Journal of Learning Design

DESIGNING FOR EFFECTIVE LEARNING

Developing Design and Management Skills for Senior Industrial Engineering Students

R. J. Urbanic
Department of Industrial and Manufacturing Systems Engineering
University of Windsor, Canada
jurbanic@uwindsor.ca

Abstract

In Canadian engineering institutions, a significant design experience must occur in the final year of study. In the Department of Industrial and Manufacturing Systems at the University of Windsor, unsolved, open ended projects sponsored by industrial partners from a variety of sectors are provided to the student teams in order for them to apply appropriate design principles to generate original, feasible, working design solutions. Students may be engaged in systems design, facilities layout, optimization or other discipline related projects. To facilitate their progress, a series of interactive workshops have been designed to expose the students to team work and people skills, time management challenges, and so forth. They were designed to be fun and to support the student project activities regardless of the project type and industry sector The course structure, an overview of the workshops, and a detailed description of the 'problem definition' workshop is presented in this work.

Keywords

Senior engineering capstone design course, Workshops, Problem definition.

Introduction

Design requirements for Canadian engineering curricula

One of the principal objectives of engineering education is to prepare graduates for the practice of engineering in industry (Canadian Engineering Accreditation Board (CEAB), 2008; Dym et al, 2005; Todd & Magleby, 2005). In order to accomplish this, there must be a balance in teaching mathematics, standard science, engineering science, and engineering design along with complementary studies. 'Engineering science' subjects involve the application of mathematics and natural science to practical problems. They may involve the development of mathematical or numerical techniques, modeling, simulation, and experimental procedures. Such subjects include, among others, the applied aspects of strength of materials, fluid mechanics, thermodynamics, electrical and electronic circuits, soil and so forth. 'Engineering design' integrates mathematics, natural sciences, engineering sciences, and complementary studies in order to develop elements, systems, and processes to meet specific needs. It is a creative, iterative, and open-ended process, subject to constraints which may be governed by standards or legislation to varying degrees depending upon the discipline. These constraints may also relate to economic, health, safety, environmental, societal or other interdisciplinary factors (CEAB, 2008). The minimum accreditation units for any Canadian engineering program are presented in Table 1.

The engineering curriculum must culminate in a significant design experience conducted under the professional responsibility of faculty licensed to practise engineering in Canada, preferably in the jurisdiction in which the institution is located. The significant design experience is based on the knowledge and skills acquired in earlier work and it preferably gives students an involvement in team work and project management (CEAB, 2008). The students should be exposed to the iterative nature of design (Figure 1) and creative problem solving, as a collection of skills and knowledge, tempered with judgement, is required to realize a technical idea in an effective manner. Quantifying the qualitative (i.e. what is the definition of clean is for a cast iron engine block, electronic device, or a food product, and how is this measured?), understanding the stakeholder expectations (which may be in conflict) and the essential functional requirements is challenging and the difficulty many students experience when trying to apply single-answer techniques to open-ended design problems can be significant and should not be underestimated (Newcomer, 2001). Practical knowledge, as well as academic knowledge needs to be applied. Platts (2004) defines mode 1 knowledge as academic and discipline based. This is acquired from reading books, lecture materials and tutorial sessions. This knowledge acquisition is emphasized in the majority of courses from years 1 to 3 in many Canadian institutions. The practical knowledge, which is action based and requires the development of good judgement as well as specific skill sets, is identified as mode 2 knowledge. Learning design strategies effectively requires knowledge in both modes. Some courses have design content in them which allows students to develop mode 2 knowledge as well as mode 1. In addition to learning to exercise good design judgement, engineers need to learn to manage themselves and work with others. Understanding the context of the problem, determining the available resources, being effective with time management (either on an individual basis or in a team environment) and strengthening other related project management / non-technical performance skills is also essential as design is a holistic process (Corden et al, 2002).

Table 1: Canadian Engineering Accreditation Board quantitative accreditation criteria.

one hour of lecture (corresponding to 50 minutes of activity) = 1 AU
one hour of laboratory or scheduled tutorial = 0.5 AU

Category	Minimum Accreditation Units
Maths + Science	420
Maths	(195)
Science (basic)	(195)
Complementary Studies	225
Engineering Science + Engineering Design	900
Engineering Science	(225)
Engineering Design	(225)
Minimum	**1950**

