FIRST YEAR DESIGN AND COMMUNICATION: CHALLENGES AND OPPORTUNITIES

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ABSTRACT

This paper reports on the challenges associated with running a design and communication program for a large cohort of first year students. By aligning the program's learning outcomes, learning activities, and assessment techniques with the CDIO syllabus, the authors show that there is the opportunity to realise the program's objectives in a sustainable manner.

KEYWORDS

Curriculum design, design-implement experiences, active and experiential learning.

INTRODUCTION

In the fall of 2002, the Schulich School of Engineering introduced a design and problem-solving stream to its first year, common core engineering program. This curriculum stream is embodied by two unique, inquiry-based learning courses: ENGG 251 (Design and Communication I) in the fall term and ENGG 253 (Design and Communication II) in the winter term. The idea for these courses came out of an internal engineering common core curriculum redesign process that began in 2000 that was intended to address recommendations by the Canadian Academy of Engineering [1], the Canadian Engineering Accreditation Board [2], and a University of Calgary curriculum redesign initiative [3], as well as address the needs of top-achieving students, re-balance faculty teaching workload, and increase the amount of "experiential learning" in our engineering programs.

In many ways, these courses appeared to achieve the original objectives set out by the 2000 curriculum redesign team. In particular, they demonstrated that it is possible to deliver a hands-on design and communication experience to 600 students per year in a design studio environment that is facilitated by an interdisciplinary team of instructors and graduate students. As well, the courses received a number of accolades from peers in the engineering education community (e.g., "best paper" awards [4] and [5]). However, this initial success did come at a price: as the first year cohort increased by 20% to 720 students per year in the Fall of 2006, the water level lowered sufficiently to further expose the rocks that had been lurking beneath the surface since the courses' inception.

In this paper we report on the challenges associated with running an experiential learning program of the size and complexity of ENGG 251/253. We begin with a summary of a recent study conducted by the Schulich School of Engineering into these courses. This study uncovered a number of issues relating to the courses' operation and the courses' relationship to the engineering common core curriculum. Most notably, the sustainability of the current operating model came into question: i.e., the long-term viability of the instructional model and the financial sustainability of the overall course model.

In order to address the issues raised in this report, the authors have looked closely at the ENGG 251/253 learning outcomes, learning activities, and assessment techniques in the context of the Schulich School of Engineering common core. In the second part of the paper, we place the ENGG 251/253 intended learning outcomes in the context the CDIO syllabus [6] and compare this existing model with a single-term version of ENGG 251/253 that was piloted in the Fall of 2008. The preliminary results of this study show that a single-term version of first year design and communication can address three of the four top-level items of the CDIO syllabus (i.e., items 2 through 4) in a more sustainable manner, with a smaller "footprint" in the common core curriculum.

FIRST YEAR DESIGN AND COMMUNICATION

The Schulich School of Engineering, like most other engineering programs in Canada, provides students with a common first year program before they choose their engineering discipline. Prior to the fall of 2002, this first year program consisted of fairly standard introductory natural science, mathematics and engineering science courses with only a minimal introduction to engineering design. Given increasing emphasis on professional skills development as well as increasing interest in experiential learning in the academic community, the Schulich School of Engineering embarked on a curriculum redesign process that resulted in substantial changes to the way first year, common core engineering was taught at the University of Calgary.

In this section, we provide some background on the motivation for change to the Schulich School of Engineering's first year engineering curriculum and focus our attention on the development of two unique first year design and communication courses. We then summarise the challenges faced in operating these courses and in their impact on first year engineering students.

Common Core Curriculum Redesign

The first year, common core curriculum redesign process that began in 2000 at the Schulich School of Engineering was motivated by a number of factors both internal and external to the University of Calgary. More specifically, the Canadian Academy of Engineering [1] recognised that graduates of engineering schools should have more than just technical and problem-solving skills: they should also be well practised in "soft" or "professional" skills such as team work, communication, project management, etc. Although students were introduced to these concepts in first year prior to curriculum redesign, it was felt that the heavy technical content of the program left little time for students to practice these skills or to digest all of the first year subject matter.

