PROGRESS WITH THE PROFESSIONAL SPINE: A FOUR-YEAR ENGINEERING DESIGN AND PRACTICE SEQUENCE

ABSTRACT

Queen's University has included a faculty-wide Introduction to Engineering course (CDIO Standard 4) for many years. We have recently revised and expanded this part of our curriculum in a move to a faculty-wide sequence of courses that will present design, communications and professional practice aspects in a consistent framework across all of our programs. Research demonstrates a need for repeated design experiences (CDIO Standard 5) throughout the undergraduate program to develop confidence and competence for professional practice [1-4]. Such experiences are mandated by reports recommending increased focus on professional engineering practice in engineering education [5,6] and increasingly required by accreditation agencies under the Washington Accord [7].

The new, four-year Engineering Design and Practice Sequence (EDPS) at Queen's is core for all students in all engineering programs. It focuses on developing competence in design process methods and tools, problem analysis, creativity, economics and entrepreneurship, engineering communications, professionalism and ethics. It was designed as project based, meeting the requirements of the Canadian Engineering Accreditation Board (CEAB), thus addressing Washington Accord based requirements, and targeting relevant CDIO Syllabus elements. EDPS is following a staged roll-out, with the revised introductory course given to first year students starting in 2010/2011 and the second year design and communications course being delivered for the first time in 2011/2012.

This paper reviews the EDPS course design process, year by year objectives and outcomes, and evaluation methods in comparison with previously published engineering design and practice sequences [8]. Experience and results from the first two years of offering the sequence are presented, including student feedback and attributes assessment. The EDPS was examined by the CEAB in their October 2011 site visit and was positively received.

KEYWORDS

Curriculum, Design, Integration, Spine, Communications, Project

INTRODUCTION

Research demonstrates a need for repeated design experiences (CDIO Standard 5) throughout an undergraduate engineering program to develop confidence and competence for professional practice [1-4]. Such experiences are mandated by reports recommending increased focus on professional engineering practice in engineering education [5,6] and are increasingly required by accreditation agencies under the Washington Accord [7].

Prior to 2011, Queen's engineering had practiced a typical "bookend approach" to engineering design. Most students were exposed to a relatively non-technical design project in first year, and a very technical capstone design project in their fourth and final year, with little design experience in second and third years. This approach has been demonstrated to lead to poor design skill retention, and, in fact, regression in both confidence and ability to apply a design process [1,4]. Professional skills development in many programs was also limited largely to the first and fourth years.

The development of a four-year Engineering Design and Practice Sequence (EDPS) of project-based courses at Queen's began three years ago, directed by a Curriculum Review Committee (CRC) consisting of representatives from all engineering programs in the faculty of engineering, a student society representative, the Associate Dean, the Director of Program Development, the NSERC Chair in Engineering Design, and members with economics, library, and professionalism expertise.

Our curriculum design draws upon the *cognitive apprenticeship* framework from Collins, Brown, and Newman that builds upon the idea of an apprenticeship which "embeds the learning of skills and knowledge in their social and functional context" [9]. Recent engineering reports have recommended curricular changes based on these approaches, including an adoption of a cognitive apprenticeship model by Sheppard et al. [6]. From Sheppard, the first principle recommended for improving engineering education is:

> "Provide a professional spine: During each year of their program, students should have experience with and reflect on the demands of professional practice, linking theory and practice. Engaging in increasingly practice-like experiences, the engineering equivalent of the clinical dimension of medical preparation would be a central feature of engineering education. This emphasis on professional practice would give coherence and efficacy to the primary task facing schools of engineering: enabling students to move from being passive viewers of engineering action to taking their place as active participants or creators within the field of engineering. In this process, the student would begin to develop an identity as an engineer." [6]

There are a number of engineering schools in North America that offer design and/or professional skills sequences or "spines" within their programs. However, based on the information available in the literature, these are either within discipline-specific programs or in engineering schools that offer "general" engineering programs with some flexibility in choice of courses or course streams [8].

