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IEEE Canadian Review

La revue canadienne de l'IEEE

The Future of Engineering and Technology Education

SPECIAL FOCUS

Space mapping and the engineer's "feel" for a problem

ICF Grant Report

Solar-powered cellphone charging in rural Ghana

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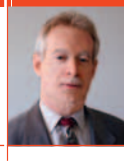

Bruce Van-Lane
Managing Editor /
Directeur de Rédaction

In 1903, then Canadian Prime Minister Wilfred Laurier rose to address the Canadian Club of Ottawa.

"The 20th century belongs to Canada," he is often quoted as saying; the actual lines were a little less concise according to historian Russell Merrifield, but the unbridled optimism was unmistakable.

Now compare with: "… Canada's success in the 21st century will be determined by our ability to harness science, technology and innovation to drive economic prosperity and enhance societal well-being."

A more cautious tone in keeping with an interdependent world unimaginable in a time barely past the industrial revolution, the source is the Science, Technology and Innovation Council in its report *State of the Nation 2012, Canada's Science, Technology and Innovation System: Aspiring to Global Leadership*.

"Talent has become the key competitive differentiator in the global economy," the 120-page report released earlier this year notes, "and having the right people in the right place at the right time positions us for success." Devoting almost a quarter of the body of the report to education in the fields of science, technology, engineering and math (STEM), the Council warns increased investment in Canada's education system is needed to keep up with the "quantity and quality of talent in other countries."

But what does a 21st century system for nurturing Canada's STEM students –and in particular those pursuing engineering and technology–look like? At the *IEEE Canadian Review*, we add our voice to this important debate through this issue's 32-page Special Focus on the Future of Engineering and Technology Education.

Prediction of a different sort forms the basis of our other main offering in this issue. Space Mapping is an approach to engineering design developed by 2012 IEEE Canada McNaughton Gold Medal recipient John Bandler. Originally applied to microwave systems design, the concept has since been adopted across the entire spectrum of engineering, from automotive crashworthiness to magnetic systems. John weaves details of his remarkable career into a comprehensive explanation of this versatile design approach.

This is the 25th anniversary year for the *IEEE Canadian Review*. You'll notice we've modernized its lay-out and design, but intend to carry on with the mission with which it was founded, "to be of interest to a broad range of Canadian IEEE members and others of like mind."

Historians can debate to what extent Canada's place in the world of the last century lived up to Laurier's prediction. At the *IEEE Canadian Review*, we're keeping our focus on meeting your expectations. ■

En 1903, le premier ministre du Canada, Sir Wilfrid Laurier, prenait la parole au Cercle canadien d'Ottawa.

« Le XXe siècle appartient au Canada », aurait-il déclaré. En réalité, il se serait exprimé de manière un peu moins concise d'après l'historien Russell Merrifield, mais avec le même extraordinaire optimisme.

Comparons ses propos avec ceux-ci, contemporains :

« Le succès du Canada au XXIe siècle dépendra grandement de sa capacité à exploiter les sciences, la technologie et l'innovation afin d'assurer la prospérité économique et d'améliorer le bien-être social. »

Le ton est plus prudent dans un monde interdépendant, inimaginable à l'époque où les invités du Cercle sortaient tout juste de la révolution industrielle. La source en est le Conseil des sciences, de la technologie et de l'innovation dans son récent rapport *L'état des lieux en 2012 – Le système des sciences, de la technologie et de l'innovation au Canada : Aspirer au leadership mondial*.

« Le talent est devenu le principal facteur concurrentiel qui fait la différence dans l'économie mondiale, lit-on dans cette étude de 120 pages; le fait d'avoir les bonnes personnes au bon endroit et au bon moment est la clé du succès. »

Consacrant près du quart de son rapport principal aux sciences, à la technologie, à l'ingénierie et aux mathématiques (STIM), le Conseil en appelle à des investissements accrus en éducation pour que le Canada atteigne « la quantité et la qualité des talents des autres pays ».

Mais que fait au XXIe siècle notre système pour soutenir les étudiants canadiens de STIM, notamment ceux d'ingénierie et de technologie? *La Revue canadienne de l'IEEE* prend part à cet important débat en proposant un numéro spécial de 32 pages dévolu à l'avenir de l'éducation en ingénierie et en technologie.

D'autres types de prédictions s'ajoutent au contenu de la présente Edition. La spatiocartographie est une approche de la conception technique élaborée par John Bandler, récipiendaire en 2012 de la médaille d'or McNaughton de l'IEEE Canada. D'abord utilisé dans la conception de systèmes à hyperfréquences, le concept trouve aujourd'hui une multitude d'applications en ingénierie allant de la résistance à l'impact des véhicules motorisés aux systèmes magnétiques. John a su amalgamer les multiples acquis au fil de sa remarquable carrière en une explication approfondie de ce versatile outil de conception.

La Revue canadienne de l'IEEE célèbre en 2013 son 25e anniversaire. Vous remarquerez que nous avons modernisé sa disposition et sa conception tout en maintenant la mission de ses fondateurs, soit susciter l'intérêt d'un vaste éventail de membres de l'IEEE Canada et des lecteurs partageant leurs valeurs.

Les historiens peuvent débattre du degré de réalisation de la prédiction de Laurier quant à la place occupée par le Canada au siècle dernier. À *la Revue canadienne de l'IEEE*, il nous tient à cœur de répondre à vos attentes. ■

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(i) Canadian members of IEEE;

(ii) Canadian members of the profession and community who are non-members of IEEE;

(iii) The associated Canadian academic (i.e., universities, colleges, secondary schools), government and business communities.

To ensure that the *IEEE Canadian Review* has the desired breadth and depth, editors are responsible for screening articles submitted according to the following general themes:

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2 - International Affairs
3 - Industry
4 - Education
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6 - Communications
7 - Computers
8 - Electronics

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Dr. Keith B. Brown, Ph.D., P.Eng., SMIEEE
2012-2013 IEEE Canada President and Region 7 Director

With summer now behind us, IEEE Canada activities are once again in full swing. The last quarter of every year also brings many new challenges on the business front -- project and budget planning for the upcoming year. For our dedicated and active volunteer members this is additional workload as they continue to manage our chapters, sections, conferences, and journal publications. At the time of writing, there are 14 IEEE–sponsored conferences occurring somewhere in Canada this fall alone. You can look forward to my brief appearance at a few of them; and, as always, I look forward to speaking to the attendees and hearing your input on how we can do better.

The first piece of information I wish to share with you is that membership is up. Our annual growth rate is 5.4% compared to an IEEE global growth rate of 2.3%, making us the third-fastest growing region. Our graduate student membership is expanding at almost 14% -- highest of the ten regions. This is encouraging news, as some of our most active members and volunteers are from this group. Overall global IEEE membership is just over 438,000 with slightly more than 52% from outside the USA for the third straight year.

The executive and steering committees met very recently and discussed our finances and strategic plan for 2014. I'm pleased to report there are no major changes required in the strategic plan we initiated two years ago and that our finances continue to be strong. Of course, we do have challenges to face: we must continue to defend and grow our brand, maintain and improve the quality of our conferences, relentlessly pursue new revenue streams, and adapt to changing technologies and demographics. This may sound like a lot of work but it's part of what makes being a volunteer leader exciting and I firmly believe we have a remarkable and talented group of volunteers who can rise to the challenges.

There have been a couple of recent and interesting changes on the IEEE global front. The first is regarding automatic membership renewals. You may have received an email about this change; when you renew your membership there should be a feature allowing for selection of automatic renewals. The second noteworthy change is with the issue of audits. When an IEEE entity (chapter, section, conference, workshop, etc) activity results in aggregate revenues or expenses of more than the prescribed threshold (historically $100k USD) a mandatory audit of the books was required (at cost to the entity). Over the past couple of decades the IEEE has grown and this threshold needed adjustment to meet materiality tests. At the February board of directors meeting in Austin, Texas the board approved raising the audit threshold limit to $250k USD. This should go a long way towards alleviating a significant cost and paperwork burden on many of our conferences and sections. Other audit triggers such as random audits and change in treasurers remain unchanged.

I should also note that Bob Alden has recently stepped down as IEEE Canadian Foundation (ICF) President, serving in that role from 2001-2013 and in other ICF positions since 1992. Bob is most recognized for his leadership in increasing representation on the ICF Board to include all Canadian areas and in driving improvement to the ICF website and services. Today, the ICF is operating as a national foundation in both official languages. For the near future, Bob will continue to support the ICF as Director and Past-President.

Consistent with established succession planning, the ICF Board has elected David Whyte as ICF President. David has been a Director of the ICF since 1995, serving as First Vice-President and VP Grants for the last few years.

Finally, I am always open to your comments or suggestions. Please send them to kbbrown@ieee.org. And keep in mind, the IEEE is you – the members and volunteers. ■

La saison estivale terminée, les activités de l'IEEE Canada battent maintenant leur plein. Le dernier trimestre nous amène à son tour son lot de défis administratifs, nous poussant à peaufiner la planification des projets et budgets de l'année à venir. Pour nos membres bénévoles, toujours aussi actifs et dévoués, cette charge de travail s'ajoute à la gestion habituelle de nos divisions, sections, conférences et publications de journaux. Au moment d'écrire ces lignes, l'IEEE parrainera cet automne 14 conférences au Canada. Je ferai une brève apparition à quelques-unes d'entre elles, espérant vous y trouver et entendre vos suggestions éclairées sur nos façons de nous améliorer.

La première nouvelle que j'aimerais partager avec vous, c'est que nos membres sont de plus en plus nombreux au Canada. Notre taux de croissance est de 5,4 % comparativement au taux de croissance global de l'IEEE de 2,3 %, ce qui fait de notre région la troisième plus rapide à croître au sein du réseau. Notre croissance est particulièrement frappante parmi les étudiants (14 %), taux le plus élevé des dix régions. C'est très encourageant lorsqu'on sait que certains de nos membres et bénévoles les plus actifs font partie de ce groupe. À l'échelle mondiale, l'IEEE compte un peu plus de 438 000 membres, dont plus de 52 % proviennent de l'extérieur des États-Unis pour une troisième année consécutive.

Le conseil de direction et le comité directeur se sont rencontrés tout récemment pour discuter de nos finances et du plan stratégique de l'IEEE Canada en 2014. J'ai le plaisir d'annoncer à cet égard que le plan stratégique que nous avons entrepris il y a deux ans a très peu changé et que notre situation financière demeure solide. Évidemment, nous avons des défis à relever : nous devons continuer de défendre et de faire rayonner notre organisation, de maintenir et d'améliorer la qualité de nos conférences, de rechercher inlassablement de nouveaux flux de rentrées et de nous adapter à divers changements technologiques et démographiques. Cela peut sembler beaucoup, mais cela fait aussi partie de ce qui rend la tâche du leader bénévole excitante. Je crois fermement que nous avons un groupe de bénévoles remarquable et talentueux qui peut relever des défis de cet ordre.

L'IEEE a connu récemment quelques changements intéressants à l'échelle mondiale. Le premier concerne les renouvellements d'adhésion automatiques. Vous avez probablement reçu un courriel à ce sujet. Lorsque vous renouvellerez votre adhésion, vous pourrez maintenant opter pour un renouvellement automatique. Le deuxième changement digne de mention concerne la question des vérifications. Lorsqu'une activité menée par une entité de l'IEEE (division, section, conférence, atelier, etc.) occasionne des revenus ou des dépenses d'ensemble dépassant un certain seuil établi (100 000 $ É.-U. jusqu'à récemment), l'entité en question a l'obligation de faire vérifier ses livres à ses frais. Or l'IEEE a pris de l'expansion au cours des deux dernières décennies et il nous fallait revoir ce seuil pour ajuster les exigences aux nouvelles réalités. Lors de sa réunion de février dernier à Austin (Texas), le conseil des directeurs a approuvé une hausse du seuil de vérification à 250 000 $ É.-U. Cette décision allégera très certainement les dépenses et lourdeurs administratives d'un grand nombre de nos conférences et sections. Les autres facteurs déclencheurs de vérifications, tels que les vérifications au hasard et les changements de trésorier demeurent inchangés.

J'aimerais signaler que M. Bob Alden a quitté dernièrement son poste de président de la Fondation canadienne de l'IEEE (FCI), après l'avoir occupé de 2001 à 2013 et après avoir rempli divers autres mandats au sein de la Fondation depuis 1992. Bob s'est fait remarquer pour son leadership exercé dans la hausse de la représentativité du conseil d'administration de la FCI afin d'y accueillir des membres de toutes les régions du Canada et dans les améliorations apportées au site Web et aux services de la Fondation. La FCI a acquis le statut de fondation nationale et fonctionne aujourd'hui dans les deux langues officielles. Bob continuera à soutenir la FCI à titre de directeur et de président sortant.

Fidèle à son plan de relève, le conseil d'administration de la FCI a élu M. David Whyte à titre de président de la Fondation. David a été directeur de la FCI depuis 1995 de même que, ces dernières années, premier vice-président et vice-président des subventions.

Enfin, je suis toujours ouvert à vos commentaires et suggestions. Veuillez me les faire parvenir à kbbrown@ieee.org. Gardez à l'esprit que l'IEEE est la somme de ses membres et bénévoles : l'IEEE, c'est vous! ■

IEEE Canadian Foundation Supports
La Fondation canadienne de l'IEEE appuie l'électrifica

In the spring of 2012 the IEEE Canadian Foundation provided a Special Grant to Emily Landry, a UBC Electrical Engineering Student, to assist with her participation in Project GROW: Ghana Rural Opportunities for Women. The Project area is in the North-East of the country (near the Sahara Desert), with the population sustained by subsistence farming.

GROW is one of many initiatives that attempt to assist the women of rural Ghana. As a result of the slave trade in the 1800s, women are still in the majority. In the rural areas they leave school early to become housewives who manage the day-to-day details of the farm; whereas in the cities, women from wealthier families can complete their schooling, and imported food goods are readily available for those who have money.

Families in the project area cope with two almost unimaginable hardships: Water must be carried several kilometres, and charging a cell phone or laptop computer requires a 1-1/2 hour trip by car to the nearest city (Bolgatanga). Given the demographics, this burden is largely borne by women. Emily and a Civil engineering student (Nicole Malkinson) travelled to the Project area to conduct a Phase-One needs assessment and feasibility study, towards making these resources locally. Phase Two will involve other students over the next few years in the detailed planning and oversight of the implementation. Emily examined the issues around electricity supply, and Nicole studied the water and irrigation issues.

The GROW area contains several villages with approximately 10,000 farmers and their families. Like many developing African countries, Ghana has a solid Cellular Telephone system in place, but power distribution and wire-line telephone systems are restricted to the larger cities, Emily reports. The goal for the electrical portion is to provide electricity to charge the phones and computers, and to support indoor lighting so that after dark adults can still access the learning tools that are available. Although there is outdoor solar-powered street lighting that was installed by the Ghana Cocoa Board, residents are prevented from taking advantage of it for reading by the Malaria-carrying mosquitoes -- let alone the inconvenience. Indoors, no lighting is the norm.

The initial step was to provide three solar-powered battery chargers. After a 12-hour solar charge, they can be used in turn to charge a number of phones. An organizational structure has been set-up similar to that of a public utility in Canada, and one of the village women has assumed the task of maintaining the chargers. The small fee levied per cell-phone-

Au printemps 2012, la Fondation canadienne de l'IEEE a accordé une subvention spéciale à Emily Landry, étudiante en génie électrique à l'Université de la Colombie-Britannique, afin de l'aider à participer au projet GROW: Ghana Rural Opportunities for Women. Le projet se situe dans le nord-est du pays (près du désert du Sahara), avec une population soutenue par l'agriculture de subsistance.

GROW est une des nombreuses initiatives qui visent à aider les femmes des régions rurales du Ghana. À cause de la traite d'esclaves dans les années 1800, les femmes sont toujours majoritaires. Dans les zones rurales, elles quittent l'école tôt pour devenir femmes au foyer gérant la ferme au jour le jour, tandis que dans les villes, les femmes issues de familles aisées peuvent terminer leur scolarité, et des biens alimentaires importés sont disponibles pour ceux qui ont de l'argent.

Les familles dans la région du projet font face à deux difficultés inimaginables: l'eau doit être transportée sur plusieurs kilomètres, et charger un téléphone cellulaire ou un ordinateur portable nécessite une heure et demie de trajet en voiture vers la ville la plus proche (Bolgatanga). Compte tenu de la démographie, ce fardeau repose en grande partie sur des femmes. Emily et une étudiante en génie civil (Nicole Malkinson) se sont rendues dans la région du projet pour mener une première phase d'évaluation des besoins et une étude de faisabilité visant à avoir ces ressources localement. La deuxième phase impliquera d'autres élèves au cours des prochaines années pour la planification détaillée et la supervision de la mise en œuvre. Emily a examiné les questions relatives à l'approvisionnement en électricité et Nicole a étudié l'eau et les questions d'irrigation.

La zone du projet GROW contient plusieurs villages avec environ 10 000 agriculteurs et leurs familles. Comme de nombreux pays africains en développement, le Ghana dispose d'un solide système de téléphonie cellulaire, mais la distribution d'énergie et les systèmes téléphoniques filaires sont limités aux grandes villes, selon ce que rapporte Emily. L'objectif pour la partie électrique du projet est de fournir de l'électricité pour recharger les téléphones et les ordinateurs, et de soutenir l'éclairage intérieur, de sorte qu'après la tombée du jour, les adultes puissent toujours accéder aux outils d'apprentissage qui sont disponibles. Bien qu'il y ait un éclairage public à l'énergie solaire en plein air qui a été installé par le Ghana Cocoa Board, les résidents ne peuvent pas en profiter pour la lecture à cause des moustiques porteurs de la malaria et aussi à cause des inconvénients occasionnés. À l'intérieur, l'absence d'éclairage est la norme.

Electricity and Irrigation for Rural Ghana
tion et l'irrigation dans les régions rurales du Ghana

charge not only provides a modest wage for the administrator, but also adds to a fund to procure more panels to support future uses. A supplier from Bolgatanga has agreed to train the villagers on maintenance of the panels, and will provide quotations for future purchases, once the villagers have established their needs.

In Phase two, the proposal is to repurpose the outdoor solar-powered lighting installed by the Ghana Cocoa Board. Several of the combined panel and light assemblies are located close to community buildings (schools and grinding mill), allowing redirecting of power to indoors. Power from each assembly's configuration of three 12-volt batteries will be repurposed as follows. One of the batteries will supply interior 12-volt LED Lamps. The other two (in series) will re-charge electronic devices such as laptops and cell phones. The Ghana Cocoa Board has supported these proposals.

Although Emily's assignment was technical in nature, the experience gave her insights into broader aspects of Ghanaian society, she says. The cities were more advanced than she had expected, and had better access to basic foods. Unfortunately, she was told that rural women who left for the cities had trouble finding jobs and often ended up on the streets. All the more reason to make life easier in rural areas, she says, and added "I felt an overwhelming connection to the people I worked with, who I admire for their richness of spirit and eagerness to help each other."

The one-time Special Grant of $1,000 from the IEEE Canadian Foundation (ICF) that supported Emily's participation in Project GROW drew upon the "Technology for Humanity Fund," one of several donor-designated funds the ICF administers; peer recognition is another major donor-designated fund. The ICF gratefully acknowledges its many donors, whose contributions enable grants to innovative projects such as GROW, as well as funding of scholarships and the support of nearly 40 McNaughton Learning Centres operated by Student Branches. ■

This article contributed by ICF Development Committee member John Mowbray. John is a Life-Senior Member of the IEEE, and the ICF Liaison to the IEEE Canadian Review.

