Supporting Active Learning Through Team Based Problem Solving and Simulation in an Integrated Biomedical Engineering Course

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Abstract *– In this paper the planning, implementation, and analysis of active learning techniques introduced into a new integrated course designed for second-year Biomedical Engineering students at the University of British Columbia are presented. The course included foundation material on circuit analysis, electromagnetics, and vector calculus. The course was delivered using a blended learning format, incorporating video content, traditional lecture time, and team based in-class problem solving. In general the problem solving activities were well received, but several adjustments were necessary during the term to optimize the effectiveness of the team-based activities. Student feedback and course outcomes are presented and discussed in the paper.*

Keywords: team-based learning, active learning, problem solving, simulation tools, electromagnetics, circuits, vector calculus, biomedical engineering

1. INTRODUCTION

A new Bachelor of Applied Science degree in Biomedical Engineering (BMEG) has recently been developed and launched at the University of British Columbia (UBC). This program was developed in partnership with the Faculty of Medicine (FoM), and is managed by the newly formed School of Biomedical Engineering (SBME), which is also a partnership between the Faculty of Applied Science (APSC) and the FoM. The first cohort of second year students were accepted for the 2018 winter academic session.

The BMEG program was designed to have a common second year that supports four diverse thematic streams in the third and fourth year of the program: Cellular Bioengineering, Biomedical Informatics, Biomedical Systems & Signals, and Biomechanics & Biomaterials. Students aren't required to choose a stream until the end of second year. Given the diversity of the foundation material required, a big challenge faced during curriculum design was the need to provide sufficient foundation material to support all four streams while ensuring the total credit load remained comparable to other second year programs at UBC. To accomplish this, seven new BMEG courses were created for the second-year program. Each course is designed to efficiently provide core content on which the four streams are built. The focus of this paper, BMEG 220: Circuits and Electromagnetics with Application to Biomedical Engineering, is a prerequisite for a core third year course, and is most closely connected with the Biomedical Systems & Signals stream. The content in BMEG 220 is also highly relevant to engineering design projects and lab courses in years two through four. This first offering of the course had an enrolment of 50 students.

2. COURSE DETAILS

2.1. Course Overview

Inspired by the previous successful combination of vector calculus and electromagnetics topics in the Electrical Engineering program [1], the new course integrates one credit of vector calculus with two credits of electromagnetics and two credits of circuit analysis. In the Electrical Engineering program at UBC, a student would take a sequence of two circuits courses covering DC and AC circuits and introductory electronics, as well as the electromagnetics course described in [1]. BMEG 220 is intended to be more efficient in terms of credit load and student workload. This is accomplished both by the curation of the material to prioritize the most critical content to support future learning, and by consolidating the coverage of certain topics that would normally appear in both courses. As an example, the electromagnetic and material properties of resistors, capacitors, and inductors were integrated into content on their behavior, use, and analysis in electric circuits. A final goal for this course was to incorporate biomedical engineering applications to motivate the relevance of the material in this discipline.

2.2. Learning Objectives

The learning objectives for the course are divided into four groups: vector calculus, electrostatics, magnetostatics and circuit analysis.

For vector calculus, students were expected to:

- work comfortably, and perform a variety of mathematical operations, with vector quantities
- set up and evaluate line, surface, and volume integrals in multiple coordinate systems
- convert word problems to mathematical equations (and then solve them)
- use the Divergence Theorem and Stokes' Theorem to solve problems

- determine when a given vector field is conservative

For electrostatics, students were expected to:

- solve for the force on charged structures in the presence of electric fields
- solve for the electric field at a point due to a variety of charge distributions
- find the electric field given the electric potential, and vice versa
- apply Gauss' law to find electric field distributions resulting from charge distributions
- use boundary conditions to determine the effect of different materials on electric fields
- evaluate the resistance, and capacitance of a variety of structures

For magnetostatics, students were expected to:

- apply Ampere's law to find magnetic field distributions resulting from current distributions
- describe the different types of magnetic materials
- evaluate self and mutual inductance of a variety of structures
- analyze the behavior of conducting structures in the presence of a time-varying magnetic field
- explain and apply Maxwell's equations
- use engineering tools to simulate electromagnetic models