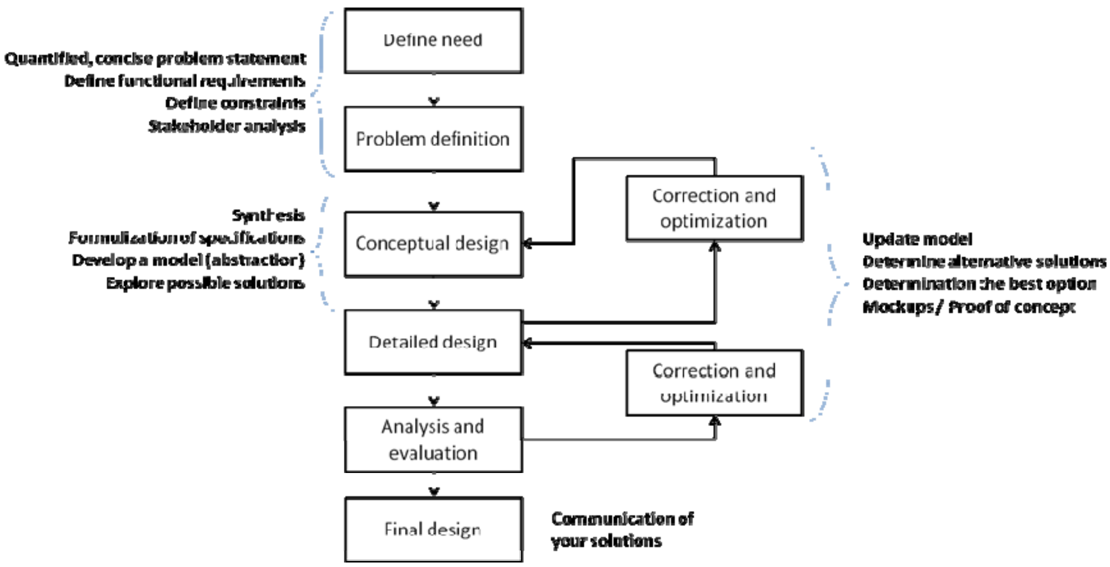

Figure 1: General engineering design process.

In order to meet the 'significant design experience' CEAB requirement, 4th year students are required to participate in senior design or 'capstone' projects. Although the goal of the capstone course is to provide senior students with an opportunity to learn design methodologies and associated skills (Eggermont et al, 2010), the composition of senior design or ‘capstone’ courses, however, varies widely (Howe, 2010).

Industrial and Manufacturing Systems Engineering at the University of Windsor

While other engineering disciplines are known for the products they design, industrial engineers (IEs) are known for the ***systems*** they design and improve. IEs integrate people, equipment, material, and information in order to enhance organizational performance by reducing costs, improving quality, throughput, and so forth. IEs bridge the gap between management goals and operational performance and may be employed in almost any type of industry, business or institution. Core industrial engineering courses focus on ergonomics, health and safety, facilities layout and material handling, operations research, statistics and quality control, systems analysis and design, and production and inventory control.

Presently in the Faculty of Engineering at the University of Windsor, the student projects are organized around departmental teams. In the Department of Industrial and Manufacturing Systems Engineering (IMSE), the capstone course runs in parallel with the design project. All students in the program undertake the capstone course for two terms, and the classes are scheduled for all day on Friday. There are no other 4th year courses scheduled during this time in order to allow students time to visit their industrial sponsors, or engage in design and implementation strategies uninterrupted. 2-3 students are involved per team, and all members of faculty in the IMSE department are engaged with advising a team project. The majority of students in the IE program have little industrial experience related to engineering. Therefore, in this course, students learn a structured design approach while working on a project sponsored by an industrial company. Potential industrial partners are contacted, and prospective projects and the project support are discussed prior to the term start. The projects must be unsolved real world problems related to the IE discipline so students can explore possible design problems and solution alternatives. Projects are sponsored by industrial partners from a variety of sectors (automotive, manufacturing, food processing, recycling, health care, pharmaceutical, warehousing, architectural and so forth). Targeting a diverse set of industrial sectors is deliberate: it is important for students to learn that the foundational design principles and methods core to the discipline can be used to define and solve a wide range of disparate problems. Sample projects are listed in Table 2.

The primary course goal is to have student teams experience design (Dym et al, 2005) in order to produce interesting, feasible, working design solutions for a real, open ended problem. The projects are large in scope in order to (i) encourage team work, (ii) encourage the usage of fundamental problem solving tools so that the students experience engineering design in action, (iii) encourage students to be creative, and (iv) provide exposure to the practical challenges in materializing ideas. Many teams must learn something new about the project application domain or must learn some new technology that their project demands. These projects force the students to spend effort in rigorous problem definition, emulating real world situations. The stakeholders need to be defined, and their needs and expectations determined quantitatively. The students need to integrate course materials as appropriate to advance basic system concepts to a prototyping and/or implementation level. They must be able to support all design decisions by defensible engineering analysis and reasoning. Academic and industrial advisors support the student efforts, but the student teams are self directed. The faculty advisor will provide technical guidance and mentoring in order to ensure that the design approach and solutions meet the academic requirements, and the industrial advisors will help facilitate data gathering, provide specific technical guidance, on-site training, and other related tasks specific to the problem and environment at hand. It must be noted that the students are not employees of their sponsors.