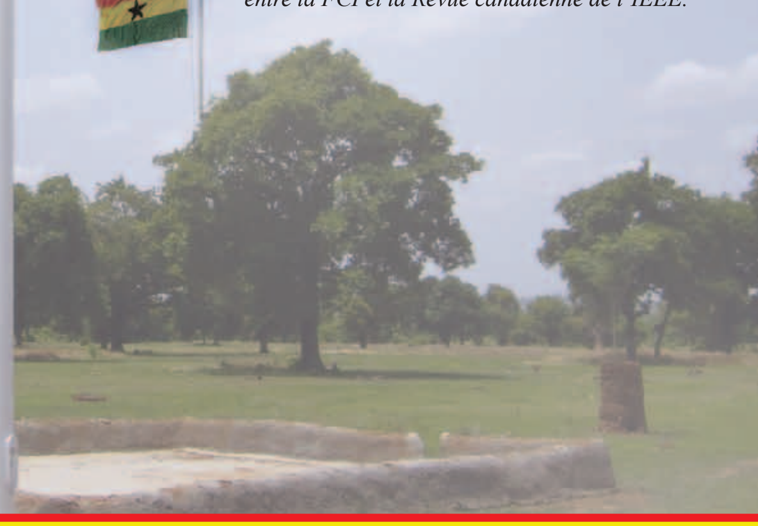
La première étape consistait à fournir trois chargeurs de batteries solaires. Après une charge solaire de 12 heures, ils peuvent être utilisés à leurs tours pour charger un certain nombre de téléphones. Une structure organisationnelle, similaire à celle d'un service public au Canada, a été mise en place, et l'une des femmes du village a assumé la tâche de maintenir les chargeurs. La petite redevance perçue pour chaque charge de téléphone portable fournit non seulement un salaire modeste pour l'administrateur, mais ajoute aussi à un fonds destiné à procurer davantage de panneaux pour soutenir les utilisations futures. Un fournisseur de Bolgatanga a accepté de former les villageois à l'entretien des panneaux et de fournir des devis pour de futurs achats, une fois que les villageois auront établi leurs besoins.

Dans la deuxième phase, la proposition est de réutiliser l'éclairage solaire extérieur installé par le Ghana Cocoa Board. Plusieurs des panneaux combinés à l'éclairage sont situés à proximité de bâtiments communautaires (écoles et moulins), permettant la redirection de puissance à l'intérieur. La puissance de chaque ensemble de trois batteries de 12 volts sera réaffectée comme suit. Une des batteries fournira en électricité des ampoules intérieures à DEL 12 volts. Les deux autres (en série) seront utilisées pour recharger des appareils électroniques tels que les ordinateurs portables et les téléphones cellulaires. Le Ghana Cocoa Board a soutenu ces propositions.

Bien que l'affectation d'Emily était de nature technique, l'expérience lui a donné un aperçu plus large de la société ghanéenne, dit-elle. Les villes étaient plus avancées que ce qu'elle avait prévu, et avaient un meilleur accès aux aliments de base. Malheureusement, on lui a dit que les femmes rurales qui ont quitté les villes avaient du mal à trouver un emploi et se retrouvaient souvent dans la rue. C'est une raison de plus pour rendre la vie plus facile dans les zones rurales, dit-elle, en ajoutant « J'ai senti une immense connexion avec les personnes avec qui j'ai travaillé, que j'admire pour leur richesse d'esprit et le désir de s'entraider. »

L'allocation spéciale ponctuelle de 1000 $ de la Fondation canadienne de l'IEEE (FCI) qui a appuyé la participation d'Emily dans le projet GROW a fait appel au « Fonds technologie pour l'humanité », l'un des nombreux fonds ciblés par les donateurs et qu'administre la FCI. La reconnaissance par les pairs est un autre important fonds ciblé par les donateurs. La FCI tient à remercier ses nombreux donateurs, dont les contributions permettent de subventionner des projets innovants tels que GROW, ainsi que de financer des bourses et de soutenir près de 40 Centres d'apprentissage McNaughton exploités par des branches étudiantes. ■

Cet article a été écrit par John Mowbray, membre du comité de développement de la FCI. John est un membre senior à vie de l'IEEE, et assure la liaison entre la FCI et la Revue canadienne de l'IEEE.



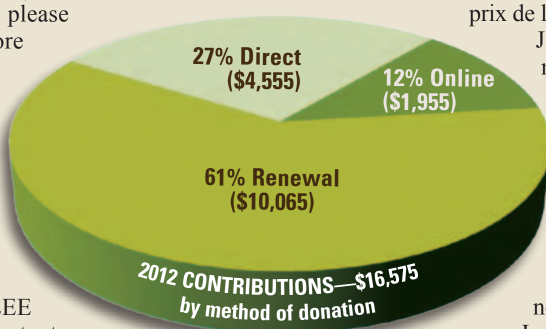
From the President—I would like to acknowledge and thank those of you who have generously given to the IEEE Canadian Foundation in 2012. Your gifts allowed us to enhance the learning experience for engineering students across Canada with our programs of McNaughton Centres and Scholarships.

Co-funding of special projects develops engineering or science skills at all levels. Our Special Grant recipients are required to submit project reports which are reviewed, saved and often highlighted as "Success Stories" both on our website and in this magazine. Increasingly, these projects use technology for the benefit of humanity.

Our General Fund is crucial to our ability to operate each and every year, and your undirected donations allow us to keep our base strong.

Our Endowed Funds support a wide range of awards, prizes and scholarships. Please consider a directed donation to endow an IEEE Canada award or create a new award of your choosing.

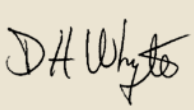
I appreciate your past support and urge you to continue and increase your contributions where possible. If you have not yet made a donation, I urge you to please do so—we could do so much more with your financial support. All the different ways to give and donor recognition programs are fully described on our website.



The IEEE Canadian Foundation wants to hear from you – if we can better engage and support our community, please let me know.

I close by thanking the many IEEE volunteers in Canada who contribute to the all-volunteer effort that is the IEEE Canadian Foundation. Foremost to Past-President Bob Alden, who guided and inspired this organization as President from 2001 until this spring. I acknowledge the invaluable assistance of Luc Matteau, John Mowbray and Paul Fortier in the preparation of this document.

Yours sincerely,



David H. Whyte
President
IEEE Canadian Foundation

2012 Year in Review—Donations from individuals in 2012 were $16,575

Of particular note, the Canadian Life Members Fund (CLMF) received donations of $1290. The chart shows the distribution between the IEEE membership renewal process (in US funds), our own Canadian online donation service (with receipts by return email), and cheques made payable to the "IEEE Canadian Foundation Inc." mailed to our treasurer.

Every gift makes a difference. The honour roll formally recognizes all donors contributing $25 or more. The foundation extends its thanks also to those donors who are not listed

Message du Président—Je voudrais reconnaitre et remercier ceux de vous qui avez généreusement donné à la Fondation canadienne de l'IEEE en 2012. Vos cadeaux nous ont permis de procurer une meilleure expérience pédagogique aux étudiants en génie à travers le Canada par l'entremise de nos programmes de Centres McNaughton et de bourses.

Le cofinancement de projets spéciaux sert à développer des compétences en ingénierie et en sciences à tous les niveaux. Nos récipiendaires d'allocations spéciales doivent soumettre des rapports de projet qui sont révisés, sauvegardés et souvent mis en évidence comme "Histoires à succès" tant sur notre site Web que dans ce magazine. De plus en plus, ces projets utilisent la technologie au bénéfice de l'humanité.

Notre Fonds général est crucial pour notre capacité de fonctionnement annuel et vos dons non dirigés nous permettent de maintenir une base forte.

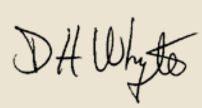
Nos fonds dotés supportent une large gamme de récompenses, de prix et de bourses. S'il vous plait, considérez faire un don dirigé afin de doter un prix de l'IEEE ou créer un nouveau prix de votre choix.

J'ai apprécié votre appui passé et je vous recommande vivement de continuer à faire ainsi et augmenter vos contributions lorsque c'est possible. Si vous n'avez pas encore fait de don, je vous recommande vivement de le faire – nous pourrions faire tellement plus avec votre appui financier. Toutes les façons différentes de donner et les programmes de reconnaissance des donateurs sont entièrement décrits sur notre site Web.

La Fondation canadienne de l'IEEE aimerait vous entendre – si nous pouvons mieux engager et supporter notre communauté, s'il vous plait laissez-le moi savoir.

Je termine en remerciant les nombreux bénévoles de l'IEEE au Canada qui contribuent à l'effort de volontariat que constitue la Fondation canadienne de l'IEEE, en premier lieu le président sortant Bob Alden, qui a guidé et inspiré cette organisation comme président depuis 2001 jusqu'à ce printemps. Je voudrais souligner l'aide inestimable de Luc Matteau, John Mowbray et Paul Fortier dans la préparation de ce document.

Veuillez agréer l'expression de nos sentiments les plus distingués.



David H. Whyte
Président
Fondation canadienne de l'IEEE

L'année 2012 en revue— Les dons d'individus ont été de 16,575 $ en 2012.

Notons de façon particulière que le Fonds des Membres à vie canadiens (CLMF) a reçu des dons de 1290 $. Le graphique illustre la distribution entre le processus de renouvèlement d'adhésion à l'IEEE (en fonds américains), notre propre service de don en ligne canadien (avec des reçus par retour de courriel) et les chèques faits payables à "la Fondation canadienne de l'IEEE Inc." expédiés par la poste à notre trésorier.

Chaque cadeau fait une différence. Ce tableau d'honneur reconnaît formellement tous les donateurs dont la contribution s'élève à 25$ ou plus. La Fondation étend aussi ses remerciements à ces donateurs qui ne sont pas inscrits.

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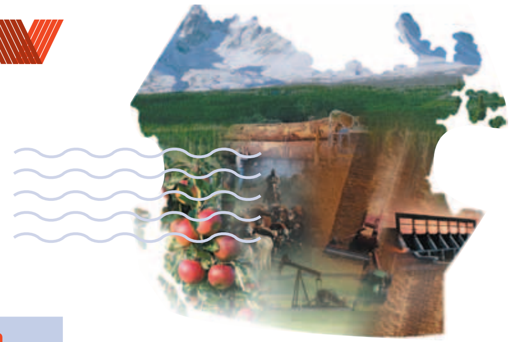
A View from the West



By **Terrance Malkinson**

British Columbia Forecasts for employment and doing business in British Columbia are provided in "Lucky 2013?" [BCBusiness. pp. 50-55. January 2013. www.bcbusinessonline.ca]. Based on a survey of 250 readers the article provides insights from the twenty-two questions asked covering topics such as business optimism, challenges and concerns, employment prospects, and salaries. Emerging from the survey is a feeling that the BC workforce is optimistic but is divided on how to move the province forward economically.

A profile of Lemare Lake Logging one of British Columbia's largest logging and road-building contractors, by Robin Brunet is the cover story in the November-December, 2012 issue of Canadian Forest Industries [pp. 10-13.www.woodbusiness.ca] This company has built its reputation by excelling when challenged by extreme circumstances. Acquisitions have played an important role in the company's growth and in the future the owners will continue their strategy of flexibility and taking advantage of new opportunities.

The 11th annual survey of "The Best Companies to Work for in BC" is provided in the December, 2012 issue of BCBusiness [pp. 49- 69]. Data was analyzed from employee surveys and executive questionnaires. Details of the methodology are provided. Leading the ranking for companies having more than 100 employees is HootSuite Media Inc. (digital technology services), followed by Daniel Hospitality Group (family restaurants) and Para Space Landscaping Inc.(landscaping) For companies employing 100 or fewer people Strangeloop Networks Inc. (digital technology services) leads the list followed by Kardium Inc. (health sciences and services) and Habanero Consulting Group Inc. (professional services and communications). Profiles of the twenty finalist companies as well as a series of other articles provide insights into why companies are successful.

Alberta Professionals from the University of Calgary were members of a 32-person panel of global experts examining the important issue of the management, assessment and prevention of concussions in sport with the goal of improving outcomes. The "Consensus Statement on Concussion in Sport" has been released and the full report is available in The British Journal of Sports Medicine [47(5):250-258. April, 2013. www.bjsm.bmj.com]. The consensus report is based upon medical experience, peer reviewed research and discussions at the 4th International Conference on Concussion in Sport held in Zurich in November, 2012. The report details the current state of knowledge and provides important reader-friendly information on this topic of importance not just to professional and amateur athletes but also for parents who need to provide authoritative advice and guidance to their children in their athletic endeavors. One of the key findings emerging from the report is that there is no good evidence that mouth guards and helmets prevent concussion and paradoxically they may even encourage players to take greater risks. Concussions were the topic of an earlier article in IEEE Canadian Review by the author ["Concussions, Athletics and the Profession of Engineering" No. 66. Summer, 2011. pp. 32-33].

Alberta's Business Person of the Year 2012 is Gregg Saretsky, President and CEO of WestJet Airlines. He is profiled in the December, 2012 issue of Alberta Venture. [pp.30-34. www.albertaventure.com]. As President and CEO he has made a number of innovative changes in the business operations of WestJet and is known as a leader who is empathetic and skilled at relating with people. He places considerable value in the company's human resources including the provision of mentoring and leadership development programs. He joined WestJet in 2009 after working in the airline industry learning from the many diverse positions he held. A second article in the same issue of Alberta Venture by Max Fawcett ["Alberta's Annual Review". pp.37-46] provides a summary of the good and bad news stories of 2012.

The November 2012 issue of Alberta Venture focuses on innovation in the province. A feature article "25 Most innovative Organizations in Alberta" starting on page 52 profiles 25 innovator organizations that are changing their industries, the province and the country for the better.

Saskatchewan Saskatchewan's top 100 companies are ranked and profiled in the September 2012 issue of Saskatchewan Business Magazine. [pp. 8-22]. In his introduction Paul Martin discusses his observations on business developments and how agriculture and agriculture support industries are reclaiming their role as provincial economic drivers. Leading the ranking as it has done for many years is PotashCorp, followed by Federated Co-operative Ltd. and Canpotex Ltd. In the subsequent issue of the Magazine [October-November, 2012. pp. 16-18] thirty-six growing Saskatchewan companies that are considered to be frontrunners for inclusion in next year's top 100 are provided. Saskatchewan's Business of the Year MOSAIC, the world's largest producer of crop nutrients with net sales of $11 Billion last year is profiled in the December, 2012 issue [pp. 8-17].
In the cover story of the October-November issue of Saskatchewan Business Magazine Anne Lazurko discusses how with over $15 Billion in assets and $11 Billion in lending the credit union system is a growing and major player in Saskatchewan banking. Today, there are 60 credit unions in Saskatchewan that serve over half a million members in 270 communities and employ more than 3,500 people, capturing a 23% market share in consumer credit and residential loans and a 53% market share in commercial lending.

Other Canadian Stories The cover story of the February 18, 2013 issue of Canadian Business [86(1/2. www.canadianbusiness.com] is a special report "Outlook 2013" pp. 51- 70], a collection of forecasts for the year 2013. Topics covered include house prices, Facebook, banking, national economy, global developments, and people/companies, and commodities to watch. The previous issue 85 (21/22. pp.29-48) provides a special feature on 2012 winners and losers. The December 10 issue [85 (20) pp. 29-53] profiles Canada's 100 wealthiest people - what they are worth financially and how they achieved financial wealth.

Predictions for change in Canada's air transport sector in 2013 are provided by David Carr in "Shaken but Not Yet Stirred" in the November-December 2012 issue of Wings. [pp. 20-23]. www.wingsmagazine.com]. New subsidiary airlines and new aircraft are but two of these.

Canadian Grocer published its technology issue in January 2013. The cover story "It's Your Future Calling" by Corrine Sandler discusses the digital conversion of the supermarket by smartphones, QR codes, and apps. An accompanying article "The Tech 10" [pp. 50-52] provides a glimpse of what technology is forecast for supermarkets.

The Top 50 Canadian Brands are ranked by Steve Brearton in The Globe and Mail:Report on Business 29(6): 24-29. January 2013. The banking industry leads the ranking with TD Bank followed by the Royal Bank of Canada and Scotiabank. ■

About the Author

Terrance Malkinson is a communications specialist, business analyst and futurist. His career path includes technical supervisor and medical researcher at the University of Calgary, business proposal manager for the General Electric Company, and research administrator with the School of Health and Public Safety at SAIT Polytechnic in Calgary. He is currently an international correspondent for IEEE-USA Today's Engineer, associate editor for IEEE Canadian Review, and a member of the editorial advisory board of IEEE The Institute. He was Vice-Chair of the IEEE-USA Communications Committee (2004-2010), and editor-in-chief of IEEE-USA Today's Engineer Digest (2004-2008). He was an elected Governor of the IEEE Engineering Management Society as well as past editor of IEEE Engineering Management. He is the author of more than 420 publications, and an accomplished triathlete. malkinst@telus.net

Going Global: Exploring Opportunities for International Growth and Expansion

By **David G. Michelson**

Manufacturing is vital to Canada's economy and to the prosperity and living standards of all Canadians. It is the most important wealth-generating sector of the Canadian economy, and the largest single business sector in Canada.

It is widely acknowledged that Canadian manufacturers must enter into global markets in order to achieve long-term growth and return value to their investors. In the past, many believed that firms must establish themselves domestically before seeking international opportunities. The business community has since recognized that firms can be "born global," i.e., established with the capability to compete in international markets and coordinate resources and activities across national borders from the start. In the business literature, such firms are also referred to as "global startups," "instant internationals," and "international new ventures."

Whether a firm is starting up, established domestically and seeking to enter global markets for the first time, or seeking to expand an existing international presence, developing business opportunities in global markets requires access to information and resources that are either difficult or expensive to acquire independently.

Through the Canadian Trade Commissioner Service (TCS) of the Department of Foreign Affairs and International Trade (DFAIT), the Government of Canada is committed to providing Canadian firms, and particularly startups and SMEs, with on-the-ground intelligence and practical advice on foreign and global markets that will help them make better, more timely and cost-effective decisions and thereby achieve their goals abroad. This includes helping firms determine whether they are internationally competitive, decide upon a target market, collect market and industry information, and improve their international business strategy.

Because the Canadian Trade Commissioner Service helps thousands of companies each year tackle concrete problems and pursue opportunities in foreign markets, they have a wealth of insights and advice to offer. Because they are part of Canada's network of embassies and consulates, they have a presence in more than 150 cities worldwide and have privileged access to foreign governments, key business leaders and decision-makers. This gives them a unique capacity to gain market intelligence and insight, and reveal opportunities for Canadian companies. Because they maintain offices in many cities across Canada, they are readily accessible.

Canadian Manufacturing Sector*

- 1.8 million Canadian employees, or 10.5 per cent of the workforce; the sector added 115,000 jobs in 2012 alone;
- $1.85 billion paid in weekly average salaries to Canadians — more than any other public or private sector in Canada;
- $166 billion in GDP — 14 per cent of Canada's total;
- $280 billion in exports — 63 per cent of Canada's total and more than double natural resources;
- Three-quarters of all private sector research and development activity;
- $3.15 in economic spin-off for every $1.00 in manufacturing output; and
- 30 per cent of the tax revenues paid by businesses to all levels of government in Canada.

*statistics courtesy of Canadian Manufacturers and Exporters

A highly visible component of the Canadian Trade Commissioner Service activities are the trade missions that allow delegations of Canadian business and academic leaders to meet with key business leaders and decision-makers and tour facilities abroad. DFAIT funding programs such as the Global Commerce Support Program (GCSP) and International Science and Technology Partnerships Programs (ISTPP) contribute up to 50% of eligible expenses towards various international business development activities. The ISTPP provides funding for joint R&D projects with China, India, Brazil and Israel.

Any firm that is part of the Canadian business community, contributes to Canada's economic growth, has a demonstrated capacity for internationalization and has good potential to add value to the Canadian economy, can benefit from TCS services. TCS services are offered free of charge to client companies and organizations. For more information, please visit http://www.tradecommissioner.gc.ca/ ■

David G. Michelson is with the University of British Columbia, Dept. of Electrical and Computer Engineering in Vancouver, and is Industry Relations Chair, IEEE Canada.

Going Global: Above and Beyond

Neptec (www.neptec.com) is a privately owned, Ottawa-based company that designs, builds and implements real-time 3D sensor systems and applications. It has been a NASA prime contractor since 1995 and has delivered space-certified flight machine vision systems for three different NASA programs. Its sensor systems were used initially for Space Station assembly and subsequently for Shuttle tile inspection. More recently the company designed a state-of-the-art sensor to facilitate rendezvous and docking to the ISS. It has received multiple awards and the highest possible annual NASA contractor performance rating for two years in a row.

From 4-8 June 2012, Neptec was one of nearly 30 companies from the building products and construction, aerospace, and mining sectors that participated in a Canada Trade Mission to Russia organized by DFAIT's Trade Commissioner Service. Coming together to discuss future joint projects in the aerospace field, representatives from Neptec, DFAIT and the Canadian Space Agency met with high-level representatives from the Russian government and space industry including Russian partners Roscosmos and TsniiMASH. The trade mission, which was led by the Honourable Ed Fast, Minister of International Trade and Minister for the Asia-Pacific Gateway, involved meetings held in both St. Petersburg and Moscow.