DESIGNING THE QUEEN'S EDPS COURSES

CDIO Standards 3, 4, 5, 7, and 8 mandate the curriculum components that are key to the EDPS, as well as their integration [5]. Those standards are: Integrated Curriculum, Introduction to Engineering, Design Build Experiences, Integrated Learning Experiences, and Active Learning. The standards require at least two design/build experiences integrated into the core curriculum.

The CRC draws on considerable experience in offering project-based courses in a variety of disciplines, including APSC100 (Engineering Practice) [10], APSC 190 (Professional Engineering Skills), MECH212 (Design Techniques), and APSC381 (Fundamentals of Design Engineering [11]. These courses illustrated various ways and means of teaching and learning design and professional skills at both the faculty-wide and departmental levels.

The CRC adopted a curriculum design flow process [8], beginning by establishing high-level objectives to:

- enhance design and innovation capacity of our students
- be primarily project based, with appropriate scaffolding in early years to develop project management, design process, teaming, and communications skills
- incorporate graduate attribute assessment, required by CEAB [12]
- include most of the CEAB accreditation units required for engineering design
- ensure that the structure is designed to encourage future multidisciplinary projects
- encourage professional behaviour and skills
- use peer mentoring to develop leadership and provide support for early year students

Using these objectives as a starting point, the CRC focused on detailed learning outcomes for implementation in each year of the EDPS. (Table 1; outcomes for years 3 and 4 are still under development.) The EDPS is designed to work with the common first year of Queen's Engineering, with students selecting one of ten disciplines starting in second year.

Table 1
High-level Learning Outcomes for years 1 and 2 of EDPS

EDPS I Detailed Outcomes (course number: APSC100)	**EDPS II Detailed Outcomes (course numbers: APSC200, APSC293)**
● Identifies known and unknown information, uncertainties, and biases when presented a complex ill-structured problem ● Creates process for problem solving including justified approximations and assumptions ● Selects and applies appropriate quantitative model and analysis to solve problems ● Evaluates validity of results and model for error, uncertainty ● Generates ideas and working hypothesis ● Designs investigations involving information and data gathering, analysis, and/or experimentation ● Synthesizes data and information to reach conclusion ● Appraises the validity of conclusion relative to the degrees of error and limitations of theory and measurement ● Adapts general design process to design system, component, or process to solve open-ended complex problem. ● Accurately identifies significance and nature of a complex, open-ended problem ● Identifies customer and user needs	● Demonstrate enthusiasm for engineering and the discipline they have selected ● Apply design processes and tools for problem definition, idea generation and decision making ● Promote creative processes in open ended problem solving ● Apply engineering principles and theories from other disciplinary courses ● Solve an open-ended design problem (involving analysis and/or simulation and/or prototyping) ● Analyze triple bottom line (financial, environmental, and public interest) to support decision making ● Apply relevant engineering regulations/codes/standards in a professional manner ● Explain the role of professional/technical associations in engineering and discipline ● Apply teaming skills in a group project ● Identify all relevant factors and the dominant factors in the system ● Apply information search and identification,

• Gathers and uses information from appropriate sources, including applicable standards, patents, regulations as appropriate. • Produces a variety of potential design solutions suited to meet functional specifications • Performs systematic evaluations of the degree to which several design concept options meet project criteria • Compares the design solution against the problem objective • Selects appropriate measurement devices or techniques to accomplish a task • Follows protocols when using techniques, skills and tools • Demonstrates correct use of testing apparatus, databases and models • Recognizes a variety of working and learning preferences • Assumes responsibility for own work and participates equitably • Describes own temperament • Applies principles of conflict management to resolve team issues • Critically analyzes results from a temperament sorter, defending opinion of how well results apply • Analyzes impact of own temperament on group work • Exercises initiative and contributes to team goal-setting • Writes using standard formats • Writes using standard grammar and mechanics • Summarizes and paraphrases written work accurately with appropriate citations • Delivers clear and organized formal presentation following established guidelines • Creates effective figures, tables, and drawings employing standard conventions to compliment text. • Describes role of protection of the public and public interest in decision making • Demonstrates punctuality, responsibility and appropriate communication etiquette • Participates actively in meetings, helps to generate ideas	with proper citations • Demonstrate a communications strategy that considers the needs and character of the audience • Compose logical arguments based on supporting evidence • Compose with the appropriate structure and relationship amongst ideas • Prepare and deliver a presentation with appropriate language, style, timing and flow • Demonstrate writing with correct spelling, punctuation and grammar • Demonstrate conciseness, crispness, precision and clarity of language • Use appropriate formatting for a memo and a short report