For circuit analysis students were expected to:

- apply nodal and mesh analysis to solve for currents and voltages in lumped planar circuits
- apply Norton and Thevenin's theorems to find resistive equivalents of electrical circuits
- analyze circuits including ideal and non-ideal operational amplifiers
- analyze the transient response of RC, RL and RLC circuits
- use phasor algebra to find steady state sinusoidal response of AC circuits
- characterize AC filters based on their frequency response

2.3. Course Structure

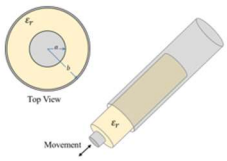
The course used a blended learning format, combining lectures and hands-on activities in student teams. Each week followed a repeatable pattern of activities. Students were expected to watch one or two short videos, made or chosen by their instructor, and answer a short mini-quiz online prior to the start of each week. The class time (1 hour on Mondays, and 2 hours each on Tuesdays and Thursdays) was divided into five 50-min sessions (referred to as "units" throughout this paper). A typical week included one unit of vector calculus lecture, two units of electromagnetics or circuit analysis lecture and two "activity units". Each activity unit included a variety of team-based problem solving and simulation activities. Students had weekly assignments facilitated through the WeBWorK platform [2] which were available throughout the week and due at the start of the following week. Formal assessment included five biweekly quizzes and a final examination. Each test had both an individual and group portion. Students had access to several textbooks at no cost through a combination of open source resources and online versions of texts made available through the UBC Library.

2.4. Problem Solving in Teams

The students were grouped randomly in teams of 3 at the start of the term. They worked with the same team during all activity units, as well as the group stage of the quizzes and the final exam. Each activity unit was supported with a worksheet that included 1 to 2 problems and/or simulation tasks. The second problem was generally a more challenging extension of the first problem. One instructor and two TAs circulated around the room and continually engaged student teams. Problems covered classic examples of electromagnetic structures and circuit topologies while having a biomedical engineering flavor to motivative student engagement. Each team was provided with a large table-top whiteboard and markers to facilitate collaboration in a traditional classroom.

The worksheets were designed to give practice on topics immediately following the lecture unit. To help student teams follow the right problem solving strategy, the problem was divided into several intermediate steps. As an example, Fig. 1 shows an in-class worksheet problem for the topic "Calculating Capacitance of Structures". In this case, the problem is asking about the capacitance of a

A capacitive pressure sensor is made of a movable dielectric core that slides inside a hollow metal tube, as shown in the figure below. Fairly accurate sensors of this type are industrially available, and can have a measurement range of 250 mm with a resolution of 0.5 μm.



The voltage V_o is applied between the inner and outer conducting cylinders. We want to find the total capacitance, when the sliding core is fully inside the metal tube. Assume that the inner and the outer tubes have radii a, and b respectively, and that the length of both is L. Follow the steps described next to find the capacitance using the formula $C = \frac{Q}{V}$.

1) *Imagine a charge density $+\rho_s$ on the inner cylinder. Use Gauss's law to draw and calculate electric field density $\vec{D}$ and the electric field $\vec{E}$, at distance $\rho = \rho'$ inside the dielectric.*
2) *Find the charge density ρ_s, and the total charge Q on the surface of the inner cylinder in terms of V_0.*
3) *What is the capacitance ($C = \frac{Q}{V}$) of the system?*
4) *Calculate the total energy stored in the system.*

Fig. 1. Example of a worksheet problem on calculating the capacitance of a cylindrical structure.

cylindrical tube, reinforcing similar steps that were taken in the calculation of the capacitance of a spherical structure, presented directly beforehand in the lecture.

2.5. Simulation Tools

In the original design of the course, it was intended that students would use two simulation tools, Electromagnetic-Works (EMWorks) and PartSim, in portions of the activity units during the term. EMWorks, a plugin for Solidworks, is designed for modeling, simulation and visualization of electric and magnetic fields [3]. PartSim is a web-based simulation platform for circuit analysis. As will be discussed in section 4, the simulation component proved to have some challenges, and as a result was only used infrequently.

