Mech 2: A Fully-Integrated Second-Year Mechanical Engineering Curriculum

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The Department of Mechanical Engineering at the University of British Columbia (UBC) has recently completed the first year of an innovative new curriculum in engineering education. The program, known as Mech 2, is a systematically designed approach aimed at developing the analytical, practical, and design skills of second year mechanical engineering students. Mech 2 is taught by a team of seventeen instructors and is fully integrated in content and delivery. It completely replaces a conventional course-based curriculum for the approximately 128 second year mechanical engineering students at UBC. In this paper we present an overview of the philosophy, curriculum, and key features of the MECH 2 program, along with an analysis of the performance of the program, which is now in its second year of delivery.

Introduction

In a traditional engineering program, students take many diverse courses at the same time and spend a great deal of energy juggling disconnected assignments, projects and mid-term exams. A consequence of this system is that most students tend to compartmentalize information along course lines and they do not see the connections among related subjects. In addition, the timing of related material from different subjects is often left to chance. Required background material in one course may come from a second course but not be presented at an appropriate time.

Innovative Approaches to Engineering Education

The Mech 2 program was inspired in part by other thriving and innovative engineering and science programs at UBC, and abroad. Two examples at UBC are the Science One program, and the Electrical and Computer Engineering Project Integrated Program.

Science One is a team-taught, first-year undergraduate Science program at UBC in which Biology, Chemistry, Mathematics and Physics are presented in a unified, integrated format [1]. The program is an academically rigorous 27-credit course that incorporates lectures, tutorials, laboratories and field trips. The features of the Science One program that inspired Mech 2 were the strong team teaching approach including weekly instructor meetings, the integrated timetabling (allowing lectures from different subjects to feed into each other where possible), and the use of regular off campus field trips as a powerful teaching tool. Published results from data obtained from the Science One program tracking student performance after the program indicates that students from this program demonstrated significantly better performance in later courses than their peers who had not taken Science One [2].

The Project Integrated Program (PIP) is a team-taught, second year electrical engineering program at UBC [3]. In this program, emphasis is on an integrated understanding of electrical and computer engineering principles, and on being able to design practical applications of those principles. The move is away from passive lectures towards group learning and project work. Although Mech 2 did not adopt the same "100%" project-based approach of the PIP program, a significant portion of the Mech 2 program is project-based and is similar in presentation and philosophy to the PIP program.

In a broader context, the hands-on emphasis of the Mech 2 program takes inspiration from the successful design-based practicum emphasis in the engineering program at Harvey Mudd [4], [5]. The problem based learning (PBL) approach that characterises all education at the University of Aalborg has inspired both the PIP program and the design portion of Mech 2 [6].

Pre-Mech 2 Curriculum

Prior to implementation of Mech 2 in September 2004, the Department of Mechanical Engineering at the University of British Columbia had a fairly conventional second year curriculum. Specifically, the second year consisted of courses in solid mechanics, rigid body dynamics, basic electrical circuits, ordinary differential equations, multi-variable calculus, thermodynamics, fluid mechanics, engineering design, materials science, technical communication, and associated labs. Students also received some limited instruction in machine shop practice and engineering software. These different subjects were all taught as separate courses; students would enrol in 15 courses in second year. That curriculum is similar to the curriculum of many North American universities. Owing to bureaucratic and logistical challenges, not only were

students taking many courses simultaneously, but the timing of the course offerings was almost completely uncoordinated. For example, students might be taught linear differential equations either long before (or worse, long after) it would be required to understand single degree of freedom vibrations.

The MECH 2 Curriculum

The primary innovation of Mech 2 was to rearrange the content of the previous second year courses into an integrated curriculum where all the material is coordinated to bring together related topics in a systematic and orderly sequence. This was done without regard to which professor or department would teach particular material. A consequent innovation of Mech 2 was to reduce (from seven to one) the number of courses students take concurrently.