EDPS I: APSC100: The first year of the experience is built on a design and professional skills course that was originally developed as part of the faculty's push for integrated learning in the late 1990s [13,14,15]. The course was developed as a team-based, project-based course to promote a sense of curiosity about engineering, and promote creative thought. The course is divided into three modules: Module 1. Problem analysis and modeling (new in 2010/2011); Module 2. Experimentation and measurement; Module 3: Engineering design. Each of these is one semester long and equivalent in weight to a standard one-semester engineering course.

EDPS II: APSC200 and APSC293: The CRC decided that the most effective way to meet the overall EDPS objectives in second year, while making efficient use of faculty time and expertise, was to implement a faculty-wide, one semester design course – APSC200. The communications objectives were put into a separate course – APSC293. The splitting of the EDPS II into APSC200 and APSC293 was made primarily for administrative reasons, as it allows a way of tracking students separately on their competencies for both communications and design. The co-ordinator is the same for both of these courses, offered for the first time in 2011/2012.

IMPLEMENTATION OF EDPS I (APSC-100)

The problem analysis and modeling module (module 1) is a semester-long integrative experience that uses concepts from engineering sciences, natural sciences, and mathematics courses to solve complex open-ended problems. The course is structured around three *model-eliciting activities (MEAs)-* problems used in class that are set in a realistic context that requires the learner to document not only the solution to the problem, but also their process for solving it [16, 17]. The situations described in the MEAs require students to create and use a mathematical model of a physical system using MATLAB, and deal with professional issues including ethical dilemmas, conflicting information, and incorrect/missing information. In the 2011/2012 academic year the problems include a failure analysis, and feasibility studies in alternative energy. Students interview a practicing engineer, read on broad engineering issues, and complete occupational health and safety training.

The experimentation module (module 2) introduces quantitative experimental design and analysis, using a progressive approach in 12 weekly sessions of 3 hours each. Two Tutorial Labs introduce collection, analysis and reporting of data, then following a systematic approach to experimental design for a very simple Hooke's Law case. Six "breadth" labs then illustrate the structure of well-designed experiments, using a variety of measuring instruments and allowing the student to improve their data analysis and report writing skills. The final component is a 3-week project where students design and complete their own laboratory experiment.

The engineering design module (module 3) centers on a team-based project where students are partnered with clients, primarily in the local community. Supporting activities focus on concepts including design process and tools, project management, information management, teaming, communication, personal learning styles, economics, and workplace safety. A key feature of this module is the use of upper year engineering students as paid project managers. These students serve as peer mentors, and are consistently highly regarded by first year students. Although they are hired to only manage these projects, in practice they also play the role of general academic peer mentors for first year students.

In hiring the approximately 50 project managers, preference is given to those who have demonstrated leadership skills, industrial experience, academic strength, communication skills, and design skills. A significant number also have formal training in design tools and methodologies. All project managers are required to hold current workplace safety and first aid certifications. They attend multiple training sessions in course objectives, design process and tools, assessment and grading, conflict resolution, and general project management. Their role includes arranging initial meetings, giving feedback on team meetings, helping the teams create design plans, timelines and goals, providing guidance and feedback on oral presentations and written reports, guiding students to resources available at the university, and evaluation of team progress and deliverables [8,10]. Table 2 shows learning objectives for each of the modules.

