INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN
ICED 03 STOCKHOLM, AUGUST 19-21, 2003

ROLES AND RESPONSIBILITIES FOR STUDENT DESIGN PROJECTS

T. Brusse-Gendre, O.R. Fauvel, D.J. Caswell, C.R. Johnston

Abstract

The roles and responsibilities of those involved in an engineering design course have evolved and been refined since the introduction of real world, industry-sponsored design projects. Both students and those helping in the course can now be provided with guidance as to expectations of everyone involved. The role of instructor has been enlarged to that of Coordinator[1] – a role that requires much more planning and management activity. (Graduate) teaching assistants have been given a much enhanced teaching role – that of a Design Coach – a role that specifically supports inquiry-based learning. Furthermore, new and expanded expectations have been placed on the undergraduate student Design Team in that they must assume much more responsibility for their learning and the progress of their project work.

Employing real-world projects has led to involvement of more people who each contribute in their own ways. Each project now has its own Project Supervisor who typically acts to connect the Design Team with the problem domain; the role of Project Sponsor is to bring a project forward along with appropriate resources. Domain Experts may be sought out by the Design Team or brought to the table by the Course Coordinator or by a Project Sponsor; they typically bring enthusiasm as well as extensive knowledge to the program.

Associated with the utilization of externally supported projects is the need to protect the intellectual property of the students and Sponsors, thereby necessitating the involvement of Legal Counsel. Moreover, the desire to have students realize and verify at least part of their design efforts introduces the requirement for significant support by Technical Staff.

In this paper we describe and explore some of the more important roles and relationships involved in the conduct of the design courses. These efforts have not been in vain as it has been observed that students have gained confidence in their abilities and become increasingly capable of independent work as both their projects and learning progress.

Keywords: Design Education, Pedagogy, Projects, Industry Participation

1. Introduction

The pedagogical approach to teaching the capstone undergraduate courses in mechanical and manufacturing engineering design at the University of Calgary has moved from one built upon the traditional instructor/student relationship towards one that utilizes a range of open-ended, real world design problems – each to be solved by a team of from three to five students. This approach prepares students to deal with not only technical aspects of design but also a number of complementary managerial and communication requirements. To this end, the learning environment for these courses has been explicitly designed to include representatively appropriate support personnel playing specific, defined roles.

---

[1] Newly identified roles are indicated using Capitalization and underlining of first use.

Through the observation of a large number and variety of undergraduate design projects that have been conducted over the past four years, (30-35 projects undertaken by up to 120 students each year) it has been possible to ascertain the roles of key types of personnel with which the design teams have interacted (or failed to do so). From these observations, perceptions of relationships, expectations and overall project progress have been distilled into the roles and responsibilities of the key players described in this paper. (It should be noted that this paper does not address the dynamics within the Design Team as this has been extensively discussed elsewhere.)

2. Background

In the fall of 1997, the Department of Mechanical and Manufacturing Engineering significantly revised the two senior capstone design courses (in the Manufacturing and Mechanical programmes respectively), in part to satisfy new design education criteria required by the Canadian Engineering Accreditation Board. Engineering schools became required to expose students to a teamwork situation in the execution of a significant design experience that would allow them to apply much of the knowledge and skills they had acquired through their academic experiences [1]. While not specifically mandated, the creators of the course felt that the students would realize the most benefit if the character and conduct of their design projects represented, as closely as possible, a “real world” situation. To accomplish this, real, interdisciplinary, open-ended projects - suitable to the abilities and time limitations of students - were procured from industry and the community.

Necessary to the introduction of this number of real world projects, the pedagogical approach to teaching design moved towards one wherein students took responsibility for both their learning and the progress of their design projects, from inception to the development and testing of prototypes. This allowed students to apply engineering fundamentals as well as providing opportunities for project management, interdisciplinary interaction, and gaining experience of dynamic, real world challenges.