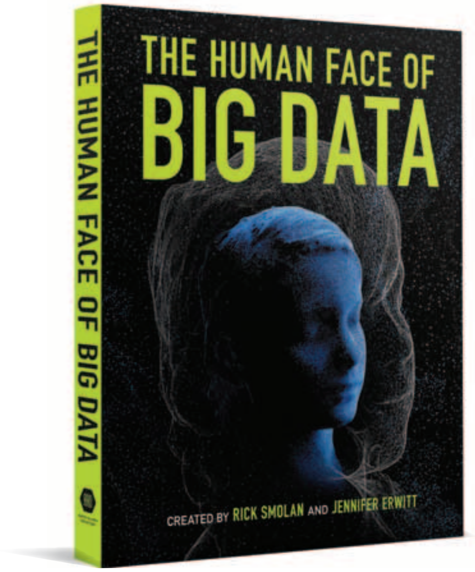
Before the mission began, Larisa Beach, Neptec's Vice-President for International Business Development, noted that, "As part of our global diversification plan, Neptec is actively pursuing opportunities in Russia—space technology being one of the key areas of Russia's modernization program. With our long history of innovation and reliability, Neptec sees this mission as an opportunity to further establish Neptec's foothold in this market."

After the mission concluded, Larisa Beach stated that, "Thanks to the support of the Embassy, the Canadian Trade Commissioner Service and of course Minister Fast himself, we were able to make significant progress in our efforts to partner with Russia on projects of mutual interest. This is a major step forward in our negotiations and were it not for this trade mission, we wouldn't have been able to get such impressive attendance at one table." Trade between Canada and Russia has intensified over the last decade, reflecting Russia's emergence as a major global economy. According to DFAIT, bilateral merchandise trade expanded to nearly $2.8 billion in 2011 from about $620 million in 2002.

Neptec has acknowledged the important role played by DFAIT team members, as well as Minister Fast, for hosting this important event. "The presence of high-level government support sent a very strong message regarding Canada's commitment and interest in the Russian aerospace market," said Beach. "We will use the foundation laid during the mission to build stronger partnerships for the future."

Book Review/Revue de livre

By **Jon Rokne**



The Human Face of Big Data by Rick Smolan and Jennifer Erwitt tackles one of the trendiest terms in modern computing. The authors have made a serious and positive effort to enliven the concept of Big Data and make it accessible to everyone.

It is a well considered book that offers its information in a manner most often seen in an elementary school text. It is Smolan's and Erwitt's premise that as a citizenry it is vital that we learn more about the uses and possible abuses of information distilled from Big Data. The book is a huge affair measuring 11 by 14 inches; its pages loaded with a range of vibrant images, formats, colour bursts and print types. It is visually inviting and textually sustaining; informative for thoughtful as well as distracted readers.

In order to more deeply appreciate what Big Data offers it is useful to consider what is generally meant by the term data. A data item (or datum) is the quantization of a variable in time or space. For example, the noon temperature at a specific location is one data item. If this is recorded for every day of a year, then it is data consisting of 365 data items (or 366 data items on a leap year). Extrapolating further, if the temperature is recorded for every millisecond at 10^6 locations for one year, there would be 315576x10^6 data items. This data is an example of 'Big Data,' since the magnitude of the data has been too unwieldy for ready processing with earlier technologies.

Most of the data that was gathered in the past was not recorded in great detail since the means for storing and analyzing were not available. Advances in computer technology have now given us the ability to analyze such data sets. As a result new, often surprising information can be extracted with analytic tools to yield intriguing insights and information for the engaged mind. Their volume explores the Big Data paradigm and how it affects a number of fields in science and society. The authors make this conceptually complex work accessible to the general public and provide value to professionals by inviting experts in a variety of various disciplines to explain how Big Data is relevant in their field.

> ***"a valuable resource for anyone interested in obtaining a good general overview of the complex phenomena arising from the study of Big Data."***

A foreword by Rick Smolan (A planetary nervous system) and an introduction by Dan Gardner (An ocean of data) enhanced by images portraying typical Big Data scenarios in everyday life sets the theme for the volume. There are hints at the variety of applications of Big Data as well as words of warning that every new technology has its risks and results for which we are unprepared. Questions of privacy, profit, storage and rights prickle the reader's sense of propriety.

There are eight sections in the main part of the volume. Each section is introduced by one or two essays by experts who discuss a topic as it relates to Big Data. These are followed by images with accompanying text showing specific situations where Big Data is gathered, stored, used and analyzed.

The first section, "Reflecting in a digital mirror" by Juan Enriquez, shows how Big Data has already become part of our lives, how it can be used to improve our lives and how it compares to the data that a human absorbs every day.

The next essay "Our data, ourselves" by Kate Greene ponders the gathering of data by individuals in self-tracking mode. This, somewhat narcissistic activity, can be used to improve our lives by informing us on the state of our physical health, though such tracking is less likely to improve our mental health, and possibly be detrimental to it.

In the essay "Quantifying myself" A. J. Jacobs discusses the possibility of recording detailed data about a single human (an experiment also initiated by Gordon Bell, the father of the VAX). A positive aspect of this obsession may be that one's lost objects could be retrieved by rewinding to the last action involving the item. It is interesting to consider whether such recordings could be used in a court of law or would the scourge of evidence tampering render the documentation unusable.

"Dark Data" is the theme of the next two essays by Marc Goodman and Susan Karlin. Here they explore Big Data from the louche side of society. Goodman notes that: "Access to data not only affects traditional forms of crime, but also amplifies what any one criminal can accomplish in unexpected ways." An interesting use of Dark Data has been to identify and repurpose information as discussed by Susan Karlin who shows how Dark Data can be used in urban planning for greater social justice.

"The pulse of the planet" by Ester Dyson expands on Smolan's introductory comments on the planetary nervous system. She notes: "We now live in a world of billions of intelligent devices that are self-aware, that communicate among themselves as well as with computers, and ultimately with people". Clearly this has the potential of creating huge volumes of data, in other words, Big Data.

Data gathering from large networks of individuals is the topic of "How crowdsourcing is changing science" by Gareth Cook. One fascinating example is the decoding of a massive amount of fragile papyrus manuscripts from the city of Oxyrhynchus. In this instance crowdsourcing consists of distributing the decoding task over a large number of individuals each handling a few manuscripts.

Michael Malone writes about "A demographic of one" where he discusses the data explosion available to everyone with an Internet connection.

"The art of data" by Aaron Koblin touches on the field of visualizing Big Data, that is, how can we get an overview of a Big Data set in a reasonable fashion. One of the images displayed shows 63,779 cross references in the Bible.

In the final essay "Data driven" Jonathan Harris notes that all aspects of society and science such as marketing, economics and astronomy are now strongly shaped by Big Data.

Big Data is mostly stored on cloud computing facilities. The most prominent example is Amazon Web Service (AWS). Its customers include governments and private enterprises. At the end of 2012 AWS stored more than one trillion objects. AWS predicts that in the near future extracting facts and information from this data will require an army of 190,000 skilled professionals.

"The Human Face of Big Data" is not a book to be read in one session. It is a smörgåsboard of information on Big Data in all its forms and uses and as such it is best sampled in small tantalizing slices. The well designed web site HumanFaceofBigData.com enhances the book by providing valuable online information.

The financial contributions toward creating the book are acknowledged in the closing pages.

The book is a valuable resource for anyone interested in obtaining a good general overview of the complex phenomena arising from the study of Big Data, what it is and where it might lead us and perhaps, most importantly what are the important existential questions that Big Data exposes us to. ■

Author: Smolan, Erwitt
Publisher: Against All Odds Productions
ISBN-13: 978-1454908272
Date: November 20, 2012
No. of pages: 224

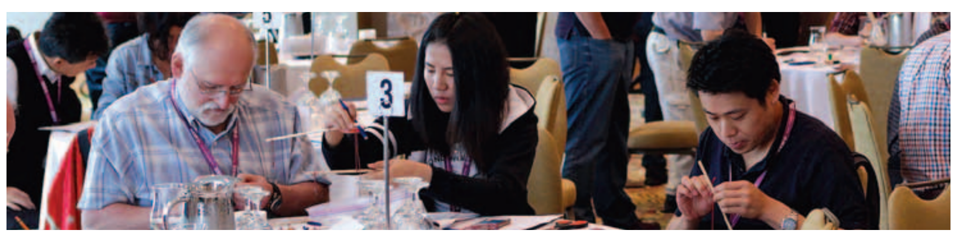
Cross-Border Teaching Gets Top Grades at Vancouver Workshop

TISP Canada's third workshop connects Seattle and Western Canada volunteers

Photos courtesy of Steve McClain

The third national workshop of IEEE Canada's Teacher In-Service Program (TISP) broke new ground last spring, bringing together roughly 50 participants from both sides of the border.

Teachers from the greater Vancouver area were joined by IEEE volunteers from Western Canada, the Prairies and Seattle, Washington, on May 10 and 11 for one-and-a-half days of hands-on lesson-based activities. Featured on this page is the "Rotational Equilibrium" lesson from the tryengineering.org web site. Also sampled was the "Ship the Chip" lesson plan, wherein participants design packaging capable of ensuring survivability for a single potato chip released from shoulder height.

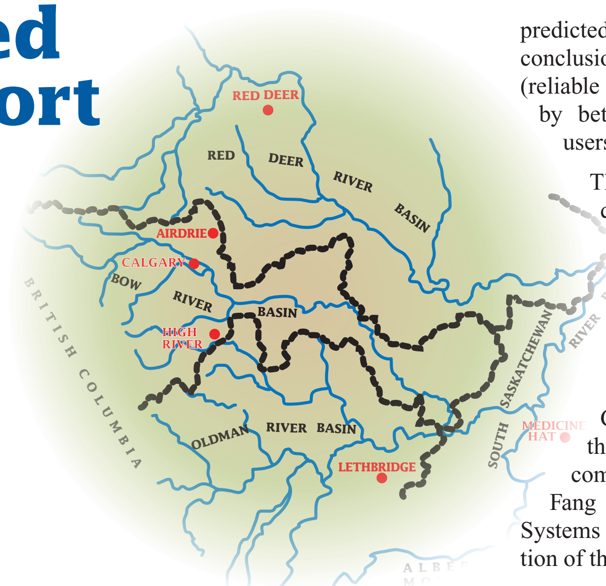


The goal of this workshop, as with the two preceding national workshops (April 2011, Mississauga; May 2009, Montreal) is to equip IEEE volunteers to lead workshops with local elementary and high school teachers. In some instances, TISP Canada volunteers, also called "Champions," go into classrooms themselves to lead design-oriented lessons. Other volunteers work with members of related professional associations in creating joint progamming for outreach events such as Engineering Month. There are TISP Champions in most IEEE Canada sections, ready to welome new volunteers.

For information on how you can get involved with TISP Canada activities, contact Anader Benyamin-Seeyar, TISP Canada Committee Chair, at anader.benyamin@ieee.org, or visit the website at http://www.ieee.ca/tisp/

Water Allocation Distinguished Lecture Report

By **Patrick Finnigan**



Professor Liping Fang, Ph.D., P. Eng., FEIC, FCSME, Associate Dean, Undergraduate Programs and Student Affairs, Faculty of Engineering and Architectural Science, Ryerson University (lfang@ryerson.ca) gave an excellent IEEE Canada Distinguished Lecture on the topic of "System-wide Cooperative Water Resources Allocation" last December to an audience of more than a dozen attendees.

After reminding the audience about the importance, scarcity, uneven distribution and quality of the world's water supply, Dr. Fang delved into the general trans-border water allocation principles and its varied uses for navigation, power-generation, industrial, agricultural and essential use for citizens. The real question in all of this is "Whose water is it?" There are various "riparian" and other international (and national) protocols on who can use it, pollute it, pay for it etc.

By building graph models of water supply and distribution, including storage nodes and allowing for "reverse-flows" of water being re-used, and by annotating the nodes and links in the graph with constraints, he has been able to model effective co-operative allocation of the water resource(s) to all users, and meet their goals for availability and cost as well. The models he has developed perform a two-step allocation: 1) a rights allocation using three modeling techniques including maximum net flow, and 2) a re-allocation based on net benefits, which also uses three modeling techniques including Lexicographic Minimax Water Shortage Ratios (Luis, 1999), and the novel "Co-operative Reallocation Game." The Co-operative game lets a group of users in the water network maximize their benefits using it, while at the same time respecting the criteria of individual users up and downstream. It is based on the "Nucleolus" model or "Shapley value" (after the Nobel economist Dr. Lloyd Shapley).

Finally, Dr. Fang ended his talk by showing how his model(s) could be used to better re-allocate water in the South Saskatchewan River Basin (around Calgary). This model graph had 55 nodes, 17 reservoirs and 17 stakeholders. By concentrating on the 4 largest stakeholders, and water data for the full-year period, by month in 1995, Dr. Fang and his graduate students have been able to better predict how to allocate the water resources, especially by 2021, when it is predicted 50% less water will be available. The conclusion was that better allocation efficiency (reliable supply, lower cost) could be achieved by better co-operation among the biggest users.

The audience had several interesting questions for Dr. Fang, including perhaps that the techniques he and his team have developed might well be applied to supply-chain management electric power generation and distribution.

Dr. Alexei Botchkarev, Chair, Systems Chapter, IEEE Toronto Section, hosted the session, introduced the speaker, welcomed the audience, and presented Dr. Fang with a token of the IEEE Toronto Systems Chapter's appreciation for his presentation of this IEEE Canada Distinguished Lecture.

Patrick Finnigan (SMIEEE) is a Toronto-based instrumentation consultant and a member-at-large of IEEE Toronto Section executive

CONTEXT

Southern Alberta Flood

Spanning 55,000 square kilometres with a clean-up and reconstruction bill expected to reach $5 billion, this past summer's flood in southern Alberta has highlighted the need to have better models for an *excess* of water supply—or at least received over too short a time period.

The need for flood-event modeling will only increase as a result of continued climate change, says Professor Slobodan Simonović of the University of Western Ontario's Department of Civil and Environmental Engineering, and also with the Institute for Catastrophic Loss Reduction (ICLR), affiliated with the University.

"The intensification of the hydrology cycle is becoming visible in the number of floods and the magnitude," Simonović says, referencing studies done at the Institute. "Also, more floods are from summer storm events as compared to the traditional flooding following the spring snow melt. Not only do they cause river overflow, but they overload municipal infrastructure."

Urban flooding is increasingly becoming a problem as municipalities struggle to identify priorities, according to Simonović, who notes this level of government has the fewest resources of any. However, the tools exist for assessing the change in risk to municipal infrastucture for specific locations due to climate change, he says. In particular, he points to recent studies his group conducted concerning the Upper Thames Watershed on behalf of the city of London.

"I'm not saying it's easy or we have all the answers, but we can provide some guidelines to help politicians, and decision- and policy-makers. But policy-makers must be prepared to act on the information."

N.Ed. Readers interested in information about how flood risks are assessed and taken into account may wish to consult *Floods in a Changing Climate: Risk Management*, by Slobodan Simonović, Cambridge University Press, 2013.

A Tale from the East

By **Dave Hepburn**

SCROLL BACK 44 YEARS, in a country called Pakistan… Well, actually it was one country divided into two parts: East Pakistan and West Pakistan. Not a very handy arrangement, given the two were some 1,500 km apart. But nevertheless, in those days it was an OK place to live and work. It has gone down hill a bit since then—some would say—unfortunately. Of the two parts, West Pakistan was at that time relatively more advanced and prosperous, while the East lagged behind, more than a bit. Yours truly was one of a team of about 10 Canadians whose assignment it was to help the East Pakistan electric power system catch up with their confreres on the other side. This assignment required a certain amount of commuting between Dacca (as it was then spelled) where we lived, and Lahore, which had the nation's only means of simulating power system flows in an extensively interconnected network. An A.C. network analyzer no less. Computers had not yet arrived in the east at that time—and yes, an ac board still makes an ideal teaching tool.

So it was that on one occasion, I was asked to take two of our East Pakistani trainees to Lahore for a couple of weeks. The only sensible affordable way of getting there was to fly via the national airline Pakistan International Airlines (PIA, which still exists). I say affordable because part of the glue which kept the two parts together was to offer heavily subsidized air fares. For the record, the economy class ticket was $50, which was a knockout, even 44 years ago. But unfortunately all flights were fully booked for several weeks ahead. But then I had a brainwave: part of my contract as a "foreigner" was permission to travel first class within the country. This was really intended to apply to train travel, where all too often the only alternative was to ride outside on the roof. And anyway, it certainly wasn't possible for Pakistani nationals to travel by train across India. So I reasoned that travel from Dacca to Lahore was also "within the country," and with the greatest of good luck, I managed to book two first class tickets and one economy ticket. The Canadian government was paying anyway, so what the heck. And symmetry being what it is, it seemed logical that the two trainees should get the first class tickets, while yours truly should get the economy ticket. And, don't be alarmed, even in those days, no one was allowed to ride outside on the roof of a DC 3.

Once in Lahore we encountered another bureaucratic difficulty. Government rules for government employees stated that while the government would pay for their hotel, the employee was expected to pay for his/her own meals. The logic being that since they had to eat at home anyway, why should they not pay when away from home also? The fact that a meal in even a modest hotel probably cost the equivalent of a week's pay seems to have escaped the bean counters. I soon found that they were practically starving. So we struck another deal. People on the sub-continent like to eat late. Really late, like 11.00 p.m. But it was agreed that if they would eat with me at, say 7.30 p.m., all three meals could be booked to my room as a lump sum and no one would be any the wiser. And so we lived happily ever after.

Well, not quite ever after. The whole arrangement of East and West Pakistan dissolved in conflict two years later—East Pakistan became Bangladesh and the Canadian team was disbanded.

But then, some 15 years later, in 1984, the notion of assisting the Bangladesh Power Board was revived and international competitive bids were called for. The prices that came in were close, but it soon became agreed that "if the same gent who treated us so well last time can join us again, that company can have the contract." And so it came to pass.

And, dear colleague, in case you think this tale is just malarkey, it came to pass that the same process repeated itself yet again ten years later in 1994. By that time of course the trainees of 1969 had become senior people able to make their own decisions and make them stick.

So there must be a moral there somewhere. ■

Dave Hepburn (LSMIEEE, P.Eng.) is an electric power systems specialist who began a 40-year career in managing overseas projects in the late 1960s. After some years with Hydro Quebec, he joined Acres Consulting in 1965 as Chief Electrical Engineer on Churchill Falls in Labrador, then took on international assignments ranging from long-term planning to economic/financial studies, irrigation requirements, environmental appraisal and gender equity considerations. He has worked in 28 countries. In 1995 Dave took early retirement from Acres to continue as an independent consultant for the World Bank, the Asian Development bank, CIDA and the not-for profit Canadian Executive Services Organization (CESO). He is the 2013 recipient of the IEEE Canada M.B. Broughton Central Canada Merit Award for his long-standing IEEE Educational Outreach activities.

N.Ed. "Experiential Learning" shares the real-life lessons of our readers that only experience can teach. If you have a tale to tell, then target it to our managing editor, Bruce Van-Lane, vanlane@ieee.org. It can be about your "schooling," or that of a colleague's – all we ask is that it be true!

ILLUSTRATION BY PAL

In Praise of Vice-Grips

By **Miro Forest**

I WAS A RELATIVELY YOUNG Engineer, and had worked in the area of long haul analog microwave system design and field operations for a while (late 1970's).

As a result of some miscues in the planning department, there was a microwave path (in the 7 GHz band) that was in the process of being established, but it had taken so long that in the mean time, there had been a high rise apartment building erected in just about the worst spot - right at about mid-path, creating an obstruction.

When this came to light, there was considerable consternation since it implied that towers would have to be modified (i.e. heightened) or (worse yet) moved to new sites. But in this problem I saw an opportunity.

Since the new high-rise was at about mid-path, and we knew the terrain geometry, I thought we could carry out some nifty and usually very impractical propogation measurements. All I needed was about 3-weeks of data. I had to find a spare transmitter, receiver, waveguide components and measuring/recording equipment. So I talked my supervisor into lettng me have a go at the project so long as my other design work was completed on time and on budget.

I scrounged the radio equipment temporarily from the group that did remote video pick up feeds for the CBC (e.g., the Grey Cup parade, golf tournaments etc) since I only needed a 1-way link, I dusted off an old (ancient, really) chart recorder to record the received signal level, but I still had to find the waveguide components to connect everything together. Normally, we would buy the various 7 GHz waveguide bends and components needed, but I did not have this option.