Table 2: Sample IE capstone projects for 2009-2010 and 2010-2011.

Title	Synopsis	Industrial Sponsor Type
Evaluation and analysis on current processes associated with blood specimen order, collection, transportation and critical result reporting	Inconsistent practices in preparing laboratory specimens for automated analysis causes errors and delays that directly impact quality of care and safety of patients. The reporting of critical results has similar deviations in practice. The resulting inappropriate resource utilization is a secondary but equally important by-product of these non-standardized practices. This situation is of particular concern in the xxx Emergency Department, where rapid feedback of laboratory results is a critical element in diagnosing patients. An in-depth investigation and analysis of current processes is needed for: order processing; specimen collection; specimen transportation and critical result reporting for lab tests ordered in the Emergency Department.	Hospital
Determination of best practices for removing gas and gas tank assemblies from End of Life vehicles	At the present, little or no work has been done assessing the ergonomics of the dismantling processes or an analysis of the efficiencies of the processes, nor have formal work models / methodologies been developed. Students will work with the industry preceptor to receive training, and with appropriate mentors to understand the scope of the problems for small, medium and large size enterprises.	Recycling Assoc.
Engineering services in prototype design and manufacturing	Rapid prototyping technologies enable designers to readily fabricate a physical model of a complex free form object, and new applications are developing in different sectors. Industrial engineering students will investigate different technologies, and will develop a design methodology and business model for modeling scale models of architectural buildings. The new Centre for Engineering Innovation building is used as a case study for the proof of concept their design methods. Internal and external details, as well as the exterior finishes can be modeled and readily manufactured at different scales.	Architectural
Developing business and quality systems using ISO 9000 standards	XXX has no office automation at this time. There are many paper procedures that should be automated, and in a manner that conforms to the ISO standards. In addition to process mapping, streamlining procedures, automating the systems (work orders, purchase orders and so forth) ergonomic analysis needs to be done for the maintenance and house cleaning duties, and alternative solutions to be investigated.	Church college
Blow moulding line process improvements	Workstations need to be designed, and a feasibility study performed in order to assess the anticipated throughput for the assembly process. Physical prototypes will be required for the assessment process.	Manufacturing

Optimize business & production systems: (i) Optimization of quoting & scheduling of job orders (ii) Modeling and analysis of material storage	The company is currently running on a very fragile system to process Request for Quotes (RFQ's) from its initial stage to the end product. The company would need to integrate either a new system or revise the current one in order to optimize the net profit. The different stages in the entire process involve getting an RFQ, preparing a quote, receiving a P.O from the customer, programming the jobs and scheduling them on floor. The company is also looking forward to implement some kind a system to track inventory. This project will be broken into 2 sub-projects: design of an ordering and tracking system, and a facilities layout and material storage project.	Manufacturing

How well are the students prepared at graduation?

Through self assessment surveys from various engineering programs which contain feedback from industrial contacts and alumni, (Ohio State University (OSU), 2006; Worcester Polytechnic Institute (WPI), 2002), it is apparent that students graduate with the fundamental knowledge of their discipline, but there are weaknesses associated with formulating and solving problems, effective communication (Norback et al, 2010), understanding societal issues, and professional ethics (an example is presented in Table 3 – the bolded text indicates significant differences for key program objectives). The results from these recent self assessment surveys complement a skills ranking survey presented by Valenti (1996), as shown in Figure 2.

Table 3: Importance versus preparation for graduate engineers (adapted from WPI,2002)

Assessment of Program Objectives	**Importance to your profession (*)**	**WPI preparation (**)**	**Difference**
A fundamental knowledge of my major discipline	3.96	4.3	-0.34
Formulating and solving problems in my field of professional practice	**3.7**	**3**	**0.7**
Ability to design a product, process, or systems	4.2	3.9	0.3
Ability to take a leadership role in a professional project	**4.6**	**4.1**	**0.5**
Understanding and applying the code of ethics for my chosen profession	**3.7**	**3**	**0.7**
Understanding current societal issues	**3.3**	**2.4**	**0.9**
Communicate effectively orally	**4.6**	**3.4**	**1.2**
Communicate effectively in writing	**4.6**	**3.6**	**1**
Using process skills necessary to be an effective member of a team	4.3	3.9	0.4

All respondents
(*) 1=never used, 2=rarely used, 3=useful, 4=often useful, 5=always necessary
(**) 1=no prep, 2=slight prep, 3=some prep, 4=good prep, 5=excellent prep

Practices	Percent
Teams/Teamwork	94
Communication	89
Design for Manufacture	88
Professional Ethics	85
Creative Thinking	85
Design for Performance	85
Design for Reliability	82
Design for Safety	80
Concurrent Engineering	74
Application of Statistics	73

- Important for job success
- Large time demands

Interfacing with multiple teams/people, including business and support departments

Figure 2: Knowledge emerging engineers need to know – ranking skills valued by industry and academic representatives (Valenti, 1996).

