BLENDED AND PROJECT-BASED LEARNING: THE GOOD, THE BAD, AND THE UGLY

Alexandra Meikleham, Ron Hugo, Robert Brennan

Department of Mechanical and Manufacturing Engineering, University of Calgary

ABSTRACT

Since its inception, the CDIO initiative has advocated the use of experiential learning. Problem- and Project-based learning (PBL and PjBL) have been widely acknowledged as an approach to dovetail experiential approaches into the learning process. The often-cited benefit of this approach is that participation in experiential projects in which students take on roles that simulate professional engineering practice results in dual-impact learning experiences. These experiences encourage the development of both technical knowledge and professional skills – consisting of personal and interpersonal skills, and product, process, and system building skills (Crawley et al., 2014). A drawback to PjBL is that it requires considerable contact time for facilitation, therefore blended learning has been identified as a method to free up limited contact hours for more active engagement. This paper presents our experience implementing blended, project-based learning in a technical fluid mechanics course, including contextual factors which impacted effectiveness of this approach. Student engagement with online lecture material was analyzed using user watch minutes; it was found that techniques implemented to reduce cramming appeared to be effective in achieving this goal. Data from end of term student feedback surveys was used to gain insight into student satisfaction with this blended project-based learning class. Findings from this course were compared with student responses on previous blended and traditional delivery courses. Findings indicated that when perceived workload increased, student perception of quality of instruction decreased. An analysis of expected vs. actual hours revealed that while hours dedicated to course work were lower than expected, students perceived the course load to be much higher than other courses. This suggests that time spent on this course required a higher level of activity and engagement per hour than what students are used to. Instructors should consider whether institutional support exists for the time- and resource-intensive development process of project-based learning, as promotion and tenure reviews could be negatively impacted by student evaluations. The paper will close with a discussion on insights that can be utilized productively by instructors to inform future PBL/PjBL development.

KEYWORDS

Project-based learning, PjBL, PBL, Blended learning, Student-centered learning, CDIO approach
Standards: 2, 3, 5, 7, 8

INTRODUCTION

Project Based Learning

The CDIO approach promotes the use of dual-impact design-build experiences which promote the development of new skills and reinforcement of fundamentals (Crawley et al., 2014a). Project-based approaches ground learning experiences in the real world and transfer responsibility for knowledge development from the instructor to the learner. While project-based learning offers opportunities to demonstrate and develop higher-order learning and professional skills, such as critical thinking, team-work, and leadership, there are many challenges associated with its implementation. While these approaches are beneficial in that they are fundamentally student-centered with respect to knowledge development, this is often not the only criteria that course instructors and designers need to consider when developing project-based approaches. The challenges to widespread dissemination of project-based learning have been discussed by many authors. A study by Norman & Schmidt (1992) revealed that knowledge, even if gained in the context of problem-based learning, may not be easily transferred to new contexts without explicit instruction on the process of transfer. This additional step could represent a barrier to student learning and instructor uptake due to the addition of even further time investment.

Designing and implementing meaningful project-based learning experiences also requires a great deal of creativity and time investment before, during, and after the activity. To support self-regulated learning and formative assessment practice, instructors must spend time facilitating course delivery. To ensure knowledge is transferred to new contexts, additional planning and communication must also be done. Designing and facilitating the experience with the use of formative assessment is usually not sufficient; institutional and systemic constraints often mean that instructors must also summatively assess these activities. Biggs & Tang (2011) offer guidance on constructive alignment for outcomes, activities, and assessment, however under time and resource constraints it can be difficult and unrealistic for instructors to deliver effectively in all areas. Even if instructors are willing to invest additional time into developing effective learning experiences, institutional incentives rarely reward the disproportionate level of time investment required for these approaches (Graham, 2016). Yeo (2005) identified two common barriers to project-based learning: instructors do not easily concede instructional power to students, and students are often too comfortable in their current “reception” role. Without a change in incentive structures for students and instructors it may be an unrealistic expectation that these behaviours change.

Research Questions

To better understand blended, project-based learning approaches, a study was conducted in which these approaches were implemented within a traditionally technical course. Research questions for this particular study were:

- How can student engagement be increased in a blended learning environment?
- What benefits and drawbacks are there to blended and project-based learning that should be considered?
- How do students perceive blended and project-based learning in a technical course which is usually taught in a traditional manner using scripted laboratories?