I looked at what was available and found we only had larger 4 GHz waveguide parts - waveguide size is inversely proportional to frequency. I did some calibration checks, and based on the calculations I made, thought that I could get it all to work. In this region of the radio spectrum, size matters a lot.

Aside from the theoretical issues, one of the biggest problems was how to hold all of these waveguide parts together so there wouldn't be much, if any signal leakage or signal loss at the flanges. And because of the different waveguide sizes, the bolt holes on the flanges didn't line up.

I needed a strong, secure joint, so what to do? Ordinary clamps were too clumsy and wouldn't allow good alignment of the waveguides. I ended up using vice-grips to hold the components together - strong, allowed alignment, easy to use. Frankly, it was not a pretty sight but it worked.

I collected the data and found that our propogation models were overly conservative. Sometime later, and partly because I had done this testing, I was asked to head up a new group that was to introduce new long haul digital microwave radio into the Canadian backbone network. That turned out to be a really fascinating assignment, which then led to other assignments overseas to work on "troubled" microwave systems.

In those asignments, I always made sure I had several sets of vice-grips in the toolkits. ■

Miro Forest (SMIEEE, FEC, P.Eng.) was actively engaged in the design, engineering, installation and operation of long haul microwave radio transmission systems. From 1992 to 2002, he worked in the competitive local and long distance carrier business, as an Engineer, Consultant and eventually Senior Executive. In 2002, he founded a ultra-high reliability and security data centre business in Waterloo Region, which was successfully sold in 2009. He is the founding President of the IEEE Canadian Foundation (ICF), receiving IEEE Canada's Wallace S. Read Outstanding Service Award in 2005 for his work over two decades with the ICF and its predecessor organization, IEEC Inc.

Do You Speak My Language?

New IEEE benefit helps ready members for global opportunities

By **Lynn Koblin**
IEEE Sponsored Discounts and Insurance Program Manager

For technologists, "mobility" can mean much more than wireless communications: it may well be a description of their careers. Skilled workers and corporate managers are relocating where the jobs are, and the trend to follow employment opportunities across borders is expected to continue. Fluency in multiple languages is a skill that will open many doors. To help members attain that marketable edge, IEEE has introduced language instruction from Rosetta Stone as one of its new benefits.

Full immersion is said to be the "best" way to learn a language, if you can. But career migration today does not always provide that opportunity—the life of an expatriate has changed somewhat. The traditional image suggests the foreign family ensconced in a well-appointed residence, living in comparative luxury amid the locals for a few years. That picture is morphing into a long distance commuter—a road warrior, working in-country for only a few weeks at a time and coming home for weekend visits. According to a series of blog posts about expatriate life, published by IESE Business School at the University of Navarra, when the company or the employee does not want to relocate the job permanently, then the employee may be sent only temporarily abroad as part of a project team; that lifestyle does not afford much time to absorb a new language. Alternatively, equipped with language skills and an internet connection, other entrepreneurial individuals are discovering a refreshing variety of global assignments—from wherever they choose to reside. Employees "on the move" will possess both the technical expertise and the language fluency to participate successfully in these types of career options.

Of course, permanent expat opportunities are still available for the candidates with the right fit. Recruiters want to see language fluency on the resume, and will pay a premium for it at times. One career advice site in the UK noted that candidates with proficiency in Spanish are in high demand there, with that language being the second most influential language in the world after English. The ability to speak Chinese or German, for example, could also raise candidates' employability and salary, according to that source.

Consistent with global trends, many IEEE members anticipate making life-changing moves in the course of their careers, or as managers, expect to relocate talent in their companies to support business objectives in new markets. In a 2010 global member survey about career mobility, 54.2% of IEEE members responded affirmatively that better employment opportunities may lie outside their native country, and approximately 36% said they are likely or very likely to consider those options. Thirteen percent of those surveyed agreed or agreed strongly they would be working in another country in the near term.

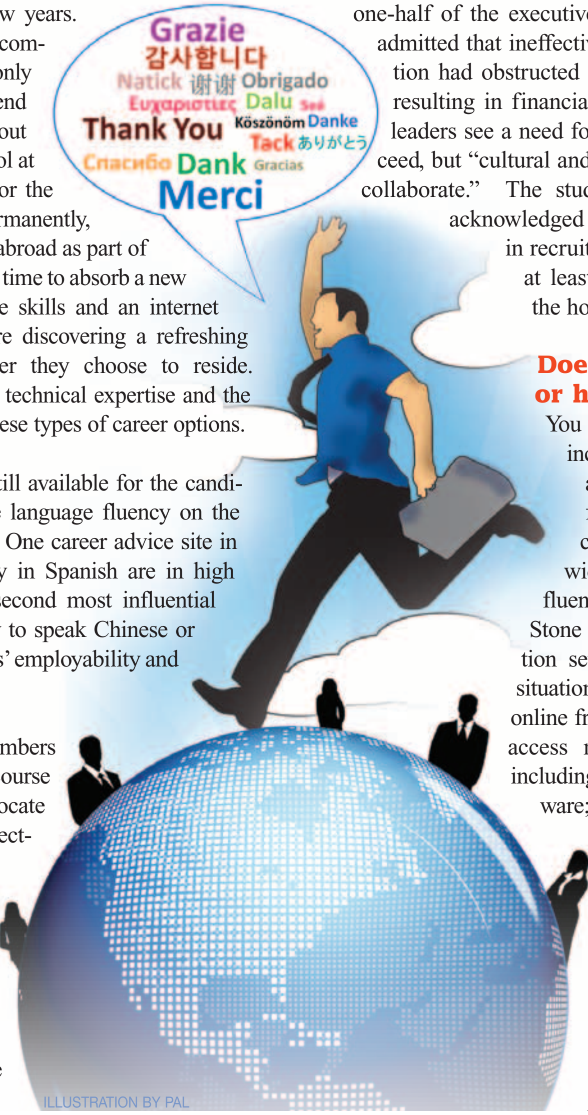


ILLUSTRATION BY PAL

When IEEE members were asked about the types of skills they would need to develop or improve in order to consider career opportunities abroad, 60% of members named language skills, compared to 26% who named technical skills. Drawing from members around the world, it was no surprise that the survey found 44.5% of respondents to be bilingual; an impressive 19% indicated they are polyglots. On the other hand, 36.5% of responders speak only their native language. Approximately 77% of responders believe that fluency in English is important or very important for their careers, while approximately 56% believe that fluency in a language other than English is important or very important.

While English is one of the most influential languages in the world, companies that primarily do business in English are finding increasing need to become more linguistically diverse, in order to thrive in multicultural markets. A 2012 study by the Economist Intelligence Unit, "Competing across borders: how cultural and communication barriers affect business," found that fluency is related to a company's financial success, noting, "Around one-half of the executives surveyed for the purpose of this report admitted that ineffective communication or inadequate collaboration had obstructed major international transactions, inevitably resulting in financial loss." The research showed that business leaders see a need for cross-border partnerships in order to succeed, but "cultural and linguistic diversity can make it difficult to collaborate." The study interviewed numerous companies that acknowledged multilingual skills were becoming a factor in recruitment: 39% seek candidates with fluency in at least one non-native language for positions in the home country.

Does your language fluency help or hamper your career?

You can prepare for broader opportunities and increase your likelihood of success by taking advantage of IEEE's latest member benefit for language instruction. Through a new discount negotiated by IEEE, members worldwide can learn any of 24 languages, or improve fluency skills they already have, with Rosetta Stone TOTALe. Rosetta Stone TOTALe is a solution set that can give members the training and situational practice they need, with convenient access online from a computer or mobile device. Users will access multiple types of learning environments including: Rosetta Course, the interactive course software; Rosetta Studio, which brings the learner in contact with a language practice partner; and Rosetta World, the online community where learners can share language with many other participants. ■

If you are considering giving your career a multi-lingual, competitive edge, then get more information about the Rosetta Stone TOTALe language instruction program and the exclusive IEEE member-only pricing, at IEEE.org/go/discounts.

IEEE Canadian Review
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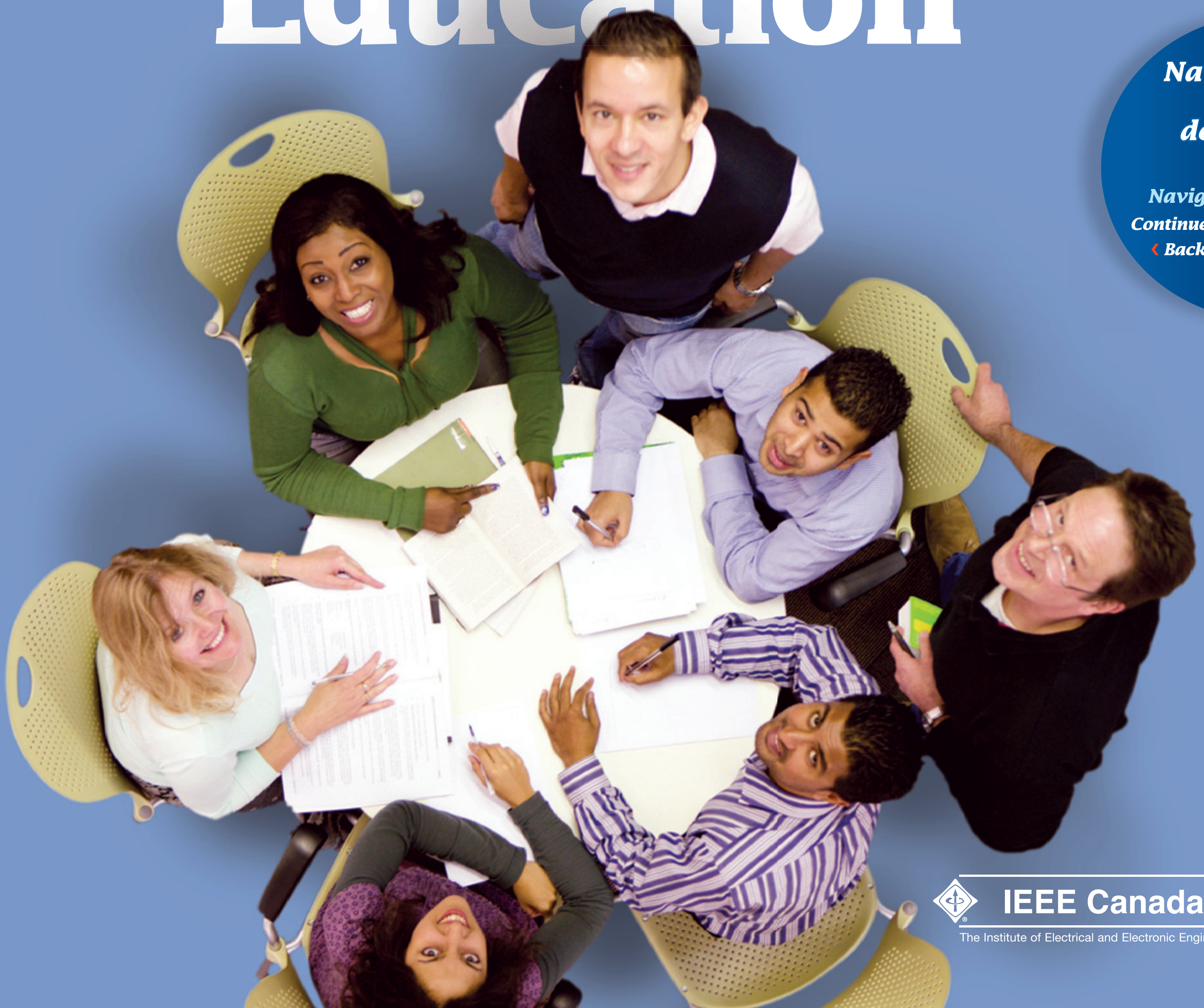
SPECIAL FOCUS

The Future of Engineering and Technology Education



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IEEE Canada
The Institute of Electrical and Electronic Engineers Inc.

Are we educating engineers/technologists for the 21st Century?

"Developing world-class talent is the foundation for Canada's success now and in the future. Nurturing and growing the knowledge and skills of people through all stages of their lives allows them to contribute to society and the economy, and it underpins the country's progress and competitiveness in all areas. Investment in ongoing, high-quality education, training, and mentoring of our talent must be a priority."

State of the Nation 2012, Canada's Science, Technology and Innovation System: Aspiring to Global Leadership, page 78
Science, Technology and Innovation Council (STIC); 2013

CANADIAN UNIVERSITIES AND COLLEGES – AND INDUSTRY AND GOVERNMENT– must together recognize and address an array of challenges to ensure Canada develops a knowledge economy. This is critical to sustain/enhance the standard of living for all. Engineering and technology education are critical enablers.

New approaches are required by educators. According to Sethuraman Panchanathan, Senior V.P, Office of Knowledge Enterprise Development at the University of Arizona, they must "weave entrepreneurialism across the fabric of the institution through student and faculty experiences to promote a truly entrepreneurial culture."

Looking at current trends and the traditional structure of engineering and technology education in Canada, a number of questions arose around how we can move our education system to where it needs to be in order to provide the workforce of the 21st century. We hope to shed a light on these questions with responses from our cross-section of contributors, from university and college educators, industry leaders, engineering students (current and recently graduated) and specialists in engineering and technology education.

Some Facts and Trends

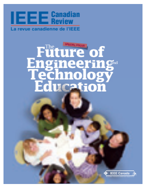
Future labour force needs cannot be met with current policies. This phenomenon is visible today and predicted to get stronger with significant impact from 2016 forward. (*People without Jobs–Jobs without People* (Ontario and Canada); Rick Miner, 2010)

Global student mobility is essential to today's Global Economy: "The search for the best talent is a race taking place at the global level. Competitive firms and institutions vie to attract the brightest people in their fields, from wherever they come. This talent is increasingly willing and able to relocate to take advantage of the opportunities and benefits an international career can bring." *State of the Nation 2012*, STIC, 2013

Lost GDP is $28.4 billion in Ontario annually due to skills gap ($24.3 billion) and skills mismatch ($ 4.1 billion). There is already evidence of skills shortages in science, technical services and engineering; engineering and electrical trades and professions are the top 2 out of 20 occupations that are expected to have difficulty filling their skilled workforce needs. (*The Need to Make Skills Work: The Cost of Ontario's Skills Gap*, The Conference Board of Canada, 2013)

Technology in education is changing the education and training delivery models, e.g., free on-line learning materials are becoming widely available (MIT courses, Khan Academy, coursera, to name a few).

Experiential Learning is gaining momentum: "High levels of student interest and participation in postsecondary Work Integrated Learning (WIL) programs, the endorsement of both industry associations and career development practitioners for the economic and human capital benefits of WIL, and government policy proposals to expand WIL programs suggest that work-integrated learning is here to stay as a vital component of a postsecondary program of study." (*Work-Integrated Learning [WIL] in Ontario's Postsecondary Sector: The Experience of Ontario Graduates;* The Higher Education Quality Council of Ontario (HEQCO); 2011)



Special Focus Associate Editor

Maike Luiken is Director, Bluewater Technology Access Centre at Lambton College, and President of Luiken International Consulting. Previously she was responsible for the facilitation and management of all applied research projects at the college, comprising small to multi-disciplinary inter-organizational, multi-year research projects spanning multiple disciplines from technology to health. Maike recently spearheaded establishment at Lambton of the first NSERC Industrial Applied Research Chair for Colleges. Prior to joining Lambton College, she was Vice-President Research Alliances, National Capital Institute of Telecommunications (NCIT), Ottawa. At NCIT, Maike founded and led the Ottawa Photonics Research Alliance (OPRA), and co-founded the Ottawa Wireless Research Alliance (OWRA).

Bridging between academic preparation and workplace practice

Ibrahim Gedeon

WHAT I WANT, when I want it, and how I want it is the current information and communications user paradigm; this shift in user behaviour and needs is causing service providers to transform their way of doing business. The transformation undertaken by the information and communications technology (ICT) and service provider industries should be supported by a parallel transformation in how academia approaches educating young minds.

Never before in the history of our industry has the focus on applied science been more important than today.

In industry we feel that the education system is becoming polarized between students who specialize to the Nth degree and those who have a fairly superficial academic training. It is like having to navigate from 100,000 feet to 1 foot in a digital fashion, we are not afforded the whole range of expertise. It is fairly difficult for us in industry to navigate graduating students who are at polar opposites As the current academic focus tends to be on science or practical science; thus applied science is falling through the cracks; particularly in the area where there is already an established academic rift, between computer science and communications.

The industry will always need the two book ends of applied science and practical science, there is a role for both in our world, however the need is shrinking. Thus today the applied usefulness of a graduate technology professional is reduced and lots of training is required. Think of it in terms of having people who build applications with no knowledge for the underlying infrastructure, and people who can tell me how fast the atom can accelerate; both are needed. But how does my industry move things forward without the individuals that understand how things actually work at an applied level.

About the Author

Ibrahim Gedeon is the CTO of TELUS Communications Inc. and TELUS Mobility, responsible for technology strategy, service and network architecture, service delivery and operational support systems. He is responsible for the Wireless-Wireline service and network convergence, enterprise applications and network infrastructure strategies and evolution. Mr. Gedeon began his career in telecommunications engineering and research in 1990 when he joined Bell Northern Research. He moved to Nortel Networks in 1994 and in 1996 was named vice president and director of Data Network Engineering, and vice president of Internet Brand Management in 1999. He was appointed senior vice president of Wireless Engineering in 2000 and led the global engineering team responsible for operations, sales support, and systems engineering.

OPINION

by David G. Michelson

THE ERA IN WHICH CANADIAN engineering students simply attended lectures, solved problem sets, conducted set lab experiments and wrote mid-term and final exams is rapidly fading from memory.

Canadian engineering students have been participating in co-op programs and acquiring practical knowledge from the engineering workplace over several fourth-month work terms for decades. Engineers Canada and the Canadian Engineering Qualifications Board and the provincial and territorial associations now allow engineering students to count some of this experience towards the satisfactory engineering work experience they must accrue before becoming eligible for registration as a professional engineer.

As set lab experiments in second and third year are replaced by team-oriented design projects and capstone projects in fourth year increasingly emphasize solving design problems for external clients, and as lecture courses increasingly incorporate group application exercises and industry practice, the gap between theory and practice has never been as well covered.

Best of all, our colleagues in industry have never been so willing and interested to help us engage our students in group application exercises and capstone projects. There is undoubtedly still room to improve, but the momentum is clearly in our favour.

David G. Michelson is with the University of British Columbia, Department of Electrical and Computer Engineering in Vancouver.

Another analogy that most will resonate with is motor racing; a good driver needs to understand how the vehicle is maintained and built to get optimal performance out of their vehicle. Similarly the person building parts should understand how the vehicle is built and maintained. You see the theme, the mechanics and architects of vehicles are that joint medium for the whole eco-system. So what is the equivalent in our industry and how can academia expose graduating professionals to that applied middle ground?

Some call them architects, some system engineers, some applied scientists; the reality is that a lot of work is highly specialized and more focused training is needed. Support from industry is critical to ensure that skills are optimized.

Continued on page 13 ›

Ensuring professional skills development

Brian Frank

EVERY YEAR I interview over 50 upper year engineering students to manage first-year team design projects. The discussions arising in these interviews serve as an annual refresher on students' perceptions of engineering and non-engineering employers. Students frequently comment that during interviews they are asked to relate their experience running projects, working with clients, and communicating. Grades on transcripts get them in the door, they say, but it's their design experience, team experience, and extra-curricular experience that gets them the job.

These anecdotal stories align with conversations with industry representatives, as the conversation usually goes along the following lines: we know from experience that Canadian engineering students have solid technical skills which we will supplement with our own specialized training. We are looking for students with the ability to learn quickly, work well with a team and a client, think creatively, and take initiative.

> *We are looking for students with the ability to learn quickly, work well with a team and a client, think creatively, and take initiative.*

The 2007 and 2009 reports of the Engineering and Technology Labour Market Study commissioned by Engineers Canada and the Canadian Council of Technicians and Technologists point to a high level of satisfaction with core technical skills of recent engineering graduates [1]. It highlights a gap in non-technical skills including written and oral communications, project management, and teaming. Overall 64% of employers were satisfied with the non-technical skills of new hires with 0-5 years of experience after an engineering degree, compared to a satisfaction of 87% for science-based skills [2].

