THE CANADIAN DESIGN ENGINEERING NETWORK [CDEN/RCCI]: SHARING ENGINEERING DESIGN EDUCATIONAL TOOLS WITHIN THIRTY THREE SCHOOLS OF ENGINEERING IN CANADA.

I.Yellowley[1], R. D. Venter[2] and F. A. Salustri[3]

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The prime objective of CDEN/ RCCI is to support all Canadian universities in the delivery of world class Design Engineering education and to give particular emphasis to achieving a broad based discipline coverage, through project based learning, at universities. The concept is simply to bring *best practices* in Design Engineering education to the fore and to make such best practice modules available among Universities on user friendly file servers. Flexibility is essential, yet there must be sufficient structure to facilitate convenient user access to all categorized materials. Such materials include fundamentals, technology concepts, lectures, case studies, design projects and other tools that will enhance Design Engineering education.

1. Introduction

CDEN, also identified in the French language as RCCI, Réseau Canadien de la Conception en Ingénierie, has received seed funding from the Canadian Natural Sciences and Engineering Research Council [NSERC] to promote the development and the *sharing* of educational engineering design tools among all Engineering Schools within Canadian Universities.

The design process is clearly critical to the economic well being of any developed country. The value of a product (or process, or system), its efficiency, environmental impact and consumer appeal, are all determined by design. It is unfortunate then that the practice of design, the development of design methods and the supervision of young designers are activities which have not been highly valued or indeed sufficiently rewarded within our Universities, as compared with the publication of science based research undertakings.

The CDEN/ RCCI network will enable the communication of best practices between schools, promote the production and *sharing* of courseware, help inject more real design experiences into the university, and allow all schools to access the best available expertise in areas of detailed interest. The network will facilitate the joint development of multi-discipline design related courseware modules, including lectures, case studies and open-ended design projects. The focused intent is to put in place the mechanisms to ensure that the practice of design will be central to the education of the next generation of engineers. Engineering design researchers and educators are few in number and scattered throughout the country. The Canadian Design Engineering Network will serve to support existing faculty with design materials and encourage schools to

[1] Professor of Mechanical Engineering, University of British Columbia, Vancouver.

[2] Clarice Chalmers Chair of Engineering Design, Department of Mechanical and Industrial Engineering, University of Toronto, Toronto

[3] Associate Professor of Mechanical Engineering, Ryerson Polytechnic University, Toronto.

collectively build the *critical mass* within a team environment needed to promote the importance of design and effect significant improvement in existing programs.
The NSERC Design Chair Initiative is an excellent initial step along the path to improving the visibility and status associated with engineering design. The NSERC program will enrich University programs through the integration of new faculty with significant professional design experience and a mandate to encourage the practice of design. The network will thus form an integral, mutually support mechanism for the new NSERC Design Chairs.

CDEN/ RCCI will also encourage Canadian industry to take a direct role, both in the provision of design problems and student supervision. The first two years of operation must be recognized as a start-up phase [1], during which communication structures will be developed and new linkages with industry established.

2. Structure of the Network

The central aim of the network is to collectively make available, in modular format, the best design education tools, from which each school can select what it chooses to embrace in their design education process. Differences in size and emphasis among various schools, the variations in culture among disciplines, and the different requirements of undergraduate and graduate activities mean that CDEN/RCCI must build significant *flexibility* into the system, hence the modular approach. The ideal solution, from a system viewpoint, must allow extreme ease of entry, and considerable flexibility of both the rate and amount of use.