METHOD

Course Design

In Summer 2017, a fluid mechanics course was offered in a blended format, with approximately 20 hours of lecture videos of technical nature offered online on the video site YouTube.com. These videos were previously described in (Hugo & Meikleham, 2016). In-person lecture time was then utilised to facilitate active learning through use of a personal response system (i.e., clickers) with guided formative assessment, and to conduct design-build activities in preparation for five project-based laboratory experiments. Scheduled laboratory times were used for team-based guided experiments, where students were given objectives and guided formatively through the learning process, and were otherwise required to formulate their own hypotheses and experimental procedure. A brief description of the five experiments, course assessment types and statistical comparison of student performance can be found in a companion paper (Meikleham et al., 2018 [in press]).

Cornell Notes

In previous research on engagement in online learning, we reported on a variety of techniques used to facilitate feedback, formative assessment and self-regulated learning in the context of online courses (Meikleham & Hugo, 2017). In particular, Zhang et al, (2016) reported using Cornell Notes to facilitate student engagement in a blended learning environment. In a 2015 offering of a blended delivery course, one of the authors of this paper found that YouTube video watch minutes peaked the evenings before exams: students appeared to be “cramming” the material. In this course, Cornell Notes were implemented in an attempt to promote earlier engagement, and open up new channels of formative assessment, with the absence of formalized lecture time. Cornell Notes were given a weight of 5% of the final mark and were due three days before each week’s PjBL experiment and corresponding weekly quiz.

Data Collection and Analysis

The experience of offering a blended project-based learning class will be examined through both qualitative and quantitative lenses. YouTube.com offers access to valuable user analytics which help to provide an insight to user engagement with the course content. User watch minutes plotted against key dates in the semester were used to compare engagement across two similar courses from a 2015 and 2017 offering. Ratings on a variety of questions from end of term student evaluations were compared across the two years. A bubble plot relating workload with overall course instruction was used to explore results from two courses offered between 2000-2005 using traditional face-to-face lectures and scripted laboratories, courses taught from 2013-2015 using blended delivery and scripted laboratories, and courses taught from 2015-2017 taught using blended delivery and project-based laboratories. In the 2015 course offering, only three of the five laboratory experiments involved project-based learning with only one of these requiring extra time beyond the scheduled laboratory period. The other two laboratory experiments were scripted involving step-by-step instructions as applied to existing equipment. Qualitative reflections are made based on student observations from the Summer 2017 semester.

There were 53 students enrolled in this summer course, approximately 20% were Civil Engineering students, and 80% were Mechanical engineering students. Distribution of year of study from first to fourth year was 4%, 30%, 60%, and 8% respectively. Gender distribution was approximately 80% male and 20% female.

Student End of Term Surveys

Anonymous end of term student surveys are conducted by the administration to gather data on student satisfaction and experiences in each course. Students are asked to rate the course and instructors on 12 criteria ranging from instruction to evaluation and support, ranking is on a Likert scale from 1-7 ranging from unacceptable to excellent.

Limitations

The design of this course was such that it offered many “active” interventions at one time. On the one hand the classroom was flipped, where students were required to take responsibility for watching YouTube lectures on their own time, on the other hand the student contact time was used in active engagement where the students guided their own discovery with facilitation by the instructors. This may have been a difficult adjustment for many students. It is difficult to ascertain for certain which of the interventions the students had affinities towards, and which were the ones the students rejected. The analysis presented in this paper was motivated by reflections from informal discussions with students and teaching assistants, and formal findings from the end of term student surveys. Many of the analyses in this paper were motivated by questions that arrived from day-to-day interactions with the students. Since the course was not run as a controlled experiment with different interventions tested and controlled, it is impossible to parse out which of the interventions truly led to the results we observed. Where possible we have included anecdotal experience that may help to contextualize the findings, however no causal relationship can be determined.

This course was offered during a condensed summer semester which provided the benefit that students and instructors could be completely immersed in the experience. It is possible, however, that this led to a selection bias with a sample of students that were unrepresentative of the population. Students studying in the summer are more likely to represent two extremes of the population: they are either repeating the course due to previous failed attempts or are keen to accelerate their programs. Students repeating courses with labs are often given credit for the lab component in their subsequent attempts if they have passed the lab previously. In this offering the students were not given credit for past labs as the project-based active learning labs were not considered to be substitutable to previous course offerings. This may have negatively impacted student attitudes causing a bias in their perception of the course.

RESULTS

YouTube Watch Minutes and Cornell Notes

Figure 1 and 2 show a comparison of user watch minutes for the fluid mechanics YouTube videos from 2015 and 2017 during which a comparable version of the course was offered by the same instructor. Red dashed lines indicate quizzes and exams.