3. RESULTS

In this section, student performance and feedback is presented. Emphasis is on the relationship between student preparation for the class, engagement in team activities, and the individual performance in a start-of-term diagnostic test, assignments, and tests throughout the term.

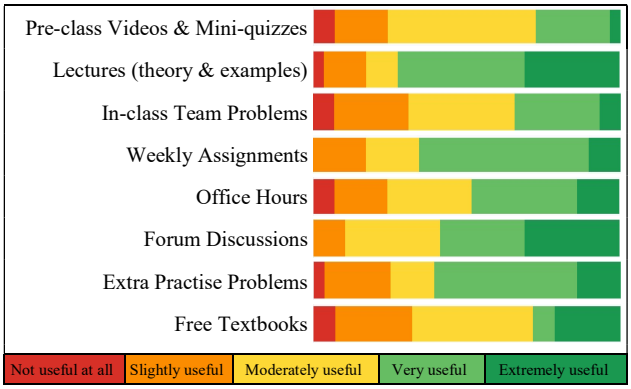
3.1. Mid-course Student Survey

A 10-min long anonymous survey was administered in the middle of the course, during the reading break. The survey had three short pages, and was focused on the experience of the students with course resources and team-based learning. The response rate for the survey was 58%.

3.1.1. Usefulness of Course Resources. Table 1 shows the student response to the first question of the survey, where they were asked to "rate the impact of the following course resources on their learning". Not surprisingly, the most popular resource still remained to be the class lectures (mean score 3.83/5), followed by forum discussions (3.79), and the weekly online assignments on the WeBWorK platform (3.59). Students also showed appreciation for extra practise problems (3.46) more than the in-class team-problems (3.03), and their free textbooks (3.11). A score of 3 corresponded to the option "moderately useful".

To understand the relationship between the self-reported usefulness and the actual use of the optional resources in the course, we looked at the use of the discussion forum and the extra practice problems. On average, from the total of 240 posts on the Piazza forum, each student viewed 113 ($\min = 0, \max = 204$), and contributed to 12 ($\min = 0, \max = 92$). This shows that the majority of the students were "listeners" on the forum, reading instructor responses to others' questions. For the two review packages shared on the WeBWorK platform for extra practise, the use pattern was different: the review package on DC circuit analysis saw 40% of the students attempting on average 4 of the 8 problems, while an electrostatic review package released at the reading break was attempted by only a few students. We suspect that the release timing of these review packages was crucial in their uptake by the students. The circuits package was released shortly before the relevant quiz, while the electrostatics package was released at a time when the next assessment of this material was the final exam, which was several week in the future.

Table 1: Student mid-course feedback on the impact of different resources on their learning.



3.1.2. In-class Problem Solving. In the second question of the survey, students were asked to give their feedback on the in-class team problem solving activities by selecting one option per statement. Table 2 shows the average "agreement" score on each of the statements. On average, students found that dividing the 2-hour sessions between lecture and activity units made the sessions more active and engaging. As expected, the formatting of the problems into several steps was very popular with the class.

Completing the worksheets was a for-credit activity, with 10% of the course grade allotted to it. As the course progressed, management of these activities required multiple adjustments in response to student progress. Initially it was assumed that students would complete the worksheets in class, but it became apparent that most teams were not able to do so. Students were then given the option to hand in any unfinished portions of the worksheet at the

Table 2: Student mid-course feedback on the impact of different resources on their learning. Scores 1 to 5 correspond to "strongly disagree" to "strongly agree".

	Mean	Std
Compared to a 2hr lecture, I find the team portion makes the class more active and engaging.	3.79	1.21
I believe solving problems in my team helps me practise problem solving.	3.59	1.16
I like that the in-class problems include step-by-step instructions.	4.10	1.06
I like having the option to return the second problem later in the week.	2.76	1.45
I like having PartSim or EMWorks simulations included in the team problems.	2.31	0.91

beginning of the next class. Regarding this change in hand-in policy, student feedback in the mid-course survey was surprising. While the instructor has observed a positive shift in students' attitude and engagement pattern with the worksheets, it seemed that students didn't find working outside of the classroom with their team convenient.