Mech 2 is delivered through four main courses presented in series rather than the conventional format of a large number of distinct courses presented in parallel. The courses are:

- MECH 220 Engineering Skills Practicum
- MECH 221 Engineering Science 1
- MECH 222 Engineering Science 2
- MECH 223 Engineering Design

The Mech 2 program and the four courses are structured to ensure good communication within a team of instructors who together cover all disciplines. Consequently, material in Mech 2 is presented in a much more logical and efficient manner. Not only is the timing of material well thought out, but duplication is minimized. In addition, physical experiments, computer labs, field trips, and other supplementary activities are all delivered according to a schedule that closely follows the lectures.

The Mech 2 course sequence begins in the first semester with MECH 220, a four-week technical skills practicum. This practicum includes hands-on instruction in machining, computer-aided design (CAD), electronics, and drawing. The students next take MECH 221, a ten-week engineering science course in dynamics, solid mechanics, electrical circuits, materials engineering, and differential equations. After a two-week university break, the second semester starts and students go on to take the first part of a seven-week course in engineering design, MECH 223. The first part has a design project focused on the material of MECH 221. MECH 222, a seven-week engineering science course in thermodynamics, fluid mechanics, and multivariable calculus, follows the first part of MECH 223. Finally, the second part of MECH 223, with a focus on the design of a thermo-fluid system, closes the year. APSC 201, a course in technical communications, is separate from MECH 2 for accreditation reasons, but is otherwise fully integrated with the MECH 223 design course.

Engineering Practicum (MECH 220)

The first course in Mech 2 (MECH 220) is a practicum in which students complete four one-week modules in machine shop practice, instrumentation and electronics, CAD, and engineering drawing. The class is divided into four groups of 32, and each group rotates through each module, reducing the demand for resources. At the end of the four weeks, students have modeled, documented, fabricated and tested their own fully working, electronically controlled magnetic levitation device. Assembly time is allowed at the end of the practicum so that students have time to finalize their device and obtain the satisfaction of a completed electro-mechanical project.

A primary objective of this course is to develop students' hands-on skills in a variety of areas important to mechanical engineering as well as to develop skills that can be used later in other Mech 2 courses. Another objective of MECH 220 is to give students exposure to a typical mechanical engineering project in which concepts and from disparate disciplines are integrated during the design process. The design process provides some insight to students who are still unsure of exactly what mechanical engineering involves. This start to second year contrasts with a conventional program, in which students continue to develop their theoretical understanding of engineering in second year prior to seeing practical applications.

The MECH 220 course is structured around a magnetic levitation device (the MagLev) that the students build. Figure 1 shows an assembled MagLev and Fig. 2 shows the interior components. To construct the MagLev, students produce relevant engineering drawings, generate CAD models, machine the primary components, build the circuitry, and assemble and test the final device. Each module is arranged to give group instruction followed by individual hands-on practice. Extra time is provided at the end of each day and at the end of each week to accommodate less-experienced students or students who need a little more time.

Figure 1: MagLev Device in Operation

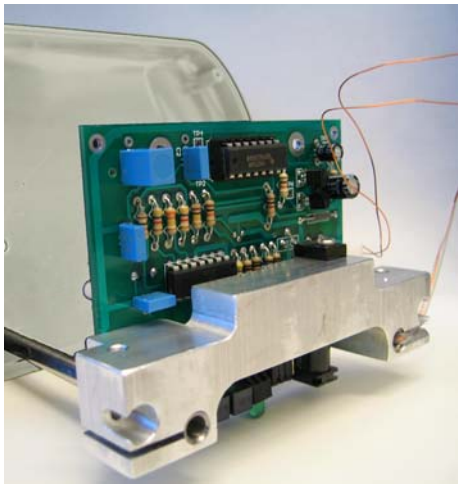

Figure 2: MagLev Interior

The focus of the engineering drawing module is on giving students basic skills for interpreting and creating orthographic and isometric views of parts and assemblies. It is taught using manual drafting with emphasis on industry-standards for drawings of parts, assemblies, structures, and layouts. Sketching and methods of documenting design ideas and changes are also covered. As part of this module, students produce orthographic drawings of components similar to those on the MagLev.

In the CAD module, students learn the fundamentals of computer-based solid modelling and drafting. The module is taught using the Unigraphics NX2 software package (switching to NX3 in 2006). Students produce solid models of all major components of the MagLev device as part of this module.