The first stage in building the C-DEN initiative is the provision of very basic information in an easily accessible way to all schools. This implies local storage (*mirroring*) of the material, (basic lecture notes, case studies, laboratory manuals and catalogues or reference materials). Each school will need a minimum of a single computer connected to a local network and the CDEN network to download and update the material on a regular basis. Personnel considerations, even at this level, are a little more complex. One needs to have a champion at each school who knows what CDEN has to offer and the best way of accessing and integrating the material with the various design courses using local facilities. A local CDEN Committee, chaired by the C-DEN champion and comprising members from several departments, ensures that available material is optimally used. Centralized tasks of information sharing, reviewing of basic material, selection of best practices and identification of new requirements are handled by a national program committee that meets as required. The Program Committee is comprised of champions from the various nodes (each school potentially qualifies as a node).

Each school will have the chance to influence which modules are produced and to cooperate in their production. It is not envisaged that the same courses will be given at each school. Rather, the basic modules are used in whatever way the instructors at each school think is best for their particular Program. It is anticipated that each school will download the basic modules of interest. Updated versions would always be maintained at the servers. To ensure that the material is most useful, the modules will be largely self contained with some reference to fundamental (lower tier) modules as is required, and be relatively small so as to be accommodated in one or

more fifty minute lectures. The CDEN servers will also make available standard reference materials (standards, material properties, catalogues, etc.) to all schools for use in design projects.
The undertaking at the undergraduate level is complex. At steady state there may be as many as 300 faculty actively involved, at up to 34 sites within five regions which comprise all Schools of Engineering within Canada, see Figure 1. The interaction within schools, curriculum committees and the network will have to be carefully managed. A key issue is the ownership of the educational materials, and the granting of license to CDEN/ RCCI members to use it.

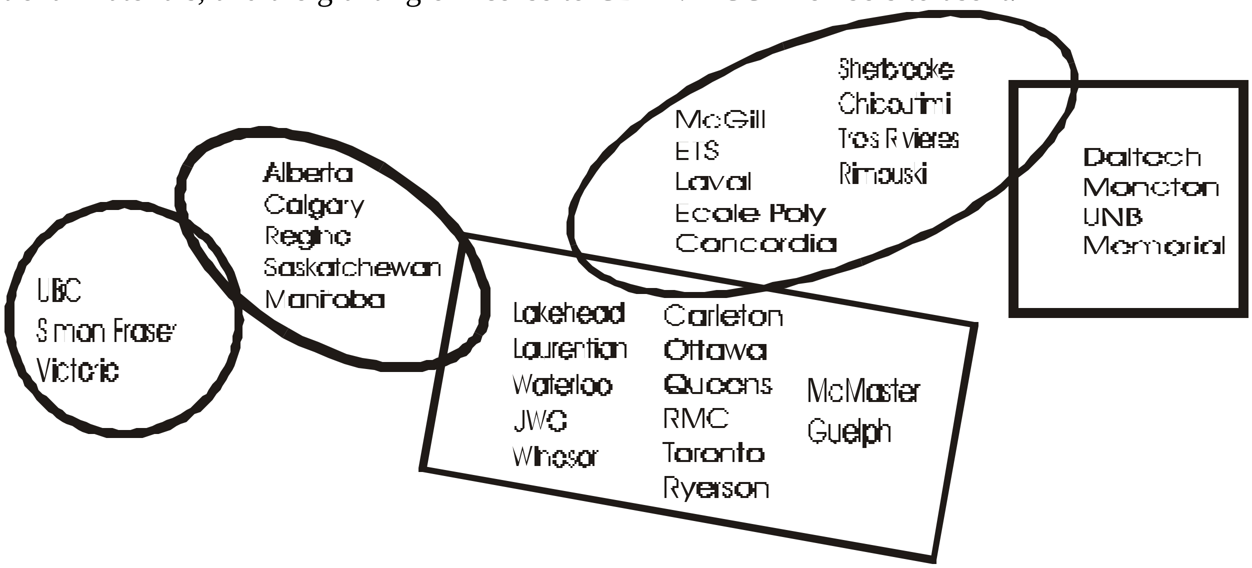

Figure 1. The CDEN/RCCI Network. NSERC Engineering Design Chairs at Sherbrooke, Calgary, Manitoba, Ecole Polytechnique & Daltech. Eleven additional Chairs to be awarded.