Continued on page 13 ›

About the Author

Brian Frank is an associate professor at Queen's University, where he has taught courses in electronics and wireless systems. He is the DuPont Canada Chair in Engineering Education Research and Development, and the Director of Program Development in the Faculty of Engineering and Applied Science where he works on engineering curriculum development, program assessment, and developing educational technology. His research areas are in engineering education, including assessment and critical thinking development, and in microwave integrated circuit design. He is a co-founder of the Canadian Engineering Education Association and coordinator of the Engineering Graduate Attribute Development Project (EGAD).

David G. Michelson

TODAY'S GRADUATING STUDENTS likely have the best set of soft skills–the interpersonal, communication and leadership skills that they need to fully benefit from their studies and succeed in their careers – of any cohort in Canadian history. Not only are they confident, work well together, communicate effectively and can plan ahead, each new group appears to build on the successes of the last.

Part of the credit goes to their parents, many of who work in the technology sector and are doing an outstanding job of encouraging and supporting their sons and daughters. Part of the credit also goes to Canadian industry, the energy and enthusiasm with which employers have embraced co-operative education, and the encouragement and support that students receive in the workplace and bring back to their university when their work term concludes. Since its modest beginnings in the late 1950s, co-operative education has changed the way that undergraduate students view both themselves and their intended profession.

Part of the credit goes to modern information technology and the manner in which it literally puts the knowledge and experience of the community and the profession at all of our fingertips, including those of today's graduating students. It is interesting to note the extent to which modern information technology also levels the playing field by ensuring that everyone has more or less equal access to the same vast repositories of on-line information.

Student-led and organized extracurricular activities have long been effective and popular venues for imparting and developing soft skills. However, the need to deliver soft skills training more consistently across a growing and increasingly diverse cohort has motivated recent interest in incorporating soft skills training into the formal engineering curriculum. The rapid and effective manner in which Canadian universities have responded is noteworthy.

Part of the credit goes to the Canadian Engineering Accreditation Board (CEAB) and its parent organization, the Canadian Council of Professional Engineers, popularly referred to as Engineers Canada. Formed nearly 50 years

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About the Author

David G. Michelson is with the University of British Columbia, Department of Electrical and Computer Engineering in Vancouver. In addition to his role as Chair of IEEE Canada's Industry Relations Committee, he also serves as a member of the Board of Governors of the IEEE Vehicular Technology Society (and Editor of the IEEE Press Series on Vehicular Technology), Member of the Board of Governors of the IEEE Communications Society (and Director of Education), Member of the IEEE History Committee and Member of the IEEE Canadian Foundation. He can be reached at dmichelson@ieee.org

Accommodating foreign-trained engineers

Turning Differences into Opportunities

Marcia R. Friesen

CANADA, A NATION of almost 35 million people, welcomes approximately 250,000 immigrants annually. In contrast to the historical profile of the immigrant as an unskilled labourer, the federal and provincial governments in the past 10-15 years have preferentially recruited immigrants who have training and experience that matches Canada's existing and projected labour shortages in the professions and skilled trades. Canada's federal immigration ministry reports that immigration is projected to account for all net labor force growth in Canada within the next decade and all population growth within the next two decades.

Requirements for licensure:

In the regulated professions like engineering, medicine, law, and nursing, registration with the provincial regulatory body is a legal requirement to practice the profession, and this is a surprise to many newcomers. Many internationally-educated engineers (IEEs) arrive from countries where the university degree alone confers right to title and right to practice. For IEEs, the process to become registered as a P.Eng. with a provincial engineering association generally includes the association's evaluation of past credentials, an assigned set of technical exams to confirm technical qualifications, and a minimum of four years of professional experience (of which one year must be Canadian engineering experience).

Collectively, the provincial engineering regulatory bodies in Canada receive approximately 6,500 applications for licensure from IEEs annually. This number is not necessarily equivalent to the number of IEEs that have entered Canada in a given year, as there will be applicants who will be assessed not to be engineers (e.g. architects, engineering technologists) and other IEEs who never apply to a provincial association for licensure. However, the figure provides a sense of the scope of the issue in a profession of 250,000 professional engineers nationally.

Challenges facing immigrant professionals:

Government, industry groups, and IEEs all paint a consistent picture of the challenges facing immigrant professionals working to re-enter the engineering profession upon arrival in Canada. In two recent studies, Statistics Canada reported that the two key challenges facing immigrant professionals relative to career re-entry are difficulties in having foreign credentials formally recognized by regulatory bodies and gaining career-related Canadian employment. In a long-term study by Engineers Canada, IEEs confirmed these conclusions, highlighting the 'chicken & egg' experience that the absence of professional registration is a liability when seeking employment, and Canadian employment experience is a requirement in order to be eligible for professional registration. The Canadian Labour and Business Centre, a former organization that for several decades acted as a business and labour forum for partnership and dialogue on labour market and skills issues, echoes these challenges. The CLBC added professional communication competencies as a key determinant of an immigrant professional's employability. Thus, immigrant professionals often find themselves on the margin or even excluded from the professional workforce –

> *"In two recent studies, Statistics Canada reported that the two key challenges facing immigrant professionals relative to career re-entry are difficulties in having foreign credentials formally recognized by regulatory bodies and gaining career-related Canadian employment."*

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About the Author

Marcia R. Friesen P.Eng., Ph.D., is Assistant Professor in Design Engineering and Director of the Internationally-Educated Engineers Qualification Program at the University of Manitoba, Canada, and Vice-President of the Association of Professional Engineers & Geoscientists of Manitoba. She earned a B.Sc. in Agricultural Engineering, Master of Education in Post-Secondary Studies, and Ph.D. in Biosystems Engineering. Her research focuses on engineering education and qualifications recognition for internationally-educated engineers, as well as health care modelling and simulation in computer engineering. Prior to an academic career, she gained experience in the engineering consulting sector as a design engineer in Manitoba, Canada.

Are we creating a culture of entrepreneurialism?

Repeat After Me

A recent graduate prescribes more open-ended assignments to boost entrepreneurialism

Emily Landry

AS A RECENT graduate of UBC's young Okanagan campus, I wanted to share my thoughts on this topic based on my own experience. In particular, I'd like to explore the possibility that our system is too heavily weighted on a student's ability to memorize, and inadvertently diminishes the initiative that would be needed by a successful entrepreneur.

Let me begin by stating that I was very lucky to have partaken in an extremely modern approach to engineering education. Attending at a time when our engineering building was still in its planning stage was a unique opportunity. The atmosphere on campus was new and exciting, and many of the students I knew had a sense of being a "pioneer" as far as forming student groups and establishing traditions goes. The entire faculty was new as well, and many professors were eager to get input from students on their course design and teaching methods. Due to the small campus size, as well as the ongoing accreditation process, the professors were highly accessible to undergraduate students, and undergrads that were involved in academic research even outnumbered the grad students.

I think we all knew we had to contribute in some way to the successful launch of our new school, as its success was intimately tied to the long-term value of our degrees. With all of the opportunity to contribute to our school's creation, many of us pulled our sleeves up and jumped right in. In spite of this extraordinary willingness on behalf of both our faculty and student body, some of us still struggled with what seemed to be an elusive barrier as far as our educational process was concerned.

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About the Author

Emily Landry is an Engineer-in-Training in the Equipment Testing and Commissioning Department, Transmission Division, BC Hydro. Emily graduated in 2012 with a Bachelors degree in electrical engineering from UBC. As Vice-Chair and Chair of the IEEE Student Branch, she opened and supervised a learning centre for students with the support of an ICF McNaughton Learning Resource Center grant. She is also co-founder and past-President of the UBC Okanagan Engineers Without Borders Chapter, and was an Undergraduate Research Assistant in the area of photonics. She created and operated a peer mentoring/tutoring service for two years, and was the APSC Student Senator on the UBC Senate.

Enhancing innovation and entrepreneurial skills among students

Vince Thomson

NOWADAYS, PROVIDING PRODUCTS and services is global and there are few constraints due to distance and the need for local personalization. Companies during the original wave of globalization competed on cost, with developing countries pitted against developed countries based on wage differences. As a consequence, developing countries, especially China, built up a large number of manufacturing companies that compete very well internationally.

Today, the competition has moved to innovation of products, services and operations. Ordinarily, one thinks of revolutionary innovation, the creation or radical improvement of products. Many times this is brought about due to a market discontinuity, such as a new soap for washing in cold water because customers wish to save energy, or due to a new invention such as the Blackberry. However, incremental innovation, the continuous improvement of processes, services and products is more common and more valuable for companies since it has a greater effect on their bottom line. Many small improvements in business and production processes add up to a significant reduction in cost. Although companies create a new product from time to time, they mostly improve existing models to satisfy customers. These improved products are a company's lifeblood.

Over the past 20-30 years, developed countries have had stagnating economies where it has been difficult to increase jobs and disposable income—wealth. They are focusing more and more on innovation as a way to create new opportunities and jobs. Recently, developed countries have been creating strategies to promote innovation to help their

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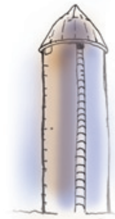
About the Author

Vincent Thomson is the Werner Graupe Professor of Manufacturing Automation with the Department of Mechanical Engineering at McGill University. Vincent has been involved in manufacturing and information technology related research for the past 30 years at McGill University and the National Research Council (Canada). His research interests include manufacturing, real time control and process management. Vincent is currently working with many aerospace companies on such issues as the management of design change, the requirement for close collaboration with suppliers, the measurement of development performance, and the reduction of time to market. vincent.thomson@mcgill.ca

Enabling mobility for both students and professionals

You can get there from here



Reducing transfer barriers between Canada's community colleges and universities

Victoria Hurlihey

GONE ARE THE DAYS when a university education alone would guarantee job security post-graduation. Many jobs, particularly in technical fields, will increasingly require a combination of the theoretical background obtained through the completion of a university degree, together with the practical training of the kind offered by colleges and co-op programs.

This is a trend identified by many, including Dr. Rick Miner, former Seneca College president, in his 2010 report, Jobs Without People: Canada's Labour Market Future. Industry representatives are also calling for greater emphasis on the practical for engineering graduates (see Ibrahim Gedeon contribution on pg. 3).

In his report, Miner puts forward a set of recommendations to help fill the gap he identifies between the nature of the jobs a knowledge-based economy has to offer, and the present set of skills of our workforce. One recommendation in specific calls for reducing the barriers for students moving between colleges and universities, stating "credit transfer arrangements are often a nightmare," and noting "students often spend much longer than necessary getting to graduation in the program they have finally chosen because their prior learning experiences were not fairly and effectively recognized."

Unfortunately, negotiating the transfer of credits and recognition of prior training are just a couple of issues encountered by such students. In this article, we will explore some of the historical reasons behind some of these obstacles and how different Canadian postsecondary institutions are addressing the issue. In particular, we will focus on examples of the kinds of agreements between postsecondary institutions that have been established to facilitate transfer. We also look at some possible approaches to

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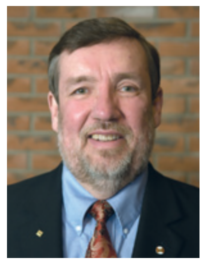
About the Author

Victoria Hurlihey has worked in the field of student services at the University of Toronto for over 10 years. She is currently a Student Services Officer at the School of Graduate Studies, University of Toronto. She is also currently enrolled in the MA program in Higher Education at OISE, where her area of interest is college-to-university transfer programs in Ontario. Her paper, "College-University Transfer Programs in Ontario: A History and a Case Study", appeared in the Fall 2012 issue of The College Quarterly, published by Seneca College of Applied Arts. Victoria has an Honours BA from the University of Toronto and a MA in English Literature from Queen's University. She can be reached at victoria.hurlihey@utoronto.ca.

There and back again

International exchange programs build careers, character and cultural awareness

Keith Hipel



IN THE SUMMER of 1987, Professor Norio Okada, a faculty member at Japan's Tottori University, engaged me in a research discussion in the hallway of the heavy laboratory area of engineering at the University of Waterloo. We were soon approached by an undergraduate student in Systems Design Engineering. "Since you often go to Japan for research," she observed to me, "couldn't you please start an exchange program for undergraduate students?"

After quickly glancing at one another and smiling, Professor Okada and I blurted out together "no problem." That very evening, we put together an agreement between the faculties of engineering at the two universities. This agreement was later extended to the university level. The following morning, when we met with the University of Waterloo President, Douglas Wright, he immediately signed the agreement while exclaiming "An exchange program with a Japanese university–great idea!"

This was the start of one of three university exchange programs I've had the honour of co-founding with colleagues in Japan. The other two are with Kyoto University (1992) and the Tokyo Institute of Technology (2006). To date, approximately 220 Canadian and Japanese students have benefited from these three exchange programs. (See sidebars on pages 24 and 25)

On the individual student level, exchange programs build cultural awareness, character and a promising career. But there are benefits to society as a whole: when a student is living or travelling in a foreign country, he or she can observe and experience the cultural design of that nation. As these students move into leadership roles, the insights they gain can help bring a broader perspective to decisions in a whole range of economic and public policy spheres.

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About the Author

Keith W. Hipel is University Professor of Systems Design Engineering and Coordinator of the Conflict Analysis Group at the University of Waterloo. He is Senior Fellow of the Centre for International Governance Innovation, and past Chair of the Board of Governors of Renison University College. A highly creative scholar who enjoys mentoring students and researchers, Keith's achievements in co-founding the three exchange programs described in this article were recognized in 2011 by IEEE Canada through its Outstanding Engineering Educator Award. Keith is also the recipient of the 2012 Japan Society for the Promotion of Science (JSPS) Eminent Scientist Award, bestowed upon "foreign researchers with a record of excellent research achievements who are mentors and leaders in their respective fields." Keith is President of the Academy of Science, Royal Society of Canada, from November 2013 to November 2015.

Women in engineering

Electrical Engineering Needs More Gender Balance

Perspective from a past Chair for Women in Engineering and electricomedical engineer

Monique Frize

The Numbers: While the Faculties of Medicine, Dentistry, Veterinary science, and Law have seen gender parity in their enrolments for decades, Engineering Faculties, particularly in the mechanical and electrical disciplines, have shown the lowest enrolment of women. The enrolment of women in universities across Canada has been greater than men for several years; women are overwhelmingly enrolled in arts, humanities, and health sciences; few are in physics, computer science, and engineering.

The enrolment of women in engineering undergraduate programs across Canada was 19% in 1996 (7,736 women) and 20.6% in 2001 (10,199 women); then numbers went up slightly but the percentage went down because more men enrolled: 19.9% in 2003 (10,456 women). In 2006, the proportion was 17.5% (9,350 women). Finally, we saw a slight turn to the positive in 2011 with 11,990 women enrolled, but the percentage was only 17.7. Looking at available absolute growth figures, between 2003 and 2011 the number of women enrolled in undergraduate engineering programs increased 15%; over a slightly shorter period (2004 to 2011), the equivalent figure for men is 20% growth.

Why a Low Enrolment of Women: Most women seek a career where they can help society and people; unfortunately they do not see this aspect in an engineering career even though many engineering activities and functions do help people and society. Moreover, young students in school have no courses in a field called engineering; a computer course is normally called a technology course and few women enroll in these. The image of engineering is of a man building a bridge or a road, working with machines and not with people. Reality is vastly different but it is invisible to the public.

Why we should care: Women are known to have good communication and interpersonal skills which are very useful for engineers when they interact with clients, suppliers, government agencies, etc… Women tend to prefer collaboration to competition. With men tending to move towards the bottom line and women looking at the context of the problem, balanced teams of engineers will create the best technological solutions and new technology designs. The purchasing power of women is quite substantial, so successful companies will consider their needs when designing new cars, appliances, and all new technologies. Women engineers will have a real positive impact on the perspectives to bring to the designs.

More Gender Balance in Electrical Engineering: The INWES Education and Research Institute (INWES=International Network of Women Engineers and Scientists), a charity organization incorporated in Canada, held a workshop in April 2011 to discuss the issues and solutions to increase the participation of women in engineering. This was to revisit the 1992 report on women in engineering entitled: More than just numbers, twenty years after the Canadian Committee on women in engineering (CCWE) had released 29 recommendations that covered the young years, universities, the workplace, and the profession. The 75 participants at the 2011 workshop developed 25 recommendations in its report.

The top three priorities in potential strategies to increase the number of girls and women becoming interested in engineering were:

TOP PRIORITY RECOMMENDATION 1

Currently, only 2.6% of young women in high school express interest in engineering. The goal is that 25% of young women will show an interest in engineering by 2016 and 30% by 2020.

STRATEGY: 1. Communicate a clear and exciting brand image of Engineering that appeals to students from elementary school to high school and their parents, through contests, social media, films, television, and books. Mobilize the participation of young people - high school students, art students, students in general - through *competition* by offering incentives such as meaningful prizes - reasonable cash value, scholarships, ipods, ipads etc. The competitions would first be regional and build into national competitions. Schools will be attracted to this – possibly teachers assigning class projects to teams participating in the competition; this would occur in the university setting as well, potentially for film class, art study class, and sociology - it would present how "Engineers Serve The World."

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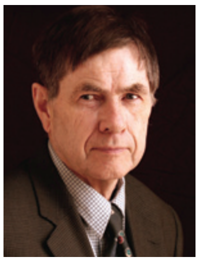
About the Author

Monique (Aubry) Frize P. Eng., O.C., was appointed Distinguished Research Professor (Retired) at Carleton in 2010 and Professor Emerita, the University of Ottawa. She has an electrical engineering degree from University of Ottawa, an MPhil in Engineering in Medicine from Imperial College in London (UK), an MBA from Moncton, and a doctorate from Erasmus Universiteit in Rotterdam. Monique Frize was inducted as a Fellow of the Canadian Academy of Engineering in 1992, an Officer of the Order of Canada in October 1993, and received five honourary degrees. She is a Fellow of Engineers Canada and IEEE. Monique received the Gold Medal of Professional Engineers Ontario in 2010 and has published over 200 papers in engineering over the last 25 years.

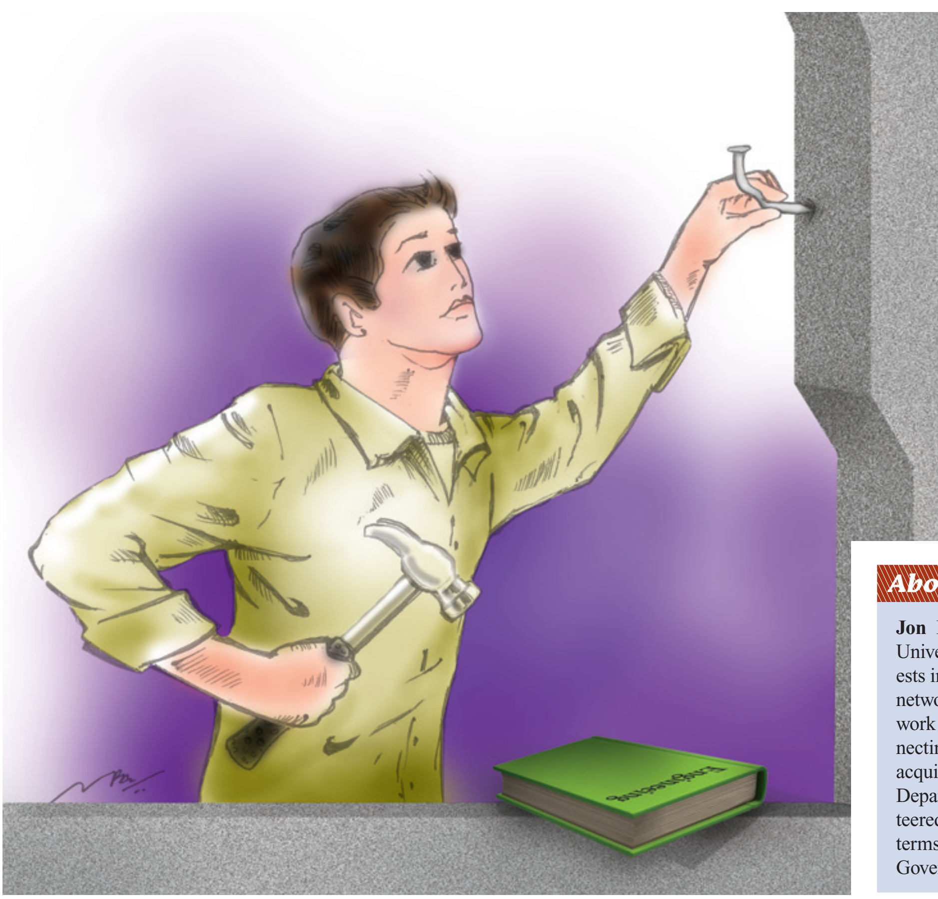
The trend towards abstraction in engineering education

Jon Rokne



ENCYCLOPEDIA BRITANNICA HAS the following description of modern engineering education: "Early engineers were trained by apprenticeship to be a skilled practitioner. As the body of knowledge gauged by observations, testing and research increased, organized programs of study were initiated in established schools. Following World War II, new trends became apparent, the result of a growing body of theoretical knowledge. Greater emphasis was placed on mathematics, physical sciences and the engineering sciences. The current trend is towards more basic and less applied courses, greater use of computers, and probability theory, and, at least in some countries, additional humanities and social sciences."[1]

This trend towards theory and fundamentals has had the effect of teaching engineers theoretical concepts, reducing the time spent on practical implementations. As expressed somewhat crudely in [2] there are some consequences of this trend: "In theory, theory should mirror reality, he often told his classes. In reality, he knew theory was bullsh ..." The vast majority of engineering educators do not quite subscribe to this rather extreme view. It is clear, however, that theory without practical understanding of the implementation of the theoretical concepts does not lead to a complete engineering education. As an example, theoretically, force, momentum and direction of force are all that is needed to put steel nails into concrete. Applying these theoretical concepts is a different matter and the actual experience with the resulting collection of bent nails would be reminders that practice and practical understanding are valuable components of the education of an engineer.