In support of the move to this inquiry-based learning approach, [2] classroom instructional-type activities (i.e., lectures, tutorials and labs) were significantly reduced to less than twenty-five percent of scheduled course time over an eight-month period, with many of the remaining lectures being forums where guests from industry shared their experiences. While at first glance it may appear that the efforts required on the part of the instructor have diminished, the reality was quite the opposite. Not only did the role of the instructor expand, it became necessary to introduce a number of other key contributors, both from within and outside of the University, to address matters transcending the scope of design methodology. These contributors took on the roles of Course Coordinators, Design Coaches, Project Sponsors, Project Supervisors, Domain Experts, Technical Staff, Legal Counsel and guest lecturers – all of which have been observed to enhance the quality of design outcomes and student learning. (Parallels to many of the concepts developed here can be found in the Boyer Commission Report [3]).

Given the inquiry-based learning approach, it is perhaps most appropriate to first view the design environment from the perspective of the Student Design Team. Figure 1 illustrates the main interactions encountered. Necessary interactions as shown by solid arrows represent the minimum requirement for all Design Teams. In most instances teams will also need to exploit technical and other resources as indicated by the broken arrows. It should be noted that ‘authoritarian’ relationships are not the norm; typically the nature of the relationships requires negotiation and communication of information.

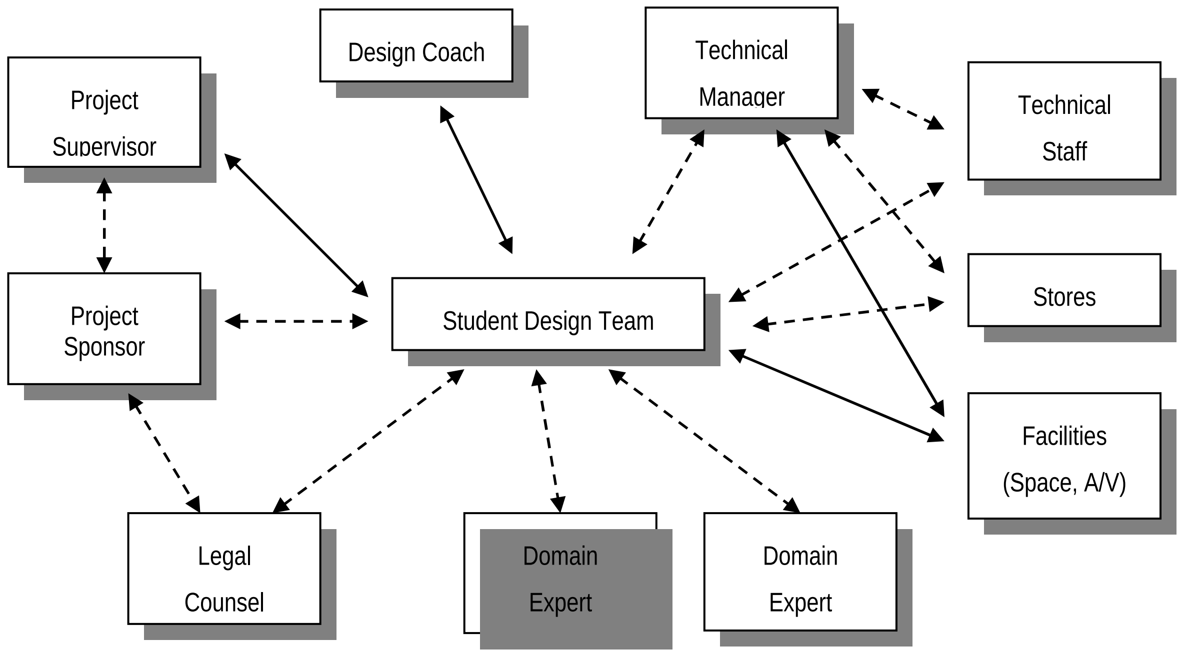

Figure 1. Mandatory (—) and potential (– –) relationships centred on a particular Student Design Team and their project. (The absence of the instructor/Course Coordinator may be notable.)