3. Module Tiers and Sorts

To share information through the development and shared use of various modules requires, in the first instance, that the modules be concisely defined. Three tiers of modules are proposed to allow for the classification of the different kinds of modules as these are created, and for identifying the opportunities to develop new modules within the evolution of CDEN/ RCCI. See the *tiers* and *sorts* of modules outlined in the matrix that is Table 1. The *tiers* are used to range modules over a spectrum from fundamental engineering science principles to open-ended engineering design exercises.

Tier 1: Addresses fundamental principles of two specific types (a) a basic qualitative or quantitative relation or law from the engineering sciences or mathematics, or (b) in design science, an empirical relation or statement about the technical aspects of product development that is likely to be true in most cases. *Examples:* Engineering Science: conservation of momentum, Kirchoff's laws. Design Science: standardization of parts lowers product complexity.

Tier 2: Addresses different technologies, methods and engineering practices. *Examples:* A *technology* module describes capabilities such as *adhesive bonding* approaches; a *methods* module address a methodology or procedure such as a design process, i.e. QFD, axiomatic design etc., whereas an *engineering practice* module might provide insight into the workings of a device or system i.e. pump or a series of pumps. Other tier 2 modules would address dimensioning, tolerancing, material selection, solid modeling, FEA etc.

Tier 3: Design. The integration of tier 1 and tier 2 modules to build toward various design modules. *Examples:* design of an electric bicycle, a fuel cell.

<table>
<tr><th></th><th>Teaching</th><th>Demonstration Problems</th><th>Student Tasks</th><th>Case Studies</th><th>Open-ended Projects</th><th>Evaluation Methods</th></tr>
<tr><td rowspan="2">TIER 1 Engineering Sci. or Design Sci.</td><td>Yes</td><td>Yes</td><td>Yes</td><td></td><td></td><td></td></tr>
<tr><td>Yes</td><td>Yes</td><td>Yes</td><td></td><td></td><td></td></tr>
<tr><td>TIER 2</td><td>Yes</td><td>Yes</td><td>Yes</td><td></td><td></td><td></td></tr>
<tr><td>TIER 3</td><td></td><td></td><td></td><td>Yes</td><td>Yes</td><td>Yes</td></tr>
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Table 1. A Matrix of Tiers and Sorts

Table 1 outlines the various *sorts* of modules in each of the three tiers. Universities will choose to use the modules in various ways. Six *sorts* have been categorized and are identified in each column. A brief descriptor follows:

Teaching Module:	representative of a lecture.
Demonstration Problem:	representative of a worked exercise or illustration.
Student Task:	similar to a demonstration problem, but without a detailed solution.
Case Study:	presentation of the design experience to emphasize the interrelationships of various principles, technologies, and methods.
Open-ended Project:	a problem to exercise the students' ability to integrate principles, practices, methods, and technologies.
Evaluation Method:	a technique used to measure the performance of students.

The early development of successful Tier 1 and Tier 2 modules, will facilitate and support the creation of the Tier 3 modules which focus on the design elements, whether it be case studies or the open-ended design problem. In subsequent years the tiers and sorts will be expanded as the sophistication of the module structures are refined.

In the start-up phase, CDEN/ RCCI nodes will be encouraged to develop modules in the matrix of Table 1 which are marked *Yes* and which will be specifically directed to the support of courses that are offered in years one and two of a four year undergraduate degree program in all engineering disciplines. In fact, most of the Tier I modules will be common to all disciplines and young engineers will begin to appreciate the common building blocks that are the foundations of good engineering practice. The equivalent classification of tiers and sorts will be used subsequently for the senior and graduate classifications.