Students machine the primary components of the MagLev during a 5-day machine shop module. The module includes instruction on machine shop safety as well as the operation of lathes, milling machines, drill presses, and other common machine shop tools. As there are insufficient resources available at UBC, the machine shop course is taught through a partnership with a local technical college (British Columbia Institute of Technology). The primary components that students produce during the machining module are the coil housing (shown on the top of Fig. 1) and the base clamp (shown in Fig. 2).

Lastly, the objective of the instrumentation module is to provide hands-on experience with electronic components and common circuits, and to develop confidence to work effectively with electronic instrumentation. During this module, students produce and test the circuitry shown in Fig 2. Students start with an unpopulated circuit board and a kit with all of the electronic components. As they progress through the module, they add components to the board and perform a variety of mini-experiments on the different circuit elements.

Once students have completed the four modules, they are given time and technical support to assemble and test their MagLev devices. Students demonstrate the function of their completed MagLevs and then they submit them for grading. A final exam for MECH 220 is given approximately one week after the completion of the course. The exam is paper-based and it focuses on many of the practical elements from the four modules.

Engineering Science (MECH 221 and MECH 222)

The second course (MECH 221) is ten weeks long and covers material in engineering science including rigid body dynamics, solid mechanics, mathematics, materials engineering, and electrical circuits. There is another engineering science course (MECH 222) that is seven weeks in duration and covers fluid mechanics, thermodynamics, and mathematics. Both courses use a combination of lectures, problem session tutorials, physical labs, computer labs, and question answer sessions as shown in the typical weekly schedule of Fig. 3. This content is restricted to four days of the week, leaving Thursdays free for special events such as industry speakers and field trips, and for work time for students.

The three lectures per day are the primary contact between students and instructors. The lectures are delivered to the full class of 128 students in a manner similar to lectures in a conventional course. The lectures are delivered by the same instructors who would teach the given subject areas (dynamics, mathematics, and so on) in a conventional program. Two instructor-led classes per week on technical communication appear in the schedule for second term (that is, for MECH 222 but not MECH 221). These tutorials are discussed further in the section on Engineering Design below.

The integrated nature of Mech 2, along with the team-based approach to teaching, allows instructors to minimize duplications in teaching while still emphasizing the natural connections in topics. For example, mass-spring-damper systems and RLC circuits are taught at approximately the same time; the duality of these systems is highlighted and teaching efforts are coordinated by the respective instructors. Necessary background information (ordinary differential equations, in this case) is also delivered to the students at an appropriate time. As a result of this approach, the instructor schedules are not fixed but rather change from week-to-week to facilitate the flow of the material. In total, the number of lecture hours per subject area in MECH 221 and MECH 222 is reduced by approximately 20% compared to the previous conventional program. The reduction in lecture hours is due to the reduction in the duplication of topics and the relocation of worked example problems (previously done in lectures) to an increased number of problem session tutorials.

Sample MECH 222 Weekly Schedule

	MON	TUES	WED	THUR	FRI
8	Tutorial	Tutorial	Tutorial		Tutorial
9	Lab Tutorial		Lab Tutorial		Tech Comm
10	Lecture	Lecture	Lecture	Field trip, quiz, or special lecture	Lecture
11	Lecture	Lecture	Lecture		Lecture
12		Lecture			
1	Lecture	Tech Comm	Lecture		Lecture
2	Lab	Tutorial			Computer Lab
3		QA Session			
4			Lab		
5					

Figure 3: Sample MECH 222 Weekly Schedule

There are five problem session tutorials each week, four in the mornings and one in the afternoon. These tutorials are led by teaching assistants in a small-group setting of approximately 32 students. The tutorial topics are closely coordinated with the lectures and each subject area appears at least once per week. The tutorial format involves working through example problems, many of which were previously included in lectures in the conventional program. The teaching assistants begin each tutorial by presenting a problem that the students initially attempt on their own. After approximately 10 minutes, the teaching assistants begin to work through the problem interactively with the class; the process is repeated with additional problems as time permits.