3. Cast of players

3.1 Student Design Team

The students themselves are considered to be the most significant contributors to, and the central players in, their design learning. They begin the process by taking a personal inventory of their knowledge, skills and interests, and then communicating these qualities in a brief resume that they submit to the Course Coordinators along with an indication of preferred projects amongst those offered. After receiving their project assignments, the team members are responsible for initiating a meeting at which they are mandated to discover each others' strengths, preferences and goals (exercises are provided to assist this effort), as well as to create a preliminary plan for the project. The next step is to initiate contact with their Design Coach as well as the Project Sponsor and Supervisor, and begin the process of defining the scope and requirements for their design project. Concurrently, students must also formulate a realistic project plan so that time, resources and risk can be managed effectively. Once again, resources are available to the students that will specifically aid them in carrying out the many exercises and milestones that they face during the execution of their projects. (These resources, specifically the Design Toolbox and Student Manual, are described by Brusse-Gendre *et al* [4], and Johnston *et al* [5], and represent the only printed material provided by the Course Coordinators to all students. Caswell *et al* [6] discuss the philosophy behind and success of this inquiry-based, "no textbook-approach".)

As the character and needs of each project vary due to their realistic nature, it would be impossible for the Course Coordinators and Design Coaches to provide sufficient specific domain expertise to every design team. This is considered to be a positive attribute in that if specific learning needs arise, students must at least in the first instance seek to address these. Students will frequently approach their Design Coach with numerous questions at the outset of their projects, to which the appropriate Coach's response is not to answer their questions but rather to suggest, in general terms, potential methods of inquiry and sources of information. This approach has been observed to be successful in that student teams rely less and less on their Design Coaches as they determine on their own which questions need to be asked – and of whom, to move their projects forward most efficaciously. This observation is supported by a study showing that, "as designers gain both general and specific experience they are able to quickly generate a problem paradigm" [7].

Over the course of the two semesters each Design Team is required to conduct four design reviews – requirements, concept, final design and a hand-off of work to the Sponsor. These four reviews provide an opportunity for the design teams to have the key stakeholders for their project (e.g., Supervisor, Sponsor, Coach and relevant domain experts) in a single meeting during which progress can be updated, questions asked, assumptions clarified, ideas critiqued, and hopefully, agreement gained on a single way forward. The Design Team is wholly responsible for the preparation, content and conduct of these reviews that form the basis of over sixty-percent of their overall grade. If Technical Staff or other resources are required, it is the responsibility of the Design Team to manage this aspect in co-operation with the Technical Manager.

The grand finale of the course is a poster session that is open to the public. This is an opportunity for students to show off their design efforts to their peers, other instructors, project stakeholders, potential employers and the media.

3.2 Course Coordinators

The faculty members responsible for the two courses are considered Course Coordinators rather than instructors as the traditional role of providing a comprehensive series of lectures is no longer the prevailing one. Instead, the guiding principle is that the Course Coordinators will provide a suitable learning environment. Specifically, they must organize all of the various players and resources so that students can participate in the most efficient and productive manner. (In a given year, for 120 students, up to 50 additional people may be involved – most of whom are recruited either directly or indirectly by the Coordinator(s).) Figure 2 illustrates the most important relationships with the Course Coordinator.

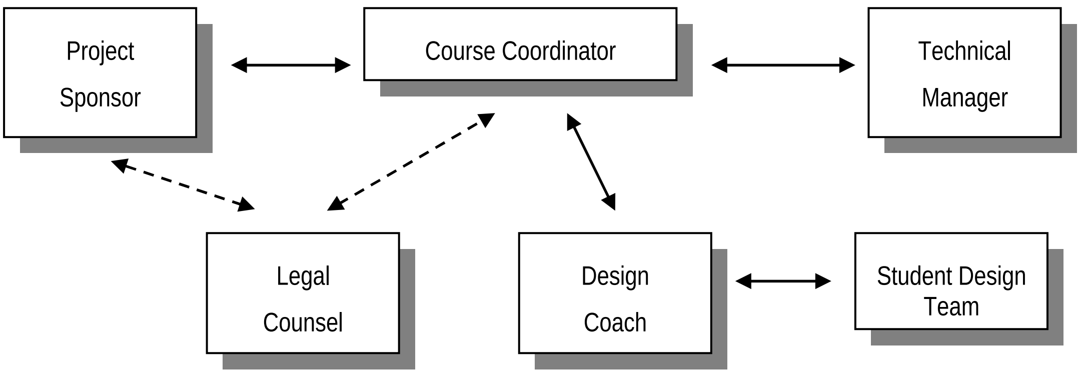

Figure 2. Mandatory (—) and potential (– –) relationships involving the Course Coordinator with regard to each particular project.