Given the growing interest around this time in moving away from the traditional "chalk and talk" lecture format classes, towards "experiential learning", the University of Calgary embarked on a campus-wide curriculum redesign process [3] that influenced the structure and scope of first year engineering common core curriculum redesign. More specifically, it was felt that, by transforming the traditional lecture-based design, practice and communication courses into a year-long "hands-on" design and communication experience, students would gain core competencies - like those described by the Canadian Academy of Engineering - by the end of first year, they would understand the relevance of lecture material

and appreciate the application of theory from other courses through the integration of subject matter in first year design and communication, and high-achieving students would have ample opportunities to be challenged.

To achieve these goals, it was felt that the first year design and communication courses should be primarily "hands-on". As a result, the courses were structured with 4-1/2 hours of laboratory time per week and only 1 hour of lecture time per week. However, it was also recognised that it was necessary to also teach the "orientation to engineering" topics that would be utilised in the design and communication courses: i.e., learning how to learn, study skills, time management, interpersonal relations, and an overview of all the engineering disciplines. As a result, two "orientation to engineering" courses were proposed to complement the "hands-on" design and communication experiences.

When it came to implementing the curriculum changes however, compromises were made in order to fit the fall and winter term design and communication courses into the first year curriculum while balancing the needs of the various departments for common core courses. As a result, it was soon recognised that the additional courses on "orientation to engineering" could not fit into the curriculum without increasing the overall number of courses in first year. In fact, given that first year design, practice and communication was taught in a single first year course prior the curriculum redesign change, the new design and communications courses resulted in a core first year course (dynamics) being moved to second year. The overall change to the first year curriculum and its impact on second year common core is illustrated in Figure 1.