Table 2
General Learning Objectives for EDPS 1 Modules

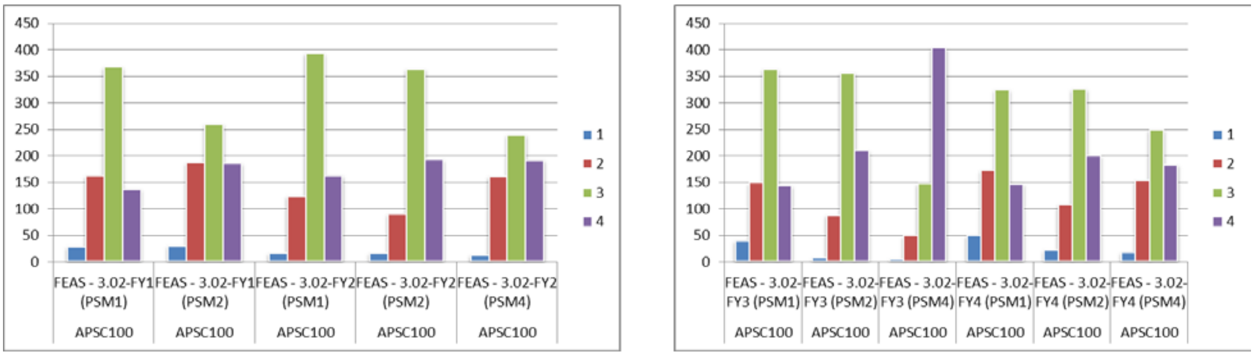
Module	General Objectives (more detailed objectives are described in [8])
Module 1: Problem analysis and modeling	● Deconstruct and solve a complex (yet relatively non-technical) engineering program using engineering design process ● Make an effective argument ● Emulate role of engineer in dealing with technical, social, environmental, and financial factors ● Create MATLAB scripts to model physical systems
Module 2: Experimentation	● use basic laboratory skills and measurement techniques to conduct an investigation involving physics and chemistry concepts ● critically evaluate results and conduct error analysis ● developing formal report writing skills through guidance and practice ● design an investigation to answer a question posed
Module 3: Team-based design project	● Apply engineering design process and tools to solve a problem ● Effectively interact with team members, supervisors, and clients ● Communicate in oral and written form to technical and non-technical audiences ● Locate, critically evaluate, and summarize information from a variety of information sources ● Manage time and resources

Assessment

EDPS I and II are delivered faculty wide to around 700 students. The assessment must provide individual student grades and outcome measures as a benchmark for future performance, as well as indications of overall success of the courses, including retention of skills and concepts learned in the first year course, all while minimizing additional workload for graders.

Most deliverables in Modules 1 and 3 of APSC-100 were mapped to faculty-wide learning outcomes (referred to as “indicators” by CEAB). More detail is in [8]. For each of those deliverables a rubric was developed targeting each learning outcome.

Graders scored the student deliverables on each outcome, and the result was stored in our Moodle course management system. The sum of the scores was used to compute a grade for each deliverable. At the end of the year each student’s score for each outcome was downloaded and analyzed to assess how well students were meeting the expectations and how well the course helped students develop on each learning outcome. For example, the figure below shows student performance on learning outcomes related to problem analysis. As can be seen, most students met expectations in creating MATLAB models (learning outcome code FEAS-3.02-FY3), but fewer met expectations in evaluating the validity and results from their model (code FEAS-3.02-FY4). This data is used to improve the course experience.



		Threshold	Target	
	1 - Not Demonstrated	2 - Marginal	3 - Meets Expectations	4 - Outstanding
3.02 - FY1: Identifies known and unknown information, uncertainties, and biases when presented a complex ill-structured problem	Information not identified properly, no information, or information copied from assignment	Some important information or biases not identified, or trivial/incorrect information included	Identifies known and unknown information, uncertainties, and biases	Meets expectations PLUS: Includes information from authoritative sources to inform process, model, and conclusions
3.02 - FY2: Creates process for solving problem including justified approximations and assumptions	No or inadequate process	Process identified misses some important factors; some assumptions left unidentified or unjustified.	Creates justified process for solving problem, suppored by information.	Meets expectations PLUS: Comprehensive process model; comparison with other possible approaches
3.02 - FY3: Selects and applies appropriate quantitative model and analysis to solve problems	No analysis, or model/analysis selected is inappropriate	Model selected; some errors in analysis or inappropriate assumptions	Selects and applies appropriate quantitative model and MATLAB analysis to solve problems, using reasonable approximations and assumptions	Meets expectations PLUS: Authoritative research used to defend assumptions and approximations made
3.02 - FY4: Evaluates validity of results and model for error, uncertainty	No evaluation of solution	Superficial evaluation of solution	Evaluates validity of results and model for error, uncertainty	Meets expectations PLUS: Evaluates conclusions and presents potential improvements