> *Theoretically, all that is needed to put steel nails into concrete are force, momentum and direction of force.*

In the past the trend towards fundamentals and abstraction was mitigated by the students having a background in practical experimentation gained from life experience, say, from working on a farm, from play or from summer jobs. The development of increasingly complex machinery has reduced this experience. This change is expressed rather well by Goodhew: "Long, long ago in the mists of the 20th century it was possible to assume that students presenting themselves to university engineering schools would have constructed models using Meccano, could wire a plug for mains electricity (and would have received a 110 or

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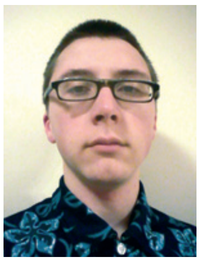
About the Author

Jon Rokne is a Professor in the Department of Computer Science at the University of Calgary, having been Chair from 1989 to 1996. His research interests include interval analysis, global optimization, computer graphics and social networks. Dr. Rokne organized the installation of the first university FDDI network in Canada at the University of Calgary, and actively worked towards connecting the University to the world wide web (WWW). He spearheaded the acquisition and installation of a top 500 supercomputing facility shared with the Department of Chemistry. An IEEE member since 1970, Dr. Rokne has volunteered in a number of capacities. In the Computer Society, he has completed two terms as Vice-President, Publications and three terms on the Board of Governors. Dr. Rokne is an Associate Editor of the *IEEE Canadian Review*.

Alternate learning / teaching / delivery models

Student sentiments

Chris Pikula



WHEN I THINK ABOUT living documents, the first thing that comes to mind would be the knowledge database that I worked with for my summer job. There were many different articles: from bug reports and solutions to customer relationship tutorials and crisis management techniques. The ability to call upon such a resource was both good and difficult. Good, in that most information that I required was available, but difficult in that it represented a fairly well aged style of information storage that I was not used to in the slightest.

So when I first thought about bringing this into an educational setting, I thought, 'Yes, we need that!" The ability to have a long term storage of information that could evolve and be used for years and years would be wonderful. It would be a great experience for people to learn how to come into an organization and to adapt themselves to it, rather than having to build their own system for the nth time.

With all ideas that are great, there immediately comes the next thought stage: If it's so great, why isn't it used? Well, there's a few issues with it. We've got the need to have a long-term medium. There needs to be the ability for it not to grow too complex, for it to still be functionally useable for people who will only experience it for a short period of time. It needs to be able to be implemented. Lastly, and most difficultly, it needs to be created with great foresight, as the style that it is created in will be the style that it will keep. These are difficulties, so let us look at each one in turn.

A long-term medium is an interesting thing. Twenty years ago, books and filing cabinets were the way it was done. Today we look at databases and wikis. In 20 years from now, it's hard to predict. Thankfully the age of computers has made such things easier. Still, keeping a portable knowledge base will be critical to the continued success of the idea. With a long term goal outlined ahead of time, this would be much easier to deal with, and problems with a lack of support, information loss, etc, would become much easier to manage.

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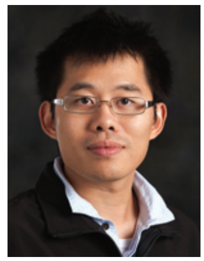
About the Author

Chris Pikula is an undergraduate student at the University of Regina in the Electronic Systems Engineering program, and helps run the IEEE Student Branch. A native of Saskatchewan, he enjoys cycling and reading. His current interests are focused towards EM simulation.

Instructor insights

Michael Lau



EDUCATIONAL DEMANDS OF the 21st century require educational institutes to re-examine accepted academic models and pedagogy. Traditional lecture formats are becoming increasingly ineffective; expanding class sizes, diverse educational backgrounds, and the breadth of knowledge required at graduation are just some of the current challenges faced today. Traditional assignments are also failing to connect a student to lesson outcomes and objectives, while laboratory exercises are a verification of lecture material rather than hands-on experience.

Guidance/mentorship learning models may be more effective than standard lecture models. Imagine a classroom doing group or project-based activities such as research or design. Simply moving to a more active style of learning promotes student engagement; the student is then an active learner who devotes more time to learning instead of being passive. Given room for creativity within an engaging topic, students are also driven to succeed because of the sense of ownership over their own work. As well, assessments done in this format become more authentic in that they become direct gauges of knowledge or performance within a specific outcome.

Anecdotally, I teach a course in Systems Packaging and one particular activity was a group presentation for flip-chip packaging. Aside from a standard marking rubric, the students were given absolute freedom within that topic. Engineering databases, industry websites, and technical references were all valid sources of information. In the end, the students produced engaging presentations ranging from flip chip's process flow, design considerations, and even a history of the technology.

A "living" document or course is one possible way to implement guidance-based learning. Generally using eLearning systems, a living course is continuously updated with contributions from past, present, and future iterations. A course may evolve depending on the feedback from previous iterations, or even during its delivery within a semester. While many traditional

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About the Author

Michael Lau has a B.Sc in Electrical Engineering and M.Sc in Electrical and Computer Engineering specializing in MEMS and NEMS devices from the University of Alberta. He currently teaches in the Nanotechnology Systems and Electronics Engineering Technology departments at NAIT located in Edmonton, Alberta. Courses currently taught include digital systems, programming, control systems, and electronics systems packaging. Aside from teaching, Michael also conducts applied research in areas such as FEA simulation and particle detection systems.

Community service learning

Learning well by doing good

Jason Foster

MY TEAM AND I *had never visited this part of the city before, let alone a food bank. Last week we were given a contact name, an address, and a couple of sentences describing a problem. A phone call, a subway ride, and now we were there.*

Community Service Learning (CSL) is an approach to teaching and learning in which students work with local or remote clients, in parallel with their classroom studies. It is considered a type of Experiential Learning, in which students are challenged to apply and reflect on topics and techniques taught in the classroom. CSL activities vary in the type of interaction with the community, the scope of the student projects, and who is responsible for identifying community partners and associated projects. Common to all CSL activities is a partner – client, user, customer – from the community, a project that can positively impact that community, and student reflection on their experience.

After talking with our contact – I mean "client" – for a few minutes, I realized that I was applying some of the techniques introduced in lecture. "Active listening" and "expectation management" had sounded pretty vague, but I could see how they helped keep this first meeting on track.

CSL can both enrich the learning experience and support the needs of the community. Students apply classroom materials to "real world" situations, exploring the benefits and limitations of the tools and techniques they have learned. Those students who are motivated to make a tangible difference to the world gain that opportunity; more inward-focused students are exposed to the challenges of collaborative, socially focused projects. The community, as individuals or established organizations, gains new perspectives, capacities, and (ideally) solutions to their pressing challenges. Through CSL, relationships between schools and communities are strengthened to mutual benefit.

> ***CSL can both enrich the learning experience and support the needs of the community. Students apply classroom materials to "real world" situations, exploring the benefits and limitations of the tools and techniques they have learned.***

Back at the University, we met with our Project Manager (PM) to debrief. The worksheet and terminology from class had worked well, but the "conversational script" had felt a little artificial. Our PM talked about the importance of being ourselves, even as we are practicing as engineers, and about the trade-offs between structure and improvisation.

Students can and do experience CSL at every level of their education. At the university level CSL activities fit naturally within many service-oriented programs and faculties, but can be adapted to suit most programs of study. Engineering, with its professional focus on client-based, real world problem solving and design, is a natural home for CSL activities. Engineering students usually experience CSL in their "design and communication" courses, although CSL can in principle be used throughout the curriculum.

We're struggling with how different our design course is from our other courses. Finding the one "right" answer to physics problems is a lot easier than having to figure out what our community client really needs! Then there's coming up with many possible solutions, finding times to meet as a team, visits to the food bank, …

Many Canadian engineering schools routinely source 4th year design projects from "real world" clients – a practice that would fall under the CSL umbrella. Some Canadian schools, for example the University of Toronto, Waterloo, and Western Ontario, have adopted more comprehensive CSL approaches where students engage directly with the community to both define and solve on-the-ground problems. Well-known examples of engineering CSL in the United States include the EPICS program at Purdue, the Community Service Work Study program at WPI, and the Humanitarian Engineering and Social Entrepreneurship program at Penn State.

Recent changes by the Canadian Engineering Accreditation Board (CEAB) are likely to prompt increased use of comprehensive CSL in Canadian engineering schools. All engineering students must now demonstrate attributes relating to design, professionalism, communication, and the impact of

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About the Author

Jason Foster has been a Lecturer in the Division of Engineering Science and the Department of Civil Engineering at the University of Toronto since 2005. He received a BASc. and a MASc. in Systems Design Engineering from the University of Waterloo. Jason provides high-level support for student engineering design activities and has been responsible for the successful delivery of the cornerstone and capstone design courses under the Praxis banner.

› Jason Foster, Continued from page 11

engineering on society, among others. CSL provides an excellent context in which students can develop and demonstrate these attributes.

I want to be an engineer to help people. I've been so focused on math and science that I almost forgot why I went into engineering in the first place! Working with the food bank has reminded me, has given me opportunities to develop my non-technical skills, and has helped me stay motivated in my other courses.

Engineering Strategies and Practice (ESP) at the University of Toronto is a prototypical example of a core, first year, CSL-oriented design experience. ESP comprises two courses, each focusing on introducing the profession and practice of engineering through instruction in engineering design, communication and teamwork. In ESP1, all teams work on a single problem inspired by a visible, accessible, local concern. In ESP2 each team is partnered with a single, external client, and is challenged to clarify and design an engineering solution to their client's everyday problem.

The more we work with our client, the more confident I am becoming in my engineering skills. I've been finding it easier to link classroom materials and the project, and our hard work and little successes are starting to become big successes. Some of my teammates had only ever worked on individual assignments before, so we were having trouble working together as a real team on a real project. Our PM met with us after class to help us out, and I think we'll do better going forward.

Two major challenges must be overcome to successfully implement CSL approaches in engineering. Especially in large courses, the logistical challenges associated with a CSL course can be overwhelming. Finding many, high quality projects; unresponsive or agenda-driven clients; internal team conflicts… in CSL courses unexpected challenges are the norm, and require extensive resources to manage.

The second major challenge is finding, managing, and maintaining connections with the community. Many universities have created dedicated organizations that support faculty members and students who want to incorporate or engage in CSL. These organizations maintain relationships with community partners, provide teaching support, and engage in active research on how CSL is best integrated into undergraduate and graduate education. Some universities link their CSL and exchange activities, allowing students to work directly with overseas communities.

Even with these supports, ongoing client management falls primarily on the course instructor. Community agencies, usually through their directors or senior operations staff, can and do approach universities, but it is the course instructor who manages the ongoing relationships between the agencies, the institution, and the students. While this management can be a burden, it can also be a blessing. Engaging with the wider community, especially in an engineering context, keeps things fresh for the instructor and helps to promote the engineering profession to the broader public.

Completing our final presentation was a huge relief. Our client really liked our design, and said that we could use them as a reference. We visited the food bank, and I got to see people actually using our solution. I hope that next year the client gets another team to implement our "Next Steps" ideas!

‹ Back to beginning

With Susan McCahan and Jason Bazylak
University of Toronto, Faculty of Applied Science & Engineering

› Ibrahim Gedeon, Continued from page 3

Students will need more opportunities to meet industry demand and a fundamental modification of how we graduate IEEE students into the workplace. I am not sure I have the answers, but this is what I propose:

Leverage the co-op program; it is a great Canadian practice. What started in some instances as a mechanism to gain industry contacts and provide students with some money to help with their tuition should evolve into a focused program. I would urge the students to stay with the same company or industry as they go about their co-op terms—easier said than done, but collaboration between the universities and industry is critical to make that happen.

Academia should install some core systems courses as part of the program. Project management and Operations Research are a must for any practicing professional. A detailed understanding of ecosystems is a must. I will date myself here, but so few graduating engineers understand power systems, and believe me that is critical since after air, water and food, power is next in our human eco needs chain. Yet the study of power systems and engineering is considered by many as not so cool. My gut feel is that you cannot build apps if you don't know how power is generated and distributed.

Industry should put skin in the game if they find that their needs are not satisfied, they must be open to mentor, hire and champion this change. We at TELUS believe that our continued success and longevity can only be fueled by always investing in new skill sets and new people. This is the only way to keep new ideas and energies flowing through our organization.

I trust this short contribution will provide a healthy start for discussion. ■

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OPINION

by Doug Houseman

COOPERATIVE EDUCATION COMES full circle - with the lack of practical work at the university level - coop sessions that are planned into the program become a key piece of the total education program. The ability to work in the field and apply knowledge in a practical fashion accelerates the readiness of young engineers to step into high value jobs.

› Brian Frank, Continued from page 4

Other countries have drawn similar conclusions about the importance of both technical and non-technical skills. The surveys reported in Educating Engineers for the 21st Century from the Royal Academy of Engineering in the UK placed importance on practical application, theoretical underpinning, creativity, innovation, and team work [3]. The 2004 report from the US National Academy of Engineering, The Engineer of 2020: Visions of Engineering in the New Century, described expectations for rapid technological innovation, global interconnection, diverse and multidisciplinary populations affected by technology that are reshaping the required skill set for engineers. It concluded that engineers need strong analytical skills, but also creativity, communication, business and management, leadership, high ethical standards, dynamism, flexibility, and the ability to be lifelong learners [4]. These kinds of recommendations are not new; similar recommendations to strengthen non-technical skills were made in the 1955 Grinter report in the US [5]. Recently a group of employers including Apple, Cisco, Intel, and Ford and non-profit educational organizations created a national organization to provide tools and resources for developing "21st century skills", including critical thinking and problem solving, communications, collaboration, creativity, and innovation [6].

Look at the program outcomes required by any of the accreditation bodies in countries with recognized high-quality engineering programs and you will see a balance of knowledge, experimentation, design, communications, ethical and social responsibility. National accreditation bodies in the Washington Accord that allows for mutual recognition of engineering qualifications

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› David Michelson, Continued from page 4

ago and served by members from both industry and academia, CEAB ensures that graduates of accredited engineering programs have the skills they need to become productive members of the profession. CEAB's method for challenging Canadian engineering schools to incorporate soft skills training into the engineering curriculum has ensured that training is consistent across both a cohort at a single school and also across the country.

Part of the credit goes to Canadian engineering schools and the senior leadership at their respective universities. Not only are Canadian universities placing increasing emphasis on both student engagement and the student experience, they are also providing faculty members and co-op coordinators with the teaching resources, cooperative learning and project spaces, and information technology that they require to meet CEAB goals related to soft skills. It's a powerful combination that is yielding rich rewards.

Part of the credit also goes to the increasing number of faculty members and co-op coordinators in Canadian engineering schools who have accumulated significant industry experience before returning to academia. They are both well prepared to help students develop the skills that they will require in order to succeed in the workplace and highly motivated to do so.

There are still gaps to fill, but support for filling them has never been stronger. Perhaps our greatest challenge is to more effectively communicate the recent enhancements to our engineering curriculum to our colleagues in industry and engage them more directly in helping our students to further develop their soft skills. ■

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› Brian Frank, Continued from page 13

(Engineers Canada, ABET in the USA, Engineering Council UK, Engineers Australia, Institution of Professional Engineers New Zealand, etc.) have required development of these attributes in engineering programs [7].

This kind of perspective is not unique to engineering; business schools, and medical schools are increasing the weight of non-technical skill development. The title of a recent Globe and Mail article, "B-schools help students reveal soft skills"[8], is a recent example, though I would argue that using the term "soft skills" undermines the importance of fundamental skills like communications, leadership, and work ethic. Engineering students frequently pursue careers in these and other professions.

This is not to imply that a university program should focus exclusively on the immediate but changing needs of employers; university programs are not intended to be vocational programs. University programs do, however, serve a crucial role in providing a foundation for core skills that will serve students well for careers and participation in broader society. The need for skills like critical and creative thinking, independent learning, effective communications, and initiative are not going away anytime soon.

Professional skill development in engineering programs

Engineering programs are putting significant effort into developing the professional skills, which for the purpose of this article will be defined to include non-technical skills and attributes like information management, leadership and teamwork, professional and ethical responsibility, understanding of the impact of engineering activity, written and oral communications, general critical thinking, initiative, and self-regulation. A 2012 survey of engineering programs found that the topics of greatest focus for redevelopment in the 135 responding institutions were, in descending order of priority: teamwork, communications, open-ended design and problem solving skills, and engineering fundamentals [9]. This does not imply that teamwork and communications are more important than engineering fundamentals, but rather that historically our engineering programs have a solid track record in the fundamentals, and there is room for improvement in professional skill development.

Some universities are beginning to define expectations for core skills to be developed and assessed in all graduates; Purdue University's College of Engineering defined their own attributes that include a balance of knowledge areas, abilities (leadership, teamwork, communication, etc.), and qualities (innovative, work ethics, adaptability, etc.) [10]. University of Kansas' KU Core [11], requires development in critical thinking and quantitative literacy, communication, and integration and creativity across all programs in the university. The University of Guelph Learning Outcomes, based partly on the AAC&U Leap Essential Learning Outcomes [12], include critical and creative thinking, global understanding, communicating, and professional and ethical behaviour [13].

Not only is greater emphasis being placed in developing professional skills, but the way they are being developed is also changing. The historical perspective is that of the outsourcing model; these skills like communications, ethics, project management and business have frequently been developed in service courses delivered by non-engineering departments, with little connection to the rest of the curriculum. While it is important to expect students to diversify their education and understand key concepts from humanities and social sciences, relying on disconnected service courses may limit the ability of students to transfer their knowledge to an engineering context. The degree to which students can transfer knowledge and skills from one context to another depends heavily on whether those knowledge and skills were developed and used in multiple contexts [14]; developing mastery of skills requires practice in integrating those skills [15]. Cognitive science is showing that the connections between information is important.

The goal of education is to develop knowledge and skills that are transferable to a variety of settings, careers, and activities. Students need opportunity to develop individual, "component" skills, and the ability to integrate them to solve realistic problems. The context of the activities is important, as student motivation is a significant factor in learning, and tasks that are set in the disciplinary context and have connections to other academic experiences can increase the perceived value of the work [15].

"The goal of education is to develop knowledge and skills that are transferable to a variety of settings, careers, and activities. Students need opportunity to develop individual, "component" skills, and the ability to integrate them to solve realistic problems."

Engineering programs are more frequently using integrative, open-ended problem-solving experiences as a vehicle for developing professional skills and applying technical knowledge. A variety of models have been demonstrated for integrating professional skills like technical communications into the engineering curriculum, including partnerships, team teaching, communication modules, expert feedback, and communications across the curriculum [16]. In some cases these experiences begin in the first year of the engineering program using community service learning projects as the context for professional skill development (e.g. University of Toronto [17], [18], and Queen's University [19]). These provide early exposure to working with clients, working in teams, managing time and money, dealing with conflict, and considering the social and environmental impact of engineering work. Some programs integrate professional skill development with co-op placements (e.g. University of Waterloo [20], [21] and Dalhousie University [22]). The University of Utah's CLEAR program is an example of a collaboration between humanities and engineering programs in which a program coordinator works with doctoral candidates from the humanities to integrate communications, leadership, and ethics into designated engineering courses [23], [24]. Since these skills require repeated practice in a variety of settings to develop, some have advocated for a professional spine of courses throughout a program that integrates technical knowledge with professional skills on open-ended design projects [25], [26].