Students also complete one or two physical laboratories each week. The labs are conducted in groups of four students (32 groups in total) and are supervised by teaching assistants. Like the tutorials, the labs are closely tied to the lecture topics. As a result, 32 individual experiments (each one done by every group) must be completed within a short time period. In most cases, there are two different experiments conducted per week in eight different time slots; to accommodate all groups, this requires four stations for each experiment. In some cases, particularly where lab hardware is limited, two stations per experiment are used and labs are conducted over a two-week period.

Before each lab, students attend a lab tutorial during which the teaching assistant reviews the theory behind the experiment and discusses the relation of the lab to the other course topics. Students prepare for the lab tutorial by reading the background and procedure for the lab in advance. In order to ensure that students complete (and understand) the pre-readings, there is an online pre-quiz administered through WebCT, a web-based course management tool for instructional use [7].

In addition to the physical labs, there is one computer lab each week. In the computer lab, students work in pairs and use MATLAB to solve a problem or perform a calculation related to recent lecture topics. A teaching assistant begins each computer lab with a short tutorial on the lab topic and then spends the remainder of the period circulating among the student groups, providing assistance as needed.

Students also participate in a question and answer (QA) session once per week. The QA sessions give students a chance to get assistance in areas they are having difficulty with through peer teaching and through additional interaction with the instructors. Another benefit of the QA sessions is that they provide students an opportunity to ask interesting questions that are too broad to be answered in a lecture; for example, students can ask a question about the aerodynamics of golf balls, which in a lecture would be a substantial digression. The QA sessions also benefit the instructors by providing direct feedback on the course areas in which students are having some difficulty. Each QA session has one instructor working with one quarter of the class (thus, there are four QA sessions each week). Students work in the same groups of four as in their physical labs and each group formulates a question for the instructor to answer. Students are asked to come to the QA session with questions in mind. Questions that promote serious thought about course concepts are specifically encouraged. In the first portion of the QA session, students discuss potential questions within their group and try among themselves to answer as many of these questions as they can. The students then select a single question to give to the instructor. The instructor collects and answers the questions for each of the eight groups and records a grade based on the question quality.

In MECH 221 and MECH 222, Thursdays are reserved for special events. For most weeks, there is a 60 to 90 minute integrated quiz held during this time. Quizzes are formatted with up to five short-answer questions (each designed to take approximately 5 minutes to answer) and one or two long-answer questions (each designed to take approximately 25 minutes to answer). The short-answer questions are drawn from all subject areas in the course while the long-answer questions focus on one or two subjects. Guest speakers from industry or other areas of academia are often brought in for a lecture following quizzes.

The other major use of the time on Thursday is for field trips and other special events. In the MECH 221 course, there is a field trip to a local indoor rock climbing gym (see Fig. 4); in addition to being an enjoyable instructor-student event, the field trip is organized to emphasize important course concepts such as impulse and momentum, safety factors, and free-body diagrams. There is a similar field trip in MECH 222 where students go kayaking (see Fig. 5). In this case, they investigate a number of fluid mechanics phenomena such as buoyancy, resistance, and thrust. For both field trips, students submit a lab-style report for marking. Other examples of field trips and special events include a trip to an exhibit on global design (called "Massive Change" [8], [9]), a panel discussion on urban transportation alternatives for the future, and an examination of gas turbine engines and aircraft at a local technical school of aircraft maintenance.

Figure 4: MECH 221 Rock Climbing Gym Field Trip

Figure 5: MECH 222 Kayaking Field Trip

At the end of MECH 221, students write three integrated final exams; each exam touches on all topic areas but has particular emphasis on one or two of the areas. At the end of second term, students write two final exams for MECH 222; each exam covers all three topic areas.

Engineering Design (MECH 223)

The final course in the Mech 2 program is MECH 223, engineering design. This course combines the practical elements of MECH 220 with the engineering science of MECH 221 and MECH 222 and it introduces students to a formal design process. MECH 223 is divided into two parts: one that occurs at the start of the second term, after MECH 221, and one that occurs at the end of second term, immediately following MECH 222. The highlight of each part of MECH 223 is an intensive design project (common to the entire class) that concludes with a competition. The projects are supported with lectures on design theory and technical communication, workshops on group dynamics and rapid visualization, and computer labs on CAD and material selection. Unlike the other Mech 2 courses, MECH 223 is taught in a fully team-based learning approach.