Students were also not in favor of having simulations incorporated in the worksheet problems. This, as the instructor soon realized, was due to the very compact nature of the course schedule, and the fact that such simulations were not tightly tied to any assessment in the course. As expected, students tended to underestimate the learning impact of such tools in understanding and visualization of abstract concepts such as fields and potential, favoring their omission to achieve a more manageable workload in the activity units.

3.1.3. Teamwork. In the third question on the survey students were asked to "provide a reflection on their practices as a member of their team" by selecting one option per statement. Students were reminded that their responses would be anonymous. Table 3 shows on average how often students identified with each of the statements. Overall, students self-reported that most of the time, they come to the class ready, they felt comfortable sharing their thoughts with their team, they contributed to their team constructively, and they felt responsible for finishing the work on time. Nevertheless, students mentioned they only sometimes reviewed the solutions to the worksheet problems later on, with 5 students stating they never did so. This may have been a source of the challenges some students experienced in the quizzes.

Table 3: Student mid-course reflection on their practices as a member of their team. Scores 1 to 5 correspond to "never" to "always".

	Mean	Std
To be ready for teamwork, I attend the lectures and do the pre-class activities.	4.69	0.65
I feel comfortable sharing my thoughts and ideas with my team.	4.69	0.83
I feel responsible for finishing the problems on-time, and completing the in-home section.	4.41	1
I feel I contribute constructively to my team.	4.66	0.71
I review the solutions later, either on Piazza or with my classmates.	2.62	1.19

The next question on the survey asked students to rate their experience with their teammates on statements similar to the ones they used for self-reflection. This question was added to the survey as an anonymous alternative to the iPeer evaluations. Table 4 shows a summary of the student responses. Although the average score on each statement is slightly lower than its corresponding statement in Table 3, there are no statistically significant differences.

Table 4: Student mid-course reflection on their experience with their teammates. Scores 1 to 5 correspond to "never" to "always".

	Mean	Std
To be ready for teamwork, my teammates attend the lectures and do the pre-class activities.	4.52	0.56
My teammates are respectful and listening when I want to share my thoughts and ideas.	4.48	0.97
My teammates share responsibility for finishing the problems on-time, and completing the 2nd problem.	4.31	0.95
My teammates contribute constructively to our team.	4.59	0.89

3.1.4. Success Stories and Challenges. The last three questions on the survey were designed to gather deeper student feedback. We asked students what had been working well for them so far in the course, what they found challenging, and what changes they would recommend to enhance their learning experience. In the following paragraphs, we thematically categorize the responses.

From the 26 students who wrote in response to what has been working well so far for them in the course, 14 mentioned teamwork with 4 specifically mentioning how they find the bouncing between lectures and teamwork in the same session useful. One student wrote: "*I like the two different teaching styles bouncing off each other. It gives a more well-rounded understanding of what is going on."* Another student wrote: *"The lectures are great, especially the examples and the notes getting posted online. The in-class assignments help me apply what I learn immediately, which is useful for long-term memory. "Arguing" with my teammates is actually quite fun and helps me realize my own misunderstanding*.". Another student compared their active learning experience in mixed lecture-teamwork sessions with 2hr lectures: "*I like the structure of the class. I like the team portion also. Two-hour lectures are very exhausting and I do not learn anything, in-fact it gives me more work because I have to go home re-read and re-write all my notes again and then do webwork which is not always as useful.*" Getting immediate feedback from their peers, TAs and the instructor was repeatedly mentioned. One student wrote: *"(I like) the group work. Having time to actually run through some questions and getting immediate feedback is very helpful.*" Students clearly still enjoyed having the traditional lectures with example problems solved by their instructors, as part of these sessions. One student wrote "*I have enjoyed lectures as they give me a strong foundation and clearly lay out the concepts in a way, I can refer to later*".

