongoing course development and improvement based on student feedback (in part from the CEAB graduate attribute pre-post course skill self assessment), assessment of student work, instructor feedback and observations, improves student engagement and satisfaction. Students and instructors both noted improvements in student learning and experiences when students were able to complete the pre-work and discuss the material with their peers and instructors. When this was not the case the student perception of the format seemed to suffer. Students with self-reported below average GPAs reported more satisfaction with the blended format than peers with above average GPAs. Students reported the course helped them to develop skill in all of the CEAB GA. We noted a dissonance between the survey and some interview responses related to non-graded pre tutorial assignments – some students were still behaving strategically rather than engaging in deep learning. However, the over all the transition was a

success. We achieved our goal to preserve or enhance instructor-student interaction (the core of a design course) in the face of increasing enrolment and improved student engagement and satisfaction.

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