The coordination efforts on the project management side involve securing 30 to 35 separate projects having adequate scope, complexity and support, then continually monitoring the relationships between the Project Sponsors, Coaches and Design Teams. This process typically begins six months prior to the start of the course. Information and application packages are sent out to a large number of companies, not-for-profit organizations and individuals who have either shown an interest in the program or have been highlighted as a potential contributor. Within a few weeks of sending the packages, one of the Course Coordinators arranges to meet with potential contributors either in person or by telephone. The purpose of this meeting is to answer any questions as well as to judge the potential level of interest and commitment. Within the three months prior to the start of the course, the Coordinators receive and evaluate the project proposals, refine the project definitions as required with the Project Sponsors and prepare postings for the selected projects. It is these postings that are presented to the students in September. Once students have “applied” to work on the desired projects, the Coordinators staff the projects, in the first instance based on preference, and in the second, based on the skill set required for the problem domain.

On the instruction side, the Coordinators deliver some lectures and facilitate many of the learning exercises, primarily in the first few months of the course. The topics for these sessions are mainly on design methodology – for example, design for ‘x’ – and on project management. As the year progresses, the Coordinators arrange for experts from industry to share their experiences on special topics that are likely to be relevant to most if not all Design Teams and likely to be useful preparation for future engineers-in-training.

The final role of the Course Coordinators is to provide training for the Coaches and coordination of the evaluation process. The main fora for this activity are weekly meetings in conjunction with a graduate course on design pedagogy [8].

3.3 Design Coaches

The Design Coaches are typically M.Sc. and Ph.D. graduate students. Each of the (typically) five or six Coaches each year are assigned to work with approximately five Design Teams for the entire duration of the course. They typically meet with these teams on a bi-weekly basis in order to monitor their progress and offer guidance when appropriate. The Coaches are not required to become experts on each of the projects they coach but rather are encouraged to stand back and pressure the students to gain the requisite expertise for their projects. Further, the mandate of the Coaches is to allow students to uncover the answers regarding design process even if it means they may flail about somewhat; receptivity grows greatly with need.

Another responsibility of the Coaches is to evaluate the work of the students. For their design teams, this is accomplished primarily at design reviews where the review and the work leading up to the review are assessed. To account for differences in marking styles between Coaches, the Course Coordinators attempt to attend as many reviews as possible, compare the marks submitted by each Coach and adjust accordingly to mitigate differences. For each of the two quizzes, Coaches submit potential questions, which are vetted and refined by the instructional team (Coaches and Course Coordinators) and subsequently included on a quiz. Each Coach is required to grade the answers to the question he or she has submitted.

The outcomes of the graduate student as Design Coach approach are two-fold: a large class of students is able to experience the benefits of the small class environment, and the graduate students are able to apprentice as educators under the guidance of a Course Coordinator. This is one of the key elements cited by the Boyer commission for the improvement of undergraduate and graduate education [9].

3.4 Industry and Community Participants

One of the key factors to success for the design course is the group of representatives from industry and the community. To-date, they have volunteered well over 6000 person-hours working directly with students in the capacity of Project Supervisors. People who have offered their expertise at design reviews, provided guest lectures, facilitated workshops and participated in user trials have donated countless more hours. These volunteers may be individual contributors or may represent one of the many local, national or international organizations that have been, and continue to be, involved in the course. The diversity of these organizations is vast: small, family-run manufacturing shops to global, high technology and oil and gas corporations represent the industrial sector; not-for-profit organizations such as those supporting persons with disabilities, Olympic athletes, local police and fire personnel, and medical practitioners including surgeons, represent community participants.