The first design project in MECH 223 is based on material from MECH 221. For 2005, the project was inspired by the Cassini-Huygens mission to Saturn and Titan. It focused on kinematics, dynamics, electronics, and materials engineering, and involved an increasingly difficult series of challenges on a two-dimensional inclined playfield. Students worked in assigned teams of five or six to design, build, and operate a ballistically-launched vehicle (Cassini) that was required to travel along the playing surface and then release a second vehicle (Huygens) towards a target. Teams were awarded points for launching automatically by referencing an electronic launch signal; for separating the Cassini and Huygens vehicles in a zone that was defined at the start of each round of competition; for having Huygens reach a target (representing the moon Titan); and for having Cassini reach the end of the table with position and velocity appropriate for orbit around Saturn. Score bonuses and penalties were then applied based on the weight and cost of the vehicles, and on the time required to complete the mission. Figure 6 shows a photograph from the competition.

Figure 6: First project in MECH 223: recreation of the Cassini-Huygens mission to Saturn and Titan.

The second design project follows MECH 222 and focuses on thermodynamics and fluid mechanics. For 2005 it was phrased in terms of the transportation of dangerous goods by ocean-going vessels. Teams were required to design and construct a small cargo ship that was powered by compressed air and they were awarded points based on the volume of cargo that they successfully transported (large penalties were imposed for boats that lost cargo, became stranded, or capsized.). The difficulty of the course increased through each of four rounds of competition. For each round, teams predicted the time to complete the required navigation and they received points based on how close they came to their prediction. To assist in formulating their predictions, students were given access to a small scale "towing tank" and they were guided in the development of numerical models of ship motion. The competition was held at a swimming pool. Figure 7 shows competing students anxiously watching the winning boat.

Figure 7: Second project in MECH 223: students built cargo vessels to transport bulk cargo across a pool using pressurized soda bottles as the energy source.

The structure of both project competitions is such that important parameters (for example, the playfield inclination in the first project) were not revealed until the beginning of a competition round. This forced teams to include adjustability in their designs and to develop and use analytical and numerical models for predicting performance. Human intervention was not permitted during

the competition so teams utilized open-loop electromechanical control systems for autonomous time and distance measurement, control actions, and so on.

Each design project concludes with a formal report and an oral presentation. These elements are supported by training in technical communications that continues through the entire second term (MECH 222 and MECH 223). Each student has two hours of technical communications per week, as shown in Fig. 8. During this time, instructors address the mechanics of preparing technical documents such as memoranda, reports, and presentations while also addressing more general concepts such as style, purpose, and audience.

Although the design projects create a natural focus for the MECH 223 course, there is also formal instruction in design through assignments and classes delivered in a team based learning format. The weekly schedule for MECH 223 is very similar to that of MECH 221 and MECH 222 (see Fig. 8); however, in the team-based learning format, the lectures are replaced by a mix of mini-lectures and in class team exercises. The intention is to develop students' knowledge through preliminary readings and mini-lectures; to develop their ability to apply design skills through tutorials, in-class exercises, and computer labs; and to develop their design judgment through in-class exercises, discussions, and mini-projects. Student completion of the assigned reading is ensured through a "Readiness Assurance Process" (RAP) quiz which precedes the first classes on a topic. In total, there are six reading assignments and six RAP quizzes. Details of the team based learning approach and the RAP quizzes are discussed in detail by Michaelsen et al. [10] and Hodgson et al. [11].

Sample MECH 223 Weekly Schedule

	MON	TUES	WED	THUR	FRI
8	Tutorial	Tutorial	Tutorial		Tutorial
9	Meeting	Lecture	Meeting	Field trip, quiz, or special lecture	Tech Comm
10	Lecture	Lecture	Lecture		Lecture
11	Lecture	Lecture	Lecture		Lecture
12					
1	Lecture	Tech Comm	Lecture		Lecture
2	Const. Lab		Assembly Lab		Computer Lab
3					

Figure 8: Sample Weekly Schedule for MECH 223

As examples of in-class exercises, teams are given two opportunities to disassemble and study an inkjet printer (see Fig. 9). In these activities, students examine the selection and usage of common mechanical components (such as actuators, gears, flexible drives, and so on); the methods of manufacturing; and the design choices related to assembly and operation. These in-class exercises are preceded by out-of-class reading assignments and questions on RAP quizzes, as well as several short lectures on mechanical components and design for assembly. The activities conclude with the submission of a paper-based assignment and an in-class discussion with the instructors. The exercises create a great deal of excitement and engagement from students, and are generally felt to be much more effective at teaching students about mechanical components and design for assembly compared to conventional passive approaches (such as reading and lecturing).