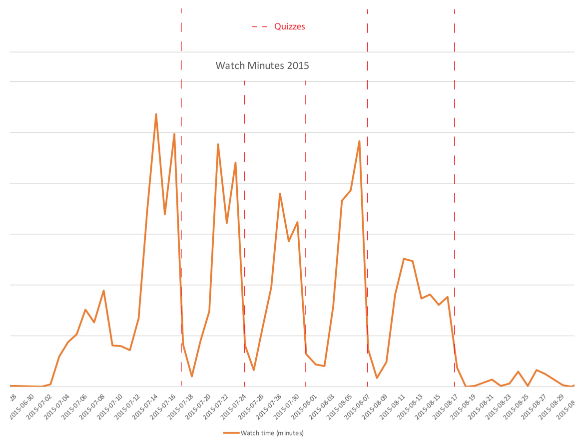

Figure 1. 2015 YouTube watch minutes.

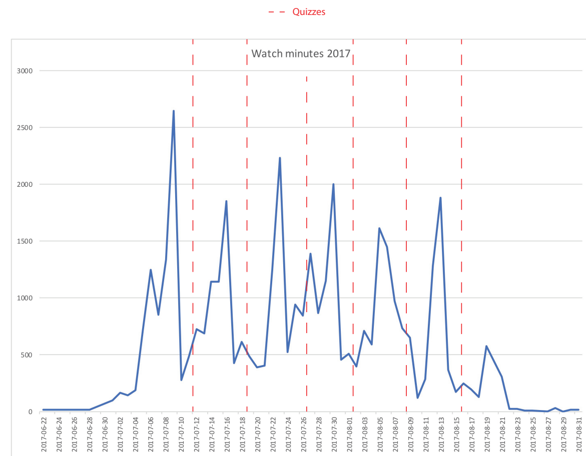

Figure 2. 2017 YouTube watch minutes.

Cornell Notes were not implemented in the 2015 version. It was found that students in the 2015 course watched the course material directly before quizzes, whereas in 2017 this was not the case. Peaks observed in the 2017 graph coincided with the evening that the Cornell Notes were due, as students rushed to get their submissions completed. Cornell Notes were therefore highly effective at influencing student engagement behaviour with the online material, despite the relatively low weight (5%) that it contributed to the final grade. In general, student response towards the Cornell Notes was negative. Several comments were made to the instructors during the semester. Students complained that they did not like having to follow a rigid structure for their note taking and that they spent many more hours on the notes than they felt contributed towards their learning and their final grade. It is interesting to note, however, that the number of students submitting Cornell Notes did not change a great deal over the semester, as noted in the graph in Figure 3.

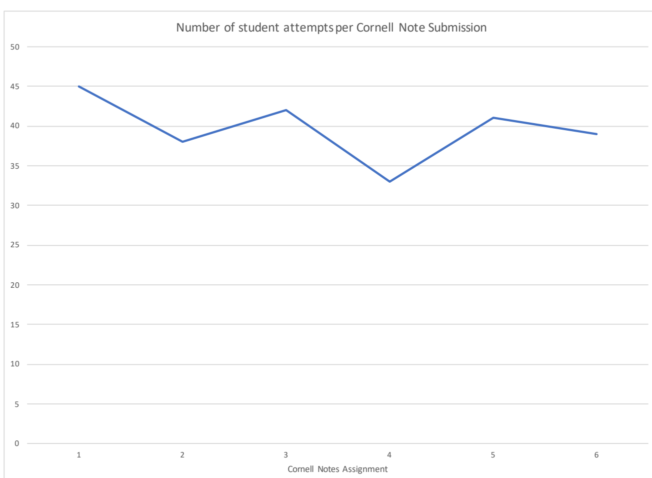

Figure 3. Number of student attempts per Cornell Notes per assignment.

Student reception to the Cornell Notes will be further discussed in the End of Term Course Evaluations section.

End of Term Course Evaluations

University-administered end of term surveys (USRIs) measure student response to a variety of questions pertaining to course load, instruction, assessment fairness and respectfulness of the instructor. Figure 4 and Figure 5 show average student response to the USRI questions for both the 2015 and 2017 deliveries. In most categories there was an improvement in student response from 2015 to 2017, indicating that students were more satisfied with the 2017 course offering despite the increased workload (in the form of Cornell Notes and more involved project-based learning laboratories).

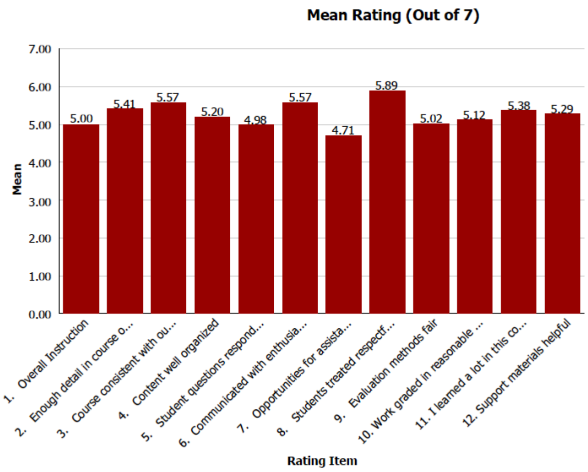

Figure 4. 2015 USRI Results.