Project Sponsors are individuals or organizations that have proposed project ideas or design problems and have agreed to support the conduct of these projects for the duration of the course. As a minimum, these Sponsors must commit the effort necessary to communicate the required functionality of the desired product or process to the design team, participate in design reviews and provide the team with timely feedback. Some Sponsors are able to support the design program by providing financial support for their project or the program in general, or donate through gifts-in-kind in the form of materials or fabrication of prototypes.

Ideally, and in most cases, the Project Sponsor (or an individual from the Sponsor’s organization) serves as the Project Supervisor. In instances where this is not viable, another, more appropriate individual is identified by the Sponsor to fulfill this role. This Project Supervisor typically meets with the Design Team bi-weekly and serves as the prime domain expert for the project. The Supervisor is a key participant at all design reviews and often arranges for other Domain Experts to attend the reviews. Additionally, the Supervisor may arrange for students to observe environments that may aid their understanding of the design problem. For example, students developing surgical tools are often permitted the opportunity to witness an applicable surgical procedure. In this way, the methodology of the course creates a real world design environment in which “Bringing different points of view together and trying to create a shared understanding among all stakeholders can lead to new insights, new ideas, and new artifacts” [10].

Over the years of offering the course, there have been primarily three main project types: academic, competition and industry/community. Each provides its own unique relative benefits and challenges.

Academic projects have ranged from those that are practical in nature, such as the development of apparatus for use in laboratories, to those with a more “proof-of-concept” focus such as examining the feasibility of capturing and converting engine exhaust into a usable energy form. Typically, the faculty member who initially proposed the project serves both as Project Sponsor and Supervisor. If required, projects are usually funded through existing research budgets.

The co-location of Project Supervisors and students as well as the relative stability of schedules results in greater accessibility of Project Supervisors and increased compliance to time and meeting commitments. As projects are often tied to the Project Sponsor’s primary research interests, their dedication to the project is sometimes greater than that of their industry counterparts. Along the same vein, these connections to research have sometimes resulted in the Project Sponsor inadvertently guiding the student team to cross over from the design realm into the research domain. This poses difficulty for the students as they attempt to apply design methodological practices and meet the key deliverables required in the course curriculum.

The relationship between the students and their Project Sponsors/Supervisors has been notably different for some academic projects. The students do not always seem to exert the same degree of confidence they do with external sponsors and instead return to the familiar role of teacher and student. The students tend to look to their Project Supervisor for greater direction and seem to be less likely to challenge their Supervisor or to exert independent thinking. It is not clear whether this is due to the entrenched behavior of the students or in response to the Supervisor's approach.

Competition projects are unique in that they typically do not automatically have a well-defined Project Sponsor other than the students themselves. For many of the projects, the Society of Automotive Engineering (SAE) projects in particular, there may also be multiple student teams working on different sub-systems and these teams often include students not enrolled in the course but participating on an extracurricular basis. In the past, many of these design teams worked only with the guidance of the Course Coordinators and Design Coaches. However, the successful practice now is to find an appropriate Project Supervisor that can bring some expertise along with a different perspective to the team. It has been a significant challenge to recruit and retain appropriate Project Supervisors who exhibit a high level of dedication based primarily on personal interest in both the project and in working with the students. For the SAE projects, the Project Supervisors have characteristically been professional engineers, technologists, or academics who may be dedicated hobbyists or specialists in the areas of automotive or airplane design. Securing supervisors for the Mines Action Canada competition projects has been somewhat more challenging but no less successful, with students benefiting from the guidance of a professional engineer and a senior bomb squad technician from the local police force.

Another unique feature of the competition projects is that the requirements that form the requisite product development specification are not garnered from the Project Sponsor and "customers" but rather from the competition rules and guidelines, other sub-system design teams, and input from the Project Supervisor and other domain experts. As the competition rules often direct many aspects of design in addition to providing open-ended requirements, the students on these teams sometimes have difficulty grasping the concept of requirement versus design.