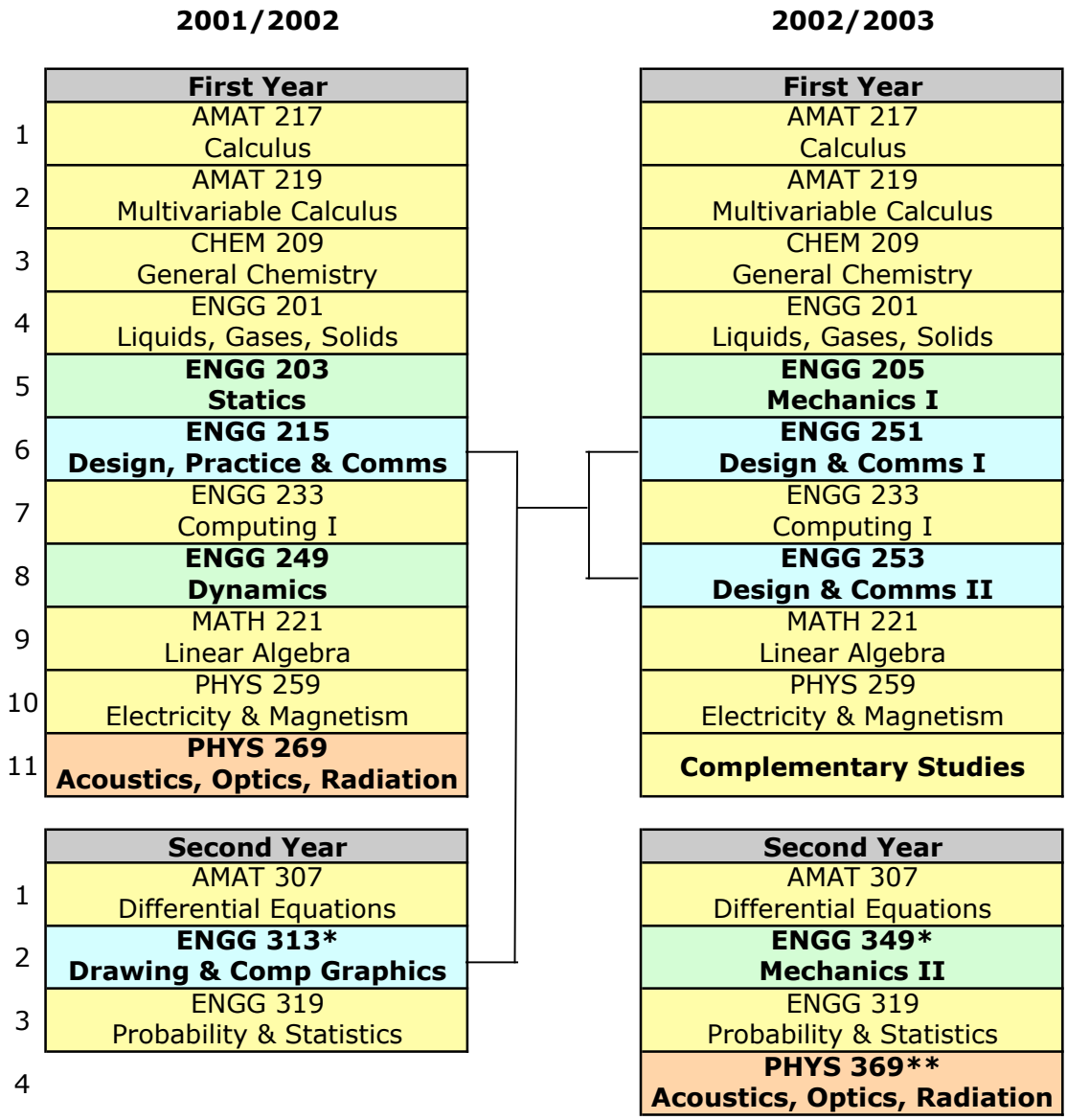
The end result of the curriculum redesign process was a substantial "hands-on" design and communication experience, offered in two courses that spanned both semesters of first year (ENGG 251 and ENGG 253). These courses provided ample opportunities to introduce and utilise many aspects of the CDIO syllabus, but provided little opportunity for teaching these concepts.

Initial Experiences and Observations

As would be expected with the introduction of two experiential learning courses, the total number of instruction hours increased substantially. For example, the total number of instruction hours almost doubled with the new design and communication stream shown in Figure 1: i.e., from 952.5 hours for ENGG 215/313 to 1,879.6 for ENGG 251/253. This increase in instruction hours created a number of operational challenges.

As can be seen in Figure 1, design, practice and communication (i.e., ENGG 215/313) was previously split over two years. Since the second course on graphical communication (i.e., ENGG 313 "Drawing and Computer Graphics"), was not taken by three of the School's nine programs (i.e., Computer, Electrical, and Software Engineering), and since enrolment in second year courses tends to be lower than enrolment in first year courses (i.e., given first year attrition), the change to two first year design and communication courses resulted in a substantial increase in enrolment in this aspect of the first year program.

One may argue that this enrolment change was offset by moving "Engineering Mechanics II" (ENGG 349) to second year (this course is not taken by Computer, Electrical, and Software Engineering). However, our experience has shown that experiential learning courses are much more sensitive to large increases in student enrolment than are more traditional lecture-based natural science and engineering science courses like "dynamics": i.e., substantially increasing the number of students who take a second design and communication course in first year is not offset by an equivalent reduction in the number of students who take "Engineering Mechanics II" in second year.



* except ENCM, ENEL, ENSF
** excpet ENCH, ENOG

Figure 1. Common core curriculum changes from 2001/2002 to 2002/2003

The increase in contact hours and student enrolment created a number of operational challenges when ENGG 251/253 was introduced in the fall of 2002. For example, time-tabling a cohort of 600 students in first year was always a challenge: however, with a course in each term that required a 4-1/2 block of time per week for “hands-on” learning, the time-table became extremely complicated. The result was a very rigid schedule that offered little flexibility for transfer students and/or students who needed to pick-up incomplete courses.