Students were further asked to identify the challenges they had faced so far. From 26 who replied, 14 students mentioned they had been struggling with keeping up with the syllabus, as the topics moved quickly, and didn't give them enough time to prepare. One student wrote: "*the combination of challenging mathematical concepts with difficult geometry and hard to understand (at least for me)*

E and M concepts." Another student commented: "*The material has been very challenging for me. I find that when I'm just starting to understand a concept we move onto another topic*." Students were also challenged by the first two quizzes, finding them hard and/or too long. One student wrote: "*I find that the quizzes are short on time. It might be nice to see where marks are allocated for each question so I can manage my time better in the quizzes."* Five students also mentioned that the weekly assignments administered on the WeBWorK platform were much harder than what they had expected, with some admitting they couldn't finish part of them without asking for help from their peers. One student wrote: "… *I also find the webworks (are) quite challenging and (I) cannot finish them on my own; the last couple (of) questions I have to ask my peers (to) help with.*" There were a few students who experienced difficulty with team activity units, and found it difficult to transition from the lecture to the problem solving in their teams. One student wrote: "… *I find my teammates sometimes don't participate in learning the material during the in-class activities; they sometimes seem pre-occupied in just finding the appropriate formula (without the background information needed to understand the formula) and plugging in our variables*." Another student commented: "… *quickly learning new material and then jumping into group work has made it very challenging to understand what is going on. There is no time to go over what has just been taught and try to absorb it before being thrown into group work*."

The last question on the survey asked students to identify changes that could improve their learning experience. Again, 26 students responded, with 12 of them asking for more examples solved in the lecture units by the instructors. One student wrote: "*It would be nice to have more time for some examples during class because I think they would help to further understand the concepts*." A few suggested decreasing the length of the team activity unit in favor of the lecture time. One student wrote: "*I would recommend maybe spending a bit more time in lecture explaining the new concepts or going at a slower pace so we can ask questions before we go into group work. So, I recommend shortening the group work a bit.*" Several students also mentioned they'd like to see some modification to the quizzes, either by making them shorter or less heavy on calculations. One student wrote: "*If the tests only involved setting up the solutions or if there were fewer questions, I think that they would be able to more accurately represent what we have learned*." Some students wanted the instructors to share more practice problems so that they can prepare better for the exams. One student wrote: "*I would love to see more optional webworks/practice problems which directly relate to the learning objectives for the week*."

3.2. Student Performance

Table 5 shows a statistical summary of the student performance in different evaluation modules of the course as measured at the end of the term. It also includes the final grade. Four students failed the course due to an inadequate individual score. Their failing grade was capped at 47 and is shown as "Fail" in the last row of the table. Table 6 shows the correlation between different evaluation modules in the course.

Table 5: Student performance measured at the end of the term.

Performance Module	Mean %	Median %	Std %	Min %	Max %
Diagnostic Test (0%)	40.6	43.8	12.6	18.75	68.75
Weekly Assignments (10%)	93.3	98.6	15.9	37.4	100.0
Bi-weekly Quizzes (32%)	62.5	62.6	13.8	33.4	97.2
In-class Team Problems (10%)	83.5	84.8	10.2	54.3	99.1
Pre-class Mini-quizzes (3%)	88.6	92.3	13.2	47.4	100.0
Final Exam (45%)	66.9	66.0	14.3	36	99.0
Final Grade (100%)	70.8	70.7	11.5	Fail	99.3

Table 6: Correlation (R^2 values) between different student evaluation modules by the end of the term.

	DT	WA	BQ	ITP	PQ	FE
Diagnostic Test (DT)	1.0	0.2	0.5	0.0	0.2	0.4
Weekly Assignments (WA)		1.0	0.2	0.2	0.6	0.3
Bi-weekly Quizzes (BQ)			1.0	0.1	0.1	0.6
In-class Team Problems (ITP)				1.0	0.4	0.1
Pre-class Quizzes (PQ)					1.0	0.1
Final Exam (FE)						1.0

It is worth noting that the score on the diagnostic test - which included 16 conceptual multiple-choice questions and was administered on the first day of class - showed relatively higher correlation with the scores on the quizzes and the final exam, compared to the scores on the weekly homework or team assignments. A factor explaining this discrepancy could lie in the individual vs. team effort. Instructors suspect that during the term many students resorted to finishing the weekly WeBWorK assignments, for which each student has a unique set of values for selected variables, by asking their peers for algebraic solutions to the problems. This observation was confirmed by some of the comments left on the mid-course survey and mentioned during the office hours. As the result, the average for the weekly assignments (93.3%) ended up being much higher than that of the tests. The same is true for the pre-class mini-quizzes, which were also administered on the WeBWorK platform. As expected, the

correlation between the scores for the bi-weekly quizzes and the final exam was reasonably strong.