Figure 1. Sample measured student performance on learning outcomes.

As a result of this kind of analysis, the faculty could draw conclusions about how the course could be improved to help students develop critical attributes. In the 2010/2011 academic year the recommendations included:

- Grader calibration: Data showed a need for greater effort will go into grader training and calibration
- Problem analysis: Focus on making an effective argument, and comparing the outcome of a solution to the originally defined problem definition.
- Design: Expand the focus on safety and risk assessment, including Occupational Health and Safety.

- Communications: Provide additional support to students with weak communication skills at the beginning of first year.
- Lifelong learning: More emphasis on evaluating information to support effective arguments
- Ethics, Equity, Professionalism, and Societal Impact: Increased priority throughout EDPS to increase perceived importance in students.

Student feedback

Every year students are asked to complete a web-based survey to gather feedback on the course delivery. Questions focus on how well the course met the original objectives, effectiveness of course activities, usefulness of personnel, etc. In the 2011-2012 academic year, feedback on Module 1 (problem solving and modeling) included:

- 70% of the respondents felt that the course helped improve their ability to solve open-ended problems
- 75% said it helped improve their understanding of the roles and responsibilities of engineers in society
- 76% said they felt it was important to develop the knowledge and skills focused on in the module

Negative comments primarily focused on the organization of the module, and understanding expectations. Only 34% of the students felt the module was well-organized. This is the second year the module has been delivered and many of the deliverables were in flux; in the next year the organization and expectations will be made more clear.

In module 2 students were surveyed on their skills in experimental design, measurement, data analysis, interpretation, and reporting. Over 60% of students surveyed rated their learning at 4 or 5 on a scale from 1 (not much) to 5 (a lot) and positive comments included:

- Coming up with an experimental design was surprisingly challenging. Very worthwhile.
- Project lab was good because it was ours to pick and ours to figure out.

Negative comments allowed us to revise some of the approaches to error analysis where students were experiencing frustration.

In the 2011-2012 academic year, feedback on Module 3 (team design module) included:

- 70% of the respondents felt that the course met the original objectives
- 77% said it helped them develop their ability to work as a team member
- 74% said it helped strengthen their ability to solve open-ended problems
- 77% said they felt it was important to develop the knowledge and skills in the module
- 90% felt that their project manager was a valuable source of guidance

Students overwhelmingly rate their project managers as the most positive aspect of the course. One comment summarizes the general feeling about the project managers: “It was helpful to get to know an upper year student for help not only in APSC 100, but for advice in other courses.”

In previous years an individual paper-based pre-post test of design process application has been used to assess the impact of the course. Students were provided with a design scenario at the beginning and end of the course, and asked to describe the process they would follow to solve the problem. The responses were scored on problem definition, conceptual design, preliminary design, detailed design, evaluation, implementation, and use of tools. Over a three year span statistically significant gains were consistently observed, particularly in the early stages of the design process [1-3].

Students, however, struggle with the open-ended nature of the design project. Only 38% said they felt they knew what was expected of them, and only 28% said they felt it was well-organized. Future effort will be directed to understanding how much of this is inherent in a first exposure to open-ended design, and how much to communication of expectations with students.