Increased contact hours, combined with the extra teaching workload associated with experiential learning activities, also resulted in a much larger instructor and teaching assistant team. For example, in 2001/2002, the design, practice and communication courses (ENGG 215/313) required 2 instructors per term (three in fall and one in winter) and 17 teaching assistants per term. The move to first year design and communication (ENGG 251/253) in 2002/2003 required the equivalent of 9 instructors and 34 teaching assistants per term. It should be noted as well that the teaching assistant load increased from 40 hours/

term to 60 hours/term. In other words, the change resulted in instructor requirements increasing by a factor of 4.5, and if one factors for actual teaching assistant hours, teaching assistant requirements increasing by a factor of 3.

This significant increase in teaching workload resulted from the increased demands of experiential learning instruction, a desire by the instructor team to run new projects every year (to avoid "roadmaps"), and an increase in student enrolment. Another big factor was course co-ordination. Given the size of the class - and the size of the teaching team - co-ordination became a significant part of the instructors' teaching workload.

The Courses' Impact on the Schulich School of Engineering

As noted previously, the first year design and communications courses quickly received accolades from our peers in the engineering education community for innovative curriculum design (e.g., "best paper" awards [4] and [5] and a 2005 ASME curriculum innovation award). This is certainly an important achievement for the faculty involved in the courses' design. However, it is also important to ask ourselves whether or not the courses are achieving the goals of the original curriculum redesign process in terms of our students' experience and their outcomes relative to the Schulich School of Engineering's common core and departmental curricula and industries needs for future professional engineers.

We conclude this section by first looking at our students' perspective on these courses, then focusing on the courses' outcomes relative to our programs at the Schulich School of Engineering. The next section of this paper will focus on the broader issue of the courses' learning outcomes and their relationship to the CDIO syllabus.

Student impressions of ENGG 251/253 were obtained from interviews with our first and second year students and written comments from the student evaluations of the courses. In general, our students feel that ENGG 251/253 is a good idea and is useful. In particular, students noted that the courses gave them practice and confidence with oral presentations, reports and teamwork; they felt that the engineering drawing instruction was useful; and, they felt that the material on the design process led to greater creativity. An unexpected benefit was also noted: our students consistently noted that the course resulted in camaraderie among students (given the number of team-based activities that they were involved in).

Despite these positive aspects of these courses, all interviewed students agree that appropriate organisation was a challenge and assessment is problematic. These problems appeared to derive from two general areas: (1) class size and complexity, and (2) course management and co-ordination.

The main difficulty appears to be a result of the course instructors' very heavy reliance on the large team of teaching assistants to teach the 4-1/2 hour labs and assess student work. From the student perspective, it appears that there is very little to no interaction with the course instructors: all of their contact is with the teaching assistants. Since the number of teaching assistants is very large, communication becomes an issue. Despite the instructors' best intentions, it is very difficult to get a consistent message out to the students; as a result, students often feel that there is no one to turn to with a question (i.e., they feel that their teaching assistants often do not know the answer) and that they are always directed to the online course management system (Blackboard [7]). Given this hierarchical structure of instruction, students feel removed from the full-time academic instructor team: i.e., students sometimes felt that instructors did not adequately consider their concerns about the course.

The heavy reliance on a large team of teaching assistants also leads to inconsistencies with respect to assessment. For example, students note that there is inconsistency across graders (i.e., "easy" v. "tough" graders) and across assessments (i.e., different grades for the same level of work). Although it is not surprising that there is inconsistency across graders (given the large number of graders), the inconsistency across assessments may be explained by increasing expectations as the course progresses.

The high number of students, instructors, and teaching assistants to be co-ordinated certainly makes organisation problematic. However, some of the instructors' decisions around course management and co-ordination may exacerbate the problem. For example, there is a reluctance to provide "too much" information to students because of the fear that it will stifle student creativity. This is certainly a laudable goal, however given that 34 teaching assistants must be coached to provide the right amount of information - not too much, but not too little - the system can easily break down to one where the student does not know the expectations for a given project and does not know where to turn to for help.