3.3. Peer Evaluations

Three iPeer evaluations were carried out during the term on Jan 28th, Mar 22nd, and Apr 19th, using the rubric shown in Table 7. For each criterion on the rubric, students needed to enter a "constructive" comment. They were also asked to self-evaluate their own contributions to their teams. The first two evaluations did not count for any marks, but students were told that their final team grade could be affected by the mark they receive in the last peer evaluation. For this reason, the results of the last iPeer evaluation were kept confidential. To motivate students to participate, late or non-responses were penalised by the mark students obtained during their last in-class team activity unit. Nevertheless, about 12-14% of the students did not participate in the evaluations.

Students showed different levels of commitment towards completing the iPeer evaluations. While some students tried to get by with minimum contribution to the process, the others took the time to leave comprehensive and constructive feedback for their peers. Giving respectful and constructive feedback was introduced in a first-year course and it was encouraging that some students appeared to have applied what they had learned previously [4].

In the self-assessment piece of the first evaluation one student wrote: "*To improve, I think I need to work on not getting frustrated when I feel confused or when I feel as if I don't understand the material as well as I want to. I will do more to prepare (using) the previous notes and read(ing) the appropriate textbook sections to overcome the confusion*." Another student left the following comment for their peer: "*I really like the suggestions you bring forward, I do hope however, that you will become less afraid of making a mistake in the future. When we are suggesting ideas for a problem it seems like you are thinking a lot just not out loud until your idea is refined."* Another student wrote: *"You are extremely smart and remember a lot and as a consequence contribute strong ideas, however I would really appreciate if we could discuss and ponder problems before asking the prof or TA for help."* Students knew that their comments on the final evaluation would be only read by the instructor (and not their peers), nevertheless, some still left detailed comments commending the good qualities of their teammates. This showed that they were genuinely interested in their teammates getting full marks for the team activity units. One student wrote: *"It was great to work with "A" as he is a very friendly and approachable person. He is willing to teach and also be taught concepts and is welcoming to testing his abilities and to challenging the group as well."* Another student wrote: *""I have enjoyed working with "B" throughout the term. She always has a great attitude to problem solving and is never overwhelmed at the task at hand... I wish she was more comfortable sharing her thoughts on a problem. We are all learning and it is okay to share something with the possibility of it being incorrect…""* These are only few examples of several positive and constructive comments that were shared over the platform during the term.

Table 7: Rubric designed for peer evaluation on the iPeer platform. Each criterion is divided into four grade levels. Students were also asked to leave written comments on each section.

Overall contributions	1	Rarely provides useful ideas. May refuse to participate.
	2	Sometimes provides useful ideas. A satisfactory group member who does what is required.
	3	Usually provides useful ideas. A strong group member who tries hard!
	4	Routinely provides useful ideas when participating in team discussion. A leader who contributes a lot of effort.
Contribution to Problem Solving	1	Comes unprepared. Does not try to solve or help others solve problems.
	2	Does not suggest solutions, but is willing to try out solutions suggested by others.
	3	Has reviewed the content beforehand. Refines solutions suggested by others.
	4	Comes prepared. Actively suggests solutions and refines solutions suggested by others.
Contribution to Group Process	1	Doesn't care about the group work and cannot be counted on.
	2	Shows minimum interest in the group work. Occasionally is absent.
	3	Cares about the group work, but occasionally is late.
	4	Always follows through commitments; attends and is on time.
Attitude Towards Teammates	1	Is rude OR disrespectful of others.
	2	May sit back and let others take control, OR may "take over" and be unnecessary argumentative.
	3	Is usually attentive and respectful; may show some frustration towards opposing opinions.
	4	Encourages others to speak and listens respectfully to the opinions of the others.