IMPLEMENTATION OF EDPS II (APSC-200 + APSC293)

EDPS II is a project-based course designed to be delivered in two parts over a 12-week semester, addressing the outcome objectives in Table 1. Common instruction is provided to all students in the first 6 weeks, and includes problem scoping, creativity, idea generation, engineering ethics, and decision making incorporating technical, economic, societal, and environmental factors, safety, engineering codes and regulations. Following an introductory project in the first week (P0), instruction in the next 5 weeks is paralleled by a hands-on, simple design/build project (P1). The final 6 weeks of the course centers around a more advanced design project delivered by each discipline (P2). The communication course includes a small number of integrated lectures, online modules, and working tutorials practicing communication in the engineering context of deliverables in the design course.

EDPS II was first offered to ~325 students in Electrical, Computer, Civil, Geological, and Mining Engineering, Engineering Physics and Engineering Math in Fall 2011, then to the remaining ~325 second year students in Mechanical and Chemical Engineering, and Engineering Chemistry in Winter 2012.

The first half-term segment (including P0 and P1) was delivered to two separate lecture sections, each with ~165 students, 8 TAs and a course instructor. Each week incorporated two lectures and two, two-hour workshops given in smaller sub-sections of about 45-60 students. Each TA was typically responsible for 5 student teams (about 20 students) and follows those teams through the entire course. Curricula included:

- **Week 1 - P0 project:**_ In this introductory week students work in groups to complete a simple design-and-build task using recycled/reused materials. The intent is to encourage creativity and team-building given minimal structure or design instruction, and also to stimulate interest in the design process and encourage students to enjoy and reflect on the experience. The task was to design a device for propelling a package towards a target. The P0 exercise is structured in two Phases, one in each workshop session:
  - Phase 1: Conceive and Design: Following an introductory lecture, student groups develop an idea for subsequent testing. At the end of the workshop they submit design description, materials list, and concept sketches.
  - Phase 2: Implement and Operate: Students gather recycled/reused materials on their own time, then build and test their device in the first hour of the

workshop. In the second hour all devices are tested.

- **Weeks 2-6 - P1 project and supporting instruction/activities:** Instruction in design process with integrated professional practice and communication skills is applied in the elements of a project-based "Humanitarian Engineering" design experience. The project is intended to be virtual, although students are not discouraged from building all or part of a prototype. After reflection on their P0 project, the same student groups select a P1 project topic from among three options, and choose a country/region of implementation for context, based on researching needs. Fall term choices were:
    - Energy Generation and Storage
    - Water supply and Purification
    - Sustainable energy cooker

  Modular lectures and active workshop exercises are delivered to coincide with the stages of the design project. APSC 200 topics include design process, idea generation and creativity, project management, integrating safety, decision making tools (pros/cons table, weighted evaluation matrix), value judgment (triple bottom line), cost estimation, and design assessment and iteration. Project deliverables are a design proposal, interim and final reports, and an oral presentation. APSC 293 communication workshops begin with a general lecture outlining the writing process, then throughout the project the topics support the various reporting aspects, including business communications and information research in a just-in-time fashion.

The second half (P2) retains the same timetabling, with departmental instructors working with disciplinary groups of students towards learning objectives common across the faculty. Departmental instructors determined if and how the lecture and workshop slots would be used based on the needs of their particular project assignment. Typically one lecture and one workshop per week retained scheduled activities and the second workshop was offered as unstructured project time, although there was substantial variation. Curricula included:

Weeks 7-12 - The P2 project: Students tackle a discipline specific design topic proposed by their department and approved by the CRC, to effectively illustrate the application of the design principles outlined in the first 6 weeks. No formal instruction was planned for this portion of the course, although some departments provided supporting technical instruction relevant to the project. Students were expected to follow the design, project management, and communication processes learned in the first 6 weeks. Although the course co-ordinator oversees this final project, the departmental co-ordinators were responsible for the specific content and structure.

Projects offered in the P2 phase varied in technical complexity, in part depending on the term offered. Students taking the course in the second term had a higher level of technical capability from their first term experience. However, several of the first term departmental instructors compensated to some degree with supporting lectures to compliment the projects.