This is not meant to suggest that standalone courses in communications, ethics, etc., do not have their place. When adequately resourced and deliberately planned to support other elements of the curriculum these kinds of experiences are extremely valuable. Universities have developed reputations for strength in professional skill development, e.g. the Leaders of Tomorrow program at the University of Toronto offering a combination of embedded material, certificate programs, and elective courses in leadership.

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› Brian Frank, Continued from page 14

Professional Skill Assessment

Recent changes in engineering accreditation requirements require programs to deliberately assess specific professional skills, and demonstrate that the results of the assessment are used for program improvement [27]. This requires programs to document where professional skills are being developed and assessed in the program (often described in a curriculum map), and to have a clear description of how student work is scored to evaluate performance. This is a subject of ongoing development by institutions across Canada, particularly in institutions that are contributing to the EGAD project (http://egad.engineering.queensu.ca) [28]. The Canadian Engineering Education Association's annual conference has become the primary national venue for sharing ideas about developing and assessing professional skills in engineering.

Conclusion

Professional skill development should not be viewed as being in competition with developing competent technical engineers, but rather enabling that skill set. The end goal of an undergraduate education is for students to have the ability to address complex real-world problems, which often have conflicting goals ("trade-offs"), multiple possible solutions, ambiguous or uncertain information, requiring judgement, and having a solution path that is not clearly known at the beginning. In order for students to develop the skills to solve these kinds of problems they need opportunity to work with complex problems throughout their undergraduate career; the skill sets for solving these differs from the skills required to solve constrained word problems [29], and requires different instructional approaches. The skills are frequently developed in experiences including client-based projects, community service projects, capstone projects, internships, co-ops, etc., which are also natural places to develop professional skills. In this way, the instructional approaches used to develop students' abilities to effectively apply engineering science knowledge to realistic problems provides opportunities to develop professional skills. ■

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The Future of Engineering

› Marcia R. Friesen, Continued from page 5


and Technology Education
Accommodating foreign-trained engineers
Turning Differences into Opportunities

something that policy analysts refer to as an underutilization of human capital. While many IEEs succeed in having their qualifications formally recognized and in regaining their former professional status, the stories of IEEs working in convenience stores and driving taxis, or working in technician and technologist level jobs are also true. For those that successfully complete the qualifications recognition process, the process often takes 3-5 years, during which time existing credentials and experience are losing currency.

Responses: The Manitoba Model:

The Internationally-Educated Engineers Qualification (IEEQ) Program at the University of Manitoba began in 2003 with the objective to increase the number of IEEs that successfully achieve qualifications recognition in the province, to reduce the time required for qualifications recognition, and to address IEEs' anecdotal reports of isolation while they are pursuing qualifications recognition.

The IEEQ Program was initially conceived as a program of academic confirmation, replacing the technical exams assigned by the regulatory body with equivalent senior-level engineering courses at the University of Manitoba. However, it quickly evolved to embrace a more holistic focus. Academics were augmented with a co-op/internship experience for IEEs to gain Canadian experience, communication development (language and the norms of professional communication), facilitating cultural fluency, and offering networking and mentoring opportunities for exposure to other Canadian engineers and engineering work environments.

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Please understand me

The Challenges of Becoming Culturally Fluent

Employers consistently note the strength of IEEs' technical skills and the value of their past professional experience. And, while credentials recognition and Canadian experience may be significant advantages in getting a job, employers identify cultural fluency as a key determinant in whether a career will progress. Cultural fluency encompasses the ability to recognize, understand, and demonstrate the culture and values of the Canadian engineering profession, and it is a key factor in effective professional practice. Cultural fluency is evident, for example, in the ability to write a persuasive email, work effectively with clients and suppliers, participate productively in team-based work, and successfully navigate conflict situations. Employers must recognize that the IEE is not operating from a position of deficit but rather from a position of difference. IEEs are culturally fluent in the norms and expectations in engineering practice in their home country. Their task is to identify how their norms and expectations relative to hierarchy, leadership, communication, team, risk, and other culturally-influenced parameters differ from those in the Canadian engineering profession. The employers' task is to support this transition in their IEE employees. One Winnipeg employer noted, "We realized that we need to have a training program for IEEs just like we do for new graduate engineers in our company, although the content is entirely different".

Professional organizations such as IEEE can likewise provide critical opportunities for IEEs to increase their understanding of jurisdiction-specific technical codes and standards in their discipline – and this may be as diverse as learning cold-weather engineering unique to Canada, working with the latest modeling & simulation software in the power sector, or understanding the primacy of the public safety & welfare in Canadian engineering ethics. IEEE may also provide critical opportunities for IEEs to network with other Canadian engineers and to find access to professional mentors.

Learn more about the IEEQ Program model at umanitoba.ca/engineering/ieeq and at eqrm.ca

What is cultural fluency?

In part, it is the ability to recognize that actions may have different meanings in different cultures, and that a given action that may be highly desirable or professional in one culture may be interpreted in another culture as disrespectful, an indicator of incompetence, or lack of professionalism, and vice versa.

> ***"Cultural fluency encompasses the ability to recognize, understand, and demonstrate the culture and values of the Canadian engineering profession, and it is a key factor in effective professional practice."***

For example, an internationally-educated engineer (IEE) in the IEEQ program had an 'a-ha moment' when we discussed hierarchy in culture. He was an electrical engineer who certified as an electrician prior to pursuing recognition of his engineering credentials in Canada. He got a job as an electrician but was laid off after three months during a time when the construction sector was booming and skilled trades couldn't find enough qualified workers. His only interpretation was that he was laid off as a matter of discrimination. Through our work in the program, he realized that his deeply-held cultural notions of hierarchy dictated a deference and respect to the technical superiority, authority, and direction of the supervisor. So, as he finished a job, he would demonstrate this respect and deference to his supervisor by sitting down and having a cigarette, waiting for his supervisor to give him his next assignment – even as his co-workers continued on other tasks around him. He realized that his actions were being interpreted as lacking initiative, being lazy, and inconsiderate to the rest of the team. Armed with this new understanding, he was able to adjust his approach.

Almost all IEEs have a similar story to tell, where an encounter in Canada went wrong – and often in the high-stakes environment of the job. One IEE

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› *Marcia R. Friesen, Continued from page 16*

Besides the University of Manitoba, there are key partners in the IEEQ Program without whom the program objectives fail. The provincial engineering association worked with the IEEQ Program to develop and approve the program structure and to confer legitimacy by accepting the program as an approved qualifications recognition pathway in Manitoba. The provincial government ultimately embraced the program as a legitimate – if non-traditional – mandate of the post-secondary sector and included it in its permanent funding umbrella for higher education in the province. Immigrant-serving agencies in the province provide preparatory settlement and information services and act as points of referral to the IEEQ Program. The engineering industry has embraced the IEEQ Program as another source of potential talent, using the co-op/internship terms as low-risk opportunities to assess fit for long-term employment. ■

‹ *Back to beginning*

came face to face with different cultural notions of hierarchy when she avoided eye contact with her boss and stood up whenever he passed her cubicle. This was intended as a sign of respect, but she noticed that it served to isolate her from her colleagues, and didn't understand why. Some IEEs spent more time on a task than the time budget allowed, driven by an internal orientation toward very detailed and precise analysis. They felt uncomfortable with the task of a 'back-of-the-envelope' analysis, even when explicitly asked for only a rough design. However, these may simply be different cultural orientations toward risk. One IEE recalled giving unsolicited input on a colleague's tasks, but noticed that he was considered brash and meddling – a culture clash over notions of teamwork.

At other times, IEEs received feedback from their boss and thought everything was fine, but then a few weeks later were reprimanded for not following up on a problem. Often this stems from IEEs' lack of familiarity with 'sandwich feedback', which is a uniquely North American feedback style in which you say something positive, then state the problem, then end with something positive. An IEE may be told by a supervisor, You've got a good start on this report. Check my notes on Section 2 and 4 as they need more work, but overall it's coming along well" and hears 2 positives plus 1 neutral = net positive. I'm going great!

An IEE in the program had an 'a-ha moment' regarding the ethical obligation of professional engineers in Canada to uphold the public safety and welfare as the primary responsibility in all engineering work. He applied for a mortgage and was approved for $400,000 with an income of approximately $60,000. He asked the banker why he was approved for such a high amount and was told, You re an engineer. The repayment rate is 99% . When applying for a passport, he noticed that engineers were one of a short list of professionals allowed to act as guarantors and this caught his attention.

Whether it is the newcomer or the long-time Canadian, a culturally fluent individual recognizes there are multiple possible interpretations for a given action, and replaces a knee-jerk judgement with curiosity and conversation to clarify the other's intentions. With Canada's population becoming increasingly culturally diverse, cultural fluency will become an increasingly important skill for professional engineers. ■

› *Emily Landry, Continued from page 6*


The Future of Engineering
Are we creating a culture of entrepreneurialism?
Repeat After Me
Enhancing innovation and entrepreneurial skills among students

One of the activities I got involved in was acting as a Supplemental Learning (SL) Leader in UBC's Academic Resource Centre. In this role I worked with our first-year students directly as part of a program to lower the infamous first-year engineering failure rate. Having struggled a great deal in first-year myself, I could relate to the need for first-year students to get help with the transition into university life. My experience in this role led me to reflect on systematic ways we could improve our engineering education. I believe I was able to identify something common to all of the students I dealt with, which has to do with what we can call "glibness." That is, the ability of a student to repeat back the correct answers without actually understanding or really participating in the educational process. Allow me to explain, starting with my own struggle.

Early in my third year I finally was able to isolate why I seemed to struggle more than some of my classmates (or at least, why I put in more effort but got similar grades). The answer for me personally lay in my educational background (I had been sent to alternative private schools and then was home-schooled through high school). While going through the engineering program, it become obvious that many of my friends could easily memorize problem-solving approaches and quickly complete their assignments, whereas I would spend copious amounts of time trying to understand what was really going on in the problem and looking up the meaning of technical words. They teased me about this to no end. However, I noticed they typically brushed off things they didn't understand, and didn't care to spend the time to really dig in if they didn't need to in order to turn in their homework. Their approaches to test preparation were typically centred upon memorizing problems they expected to encounter on exams, whereas I would pour over my notes and look up key words or go see the professor to get detailed explanations. After about two years of struggle, I eventually discovered the secret that it is much, much easier not to bother. To do well on tests, all I had to do was memorize. My grades actually improved when I tried that. However, having been very thoroughly taught by my parents as a child never to go past a word or symbol I didn't fully understand, but to stop and clear it up, I found this to be a constant dilemma in university as I tried to keep up with the volume and pace of content we were required to cover without going by things I didn't understand.

Similarly, for the students who came to me for assistance as part of the SL program, I noticed these were the type of students who weren't particularly glib. They too struggled with the amount of time it took to truly understand key concepts, while being continuously and rapidly introduced to more concepts without a strong enough understanding of the earlier ones (which were the foundation for later concepts). This is a real problem; how does a student respond to the rapid pace of the engineering program without resorting to glibness?

What I found students appreciated most in overcoming this struggle were two things: 1) breaking down the principles being taught by explaining the meaning of key words in terms they could easily understand (i.e. without using other technical terms, which is what most professors have a tendency to do), and 2) giving them practical, hands on methods of applying theory coupled with freedom to experiment and test in an undirected but supervised fashion. This second point

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› Emily Landry, Continued from page 17

allowed my students to verify the concepts they were being taught and make them their own without any pressure.

I also couldn't help but notice that not only were students resorting to glibness, but we were also highly channeled through most of the degree with very little initiative permitted or encouraged. I noticed that the institution itself seemed not to have any structure in place to foster student-initiated course content, and began to wonder why. When I asked professors about this, I realized that the faculty was concerned with the ability of its students to demonstrate initiative. Apparently a sentiment prevailed that students weren't capable of doing things like deciding on a hypothesis for an experiment, creating their own course outlines, etc., until they were graduate students or at least in fourth year. I think I railed against this more than others, and fortunately found an outlet in research which allowed me complete freedom academically. Over time I came to the conclusion that it was student glibness that ultimately prevented them from being able to really apply data and do things like create experiments or establish their own course outlines. However it seemed a catch 22 developed in which the institution would like more initiative, but because they can't conceive of how to require it systematically and achieve success, the educational process has been premised on the basis that undergraduate students can't perform at such a level. The resultant method of education, with its emphasis on memorization and its low level of student-directed course content, ironically, diminishes initiative in students that have it.

Also along this vein, we were not usually asked to identify a problem ourselves, set the solution criteria, and propose a design solution to a real problem until we got to fourth year Capstone. In fourth-year, I had two professors who made extraordinary attempts to get students to have some initiative academically and develop judgement. I could see their frustration at times when students were slow to respond to their attempts or didn't understand their intention. I couldn't help but feel that their efforts came too late in the program, and the overall grading system was shooting them in the foot. By then a sort of apathy had developed amongst the students.

As I mentioned at the outset of this article, I studied in one of the most modern academic environments available in Canada. The professors were exceptional and the school made an effort to involve students in curriculum design, with a heavy focus on design projects. The problem is clearly not a lack of effort on behalf of engineering educators.

If we want to have more entrepreneurial graduates, I believe the solution is to overcome glibness. This means universities need to facilitate student use of better study techniques. We need a grading system that is weighted on the ability to apply data, which is the true test of learning. In order for this to succeed, students need to develop the self-discipline to pause and more thoroughly clear up the words and symbols they are introduced to. Simple definitions of technical words can be incredibly difficult to find and it would go a long way toward helping students if these were compiled in glossaries to accompany courses. Theory must also be properly balanced with real-world objects. Our program at UBC Okanagan was excellent at incorporating design projects into our course work. But here I am also speaking of giving students opportunity to simply handle and observe the physical objects we study without requiring anything else of us, to increase familiarity and comfort. Once the student has understood the concepts, they need more opportunity to apply them in a way that requires judgement coupled with freedom.

Programs such as Supplemental Learning being led by Cindy Bourne, through the Academic Resource Centre of UBC Okanagan, have made incredible inroads towards incorporating the above opportunities into university education. The study techniques that raised my awareness of student glibness and gave me tools to overcome it were learned through Applied Scholastics (http://www.appliedscholastics.org), and can be used by professors and students alike. Courses that get students involved in the community such as Capstone, or Community Service Learning courses such as those taught at the U of T, also go a long way towards bringing about application and instilling judgement. I suggest the above programs be supported and fortified by any who are interested in making further inroads in obtaining more entrepreneurial graduates.

I'd like to close by acknowledging my educational influences and inspiration, including my mother Dr. Carolynn Landry, professors Dr. Jonathan Holzman, Cindy Bourne, Dr. Thomas Johnson, Dr. Wilson Eberle, Dr. Kenneth Chau and Dr. Spiro Yannacopoulos, to name a few. I greatly admire all of the above professors for their innovation and creativity in establishing UBC's Okanagan engineering school. ■ ‹ Back to beginning

› Vincent Thomson, Continued from page 6

companies compete, and thus, create wealth. The desire to stake out a territory in the innovation space has made the competition fierce. Here, developed countries can compete with developing countries on innovation better than wages. For example, in 2010, Gillette launched Guard, its first razor developed entirely in and for the Indian and other emerging markets. Guard's replacement blades cost a mere 5 rupees - 95 per cent less than the Indian version of Gillette's Mach3. Innovation is allowing Proctor and Gamble as well as GE with its PC based, portable ultrasound device to compete in Asia.

The Training Imperative

Canada lacks a strong innovation culture. As an example of an innovation culture, we can look at the United States of America. US citizens like newness. They buy newness. As business people, they take on risk to create and sell as well as use new. Canadian society and companies are more risk averse. This can change: we can improve Canada's innovation culture. We can teach it and reward it.

The easiest way to change a culture is to teach new ways in school. We need to teach innovation and entrepreneurship in school. Some universities have Master degree business programs aimed at innovation and entrepreneurship but they are few. There are also a few university and college programs which have courses in innovation and entrepreneurship. To their credit, many university and college engineering programs have specific courses and projects where students work with companies on innovation by improving the companies' products and processes. Similarly, business schools have courses where students work with companies to improve business practices. Beside these courses with direct contact with industry, there are courses where students learn about qual-

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ity improvement, process improvement, and new product development; however, they are somewhat sterile since there is no business imperative and no commercialization force which drives the project. All together, this is not enough. So, what needs to be done?

We need to develop innovation savvy graduates, and thus, improve graduates that will help to transform companies. We need all universities and colleges to graduate students who can undertake innovation and entrepreneurship at all levels in society. Innovation is needed for new products, but mostly for continuous improvement. Continuous improvement is an attitude (culture) where people are always looking for better ways of doing things whether it is products, services or production. We need students to transform society, to take on the challenge of innovation, and imbue the spirit of innovation in others.

How do we get there? Besides universities and colleges, we need courses in high school and even grade school that focus on the elements of innovation. Courses in design in grade school in the UK and Canada have been very successful in engaging students and developing skills of thinking about new ways of doing things. This can be done through new courses, and through projects and after school clubs. Invite the business community (parents) who can work with children on projects and who can give a visibility and connection to students about the business community. It is in grade school and high school that students develop attitudes about future careers and endeavours.

Competitions can be created. In the same way that there are competitions for science projects, a system of competitions for students for innovation can be started. This will increase visibility and show students that society values innovation.

Conclusion

We need to transform Canadian society to adopt the mantra of innovation. This can best be done by training students in the knowledge and culture of innovation. This needs to be organized at all levels of the school system—the earlier the better. It is not only about better training for a few engineers, but about creating an enthusiasm in society for innovation and for constant improvement. This élan for an innovation, a transformative culture is vital if Canada is to compete in the new era. ■

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promoting mobility outside of the traditional transfer agreement model.

Arguments for Mobility

In his 40 years of experience in both industry and university engineering education, the contrast between students who enter university from high school and those who transfer from college is one that M.G. (Ron) Britton, Professor Emeritus at the Faculty of Engineering at the University of Manitoba and Past-President of CEEA, is all too familiar with.

"We get really bright kids who come here from the high school model of getting correct answers for constrained questions," explains Britton. "We do that to them for another number of years. Then, when we get the kids into actually doing design, the fact that there are no correct answers -- which is the reality of engineering -- comes as a bit of a shock."

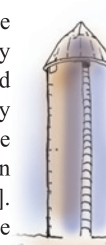
In comparison, students who enter the University of Manitoba from Red River College, "are a couple of years more mature; therefore, they are more willing to explore the theories behind the things that they learned how to do. The ones who decide that they are going to go on are probably more curious about the theory behind the things that they learned to do."

When asked if the students who enter the University from high school benefit from having mature college students in their class, Professor Britton answered: "Absolutely, without any question at all, because they are struggling to find somebody who actually has an outside chance of understanding what that 'clown' at the front of the room said. I say this with forty years of experience of being that' clown' by the way! They bring a real benefit to the kids in that class because they bring a different experience that helps make things a little bit more understandable."

Traditionally, university engineering programs in Canada have been research-focused as opposed to design-focused. Universities produce accredited engineers while colleges produce knowledgeable technicians and technologists. Britton stresses that any efforts to increase transferability between college and university engineering programs should avoid distorting the supply of either of these two streams of skilled professionals. According to Professor Britton, one of the major advantages of a college education in technological fields is the personalized and hands-on training which college students receive. Furthermore, colleges produce the capable technicians and technologists which industry needs. The goal of facilitating greater transferability between colleges and universities is not, as Professor Britton puts it, for universities to "steal" capable technicians and technologists from industry. What educators like Professor Britton are arguing for is for more cooperation and less competition between the two sectors.

Professor Britton raises two crucial points for consideration. Firstly, colleges and universities should complement each other. This leads us back to one of the recommendations made by Rick Miner regarding meeting the needs of the knowledge economy of the future. Miner suggests that this combination of "an academic education" and "employable skills" could be facilitated by increasing the number of joint programs between colleges and universities. A very good example of such a program is the collaborative Photonics and Laser Technology program offered by Algonquin College and Carleton University in Ottawa (see sidebar on page 20)

Secondly, Britton identifies multiple beneficiaries in facilitating the transfer of college students into the university engineering education system: (1) college students who would like to obtain the theoretical knowledge behind practical applications; (2) university students, who through their interactions with college transfer students, discover the practical applications of the theories which they are learning; (3) industry leaders who are seeking to employ knowledgeable and well-rounded engineers. Miner cites the efficiency gains in increased transferability by more rapid progress of students towards graduation and encourages "the various players and provinces involved in the post-secondary education system to work more closely together for the benefit of students" [5]. According to Miner, some provinces have programs which facilitate



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transferability more effectively than others; however, "there is still considerable room for improvement in this regard."