4. DISCUSSION

Teamwork during class, and group stage of the exams had their own challenges but proved to be very useful and popular with the students. As the course progressed, it was realized that conceptual problems were better suited for teamwork, as they prompted deeper conversations among the members. An example includes successful administration of 10 multiple choice questions, identical to the ones used in UBC ELEC 211 [1], in the group stage of the final exam, which resulted in an average score of 74% as compared to an average score of 61% for the same questions attempted individually by students in ELEC 211. While efforts will be made next year to include more conceptual problems in the activity units, maintaining a

balance between conceptual and numerical problems will be important in building problem solving skills.

This offering of BMEG 220 was also successful in covering a wide range of topics across the four subjects, making the students ready for their core third year course on bioinstrumentation. By the end of the course, the students had accomplished a lot, although it did take a significant amount of time for students to adapt to the pace of the course and the volume of material to be covered. Reflecting on the student feedback and performance, instructors are considering making more room for deeper learning by reducing the number of topics included in the syllabus in the next offering. This may help students to gain confidence with the material without feeling overwhelmed. It will perhaps also allow more frequent use of the simulation tools and incorporation of biomedical applications, the two elements of the course that were not fully realised in the fast pace of the current syllabus.

A few adjustments to the in-class team policies, content of the worksheets and the bi-weekly quizzes were made to optimize student performance as observed by the instructional team, and address the issues raised by the students.

The mid-course survey results showed that students were still not fully clear on how the in-class team problems related to their experience in their assignments and their bi-weekly quizzes. They took the in-class problems as separate modules, and were not reviewing them as a resource when studying for quizzes. At the beginning of the term, worksheets usually included two problems on the assumption that some groups would work faster than others. However, the instructor soon realized that distributing both problems in one package at the start of the activity unit caused anxiety and disappointment in teams that perceived themselves as struggling, because they could not finish both questions in class. As the result, some teams resorted to dividing the two questions between their members in an attempt to finish the worksheet in time. Some students also reported being lost in the team activity units, not knowing where to get started with the problems.

To address this unanticipated response by the students, the distribution of lecture vs. team activity time was adjusted from 50 and 55 minutes respectively to 65 and 40 minutes. The extra 15 minutes of lecture time was spent on providing more background for the worksheet problem, and additional intermediate steps were introduced to the worksheet problem to help the students get started. In addition, only one question was distributed at the beginning of the team activity unit; the second problem was only handed to the teams that successfully finished the first problem. Other teams would get the chance to take the second problem home and to return it at the beginning of the next session. This small change in the class policy significantly reduced the student stress, and ensured that teams solved the questions together as a whole. Instructors also started to incorporate one or two questions in the quizzes that bore some similarity to the ones solved by teams in-class. This, together with frequent emphasis on the importance of the in-class problems in the class and during the office hours, is thought to have improved student attitudes towards the in-class activities as the term progressed.

This was the first time that the BMEG 220 course was offered at UBC. The BMEG program is expanding and will reach 113 students next year, so there is a need to find the resources to allow for an expansion to twice the current class size. A major challenge lies in finding a learning space that is suitable for the combination of the lecture and team activity for twice as many students. Additionally, to properly facilitate the in-class activities more TAs comfortable with providing real-time guidance in the classroom will be required.

5. CONCLUSION

In this paper the design and delivery of a novel second year course integrating circuit analysis, electromagnetics and vector calculus was described. The course made good use of team-based problem solving to help students master the course material. The lessons learned in this first offering were encouraging in that such an ambitious syllabus could be covered in an active learning environment. Several modest adjustments were made during the course, and several more have been identified that will further improve the experience for students in the next offering.

Acknowledgements

We would like to acknowledge the UBC Department of Electrical and Computer Engineering for supporting course development through the funding of N. Harandi as a Teaching and Learning Fellow. We would also like to thank Jim Sibley at the UBC Applied Science Center for Instructional Support for providing consultation and resources on team-based learning.

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