Across disciplines and jurisdictions, survey results indicate that students must improve their problem definition as well as their oral and written communication skills. They need to know how to lead and know how to effectively work in a team in order to be successful in an industrial environment. This is consistent with informal feedback received at the University of Windsor. Consequently, there is a gap between what the students are expected to know versus their actual knowledge base. Therefore, the academic content specifically related to the IE capstone course at the University of Windsor was designed to close this gap using a problem-based learning (PBL) approach to focus on areas of weakness (Wood, 1994). The following steps, which complement the design process in Figure 1, were used in designing the workshops:

- Identify the needs and the constraints
- Identify concepts / tools / techniques that will address the needs
- Develop the learning outcomes, workshop lectures and activities with experts in the area
- Realize the design
- Evaluate and refine the activities' designs.

Students are exposed to key principles in negotiation, project management, team building, problem definition, brain storming, oral and written communications (Figure 2), and as other external design considerations such as sustainability issues. To this end, a series of PBL workshops and seminars have been developed to engage the students in these topics in an 'activity based' learning environment. The timeline of the workshops complements the student project development timeline. They were designed to be fun and to support the student project activities (Ferry et al, 2005), regardless of the project type and industry sector. These workshops vary in duration based on the students' background and interests. Group membership changes dynamically in order to introduce students to new partners and to assist them in understanding communication challenges associated with large and smaller groups. A discussion of their results occurs after an activity, where the results are examined in detail and in context of the big picture. Workshop assessment surveys are used for student feedback. The overall course goal is to prepare the students for real life challenges. This paper will focus on the describing the capstone course structure, and the 'problem definition' workshop. The 'problem definition' workshop is selected as this is the most critical step (Figure 3) in the design process. It is necessary to properly understand the problem and its constraints quantitatively prior to being able to generate a set of solution alternatives, and selecting an optimum solution.

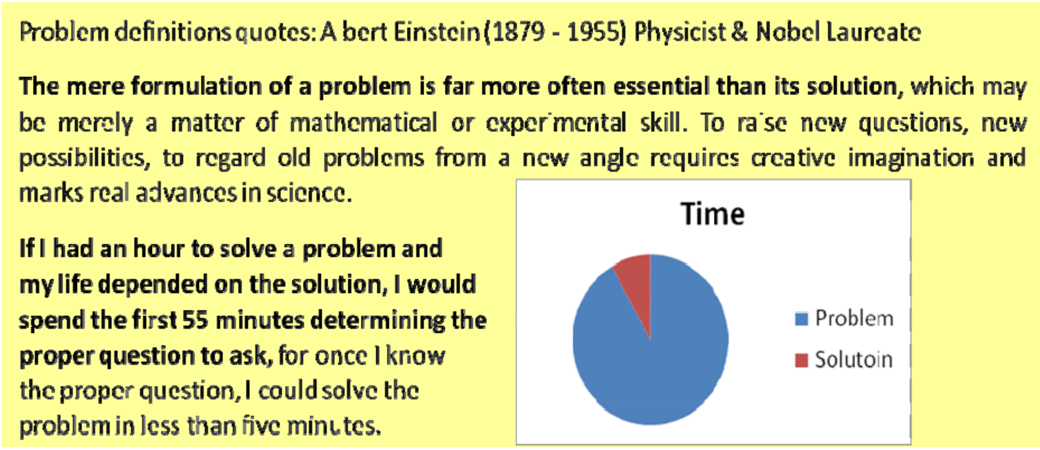

Figure 3: The importance of problem definition.

Course Structure and General Workshop Descriptions

Course outline

The capstone course is a two term course. The design process is evaluated as well as the final project. The primary grade components are as follows:

- Project reviews **30% (break down itemized)**
    - Log book (5%)
    - Assignments (5%)
    - Intermittent project report summaries (15%)
        - Proposal *(5%)*
        - Progress Report 1 (formal report) *(5%)*
        - Progress Report 2 (set of 2 pg updates) *(5%)*
    - Progress presentations (5%)
- Peer reviews **5%**
- Participation (lectures & on-site) **15%**
- Project Expo (poster or a video) **10%**
- Final presentation **10%**
- Final report **30%**

All project teams must develop project plans and assign individuals to these tasks. All projects have the same fixed deadlines for the report and presentation deliverables. Feedback on both the written and oral communication is provided throughout the course as illustrated in Figure 4. Templates and guidelines are available for the project reports and presentations. Each team prepares and presents in class, with the aid of a PowerPoint presentation, an interim presentation at the end of the first term, and their completed work at the end of the second term. The students are given 15 - 20 minutes for their presentation, with 5 -10 minutes for questions and answers. The presentations are evaluated by students, the teaching assistants, faculty and invited industrial representatives (final presentations). The students create posters to summarize their projects, which are also evaluated by faculty and the invited industrial representatives.