4. Physical Network

The network's physical architecture includes a server at each node. These servers will vary in capacity depending upon the size of the node and the magnitude of material to be stored and accessed at each site. There will be at least two locations where the complete CDEN database is stored, where authority to modify portions of the database will be managed (i.e. each acts as keeper of some data and mirrors the rest). The most common transactions will be:

- local area network access of a local server by students and faculty;
- local server access for development of instructional materials by faculty and staff;
- automated downloading of files from main servers to local servers;
- semi-automated uploading of course materials from local servers to the main servers;
- Internet-based access to selected servers for software development, specialized design areas, and distributed design activities.
- A national subcommittee will identify suitable software and standards, as well as negotiate the best possible hardware and software costs.

5. Design Module Creation

The modules will cover the full range from engineering science, through methodology, to design and practice. Such first and or second year courses are usually not discipline specific since many engineering schools have a common first year. Even in second year much of the material is representative of the basic sciences and engineering fundamentals. Such courses provide the first opportunity for students *to do real engineering*. They also provide students with the opportunity to give serious thought to the particular engineering discipline that they might wish to pursue.

The short-term quantification of deliverables is outlined. A packaged deliverable [PD] will represent a lecture, presentation, or tutorial that can be used by a lecturer(s) within a representative lecture, which is typically of 50 minutes duration [PD-50]. The format of each PD will be driven by a need for *consistency* and *ease of use*. Each PD will be indexed with a set of labels indicating the content with respect to both (a) fundamental concepts and (b) design technologies. Furthermore, not all PDs will be contained 50 minutes; depending on the subject matter, PDs structured in 50-minute multiples (e.g. PD-150) will certainly be developed.

CDEN/RCCI has developed an initial set of guidelines to assist module developers at all CDEN/RCCI nodes in the preparation of modules that each of the participating Universities would wish to develop. Three such guidelines are briefly encapsulated below; the titles and the respective prefaces provide an adequate functional description of the intent and the need to ensure a good standard of consistency of format.

- *CDEN Module Structure Guide:* Preface: This module demonstrates the typical structure of a module and provides guidelines for module authors. Though modules come in different *tiers* and *sorts*, every module should be coarsely similar to every other module. The formatting of modules (i.e. font sizes, etc.) is covered in a separate document, the CDEN Module Formatting Guide, see below. An MS Word document template for modules is also available. The structure of this document itself follows the structure defined herein, and so this document can be used as an example by module authors.
- *CDEN Module Formatting Guide*: Preface: This module presents the rules regarding text formatting of CDEN modules and is implemented in the CDEN Module Template, see below.

- *Template file for new Modules:* Preface: The preface contains an abstract of the module, a list of keywords, a specification of the target audience, a list of objectives of the module, and the context in which the modules should be used.

6. Observations on the CDEN Rationale

Technology will dramatically change the way that engineers will be educated and the societal role of the university system. There are huge opportunities to improve the educational process while achieving considerable economies. Universities have much to offer in creating the tools and in adding value to existing educational packages. However, there is a critical need to understand that new infrastructure is needed to support learning processes that go beyond typical lecture-based courses.

The success of the CDEN initiative is dependent on the desire of faculty and universities to work cooperatively. Immense gains can come from a richer exposure to design; the rewards in terms of industrial interaction are also extremely significant. The initial workload will inevitably fall on a few, however it is critical that a sense of purpose extend to all those engaged in design education. The recent NSERC Design Chairs initiative provides a large part of the solution, but it is necessary to promote the ideals vigorously to ensure that the local committees are active across all disciplines. Finally, some degree of ongoing funding for the network will be needed; the Steering Committee, advised by the Industrial Advisory Committee, will create a viable plan to ensure continued viability, before passing control to an elected board.

7. Acknowledgements

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8. References

1. I. Yellowley, R. D. Venter and F.Salustri: The Canadian Design Engineering Network [CDEN/RCCI]: enrichment of the teaching and practice of engineering. Proceedings, NSF Design., Manufacturing and Services Research Conference. January 2001. Tampa, Florida.