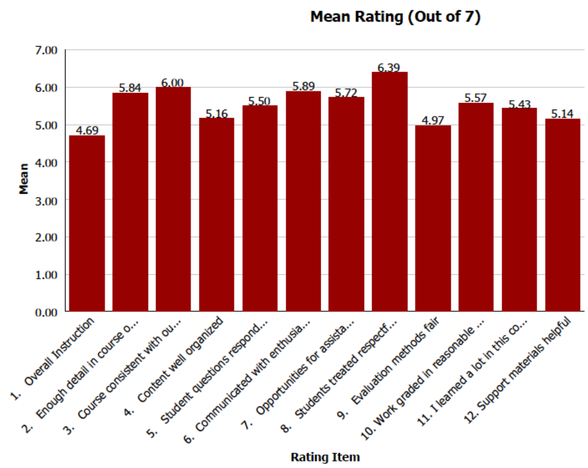

Figure 5. 2017 USRI Results.

Figure 6 shows a more detailed comparison of the change in USRI Results between 2015 and 2017, with negative values indicating "poorer" performance and positive values "improved" performance. It is noted that the responses to both Question 1 – *Overall Instruction* and Question 12 – *Support materials helpful* decreased from 2015 to 2017. In examining student response to Question 12, it is believed that the open-ended nature of the laboratories, designed to improve student learning, left students feeling less supported. Considering the response to Question 1, the students were less satisfied with the overall learning experiences offered by the 2017 course format, despite improvements being made to almost all USRI categories.

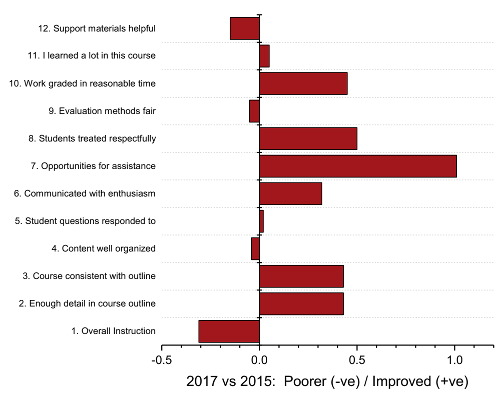

Figure 6. Detailed comparison of change in in USRI results by question.

To further understand why the response to Question 1 – *Overall Instruction* in 2017 decreased while most other USRI categories improved, the demographics for the response to Question 1 were examined. A supplemental question in the USRI survey asked students about course workload, if it was Much Lower, Lower, About the Same, Higher, or Much Higher than other courses. A bubble chart was created comparing student responses to question "1. Overall Instruction" with the demographics question "How does the workload from this course compare to your other courses?" In creating this bubble chart similar results from other courses taught by one of the authors dating back to 2000 were also considered. This included two courses from 2000-2005 using traditional face-to-face lectures and scripted laboratories (Green bubbles), courses taught from 2013-2015 using blended delivery and scripted laboratories (Red bubbles), and courses taught from 2015-2017 using both blended delivery and project-based learning laboratories (Blue and Purple bubbles).

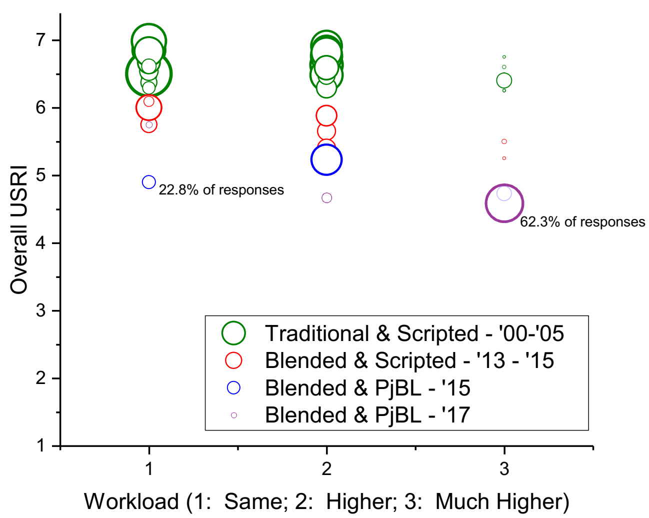

Figure 7. Bubble plot demonstrating relationship between workload, overall instruction and frequency of response (bubble sizes).