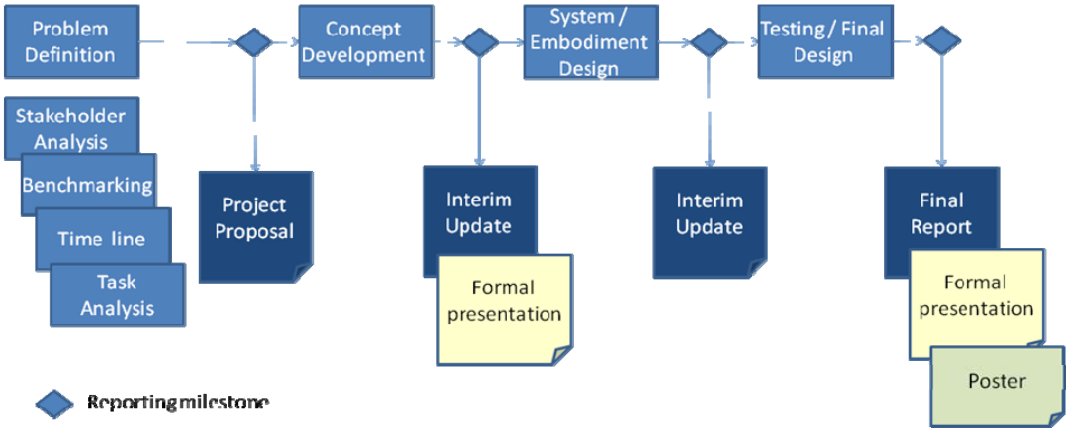

Figure 4: Capstone course flow.

The intermittent project reports are evaluated by the instructor, and may contain appraisal input from the faculty supervisors and the industrial preceptors. The percent weights for a report may be adjusted if students show continuous improvement in their work during the progress of their project in order to reward performance improvement. The peer reviews are based on the presentations, as it is important for them to critically assess project work outside of their domain, as this will be a future job function. Distorted and incomplete assessments from the students are penalized. During the first lecture, students are introduced to the course expectations, lecture outline, marking scheme, and available projects. They are tasked to initiate the formation of teams (2-3 students), and the selection of the project coordinator. The project coordinator is the single point contact for the team for correspondence with the course instructor, academic and industrial advisors. The subsequent lectures consist of workshops, approximately 2 hours in length, as itemized in Table 4. A summary of the workshops is provided in the next section.

Table 4: Workshop and learning outcomes summary.

Workshop	Expected Outcomes
Introduction to teams and teamwork (1)	(i) A discussion of the value of teams (Every member has responsibility, and working in groups is a skill); (ii) Use effective non-verbal skills when listening; (iii) Identification of preferred team roles (using the Belbin survey); (iv) Identification of the stages of group development; and (v) Feedback formats to assess group behaviours.
Introduction to project management (1)	(i) A discussion of the project management stages; (ii) Understanding effective resource utilization; (iii) Identification and understanding of personal and group performance in a time pressure environment; and (iv) Understanding the problems associated with preconceived notions.
Discussion of commonly used design tools: Brainstorming session	(i) A discussion on the stages of the design process; (ii) Itemization of design and analysis tools, and when they would be utilized within the design process stages; (iii)Project specific discussion of which tools would be appropriate
Design principles (several - as needed)	(i) An understanding of quantitative problem definition; (ii) A clear understanding of functional requirements and design parameters; (iii) Project specific discussion of which tools would be appropriate; (iv) Knowledge on benchmarking and data gathering through literature reviews, patent searches, industrial visits

Blue print reading and rapid process assessment (several - as needed)	(i) Competence related to Geometric Dimensioning and Tolerancing (GD &T); (ii) An understanding when redimensioning is required to facilitate manufacturing; (iii) Identification of 'non-manufacturable conditions' based on improperly dimensioned, missing or unclear information; (iv) The importance of discussing notes that can be interpreted differently; and (v) The ability to systematically decompose a complex drawing quickly and effectively.
How to do a presentation	(i) Understand the importance of body language, and clarity of speaking (ii) Developing effective visuals for a presentation costs, and so forth.
Sustainable engineering (1)	(i) Comprehending the issues associated with disassembly (and reassembly), dismantling, reusing, remanufacturing, and recycling. (ii) Utilizing practical Industrial Engineering tools, data, and hand tools related to real sustainability product and process design issues and (iii) Understanding systems, tooling, resource and business issues in context of human factors, materials, direct and indirect costs, etc.
Advanced measurements, inspection methods (several - as needed)	(i) Competence using standard measuring devices (verniers, calipers, multi-meters and so forth), and hand tools/torque wenches etc ; (ii) An understanding of state of the art non-contact inspection tools (laser based devices) used to verify both products and machines (alignments); (iii) Challenges associated with qualitative inspection requirements, and translating them into quantifiable measurables (i.e. clean - what does clean mean, and how is this measured?).