Project design topics included: a cell phone charger using recreational activities for energy supply; an improved mine ventilation system; and response to a chemical spill. The latter was a great example of integrating design process, professional practice, and communication. The project challenge was to manage and remediate a spill of 1000 litres of trichloroethylene on a busy street in the heart of the university campus. Student teams designed solutions to remediate the spill while also managing pedestrian and road traffic and ensuring safety of bystanders and cleanup workers. This required understanding of all relevant laws and standards, communication with external bodies such as the city's emergency response personnel and provincial oversight organizations such as Ministry of the Environment, learning and implementing safe practices required for the site, as well as the technical requirements to capture, remove, and remediate the contaminated material.

Assessment

Given the integrated nature of the courses, student assessment incorporated a combination of technical, process, and communication elements. Student deliverables were designed accordingly. For example, the P0 project (week 1) assessed the design proposal, the simplicity, reliability, efficiency and reproducibility of their prototype, the use of recycled/reused materials, and the final accuracy of their device in hitting the target. An individual written reflective submission, guided by several suggested questions, was also submitted and assessed for communication skills.

Deliverables for both the P1 and P2 projects consisted mainly of a series of project reports (preliminary/proposal, interim/progress, and final). In order to emphasize the importance of communication in engineering practice, wherever possible, course deliverables were marked and given formative feedback on both design and communication content. With the combination of open-ended projects, multiple levels of reports, and the dual nature of the assessment, students were provided with a rubric for content and clarity that could be used for all levels of reporting, combined with guidelines for each specific deliverable. Significant oversight was required to maintain consistency across the many TAs and sections. TAs participated in training and discussion prior to assessment as well as follow-up discussion and cross-assessment for calibration and adjustment.

Rubric development for design project reporting is a challenging task; however, prior experience led us to apply the "Ideas, Connections, Extensions" approach to assessment and learning [18]. This methodology incorporates three categories of learning achievement: the first is ideas, typically in the form of knowledge or information; the second, connections, demonstrates relationships between knowledge, fundamental skills, and/or previous knowledge; the third, extensions, involves the application of the new learning in novel ways, often with creative, critical, and/or reflective insight. General descriptions of these learning achievements, suitable for a second year program, were created for both content and communication, and provided to the students and the instruction/assessment team. This rubric was then applied in conjunction with the individual deliverable guidelines to provide feedback and grade. Once the TA's were familiarized with this methodology and had some practice applying it, post-assessment calibration indicated that the grading was remarkably consistent, requiring only one sub-section deliverable adjustment over two terms with dozens of deliverables.

Detailed peer reviews were required at the end of each of the two main projects. Students were instructed to divide "marks" amongst their team in two categories generally classed as knowledgability/capability and teamwork/effort, along with free-form comments to reinforce their numerical reviews. Students were informed in advance that this could adjust their mark in each of the two project phases by adding up to 3% bonus or deducting up to a 25% penalty. This, along with the individual reflection deliverables, allowed significant variation in marks within teams where appropriate.

As with EDPS I, grading for deliverables was done in the university's learning management system, Moodle, using a similar modular input process. The results from students completing the course in the first term suggest that they are meeting expectations, however a more complete review cannot be done until the remaining the students have completed the second term offering (in progress as of the preparation of this paper). Analysis of the full year sequence, combined with the student, TA, and Instructor feedback, will be used to provide enhancements for future years.

Student Feedback

Student feedback is essential, especially given the size, complexity, and first implementation of EDPS II, with multiple instructors, TA's, sections, and projects producing variation in the student experience, despite substantial efforts to keep the focus of the course on the common learning objectives. A post-course student survey was designed with this in mind, and students were asked to review the learning objectives prior to beginning the survey. These objectives had been presented to the students in the first lecture and discussed on several occasions throughout the course.

The survey incorporated 35 questions with 5-point Likert scale response options, and an invitation to include free-form comments. The first 20 questions of the survey were relevant to the overall course, such as how well it met the learning objectives, how many hours per week the students invested, and other topics regarding the organization and perceived value of the course. The remainder of the survey focused on each of the projects, P0, P1, and P2, their individual value and how well they were linked. Although the instruction during the first half of the course was in multidisciplinary sections, the workshops, P1, and P2 projects were structured departmentally (due to timetabling constraints), hence the survey data was evaluated both as a whole and by department.