The plot demonstrates that the best performance, as indicated by USRI Question 1, is achieved using traditional face-to-face delivery and scripted laboratories (Green bubbles). Blended delivery with scripted laboratories (Red bubbles) results in intermediate performance, with Overall Instruction starting to decrease for students who perceive that the workload has increased, something that was not observed with traditional delivery (Green bubbles). Blended delivery with project-based learning laboratories (Blue and Purple bubbles) results in the poorest performance. Approximately 62.3% of the respondents from the 2017 fluid mechanics course felt that the workload was "much higher" than that in other courses and these students also gave the lowest Overall Instruction rating that the instructor has encountered in nearly 20 years of teaching. Given the large span of time between 2000-2005 and 2013-2017 it is not possible to conclude if this result is due to a change in course design or a change in student habits and attitudes. Nonetheless, a reduction in Question 1 - *Overall Instruction* of this magnitude is not a positive result, especially when trying to encourage professors to adopt project-based learning in their engineering courses for the development of professional skills. This is the fundamental premise upon which CDIO Standard 3, Integrated Curriculum, is based upon. This result may help to explain why a recent survey of CDIO collaborators worldwide found Standard 10 – Enhancement of Faculty Teaching Competence – the most challenging CDIO Standard to influence (Malmqvist et al., 2015). It is possible that instructors have attempted such interventions in their courses, but when they find an increased workload with decreasing student evaluations, they quickly retreat to traditional delivery.

A second section of the USRI involved free-form student responses to two questions: *If appropriate, please comment about the Laboratory and/or Tutorial section(s) in this course* and *Please provide general comments about the course.*

Students found that labs and lectures both required too much time investment, resulting in the higher than normal course load reported in the USRI demographic questions. A word co-occurrence analysis using VoSViewer found that the most frequently co-occurring word pair in student surveys was lab-time. This supports the claim that students found the labs too time-consuming.

The following are a sample of student responses:

- *“Wish the manual explicitly told us to calculate certain things rather than leave us to “discover” what we need to find.”*
- *“We had 5 labs and therefore 5 lab reports. This is too much for a summer course. Basically meant we had to do labs every week.”*
- *“Labs were good but some of us felt it was graded too harshly.”*
- *“The laboratories were the most enjoyable portion, as it most related to a real-life situation. Conducting the experiment and picking your own methods for testing is very valuable for us in the future.”*
- *“The labs are worth 25% of the overall grade but take up 75% of the time and the exams are worth 70% and content covered had to be done on our own time.”*

Responses indicate that students in general were not satisfied with the amount of time they were expected to spend on the course, and were particularly unhappy with the assessment weighting and methods used. Rubrics were constructively aligned with learning objectives and activities for the course, however it also appears that some students felt that the marking was unfair on the laboratories. In interaction with students during the semester, some complained about being docked marks by the graders (teaching assistants – TAs) for unclear reasons. It appeared that these experiences may have negatively impacted their attitudes and therefore engagement with the course. Despite clear communication of expectations, there was sometimes a disconnect with the TAs on the importance of open-ended project-based learning. The teaching assistants also expressed that they were not experienced in learning in such an environment and were less comfortable marking in it. It became clear that there was a lack of alignment between the instructors and the previous experiences of the teaching assistants. Despite all of the time invested in developing a constructively-aligned project-based learning course, it appears that student attitudes were influenced by a factor that is not often discussed in course design: teaching assistants. While it may be argued that an effective rubric should overcome these barriers, this was not our experience in this course. The time to design and implement the course was significant for a full-time graduate student and faculty member, and to add the instruction and training of teaching assistants to the course development process would have added an additional demand that was time prohibitive. This is a clear scalability issue, as taking the time to educate and equip all teaching assistants on the benefits of this approach presents yet another barrier. A similar experience has been found with TAs having slow turnaround times on marking, yet during instructor evaluation (promotion, tenure, merit) all TAs are considered equal.

Yet another explanation may be that TAs did not grade any differently than students were used to. The difference may be that students were more attuned to the grades they received on the labs given their increased level of engagement and the time that they had invested in the laboratories. That is, the real change was that the students more closely examined the assessment that they received. With traditional laboratories, students often copy previous reports and thus they may be satisfied if they attain an average grade and are not caught for academic misconduct. Project-based learning has the potential to reduce plagiarism, however it may result in negative student perceptions on assessment.