Workshop Outlines

Introduction to teamwork workshop

The ‘Introduction to Teams and Teamwork’ workshop occurs during the second lecture as effectively working with people is critical for success, and is presented by a member of the Centre for Teaching and Learning. Students are arbitrarily set into a group, and are tasked to discuss:

- “What would a bad team experience look like?”
- “What would a good team experience look like?”

During the discussion period, it is evident that the negative experiences outweigh the positive ones, and the concept of a team charter, drafted by the participants in where they clarify roles and responsibilities to each other is introduced.

Exercises in listening, and solving a problem as an individual and in a group (a different selection of students for this exercise) are presented. Again, during the discussion period, concepts related to group dynamics (domination, avoidance, consensus testing, feedback and so forth), body language, cultural norms and communication are explored. The Belbin survey (Belbin, 2010) is used to assist individuals in articulating their preferred roles within a team. For example, if there is a team consisting of people who all prefer a leadership role, contention will ensue. Objective feedback and reporting mechanisms are discussed, along with the concept of a team charter again. At the conclusion of the workshop, the final teams are established, and the project selections are determined. The next workshop focuses on project management.

Project management workshop

The project workshop concentrates on Henri Fayol's (1841-1925) five stages of project management (Figure 5). These five stages are explored with student teams, again where the members are randomly selected, in an activity that asks students to design and create paper flying devices. The activity is brief with approximately 10 minutes to build the device, which is typically a variant of a plane, although the workshop is deliberately set up not to focus on a specific solution direction. Time is limited to demonstrate the impact of time pressure on the design approach, team activities, and the final result. The provided resources include: paper, Bristol board, tape, fasteners, and so forth. The distribution of resources is inconsistent amongst teams, to emphasize that investigation, discussion and negotiation with respect to resources may be necessary to realize a solution. Students find that limited time changes their approach to the design and execution stages of the project. The monitoring and controlling stage of project management is explored by students when they fly their planes to discover whose fulfills the objective best, which is typically assumed to be that which flies the furthest. Assuming performance requirements is examined as there no specific performance goals mentioned in the design statement. Students are then asked to comment on the following topics, related to their project: goals and objectives, task management, group dynamics, resource management, and constraints. Upon closing the activity, students are asked "what they would do differently" to relate the concepts that they've learned back to the scenario that they just explored.

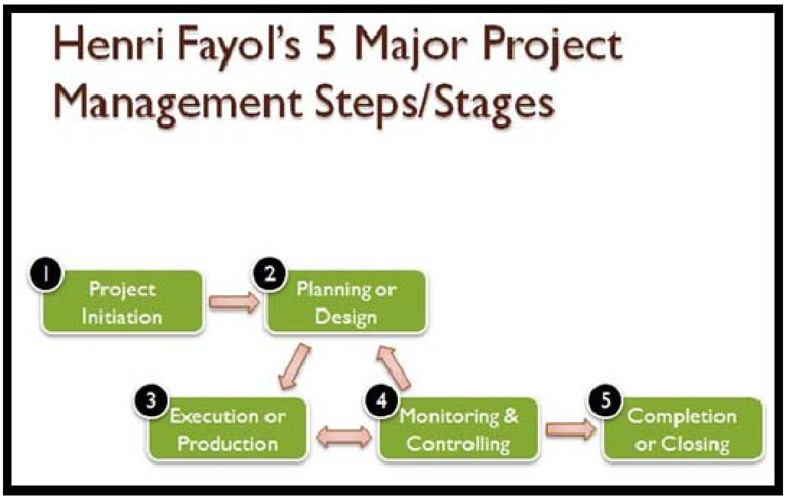

Figure 5: Fayol's 5 stages of project management.

Design process workshop

The design related workshops first start with a brainstorming session with the students providing input identifying the design stages (Figure 1), and the tools that should be utilized during that stage. It is highlighted that effective utilization of these tools and methods will provide support for design decisions. A secondary point that is made it that using the appropriate tools is necessary to meet the academic requirements of the course. A selection of student identified tools for the student decomposition of the 'identify problem' stage is listed in Table 5.

Table 5: Brainstorming results–tools and methodologies.