In comparison with other design projects, many of the competition projects place additional demands on students' time for activities such as fundraising and the requirement to fabricate a complete product. Students in the past have requested leniency in regards to course requirements because of these extra time commitments. In response, Course Coordinators have had to be diligent about stressing the expectations associated with the course versus the extracurricular nature of many of the competition project activities.

Industry and community projects are unique in that efforts must be made to protect the intellectual property brought to the project by the students as well as the Project Sponsor or any other contributors from outside the University. While this requires significant additional effort and planning on the part of the Course Coordinators and the University's legal counsel, (to be discussed later in this paper), the benefits are considerable, as working with an external "client" (Project Sponsor/Supervisor) more closely parallels a real world situation.

The characteristics of the Supervisors of the industry and community projects are as varied as the projects themselves. Often when large companies are involved, professional engineers or technicians are assigned to work with the design teams. This often creates a mentorship-type relationship. The downside is that the professional engineer is often tempted to guide the Design Team towards a solution – an opportunity that most students will gladly embrace rather than struggling with the problems themselves. Other benefits of corporate-sponsored projects are the potential availability of funding or resources, and reasonable accessibility to additional expertise. Another negative of these projects is that they are often “nice but not necessary”, as reflected by a sometimes-observed dwindling level of commitment over the duration of the project.

When smaller companies or individuals are involved, the Sponsor/Supervisor is more often than not a non-engineer and may in fact have little or no formal post-secondary education. These people sometimes need to be encouraged to work with the design teams as they are intimidated by the students’ levels of education and feel that they cannot offer a significant contribution. This is actually contrary to observation; these domain experts offer a wealth of knowledge that students do not possess and in some situations, may never possess, as is the case of the disabled skier conveying his perspective of skiing without the aid of his lower limbs. Moreover, these experts force students to focus on effectively communicating in non-engineering language in order to elicit the input of and share ideas with Sponsors such as elite athletes, medical practitioners and even a homeowner who is seeking a solution to snow build-up on his roof-mounted solar panels.

A number of guest lecturers from industry are invited to speak to the students each year in the role of particular Domain Expert. Some provide information that can be applied by teams to their current design projects while others address special topics that may not have immediate applicability but provide useful knowledge for future engineers-in-training. Some lecture topics delivered by professional engineers and technicians, suppliers, lawyers, and even professional musicians have included intellectual property and commercialization, project management, concurrent engineering, product liability, creativity, specifications, standards, and material selection and acquisition. The feedback from students on many of these speakers has been so favourable that they have been invited back year after year.

3.5 Technical and Other Support

One of the objectives of the course is to have each team realize at least a portion of their design in a way that affords opportunities for verification. For this to be accomplished typically requires the support of a variety of technical staff and other resources. In consultation with the Course Coordinators and the Department Head, the Technical Manager for the Department assumes the major responsibility for managing the course’s resources including support staff, equipment, space and facilities, and budget. Part of this responsibility is to review the proposed budgets for each of the design teams, approve and initiate the procurement of materials and equipment from internal stores or external suppliers, and manage the processing of materials in Department or Faculty workshops.

The Technical Staff in the workshops work closely with the Design Teams in the fabrication of individual parts or whole prototypes. As much as is feasible, the technicians will supervise students in the fabrication of their prototypes in University facilities to provide them with “hands-on” experience. Even in situations where the technicians execute the work themselves, they make a point of providing students with practical feedback on their selection of materials, drawings and manufacturing instructions.

Another role assumed by support staff is in the logistical planning and realization of the poster presentation. While this event may only last a few short hours, an enormous effort is made by support staff in the preceding months – facilities, equipment and materials are arranged, sponsorship secured, invitations sent, the printing of posters organized, and judges recruited to choose the top teams.

3.6 Legal Counsel

One of the challenges of student design teams working on externally sponsored projects is the protection of the students' intellectual property. Legal Counsel situated within the University's Research Services department works with the Course Coordinators, Project Sponsors and students to ensure this protection.