Time Comparison – Student

According to the university course calendar, this course is expected to consist of up to 39 hours of lecture, 19.5 hours of tutorial and 19.5 hours of laboratories for a total of 78 hours of contact ("Courses of Instruction - How to Use," 2018). Realistically, this is an over-estimate of the hours students spend in contact as holidays, midterms, and unexpected cancellations would reduce this value. Notes were kept on student-team completion times for our design-build experiences, and high and low estimates for actual student time spent on task were calculated. See Table 1 for more information:

Table 1. Breakdown of contact hours for expected, high and low values for this PjBL course

<table>
<tr><th></th><th>Traditional (Expected)</th><th>PjBL – high</th><th>PjBL - low</th></tr>
<tr><td>Lecture Hours</td><td>39</td><td>20* (online)</td><td>20* (online)</td></tr>
<tr><td>In-person Laboratory Hours</td><td>19.5</td><td rowspan="2">48</td><td rowspan="2">37</td></tr>
<tr><td>Tutorial Hours</td><td>19.5</td></tr>
<tr><td>Total Contact</td><td>78</td><td>68</td><td>57</td></tr>
</table>

*While 20 hours may be lower than the traditional value, these hours are compact and spent fully on task; there is no time spent erasing the board or answering questions, for example. In this blended delivery mode, this time was then transferred to the active tutorial and design-build sessions.

It was found that two or three student teams would regularly complete their design-build projects in less than the allocated amount of time. This resulted in the approximation for the low hours students spent in contact at 57 hours (assuming students watched all lecture videos once). There were several teams that consistently took all of the allocated time to complete their builds, and a calculation of their contact was 68 hours, which was ten hours lower than the course calendar contact hours. It is possible that teams that struggled to complete their builds in time were the ones who felt that the workload was heavier than expected.

Students are often expected to spend 1-3 hours on homework per hour of contact time, as estimated by the Carnegie Unit. Following this estimate, students would then be expected to spend 78-234 additional hours per semester on homework for the Summer 2015 fluid mechanics course. Given the shorter summer semester, this equated to 12-36 hours of homework per week. In discussion with several students during the semester, the informal estimate that students said they spent on homework was between 10-15 hours, which was on the lower end of the estimated expectation. Additionally, students admitted to watching the online videos at 2 times the speed, which means that in the extreme case they could have reduced lecture hours from 20 to 10 for the entire course.

There is no evidence that students spent more time than the institutional or standard expectation for similar credit courses. However, it appears that the students' perception is that they spent many more hours on this course than their other courses. This indicates that student engagement and activity per course credit hour increased, meaning that the students were spending more hours of this course actively engaged. In general, it appears that students are used to spending their hours more passively. It is interesting to note that institutional policies often only indicate the number of hours students are expected to be in “contact”; they often say nothing about what the depth and quality of that engagement should be. One assumes that all prescribed contact hours should be spent 100% engaged, but the reality is that this is not the case. One hour watching a concentrated online video or engaged in a project-based learning course is not equivalent to an hour sitting in a traditional lecture. In the future, post-secondary institutional policy improvements could be made to recognize and measure the nuanced differences in engagement levels associated with different methods of delivery.

Time Comparison – Instructor

The design team for this course consisted of a Professor and full-time graduate student. Planning for the Summer 2017 fluid mechanics course began months before the course was offered. Approximately 700 hours (18 hours per formal lecture hour) were spent developing and implementing the five project-based learning experiences for the students. On an institutional scale, instructors typically spend anywhere from 2 to 6 hours per lecture hour developing course notes the first time teaching a course. The development of the project-based learning experiences required, at a minimum, three times the amount of time required to develop a new course. There is a disconnect between institutional support for the number of hours required to develop these experiences and what is budgeted by the institution.

Most research-intensive universities rely to varying levels on the response to USRI Question 1 - *Overall Instruction* (or an equivalent form of question) for faculty Promotion, Tenure, and Merit Increment. As a result, most professors closely monitor their performance on this question and learn to adjust their teaching so as to maximize their score on this question. If an approach to teaching is proven to result in stronger learning outcomes yet requires more time and results in a lower response to USRI Question 1, very few professors would be willing to compromise career success (employment, professional attainment, and salary) for the sake of increased student learning.

Qualitative Instructor Observation

Learning Assessment

Informal discussions with students revealed that the general sentiment was that they did not care too much about the intrinsic value of professional development; what they cared most about was performing well on summative assessments. Grades and summative assessments appeared to provide a form of validation that students enjoyed. While validation can also be achieved formatively, the students didn’t appear to place the same level of importance on this, they expressed much deeper satisfaction based on performance on their exams. It is possible that this was because a large portion of their course grade emphasized performance on quizzes and exams, which the authors felt were important to validate technical learning outcomes.