Requirements	***Tools / Methodologies***
Identify problem and stakeholders Scope / assumptions / constraints Deliverables / outcomes Find facts Verify facts Clarify facts - quantification Analyse Requirements Verify facts Clarify facts Prioritize	**Problem definition** Benchmarking, literature review, surveys Functional requirements decomposition (axiomatic design, functional decomposition diagram) Non-functional requirements decomposition Failure Modes and Effects Analysis (FMEA) Needs assessment analysis Root cause analysis Statistical analysis Quality Function Deployment (QFD)

Problem definition workshop

This workshop consists of several interactive tasks in tandem with presented lecture material. The students are requested to perform design activities in a team setting under time constraints. There are discussions with respect to their approaches and results. It is well recognized the only way to 'learn design' is to 'do design' (Dym et al., 2005; Ullman, 1992). Hence, a set of design challenges are presented to students in a controlled environment. The design process should be learned in a dual setting: (i) in an academic environment, and at the same time, (ii) in an environment that simulates industrial realities. The first design task consists of teams working on one of three very poorly defined challenges as listed below:

- Design a Washing Device
- Design a Storage Device
- Design a Door

After completion, the group spokesperson reports on their activities. Questions are asked with respect to: what is the problem being solved; who are the stakeholders; what are the assumptions and constraints; what are the functional requirements; how are the functional requirements being met or the implementation strategy; and is this information stated in a qualitative or quantitative way? Typically, the students sketch solutions without fully understanding or clarifying the problem and confuse functional requirements and design solutions. Solutions for washing devices have included: eye washers and washing machines for clothes (although this was implied). Storage device solutions included electronic devices as well as shelving, and doors have included sketches for a garage door, office door and a pet access door. This exercise is used as a foundation for in-depth analysis for the above enquiries. This exercise illustrates that questioning is an integral part of design (Dym et al., 2005; Dym & Little, 2003).

Stakeholders are discussed in detail as being: Users, Support / Maintenance personnel, Implementers, Evaluators, Decision Makers, Legal Experts, Advisors and Team members (a partial list) and are subsequently defined for each design challenge. Emphasized is that they are involved in defining the problem and what constitutes the "proof" of success. Several students hasten to a solution that contains design details before the needs are fully understood, and often neglect stakeholders critical to their problem. The next discussion point concentrates on the necessity of defining WHAT should be done (functional requirements or FRs), prior to HOW (design parameters or DPs) this WHAT could be resolved (Suh, 2001). Understanding the difference between functional requirements and design parameters is essential for effective solution generation. The FRs are expressed as needs, and can be defined as a primary FR, a secondary FR and so forth in a hierarchical manner. Anticipated misuse, abuse, emergency usage and so forth must be considered. Explained is that positive or neutral phrasing should be utilized, with avoidance of the words "must" and "should" (Ulrich & Eppinger, 2007).

The goal of this systematic approach is to:

- Provide a fact base for justifying product specifications,
- Create an archival record of the needs activity,
- Ensure no critical customer need overlooked,
- Engage the stakeholders,
- Ensure the team understands customer/stakeholders' needs, and
- Provide a basis for the implemented (and detailed) design alternatives.

The students then perform an exercise to decompose the functional requirements in a hierarchical manner for a cordless screwdriver in a simple noun verb format. Upon completion of this exercise the students assess the FRs for a cordless drill. The items in the sample result below (Figure 6) are common to both devices. This is done to illustrate using a modular design approach, the design solutions could be used to support multiple devices, or a dissimilar device with similar FRs could be assessed to prior potential solution alternatives for their problem.

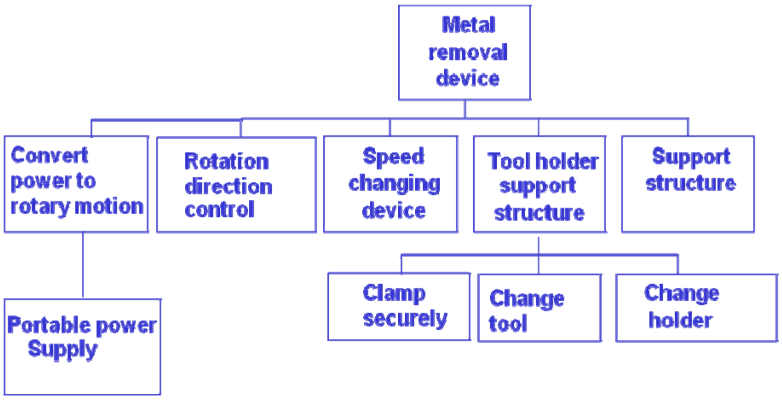

Figure 6: Functional hierarchy – adapted from Suh (2001).

The final design challenges focuses on designing a better mouse trap (Figure 7). The primary functional requirement overlooked by students is: kill versus capture. This introduces ethics into the design discussion, and to date there has been no consensus in class with respect to this FR.

Figure 7: Mouse and trap.

Blue print interpretation and rapid process assessment workshops

Students may be engaged in process design and optimization. Consequently, there are blue print reading workshops, presented along with complementary cost, floor space, and operator estimation techniques, using industrial engineering approaches. A drawing of a front engine cover for a single cylinder engine is decomposed methodically. Geometric dimensioning and tolerancing principles are reviewed, as well as the manufacturing processes necessary to fabricate the cover.