This also leads to a feeling amongst some students that assessment is unfair: i.e., how can they feel that they have been assessed fairly on a project when they don't know what the expectations are for the project?

It should be mentioned that these are student *impressions* of the current first year design and communication courses. A considerable amount of effort is put into course co-ordination and project design by the teaching team; yet, despite this, co-ordinating such a large class and teaching team has its challenges.

One may argue that it is all worthwhile however, if the courses are achieving a clear set of desirable outcomes. In the next section we place these courses in the context of the CDIO syllabus to try to answer this question.

FIRST YEAR DESIGN & COMMUNICATION AND THE CDIO SYLLABUS

Before we look at the learning outcomes for first year design and communication, it is useful to revisit the original objectives for these courses. Given that the original plan was to support first year design and communication with two "orientation to engineering" courses, the original objective was simply to provide students with a significant "hands-on" design experience in the first-year program that integrates subject matter from other common first year courses so that students understand the relevance of lecture material and appreciate the application of theory. However, given that "orientation to engineering" was also rolled into first year design and communication, the courses were also required to place emphasis on students achieving core-competencies by the end of first year.

Although these courses do appear to provide students with a significant "hands-on" learning experience, they fall short of the other objectives with respect to core subject matter integration and core competencies. This is partially because the courses are expected to deliver more than was originally expected of them; but also because they are inherently designed for instructors to "introduce" and for students to "utilise" CDIO syllabus sub-topics [6] through "hands-on" experiences and are not well-suited for instructors to "teach" syllabus sub-topics.

The learning outcomes for the first year design and communication courses fall into three subject areas as summarised in Table 1. The subject area is shown in the top of each column, with the associated intended learning outcomes below.

Learning activities are primarily set-up in the form of projects that integrate at least two, and typically, all three of the course subject areas. Although first year design and communication is structured as two, single-term courses, it effectively runs like a single, two-term course with increasingly challenging projects: i.e., two three-week projects and one seven week project in the first term (ENGG 251) and two half-term projects in the second term (ENGG 253). The earlier (three-week) projects tend to focus on introducing students to the course, team work, hands-on problem solving, and the design process; the longer projects in the first and second terms provide students with the opportunity to utilise these skills and tackle more difficult, multi-step projects with multiple deliverables.

Table 1
First Year Design and Communication Intended Learning Outcomes

Engineering Design	Visual Communication	Oral & Written Communication
Apply engineering design strategies to a wide variety of real-world, open-ended problems.	Develop the ability to sketch preliminary design concepts using isometric and orthographic projections.	Demonstrate effective written communication skills: audience focus, clear purpose, concise and effective content.
Develop design solutions within the constraints of time and resources.	Demonstrate a basic understanding of dimensioning and tolerancing.	Report progress and results using a variety of written, oral and visual formats.
Work effectively in teams.	Incorporate multiple design styles and visualization methods to generate design concepts throughout the design project.	

The two-term format gives the teaching team the opportunity to gradually ease students into more challenging projects by the second term and affords student teams with more opportunities to practice design and communication. However, it is not clear that, after one term and three projects, the second course is adding much more in terms of learning outcomes. In particular, the benefits of extra practice in the second term must be weighed with the challenges noted previously. Given that many of the challenges result from the large class size and high contact hours associated with the existing courses, we felt that it would be worthwhile to test a smaller-scale version of the courses that would be more manageable and sustainable in the long-term. The idea was to pilot a single-term version of the course with an even balance between lecture and lab hours: this would allow for a smaller student cohort (i.e., it could be run for one half of our first year cohort in the first term, and for the second half in the second term), more opportunities to introduce and teach subject matter, but also ample opportunities to utilise skills in the project-based labs/seminars.