One of the previously noted student responses to end of term surveys indicated that students perceived a misalignment between assessment weight and time spent on task. What is interesting to note is that at least one third of each quiz/exam was based directly on the design-build project that students completed. In reality, quiz/exams were not separate from, but *encompassed* material that the students engaged with on YouTube, were assessed on Cornell Notes, and reinforced by active clicker tutorials. By the time that students reached a quiz they may have been formatively or summatively assessed on the particular topic four times, not including opportunities for them to peer- and self-assess these topics in their own self-guided study. A very different picture of the ratio of time on task to time assessed would be achieved by taking a holistic constructive alignment view: that is to consider that many assessments often tested the same learning outcomes. With this view, concepts covered in the active learning labs actually represented 52% of assessment (30% came from direct assessment for reports on PjBL activities and the active clicker tutorials, and one-third of the 65% of summative quiz/exam assessments). Students appeared to view summative assessments as isolated from the project-based learning experiences, rather than a reinforcement or validation of the learning from them. This may be as a result of what Norman & Schmidt, (1992) have identified as the challenge of transferring concepts and principles to new contexts. According to their review, numerous studies revealed that:

> *"Any change in the surface features of a problem impedes the transfer so the problem solver does not recognize the similarity of the underlying concept and the analogy is not utilized. Without specific hints less than half of the individuals in an experiment recognize the similarity between a new problem situation and one they have just read and recalled"* (Norman & Schmidt, 1992).

This finding indicates that when it comes to PjBL activities, students may benefit from more explicit explanations of concept transfer on problems and exams.

Another challenge is that assessment for an open-ended project can be difficult. Both students and teaching assistants struggled with the notion of assessing projects that didn't have a black or white answer. Rubrics were developed which clearly communicated expectations for the projects, however markers still seemed to struggle with assessing reports on the open-ended labs. The course design itself placed a large emphasis on the technical components through summative assessments on quizzes and the final (representing 65% of the final grade), while the project component represented only about 25% of the final grade. Due to constraints on marker resources, it was not possible to give open-ended exam questions as this would have been difficult to manage across the different teaching assistants and would have exceeded their assigned hours. While open-ended exam questions do offer one potential solution, it is unclear how objectivity and consistency could be maintained.

There was a trade-off observed in the tension of verifying uptake of technical knowledge while also assessing professional skills. In future iterations of the course, a more integrated approach to assessing technical and professional skills is recommended. The immediate challenge with this approach is that a significant amount of time is required to develop and facilitate the teaching and learning activities, and even more hours would be required to develop and mark integrated assessments (training markers how to grade them effectively is yet another challenge).

Other authors have rejected the effectiveness of PjBL learning in disciplinary courses altogether. Kirschner & Clark, (2006) argue that human cognitive structures inhibit disciplinary learning in minimally-guided contexts. The limitation to this argument is that their study focuses specifically on declarative type knowledge, or the "methods and processes or epistemology of the discipline" (Kirschner & Clark, 2006). They do not discuss the role PjBL can play to developing psychomotor or professional skills within the context of disciplinary knowledge, which was really the gap educational reform initiatives were looking to fill in the first place (Crawley et al., 2014). We have shown in our companion paper (Meikleham et al., 2018) that the benefit of PjBL is that it brings the study of technical disciplinary knowledge into an integrated context where students can experience professional skills growth. Nevertheless, the question arises whether disciplinary courses are the best place to offer project-based learning experiences and what the optimum blend for guided learning and discovery learning is in this case.

Another explanation for student fixation on exam performance is the reality that they have developed in a system that heavily emphasizes students' self-worth through grades and ranking. Despite advocating the importance of professional skills development, potential employers still heavily consider student GPA, and therefore performance on graded assessment remains an important factor for students in engineering. Many students also expressed the belief that professional skills could be developed later when they attained a job.

Ambiguity

There was a clear discomfort with ambiguity that most students expressed during the lab portion. Despite an emphasis on peer assessment which was meant to promote internal group regulation, some students became visibly disengaged from the challenge posed by the projects, rather than motivated. In general, they had a hard time letting go of the idea that there might not be only one answer, and constantly looked to the instructors to provide that correct answer. Students appeared to dislike their instructors playing the role of facilitator.