(Under the University of Calgary guidelines, the University retains ownership of the intellectual property created by the students on their behalf, and states as much in the "Agreement for Participation" that all external Project Sponsors must sign. The Agreement goes on to state that the Sponsor has the "first-right of refusal" of the intellectual property created by the student design teams and University staff, and if so desired, the University will negotiate a world-wide, perpetual, royalty-bearing license. If the University receives royalties from the commercialization resulting from a design team's efforts, half is placed in a fund for the Design Program and the other half is distributed as directed by each individual team member in the "Student Agreement". In this agreement, students have the option to designate their share of the royalties to the Design Program Fund or to keep the University apprised of their current address so that they may receive the royalties personally. To date, approximately one-third of students have elected to designate their portion of the potential royalties to the Fund.)

The Legal Counsel also acts as an advisor to individual design teams as required, on issues such as patent infringement and confidentiality. On occasion, counsel has prepared special agreements outlining an acceptable working relationship between the University and external stakeholders. For example, the purpose of one such agreement was to protect the identity, medical condition and place of residence of disabled persons involved in usability testing of an assistance device being designed by a Design Team.

4. Conclusions

The numbers and roles of those involved in the capstone design courses have gone through a significant transition over the years. The Coordinators and Coaches have moved away from teaching *per* se and towards the facilitation of design learning. The Project Sponsors and Supervisors, who were once regarded as "clients", have been recognized for giving much more than they receive and are now considered as highly valued volunteers. It is because of the quality of this volunteerism that the Department has made the deliberate decision not to require funding from Project Sponsors at this time, as do many other institutions, but rather focus on securing the continued involvement of excellent people from industry and the community.

As the roles of each of the players have been refined and prescribed, the result has been that students have learned to interact much more appropriately with these players and have become increasingly independent. This is seen as a major improvement in course outcomes and has allowed the Department of Mechanical & Manufacturing Engineering at the University of Calgary to realize the vision developed by the Boyer Commission Report and the Canadian Engineering Accreditation Board.

5. References

[1] Canadian Council of Professional Engineers, "Accreditation Criteria and Procedures", Ottawa, 1998. Retrieved January 2000 from Canadian Council of Professional Engineers' website: www.eepe.ca/ccpe.cfm?page=ceab_1998.

[2] Hudspith, B. & Jenkins, H. "Teaching the Art of Inquiry", Halifax, NS: Society for Teaching and Learning in Higher Education, 2001.

[3] Kenny, "Re-inventing undergraduate education", Report of the Boyer Commission, 1998. Retrieved January 2003 from Stony Brook State University of New York's website: http://naples.cc.sunysb.edu/Pres/boyer.nsf.

[4] Brusse-Gendre, T., Fauvel, R., Caswell, D., Johnston, C., "Toolbox Approach to Teaching Design", Proceedings of C2E2, Victoria, B.C., 2001, pp. 250-258.

[5] Johnston, C.R., Caswell, D.J., Fauvel, O.R., Brusse-Gendre, T., "Strengthening Experiential Learning in Design through Course Documentation", Proceedings of ICED03, Sweden, 2003.

[6] Caswell, D.J., Johnston, C.R., Fauvel, O. R., Brusse-Gendre, T., "No Textbook – Building Documentary Support for a Student-Centered Design Course", Proceedings of C2E2, Victoria, B.C., 2001, pp. 259-265.

[7] Lloyd, P. Scott P. "Differences in Similarity-Interpreting the Architectural Design Process", Environment and Planning B: Planning and Design, Vol. 22(4), July 1995, pp. 383-406.

[8] Owen R. Fauvel, Daryl Caswell, Clifton Johnston, Tanya Brusse-Gendre, Colin McDonald, "Graduate Study of Design Pedagogy", Proceedings of ICED03, Sweden, 2003.

[9] See [3]

[10] Fischer, G. "Symmetry of Ignorance, Social Creativity, and Meta-Design", Knowledge-Based Systems, Vol. 13 (7-8), December 2000, pp. 527-537.

For more information please contact:

D.J. Caswell, Department of Mechanical and Manufacturing Engineering, The University of Calgary
2500 University Drive, Calgary, Alberta, Canada T2N 1N4
Tel: Int'l.+ 403.210.9886; Fax: 403.282.8406
E-mail: djcaswel@ucalgary.ca