The other changes of the MECH 223 schedule over the two engineering science courses include the replacement of laboratory experiments with dedicated time to work on projects and the introduction of required team meetings. During the "construction lab", student teams have access to the machine shop for the building of their projects. There is also an "assembly lab" during which students have access to equipment necessary to prototype their designs. Both of these activities include teaching assistant supervision. The teaching assistants also facilitate regular design meetings in which the teams meet to discuss topics relevant to the project. During these sessions, the teaching assistant circulates between five teams and gives aid on technical and group process issues for the project. The teaching assistant also checks each team's logbook to review progress and then signs and dates the logbook after the latest entry.

Figure 9: Printer Disassembly Exercise.

As a major emphasis of the MECH 223 course is on teamwork and team-based learning, a great deal of care is put into assigning students to their teams. Each team's members are carefully selected to ensure maximum heterogeneity (as suggested by Michaelsen et al. [10]). In particular, the factors considered in group formation include parameters such as the Myers-Briggs personality type, grades in MECH 220 and MECH 221, communication and language ability, and even automobile and hand-tool ownership. This heterogeneity ensures that each team benefits from a variety of different perspectives, skills and resources, and that the teams are evenly matched for the competitions. The same teams are used throughout the MECH 223 course.

To assist students with functioning as a cohesive team, several workshops on group dynamics are included in the course. The sessions are led by an educational psychologist and they focus on highlighting differences in personality type and working style and on providing tools that teams can use for fostering group harmony and for dealing with interpersonal conflict.

MECH 223 concludes with two final examinations on design and one final examination on technical

communication. The first design exam is arranged to test knowledge (mainly through multiple choice and short answer questions) and skills (through relatively short, focused questions). The second design exam is intended to test judgment through essay-style questions related to the design projects.

MECH 2 Administrative Details

Details regarding the organization and coordination of the Mech 2 program are outlined below. In addition, the policies for dealing with students that have minor academic deficiencies are discussed.

Program Organization

Mech 2 is a substantial undertaking that requires careful organization. This organization is achieved by the activities of the program coordinator, the extensive use of the WebCT online course management tools, and regular meetings between the team of instructors.

To supervise with the organization of the Mech 2 program, a full-time coordinator/instructor position was added. The program coordinator manages many of the administrative tasks that would otherwise be handled by individual course instructors in a conventional program. Examples of these tasks include class scheduling, website administration, teaching assistant coordination, and grades keeping. The coordinator also serves as the primary contact with the students, answering questions, handling registration issues, and providing advising services. Centralizing these responsibilities to a single coordinator adds efficiency in managing these tasks and ensures that students receive consistent responses. Now that the program infrastructure is in place and the instructors have a year of experience, the demands placed on the coordinator are expected to drop somewhat.

To handle the large volume of information that is delivered to the students, much of the Mech 2 organization is managed using WebCT. Regularly updated timetables, personalized for each student, are delivered via WebCT. The timetables are produced using a MySQL/PHP application specially developed within Mech 2. In addition, WebCT is used for student access to course notes, online quizzes and surveys, announcements, discussion boards, grades, and many other elements.

Weekly instructor meetings are critical in the MECH 221 and MECH 222 portions of the course, involving multiple instructors presenting material in an integrated fashion. The meetings allow instructors to modify and adjust the presentation and order of upcoming material based on feedback from students and observations by the teaching team. As well, this time is used to coordinate integrated quizzes and assignments, industry speakers, and fieldtrips. The integration of both presented and examined material is key to adjusting the student mindset from one of compartmentalization to integration.