It must be acknowledged that every project-based learning experience is different. A major limitation to the above findings is that these may not be generalizable to all project-based learning. An important factor to note is that we engaged in many educational innovations at once. We flipped the classroom, utilized active learning tutorials, and engaged in project-based learning design-build experiments. It is unclear how much of the results observed in this paper were as a result of the cumulative effects from these activies. We expect that they can be mainly attributed to the project-based learning portion, as this represented the majority of their time on task, but we cannot substantiate this claim.
Another finding that has become apparent is that student and TA attitudes and the learning culture of the institution impacted the success of this project. Students which

Implications

Our finding is that there are major cultural shifts required for project-based learning to succeed in technical courses in our institution. Due to the heavy emphasis that is placed on end of term evaluations, instructor evaluation mechanisms (end of term student surveys) would likely have to change. We also recommend that students be exposed more regularly to such projects before they are challenged to apply them in the context of disciplinary learning. This finding is in alignment with previous research that argues PjBL experiences are most effective when they are offered consistently throughout a curriculum (Thomas, 2000). A risk in an institution that has not entrenched a culture of constructivist education (Black & Wiliam, 2009; Vygotsky, 1978) is that students not familiar with this approach may negatively perceive their facilitators if they do not have an immediate answer for their question. In the complex open-ended problem space, it is likely that novice instructors and teaching assistants will face this challenge, and practitioners should be aware of this as a factor in implementation. Students unfamiliar with constructivist education may develop a negative perception of the instructor that is unable to answer their questions immediately. This means that there is a risk of further entrenching the traditional teaching culture as instructors may receive poor student evaluations at the end of term.

An additional recommendation is that it appears the students likely would have welcomed more frequent "traditional" problem-solving sessions. Perhaps this would have helped the students to master the more involved technical concepts in a manner they were more comfortable with. Self-guided learning, while offering the benefit of supporting the development of lifelong learning skills, was perhaps too much for the students to handle while they were also engaged in discovery project-based learning. It is possible that conducting a multi-pronged intervention put unrealistic expectations on the students.

It is difficult to ascertain which of the interventions presented in this paper: blended, active, or PjBL learning resulted in the effects observed. While there were many challenges, our findings are not necessarily that these approaches are ineffective, but that instructors must take several contextual factors into consideration before implementing innovative approaches in teaching, else we risk the rejection of these very important methods. For better or worse students and other key stakeholders may not be ready to embrace the process, and the long-term acceptance of these approaches may require a more metered approach to implementation. The findings in this paper support the need for a systemic approach to engineering education reform (Crawley et al., 2014; Edström & Kolmos, 2014).

CONCLUSION

A number of questions arose while offering this project-based learning course. Students, instructors, and marking assistants often struggled with the new roles that were expected of them in this regime, reflecting a need for instructor/teaching assistant development programs in non-traditional teaching methods. A closer examination of end of term surveys (USRIs) indicated that students felt that overall instruction quality decreased when their perceived workload increased. Students felt that their workload was much higher in this course; comparing the number of hours students were expected to spend versus their actual hours spent indicated that this was not the reality. This finding was likely because students were more heavily engaged during contact hours, resulting in the feeling that the workload was too heavy. The negative result experienced in the overall teaching rating may be an important consideration for tenure-track faculty members who are interested in implementing project-based or blended approaches. If institutions place a heavy emphasis on USRIs (or equivalents), which are based on student satisfaction and perception and not necessarily on the quality of their educational development, it appears that existing incentive systems could be a major deterrent to implementation of innovative pedagogy. If project-based learning does result in superior uptake of critical professional skills, and can meaningfully support the development of technical skills, the question becomes: how do we get buy in from the students for the increased level of engagement that is expected of them? How can we also reduce the barriers, such as time and resources, to develop and assess these learning experiences? We expect that findings from this experience would have been different if students had been more exposed to a culture of project-based or blended learning more frequently in their programs. Additionally, we advocate that student end of term surveys must be revised to reflect more meaningful evaluation criteria and an understanding of constructivist teaching methods if innovative pedagogy is to be encouraged. Pleiss et al., (2012) reported that student resistance to change or gaps in understanding can affect attitudes and success of such projects. Such was our experience in this course.

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BIOGRAPHICAL INFORMATION

Alexandra Meikleham *is an MSc student in Mechanical engineering at the University of Calgary in Calgary, Canada. Her current research focuses on human-centered design and on engineering curriculum development.*

Ron Hugo *is Professor of Mechanical and Manufacturing Engineering and the Chair in Engineering Education Innovation in the Schulich School of Engineering. His research interests are in the areas of experimental fluid dynamics, energy systems, and engineering education.*

Robert Brennan *is a Professor of Mechanical and Manufacturing Engineering and Head of Department (Mechanical & Manufacturing Engineering) at the Schulich School of Engineering. He has served on the Canadian Design Engineering Network (CDEN) steering committee, chaired the organizing committee for the second CDEN conference, chaired the Schulich School of Engineering's first Engineering Education Summit, served as an organizing committee member for the CIRP International Design Seminar, and is the current American Society for Engineering Education (ASEE) campus representative for the University of Calgary.*

Corresponding author

Alexandra Meikleham
University of Calgary
2500 University Dr. NW
Calgary, Alberta T2N1N4
1-514-567-8488
alexandra.meikleh1@ucalgary.ca