As of this writing, only the results of the first term survey are available, representing about half (~325) the second-year student body and seven engineering disciplines, with a relatively low response rate of 28%. Arguably the most important question on the survey, "Overall, this course was effective at meeting the objectives above" (with the explicit learning objectives listed above the questionnaire), over 70% of the students answered "strongly agree" or "agree." With the limited response rate and data from only the fall term offering, it is inappropriate to draw conclusions at this point, although there are some interesting variances. Perhaps not surprisingly, the lowest course "approval" came from a department where students have a distinct course overload (8 courses). In addition, the specific responses to the P0, P1, and P2 phases varied substantially by discipline. We suspect that the responses may correlate with the type and complexity of the P2 project; however a more thorough analysis of the complete data set is required and will be discussed in a future publication.

Implementation Challenges

The first offering of EPDS II involved a course coordinator, 10 instructors, 33 teaching assistants, a full time course administrator, and over 650 students from 10 engineering disciplines. Given the size and complexity of the course, its delivery over both terms in 4 sections and 12 sub-sections, and the 3 project phases, it was recognized from the beginning that variations and occasional issues would be inevitable.

With the second term of the course still wrapping up, it would be premature to attempt to list and explain all of the challenges from each stake-holder's perspective. However, several issues with the introduction of a faculty-wide course of this size, and with the combined faculty-department delivery method, are already evident, as follows:

- Communication amongst an instruction team of this size is critical, but extremely difficult to achieve. Significant advance planning and individual cooperation and flexibility are essential.
- Timetabling is a tremendous challenge. Scheduling the preferred arrangement of lectures and labs for every section was unachievable in the first year, and significant effort is being invested to improve this in the future.
- Course/Instructor assessment using university-wide standard formats is a requirement at Queen's, but does not apply well to modular project based courses with multiple instructors and phases. The custom survey was used to provide appropriate feedback, but students become survey-weary with all the required feedback.
- Developing the P1 project with the objective of being suitable for reinforcing design process, professional practice, and communication skills, and while making that project of relevance and interest to students in 10 engineering disciplines is a daunting task.
- While the objective of the P2 project was to provide the students with an opportunity to practice the knowledge and skills learned in the first half of the course on a discipline oriented project that would excite their interests in their field of choice, in some departments significant new technical material was incorporated, which diluted or deflected the intended learning objectives. This was particularly the case where a prior course was removed to make space for EDPS II, and to compensate the prior course material was squeezed into the 6 week P2 project.

CEAB FEEDBACK

The CEAB paid an accreditation visit to Queen's Engineering for all programs in October of 2011 [19]. Overall program feedback was positive. As program strengths they referred to "Excellent leadership" in an "innovative approach to the development of design and professional skills through implementation of a 'design spine'" that "will establish a very strong design experience with good integration of professionalism and other 'soft skills'." They also noted "national leadership" in "responding to CEAB's Graduate Attributes criteria" including "data collection initiated for first and middle year courses" in the EDPS.

CONCLUSIONS

The EDPS is a novel approach to creating faculty wide consistency in engineering design and professional practice education. It provides opportunities for students to experience a combination of multidisciplinary and discipline-specific projects throughout all four years of their programs. Students will meet a common set of design and professional practice learning objectives across all four undergraduate years of all ten degree programs. A multidisciplinary learning environment is common to the first year course, half of the second year course, and as an elective offering in the third and fourth years. The sequence provides an opportunity for students to integrate technical, design, and professional concepts in projects emulating professional practice.

The EDPS I and II component courses are operating successfully in the first and second years of engineering across all programs at Queen's. Similar principles are being applied to develop common outcomes for program specific EDPS courses in the third year of all programs as well as the existing capstone design courses. These common outcomes provide a solid basis to demonstrate the CEAB Graduate Attributes and to build a career in engineering with strong design and professional practice skills.

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