Student Assessment and Remedial Practices

The large majority of students, approximately 75%, complete all their Mech 2 courses successfully. Present among the other students is the usual range of deficiencies from minor to major. With the incorporation of multiple conventional courses into a reduced number of Mech 2 courses, there was a concern about how to deal with students who had minor deficiencies in one or two subject areas in a Mech 2 course, but did satisfactorily overall. This situation was addressed by individually tracking exam grades in all subject areas for a course (such as dynamics, mathematics, solid mechanics, and so on), and requiring that students must pass each individual subject area. In cases where students have unsatisfactory performance (<50% mark) in one or two subject areas but still pass the majority of the subject areas and pass the course overall, the interpretation is that the deficiency is likely minor and can be remedied in a straightforward way.

In this situation, the course grade is recorded as "incomplete" and students are assigned one or two remedial courses to complete within two academic terms. After completing the extra courses, the incomplete standing in the Mech 2 course is removed and the original numeric grade is assigned. In instances where students have unsatisfactory performance (<50% mark) in a majority of subject areas or in the course overall, the interpretation is that the deficiency is more profound and the student receives a failing grade and must repeat the Mech 2 course. Approximately 10% of students were in this last category, a proportion similar to that before the introduction of Mech 2.

Outcomes

The results from this first year of the Mech 2 program have been very encouraging. The amount of practical training and group work that students have received has dramatically increased from previous years. This does not seem to have come at the expense of academic performance as there was also a 2% increase in the average first term grades from the previous year. This is supported by anecdotal evidence among instructors who feel that students are performing at least as well, if not better, than previous years. Furthermore, the addition of the MECH 220 practicum and the increase to seven weeks dedicated to design resulted in projects that were far more involved and challenging than anything that had previously been attempted. Overall, the unique approach to engineering education and the emphasis on practical activities (practicum, projects, and field trips) has resulted in a surge in enrolment.

Increased Enrollment

Engineering students at UBC take a common first year curriculum and at the end of that year are assigned a space in one of ten engineering degree programs depending on their preferences, their rank in class, and the availability of space in a particular program. In 2003, prior to the implementation of Mech 2, 174 students from the Faculty of Applied Science ranked Mechanical Engineering as their first choice (relative to a quota of 120). Mechanical Engineering had a first year admission average of 75.4%, second to 79.8% of Engineering Physics, a specialized program run jointly with the Faculty of Science. In 2004, when MECH 2 was implemented, 206 students from the Faculty of Applied Science ranked Mechanical Engineering as their first choice. All 120 students entering Mechanical Engineering listed MECH as their first choice, and Mechanical Engineering had the highest first year admission average of all the programs (79.0%, with a minimum for any student of 71.2%), surpassing Engineering Physics. In 2005 193 students ranked Mechanical Engineering as their first choice, and the entering average of MECH students was 78.1%. In summary, following implementation of the Mech 2

program, more and higher calibre students than previously have chosen to enrol in Mechanical Engineering.

Improved Technical Communication

The APSC 201 technical communication course has been integrated into Mech 2, but it is still taught by the same instructors and in a manner that is very similar to the version that is still taught to Applied Science students outside of Mechanical Engineering. Consequently, it is possible to directly compare the performance of Mech 2 and non-Mech 2 students. Table 1 shows this comparison. The figures for 2003 include Mechanical Engineering students as well as all other engineering disciplines within Applied Science.

Table 1. Comparison of Performance in APSC 201 Technical Communication Course

	Non-Mech 2			Mech 2
Year	2003	2004	2005	2004
Students	686	616	371	97
Avg. Grade	66%	66%	61%	67%
Fail Rate	13%	14%	27%	3%

Although the Mech 2 students achieved only slightly higher average grades compared to the other Applied Science students, they showed a dramatic five-fold reduction in the percentage of them failing APSC 201. It is believed this success is largely due to the careful formation of student teams to include diversity in writing and communication ability; specifically, weaker students benefit from collaborating and receiving guidance from stronger students. This outcome may also be a result of the increase in the number of technical documents that the students produce (through laboratory reports in MECH 221 and MECH 222 and project reports in MECH 223).