A methodology to quickly determine the number of machines, floor space, operators, and capital investment costs is presented for various production volumes.

Introduction to sustainability issues workshop

Students will encounter challenges related to sustainable design and material recovery processes in their future. Practical issues relating to disassembly (and reassembly), dismantling, reusing, remanufacturing, and recycling are explored using random sub-assemblies provided by dismantlers (i.e., heater assembly, front door assembly (left side), steering column assembly, radiator assembly, starter motor and alternator). Students physically disassemble these components, and assess recyclability issues. The components are then reassembled. This workshop is detailed in Urbanic and Sawyer (2011).

Advanced measurements and inspection methods workshops

In the advanced measurements and inspection methods workshops, one workshop exposes students to traditional conventional measuring tools such as multi-meters, callipers and depth gauges using a Vernier scale, height gauges, 1-2-3 blocks, etc. A gauge repeatability and reproducibility analysis to assess the stability of a gauging method is also performed. The other workshop exposes students to laser alignment tools for calibrating machine tools, and using a sophisticated portable CMM for measuring components. Industrial specialists assist in presenting this workshop.

Oral communications workshop

A faculty member from the School of Dramatic Arts does a "How to Do a Presentation" seminar in which students are exposed to the power and meaning of body language, speech patterns, motion, and silence. The student teams engage in impromptu presentations on "What they had for breakfast" and other similar simple topics to practice learning points. Also, tips and techniques for strong visual impact are discussed. The key points presented in this workshop are used for the presentation evaluation matrix (Table 6) for both the interim and final presentations.

Table 6: Presentation marking scheme.

	Evaluator Name					
	①Not very successful ② Could be better ③ Average only ④ Quite Good ⑤ Very Good					
		1	2	3	4	5
Content	**A. Introduction, Objective:** Statement of the problem, clarification of the need and requirements					
	B. Approach and Methods: Relevant literature review, benchmarking, justification of suitable engineering concepts and methods					
	C. Results, Conclusions, Future Work:					
Presentation skills	**A. Professionalism** (Proper dress and demeanour, respectful and responsive?)					
	B. Clarity of Speaking (Can the speaker(s) be heard loud and clear?)					
	B. Quality of the visual aids? (Slide quality, use of PowerPoint, etc.)					
	D. Clarity of Language (Was everything [terminology etc.] clear? Any technical jargon used?)					

	E. What About Body Language? (Eye contact, speaking to everyone and not just to one or two individuals, confidence, etc.)					
	F. The Structure and Procedure (Intro, problem statement, conclusion, use of notes, invited questions, goodness of delivery.)					
	G. Response To Questions (Were the questions understood and answered to satisfaction?)					
	I. OVERALL RATING					

Summary and Conclusions

Engineering design is a systematic, intelligent process in which designers generate, evaluate, and specify concepts for devices, systems, or processes whose form and function achieve clients' objectives or users' needs while satisfying a specified set of constraints (Dym et al, 2005). It is a top-down hierarchical process where general principles are methodically applied to synthesize solutions that satisfy the need. Rules are established based on constraints, experience and preferences, limiting the design degrees of freedom (Urbanic, 2007). It is challenging for students to engage in the design process; consequently, it is a requirement for engineering students in a Canadian engineering program to undertake a significant design experience prior to graduation.

If a design project is implemented without clearly defined structure and guidance, it is likely that students will become frustrated and will procrastinate until just before design deadlines (Newcomer, 2001). Therefore, activity based workshops have been designed to provide practical exposure to realistic design issues. These workshops complement the design process and the students' progress in the capstone course. The students are involved with mini-projects and design tasks in a safe environment. Also throughout the capstone course, formal feedback in oral and written form is requested in a timely manner to assist students in keeping on track and improving their communication skills. It is essential for senior students to be able to effectively manage their time and resources when exposed to open-ended design problems, as they will be faced with similar challenges and constraints in industry. It is also important that the students perceive that the same structured design approaches can be utilized effectively to solve problems in disparate industrial sectors.

To conclude, it is important for all students to receive hands-on relevant experiences encompassing the complete design experience in order to prepare them for future engineering challenges. They need to be prepared to handle uncertainty, make decisions, deal with time and resource pressures, consider the environment and societal issues, and communicate in the language of design. Engaging in open ended industrially supported projects while taking a capstone course in parallel supports this endeavour.

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Acknowledgments

The support of Victoria Townsend in Industrial and Manufacturing Systems Engineering, Erika Kustra in Psychology, Lionel Walsh in Dramatic Arts, and Susan Sawyer-Beaulieu and Bill Middleton in Environmental Engineering is gratefully acknowledged.