In the spring/summer of 2008, a single-term course was developed with the objective of introducing students to design, communication and leadership, and to try to provide students with a better understanding of what engineering is. This course was piloted with a small group of students (20 students) in the fall of 2008.
Table 2 provides an overview of the current first year design and communication courses' learning outcomes and the pilot course's learning outcomes in the context of the CDIO syllabus. For detailed descriptions of the CDIO syllabus items and the sub-topics emphasised in the CDIO syllabus, please refer to [6]. It should be noted that, given that first year design and communication (ENGG 251/253) introduces new projects every year, the learning outcomes may vary somewhat. For example, recent projects used homelessness as a theme area and resulted in many of the sub-topics in "societal & external context" being addressed. For consistency, Table 2 only reflects those learning outcomes that are addressed every year, regardless of the projects.

Table 2
First Year Design and Communication and the CDIO Syllabus

CDIO SYLLABUS ITEM	FIRST-YEAR COURSE	INTRODUCE/ TEACH/ UTILIZE	EMPHASIZED SUBTOPICS IN CDIO SYLLABUS
2.1 Engineering Reasoning & Problem Solving	ENGG 251	T, U	2.1.1,2.1.2,2.1.5
	ENGG 253	T, U	2.1.1,2.1.2,2.1.3, 2.1.4,2.1.5
	Pilot	T,U	2.1.1,2.1.2,2.1.5
2.2 Experimentation & Knowledge Discovery	ENGG 251	T,U	2.2.1-2
	ENGG 253	T, U	2.2.1-2, 2.2.3
	Pilot	T, U	2.2.2
2.3 System Thinking	ENGG 251	T,U	2.3.1,2.3.3,2.3.4
	ENGG 253	T,U	2.3.1,2.3.3,2.3.4
	Pilot	T,U	2.3.1,2.3.3,2.3.4
2.4 Personal Skills & Attitudes	ENGG 251	T,U	2.4.1,2.4.2,2.4.3,2.4.4,2.4.5,2.4.7
	ENGG 253	T,U	2.4.1,2.4.2,2.4.3,2.4.4,2.4.5,2.4.7
	Pilot	T,U	2.4.3,2.4.4,2.4.5,2.4.7
2.5 Professional Skills & Attitudes	ENGG 251	I	2.5.1,2.5.2,2.5.4
	ENGG 253	I	2.5.1,2.5.2,2.5.4
	Pilot	I	2.5.1,2.5.2,2.5.4
3.1 Teamwork	ENGG 251	T, U	3.1.1,3.1.2,3.1.4
	ENGG 253	I, U	3.1.1,3.1.2,3.1.3,3.1.4
	Pilot	T, U	3.1.1,3.1.2,3.1.4
3.2 Communications	ENGG 251	T, U	3.2.1,3.2.2,3.2.4,3.2.5,3.2.6
	ENGG 253	T, U	3.2.1,3.2.2,3.2.4,3.2.5,3.2.6
	Pilot	T, U	3.2.4,3.2.5,3.2.6
4.1 Societal & External Context	ENGG 251	T	4.1.2-4.1.3
	ENGG 253	T	4.1.2-4.1.4,4.1.6
	Pilot	I	4.1.2-4.1.4
4.2 Enterprise & Business Context	ENGG 251	I	4.2.4
	ENGG 253	I	4.2.4
	Pilot	I	4.2.4
4.3 Conceiving & Engineering Systems	ENGG 251	T, U	4.3.1,4.3.2,4.2.4
	ENGG 253	T, U	4.3.1,4.3.2,4.2.4
	Pilot	T, U	4.3.1,4.3.2,4.2.4
4.4 Designing	ENGG 251	T, U	4.4.1-5
	ENGG 253	T, U	4.4.1-5
	Pilot	T, U	4.4.1,4.4.2,4.4.4,4.4.5
4.5 Implementing	ENGG 251	T,U	4.5.1,4.5.3
	ENGG 253	T,U	4.5.1,4.5.3
	Pilot	T,U	4.5.1,4.5.3,4.5.5-6
4.6 Operating	ENGG 251	I	4.6.5
	ENGG 253	I	4.6.5
	Pilot		

This assessment of the current first year design and communication courses' learning outcomes and the pilot course's learning outcomes was performed by the instructors of these courses. In all cases, the course syllabus (i.e., "course outline") was used as a starting point; the courses' detailed syllabi, learning activities and assessment tools were then analysed in the context of the CDIO syllabus to develop the summary shown in Table 2.