Observations

The development of the Mech 2 program has not been without its challenges. Increased stress was observed among some students during the first year (2004) of introduction of Mech 2. This occurred mainly because of student unfamiliarity with the new teaching system. The majority of students soon adapted to the Mech 2 environment and were able to evolve their personal study strategies accordingly. The required adaptability seemed to be correlated to personal maturity and positive outlook.

Another factor, specific to the 2004 cohort was that the Mech 2 program was entirely new, and that students had no source of "received wisdom" from their peers in the year before. The 2005 cohort has been much more confident from the start, with only the usual minor stresses at exam time.

In terms of academic demands, students found the engineering science courses to be much more challenging than expected and they cited the condensed course durations (ten and seven weeks) as the primary cause. At this point, it is unclear whether the increased demand perceived by the students is indeed due to the condensed courses or if it is actually a normal experience found in the transition from first to second year engineering. The current students moving to third year will be closely tracked to assess if their perceptions of the program demands change as they progress in their education. The preparation phase of the MECH 221 engineering science course has already been extended through a series of review lectures and activities held during the four-week MECH 220 practicum course.

It is too early to tell whether student ability in fundamentals of engineering science is significantly better (or worse) than previous years. However, instructors have found that the Mech 2 format leads to rapid identification student difficulties in fundamental topics, allowing a faster and more holistic response than would be found in a traditional program.

The administration overhead for instructors has (initially) far exceeded the reduction in lecture hours, which is to be expected with the introduction of a new curriculum. This administrative cost is expected to stabilize at a level approximately equal that of a traditional program.

Beyond its academic objectives, an attractive outcome of Mech 2 has been a greatly increased camaraderie among students, and a much closer and more cordial relationship between students and teachers. Students, instructors, and teaching assistants have all commented on the strong sense of community that has developed in Mech 2. This is further enhanced by a number of extracurricular social events (such as barbeques, bowling, paintball, and curling) that have been held each year.

Students appear to come out the program with a more mature outlook and an increased confidence in their engineering abilities. This was seen most strongly in the MECH 223 projects, which were much more ambitious and inspiring second year projects than undertaken in previous years.

Conclusions

The implementation of the Mech 2 program at UBC this year represents a major shift in the way second year mechanical engineering is taught. The results to date suggest that the change is working as planned and our students are benefiting from it. The Mech 2 program is still being adapted in the light of practical experiences. Some minor changes have already been made for the 2005 cohort based on the experiences with the 2004 group, but the fundamental philosophy remains intact. With almost two years of experience now with the program, all the teachers are greatly encouraged, and are convinced that Mech 2 has made a good advance in the education of our students.

References

1. http://www.scienceone.ubc.ca/home/
2. Dryden, N., and MacLean, M., 2004, "Academic Performance of Former Science One Students," University of British Columbia, Vancouver, http://www.scienceone.ubc.ca/grad_performance.pdf
3. http://www.ece.ubc.ca/tikiindex.php?page=Project+Integrated+Program
4. Bright, A., and Philips, J.R., 1999, "The Harvey Mudd Engineering Clinic Past, Present, Future," Journal of Engineering Education, **88** (2)
5. Dym, C., Agogino, A., Eris, O., Frey, D., Leifer, L., 2005, "Engineering Design Thinking, Teaching, and Learning," Journal of Engineering Education, **94** (1).
6. Kjersdam, F., and Enemark, S., 1994, "The Aalborg Experiment: Project Innovation in University

Education," Aalborg University Press, http://auaw2.aua.auc.dk/faktekn/aalborg/engelsk/
7. http://www.webct.com
8. Mau, B., 2004, *Massive Change*, Phaidon Press Limited, London.
9. Mau, B., 2004, "Massive Change: The Future of Global Design," Exhibit, Vancouver Art Gallery, Vancouver.
10. Michaelsen, L., Bauman Knight, A., and Fink, L.D., 2004, *Team-Based Learning: A transformative Use of Small Groups in College Teaching*, Stylus, Sterling, VA.
11. Hodgson, A., Ostafichuk, P., and Sibley, J., 2005, "Team-Based Learning in the Design Modules of a New, Integrated, 2nd Year Curriculum at UBC," Proc. 2nd CDEN International Conference on Design Education, Innovation, and Practice, Kananaskis, Alberta.