Our comparison with the CDIO syllabus is intended to supplement similar comparisons of first year design courses at other CDIO institutions (e.g., [8] and [9]) and also help inform our

work on intended learning outcomes for these courses. For example, from a learning outcomes point of view, it can be seen from Table 2, there is very little difference between the learning outcomes of the existing design and communication courses and the single term pilot course. The main difference is that the two course model spends more time on first year design and communication than the one course model, and as a result provides more opportunities for students to utilise the syllabus sub-topics (this is not necessarily reflected in Table 2). However, without proportionally higher opportunities to introduce and teach these syllabus, the value of this extra practice time is not clear.

The existing first year design and communication course also devotes more of its syllabus to communications that the one term pilot course. A full-time, oral and written communications instructor and a full-time graphical communications instructor are assigned to the two term design and communication course, and the one-hour per week lectures are split 50% for oral & written communication and 50% for graphical communication. Alternatively, the one term pilot course relies on the course instructor to integrate oral & written communication into the curriculum, but still relies on a full-time graphical communication instructor for the drawing labs/seminars.

While the existing ENGG 251/253 model appears to be effective for drawing instruction, a recent audit of the oral and written communication aspect of the courses has shown that this aspect of the communications curriculum is not as effective. More specifically, students require more one-on-one feedback and assessment on their writing and presentations and many opportunities to practice. Although students have the opportunity to give one individual presentation in ENGG 251 and one individual presentation in ENGG 253, it is very difficult to provide the level of feedback and one-on-one attention to individual writing in classes the size of ENGG 251 and ENGG 253. Smaller classes, with more opportunities for oral and written communication practice are part of the engineering common core curriculum in second year (as part of a core technical communication course); although, the single-term course has less of an emphasis on communications strategy and structure, these outcomes are already part of the engineering common core curriculum and are offered in a manner that is more conducive to oral and written communication practice and assessment.

Finally, it should be noted that there is very little difference between the learning outcomes from the first term of the current design and communication model (ENGG 251) and from the second term (ENGG 253). Again, the two-term model provides students with more opportunities to practice introductory design and communication skills; however, given the challenges noted previously, it is not clear that this extra practice is justified.

SUMMARY AND NEXT STEPS

Based on our experience with the single term pilot course, it appears that students can receive a sufficient introduction to design, communication and leadership within the framework of a single course. Extending this experience over an entire year may blur the objectives of the course from the perspective of the students.

However, based on our experience with the two term design and communications courses, care must be taken to ensure that the single term courses does not become an attempt to “do everything”. The course should focus mostly on design, teamwork, leadership and communications. As well, there should be a brief introduction to the engineering profession and the various engineering disciplines.

As noted previously, the single term design course’s contact hours are spread evenly across lectures and labs (as opposed to the current model’s heavy weighting on lab hours). This will likely involve a slight increase in the outside-of-class work by our students, but a much more manageable timetable. This model also gives the instructors the opportunity to introduce students to concepts in design, communications and engineering more readily than with the current model, sends a better message about the importance of the material, and increases students’ “connection” with their course instructor.

Looking forward, the Schulich School of Engineering is now in the process of reviewing the first year curriculum with this work on first year design and communication as a basis. This is only one part of the puzzle however. As noted previously, the change to design, communication and problem solving in 2002/2003 resulted in other major changes to the first and second year curriculum. The School's curriculum committees are now looking at the overall picture in order structure our first and second year programs in a way that serves the needs of each of our nine engineering programs.

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