Why We Have a Mobility Problem

If greater mobility across the university and college sectors would produce engineering graduates who are better suited to succeed in industry and the knowledge economy of the future, why is transferability currently such a major issue in the Canadian field of higher education? Part of the answer lies in the current structure of Canada's postsecondary system and how we came to this point. Our Canadian system is unique. Unlike many other nations, we do not have a unified, centrally controlled, system of postsecondary education; instead, each province governs its own system of postsecondary education. Throughout the 20th century, the system of postsecondary education in each province evolved in a distinct manner. As a result, one of the most striking aspects of Canada's postsecondary system is the dissimilarity between the interrelationships of colleges and universities – both within each province and across the country. The origins of this dissimilarity may be traced back to the creation of the colleges during the 1960s and 1970s. Michael Skolnik, a professor of Higher Education at OISE, explains that two models appeared during this time: "in one model, the college combined lower-division, university-level general education with technical education programs; in the other, most or all of the colleges were intended to concentrate on technical education" [7].

The first model is based on the "junior college" system which emerged in the United States during the early half of the 20th century. The "junior college" "began as an institution whose function was to provide the first two years of university arts and sciences courses for students who were expected to subsequently transfer to a university to complete a bachelor's degree" [7]. According to Skolnik: "As with most American states, British Columbia, Alberta, and Quebec opted for the combined model, while Ontario and a small number of states chose the technical-education model [7]. As a result, "Ontario developed the largest system of technical colleges in North America that did not have any linkage with the university sector", known as the Colleges of Applied Arts and Technology (CAATs) [7].

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Algonquin College and Carleton University think global, act local

SOME CREDIT THE ENVIRONMENTAL movement. Others cite futurists. But the phrase "think global, act local" finds application in many areas of human concern. Urban planners, business gurus and educational leaders, too, can be added to the list.

Ottawa's Algonquin College and Carleton University – smack in the centre of one of Canada's largest photonics R & D hubs – are therefore in good company. Their collaborative Bachelor's of Information Technology - Photonics and Laser Technology (BIT - PLT) program combines Algonquin's state-of-the-art laboratory photonics facilities and strong industry connections with Carleton's photonics research expertise and strong programming, physics and math curriculum.

The target? Canada's annual photonics revenue is estimated to be in the $5 billion range, 60 percent of which is Ontario. Globally, the figure is put at $1 trillion.

"There is a huge demand for photonics graduates," says Dr. Wahab Almuhtadi, program coordinator at Algonquin and a driving force for the joint program's creation. "Employers snap up every student that comes through our program. Most take positions in the Ottawa area, but our graduates have also found related positions in the USA, Europe, Asia and Africa ." Now starting its second year, the PLT stream is one of three collaborative BIT programs offered with Carleton. The other two are Network Technology (NET) and Interactive Multimedia & Design. All three programs award graduates with both an Advanced Diploma from Algonquin and a Bachelor Degree from Carleton. Graduates are immediately eligible to enter a Masters of Science program.

As strong as photonics job opportunities are now, they are only expected to grow. Of the 100-plus companies in Ottawa's photonics cluster, roughly 60 percent are in the fibre optics sector. Just getting started are a whole range of photonics sectors such as health care (bio-photonics), defence and security, and lighting and energy. While the nascent sectors develop, the program has had very strong support from the five fibre optics "anchor" companies in the area. Ciena, for instance, recently donated a 2x10 Gbps (upgradable to 100 Gbps) optical transport platform (6500 series) to Algonquin's OptoPhotonics Lab and continues its support of the BIT-PLT program. Ciena together with other companies such as Alcatel-Lucent, Cisco Huawei, Optelian, Iridian, Delta Photonics, Chipworks, General Dynamics and Plaintree have 5,000 - 6,000 employees—a source of potential jobs for graduates.

Algonquin's industry ties with photonics date back to two similar programs launched in the early 2000s: Photonics Engineering Technology (PET) and Bachelor of Applied Technology (BAT) – Photonics. The final cohorts from these programs graduated in 2011. Partnerships with local industry and community organizations developed through these earlier College programs have resulted in many Coop placements, a key feature of the collaborative Algonquin/Carleton program. "Our Photonics students worked two days per week of the fall and winter term of their last year on research projects at the R&D lab facilities of local photonics companies or research institutes" Almuhtadi explains. "They interact closely with researchers and staff – often being offered jobs when they graduate." Also, input from industry on the 16-member program advisory committee is invaluable, says Almuhtadi. "If a certain course is no longer useful in the field, they'll point the way to something more relevant to the market and technology."

Another key success factor for the program is the network of supporting government agencies and industry associations in the Ottawa area, the largest of which is NRC. In partnership with Carleton, the Canadian Photonics Fabrication Centre (CPFC) was established to enable photonics companies to outsource device prototyping. The roughly 11,000-square-foot clean room fabrication facility and three-storey office wing has been operational since 2005. Where possible, program co-op placements are linked to funded applied research projects with local industry that take advantage of the CPFC. Other current supporting players include the International Photonics Commercialization Alliance, the Canadian Photonics Consortium, Ontario Photonics Industry Network and Invest Ottawa (former Ottawa Centre for Research Innovation - OCRI).

Interagency and government/industry cooperation has long been part of Ottawa's research and innovation culture. In 1999, the National Capital Institute of Telecommunications (NCIT) was founded by Carleton University, Algonquin College, the University of Ottawa, NRC, Communications Research Canada, Invest Ottawa/OCRI, Nortel, Alcatel-Lucent and Bell Canada. Amongst the several mandates of this not-for-profit incorporated business was the development of research alliances. The Optophotnics Lab is

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Quite the opposite is true of the system which emerged in Quebec and British Columbia. As Dr. Wendy Stanyon explains, unlike the development of the CAATs in Ontario, these provinces "were significantly impacted by government legislation that ensured these two postsecondary sectors would have to work together. Dating back to their establishment in the 1960's, each of these college systems has had university transfer as part of their mandate" [8]

Ontario's decision to separate the college and university sectors was based on the idea that "Ontario industry needed workers with different skills than those produced by a university education" [7] This may have been a decision which adequately fulfilled the needs of the labour market during the 1960s; however, in recent years, the lasting impact of the separation of the college and university sectors is becoming more and more of an issue for Ontarians and students from other provinces who wish to transfer to Ontario universities. The system of postsecondary education which emerged in Quebec during the 1960s addressed the needs of the labour market in a similar way, but what has evolved since then is quite different from the situation in Ontario. Quebec's postsecondary system is made up of two types of institutions: cégeps (collèges d'enseignement général et professionnel) and universities.

According to Harvey P. Weingarten, President and CEO of HEQCO and Fiona Deller, Research Director of HEQCO: "In the early 1960s, trends in Quebec society, including high population growth, industrialization, and urbanization, made it imperative for the province to create a network of institutions to absorb the new student clientele and provide technical training." [10] The motivation behind the creation of Quebec's cégeps may have been similar to those which prompted the establishment of the CAATs in Ontario; however, today's cégeps "perform a dual function – providing an intermediate level between secondary school and university (pre-university programs) and offering a wide range of technical and professional programs to students seeking entry to the work force."[10]

Perhaps the needed ongoing communication between cégeps and universities has had broader influence in how practical elements are integrated into engineering curricula. In particular, the approach of Université de Sherbrooke has not escaped the notice of Professor Britton, who notes they are doing a "marvelous job." Professor Britton explains that engineering students at Sherbrooke begin working in design teams when they enter the program; these design teams stay together and work on real projects until they graduate. If a team finds it doesn't have the needed academic background to solve a design issue, e.g., triple integrals, "a prof is simply brought in to teach the particular concept they need in order to respond to what they are doing." First started for mechanical engineering, Sherbrooke has now adopted this approach for its electrical engineering program too. Competition for spots in the programs is consequently very intense, Britton says. "Students know that they will get a good education and that they are going to be employable. Now other schools are looking at Sherbrooke and are saying, 'wow, wait a minute, can we do that?'"

In British Columbia, students graduating from high school may enter university directly, or they may choose to complete a couple of college years before pursuing a university education. Not all students who attend college in BC wish to pursue a vocational stream; instead, such students may decide to take a combination of baccalaureate and practical courses to keep their options open. A recent survey conducted by the British Columbia Council on Admissions and Transfer (BCCAT) has yielded some interesting results regarding the motivations of students who move between postsecondary institutions in BC. In A Survey of Movers, as it is aptly named, "respondents were asked at what point they had decided that they would move to their subsequent institution. Overall, one-quarter (24 percent) had decided to move to their subsequent institution before enrolling at their original institution." [1] Happily, the BC system of established articulation agreements makes such movement possible and "student mobility allows students to make effective use of the wide range of institutions and programs that make up BC's post-secondary system. Results from the survey suggest that BC's transfer system meets the needs of most students." [1]

It is interesting that the BC survey found that many individuals think about transfer before they even begin their initial studies. A recent Ontario study examining "college choice", conducted by Daniel W. Lang, a professor of Higher Education at OISE, has yielded similar results. The study, "based on two series of longitudinal surveys" conducted in Ontario "since the late 1980s", combined with a "third study – called the 'College Choice Project' – tracked secondary school students as they made decisions about attending college or university, and as they finally selected the institutions that they would attend" [4]. According to Lang: "Interviews of the students who chose to attend a college indicated a tentative interest in transfer. Two-thirds of them chose to attend a college that had some kind of articulation agreement with a university. Their

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connected to the ORAN network and will be connected to the ORION and CANARIE optical networks. This sophisticated lab is available for PLT students and for applied research, the Ciena lab will be connected to optical network Global Lambda Integrated Facility.

With such complementary expertise and a history of high level cooperation, collaboration between Algonquin and Carleton on a photonics program was a natural. Negotiations began in 2007, with several stages of approval needed on both sides. Coming to an agreement on a curriculum was one of the more time-consuming elements. "Algonquin's initial proposal called for 44 courses," Almuhtadi recalls. "After a first round of review, this was whittled down to 42 courses. We eventually settled on 40."

Marketing the new program was a high priority for both sides. Discussions with teachers and students in the science streams of local high schools was revealing: The majority of high school teachers and students didn't understand the term "photonics" – and therefore parents likely didn't either. So, instead, the new program would be called "Photonics and Laser Technology." Once the program details were further refined, a school-by-school promotional campaign was unrolled. Armed with an assembly of laser equipment demos and polished PowerPoint presentations, faculty from Algonquin and Carleton set about the goal of reaching every high school science stream from Grade 9 through 12 in the Ottawa area. Key high schools in major nearby centers, e.g., Kemptville, Pembroke, were also targeted. Marketing for the program is currently carried out by Carleton.

Scheduling classes at two different facilities has required some experimentation. In the past, students attended morning sessions at Algonquin and spent the afternoon at Carleton or vice versa. Despite the less-than-10km separation, 40 minutes to 1 hour was being lost in transportation, reports Almuhtadi. Beginning in the academic year 2012/2013, students in the PLT program will be taking labs and classes two days a week at Algonquin, and three days a week at Carleton.

While Almuhtadi sees job opportunities as the key attraction for students, he also points to class sizes of 24-30 students and the program focus on hands-on-experience and direct interaction with faculty, as compared to lecture halls crammed with 200 or more in many traditional university programs. He also cites the integration of the lab work and other practical elements of the program. "We don't just give students theory, theory, theory," he emphasizes. "We give them some theory, and then put them into action and practice. Students then enhance the theory by themselves." ■

***Contributed by Bruce Van-Lane, Managing Editor,* IEEE Canadian Review**

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interest was tentative in the sense that their choice of college was not conditional on being able to transfer. The opportunity to transfer was seen as a bonus." [4] The results of this study suggests that college-university transfer is something which is on the mind of many students entering the postsecondary system; however, unless the college in which students enrol has an articulation agreement with a university, transfer may be more difficult then they may think.

For a variety of reasons, including the inability to afford the high cost of a university education, many high school graduates may opt to enter college with the goal of transferring to university at a later point; however, many students discover barriers, such as lack of credit transferability, which prevent them from doing so. Indeed, not everyone has equal access to university education. Increasing transferability could go some way to address this inequality, as it would permit greater number of individuals whose initial choice was primarily cost-motivated to more easily earn a degree at a later date. In Ontario, understanding the conditions that promote transferability has increasingly become a government priority as it seeks to attain increased levels of student mobility closer to those in other Canadian provinces. According to Colleges Ontario, "Increasing numbers of university graduates are also pursuing college programs to help prepare them for success in their careers. In the last five years, the number of Ontario university graduates applying to college has increased 40 per cent.

Articulation Agreements in Ontario

Through articulation agreements, completion of specific programs at one postsecondary educational institution gives advanced standing to students applying for admission to related programs at a second institution. Most often such agreements are between colleges and universities. The degree to which such agreements are in place is a measure of transferability, particularly in jurisdictions like Ontario, where the system's overall structure presumes minimal movement of this kind. In other Canadian jurisdictions, such agreements are mandated either through provincial legislation or some other authority.

In a 2009 report written for the Higher Education Quality Council of Ontario (HEQCO), Andrew Boggs and David Trick examined seven articulation case studies in that province. They note that partnerships between colleges and universities benefit the institutions involved by opening up new student markets, and by widening the benefits to prospective students by allowing each side to avail itself of equipment or faculty from the other party. Such partnerships can also serve broader public policy objectives, such as giving "access to university in a geographic area not served (or underserved) by universities." But the authors cite a host of barriers to these voluntary partnerships, despite the clear benefits:

"lack of knowledge about opportunities, difficulties in negotiating agreements, lack of support from major stakeholders within the institution, disincentives to share gains, difficulties in resolving disputes, and the potential irreversibility of agreements may all discourage agreements from forming or continuing. The prospect that two institutions may cooperate in some areas while competing in others, either now or in future, has the potential to be destabilizing."

Furthermore, the rate at which partnerships are being formed (those looked at in the report are the largest of their kind) is such that the authors do not see these arrangements as having significant impact on transferability within the Province.

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Lakehead's unique value proposition

ROUGHLY 500 KM EAST of Winnipeg, the city of Thunder Bay sits pretty much midway between Canada's west and east coasts. But its central location is not what draws graduates from virtually every engineering technology program in the country to Lakehead University's Faculty of Engineering.

Like other engineering programs that accept engineering technologists, it ensures that by the time their degrees are conferred, these third-year admission students will have taken all necessary courses required by the Canadian Engineering Accreditation Board (CEAB) of the Canadian Council of Professional Engineers. It offers degrees in Chemical, Civil, Electrical, Mechanical and Software Engineering

However, Lakehead's program is unique in a very fundamental way. Having its beginnings as Lakehead Technical Institute, the engineering faculty has structured the first two years of its four-year program such that students finishing their second year have essentially the same academic background as the community college graduates who will be their cohorts for the third and fourth years of the program.

"We actually give our students, after the second year, a diploma in engineering technology," explained Dr. Allan Gilbert, Assistant Dean of the Faculty of Engineering, in a recent telephone interview with the IEEE Canadian Review. "Therefore, they are on the same standing as other students in the colleges across Canada. After two years in the Lakehead program, someone who entered directly from high school receives a program comparable to someone who entered a community college."

In fact, the Lakehead program is a somewhat upscale version, including a full-year course in calculus as well as differential equations and linear algebra. Therefore, to be on par, all college graduates coming to Lakehead start by attending a somewhat intense summer session for these two courses. "Some don't make it through," notes Gilbert, "but it's good for them to know where they stand after only spending a short while here."

The admission process for college graduates into a Lakehead engineering program's third year still entails careful examination of students' qualifications, even with Lakehead's paralleling first two years. "Every student needs a 3.0 GPA or 70% to be accepted, but then we check their transcripts to see what subjects they are missing that would have been covered in our own first and second year," Gilbert says. For example, electrical engineering students need to take a course on engineering mechanics and also one on heat transfer, as this CEAB-required material is not typically taught at community colleges. There are some restrictions, notes Gilbert, as programs need to adhere to the standards of the CEAB for the overall four years. When considering an applicant, Lakehead evaluates the diploma transcripts "on a case-by-case basis," as well as reviewing entire programs of the larger community colleges. Foreign students are typically not accepted into the post-diploma program directly because of restrictions of accreditation policies.

When asked how the newly admitted college graduates differ from the students who entered Lakehead directly from high school, Gilbert pointed out that college graduates have a level of maturity that the high school students don't have. Some of the college graduates have worked for a couple of years and discover that their career is limited by not being a professional engineer, he says, so they decide to go back to school.

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"Even the largest of the voluntary relationships we studied is intended to serve a niche relative to the size of the system. The largest single relationship will eventually enroll approximately one-half of one per cent of Ontario's postsecondary students."

From a national perspective, one of the most intriguing of the case studies looked at by Boggs and Trick is arguably not a partnership at all, at least in the usual sense of the word. Lakehead University's program accepts graduates of technology programs from community colleges all across Canada, admitting them directly into its third year. Each community college's program is evaluated individually, with no agreements made with any individual institution. See the sidebar below on Lakehead's program for a full exploration.

Addressing the Problem Locally

Lakehead's program demonstrates that, while it may not be possible to create a national strategy for student mobility, successful programs can emerge at a local level. Another example of a local program which was established to meet the educational and employment needs of a unique group of individuals is the IEEQ program at the University of Manitoba. The IEEQ program was created for internationally educated engineers who "hold an engineering degree from a university outside of Canada, have extensive engineering work experience from outside of Canada, have recently immigrated to Canada and wish to continue their engineering career and seek professional licensure with APEGM in Manitoba" (University of Manitoba). Like college graduates, internationally educated engineers bring a practical knowledge base to industry which students who entered university engineering programs from high school do not. The IEEQ program was introduced ten years ago when Professor Britton was on the board of what was then called the Canadian Council of Professional Engineers. According to Professor Britton, despite critics who presented "a million reasons why it wouldn't work, we being obstinate prairie folks just went ahead and did it." The program became a success, but much of its success was due to the relatively small size of the university and its ability to work closely with APEGM. As Professor Britton explains: "Manitoba could lead because we only have one school of engineering; therefore, we didn't have as many agendas to deal with. There is an advantage to having one school in the province. That meant that we could work all that out with APEGM because they only had one model coming at them. You couldn't do that in Ontario where you've got a whole mess of schools, and those schools each have their own agenda in terms of how they are going to do it. Typically, this sort of program will happen in a smaller location."

Conclusion

Finally, after considering all of the issues surrounding student mobility, are we any closer to answering the question: What can be done to ease student movement between programs? As in any complicated situation, the answer is not clear-cut. Student mobility will remain an issue as long as colleges and universities operate as academic silos. What is needed is more cooperation between the two sectors to make the most of the funding which flows from the same place – the province. Professor Britton states it best: "I think that the base is recognizing that we need to speak to one-another as colleagues in the same business as compared to competitors for bright young kids and provincial funding." In Professor Britton's opinion, universities and colleges are all on the same team: "We all do the same kind of thing, we just do it differently. We contribute differently. We are a team. Like a ball team, if the short stop is not playing properly it doesn't matter what the pitcher is doing. If we focus it down on the individual players, which is essentially what our education system does now, then where are we at? We don't win the game because all the players are not playing the same game. They have the capability of contributing but we have to recognize the capabilities and the training that goes into each of the pieces in that team. It is not the great isolated geek anymore, it's a design team." ■

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"Generally, students entering in the third year have a stronger motivation, a clearer idea of what the workforce is like. They know what they want."

Interestingly, according to Gilbert, there are fewer women who enter the Lakehead engineering program with a college diploma because, generally, colleges tend to have fewer female students than universities. Most of the female students entered the engineering program at Lakehead directly from high school, he says. Engineering students who enter Lakehead directly from high school may receive practical industry experience through a 16-month co-op designation (four co-op terms or semesters). The co-op "is of less interest to those coming from college who have already 'been there.'"

How does the Lakehead model stack up to a more traditional engineering program structure? One aspect that yields an interesting trade-off is that students entering from high school have repeat exposure in third or fourth year to some subjects at a more theoretical level that would normally only be taught once in a four-year program. For electrical engineering students, circuit design would be an example. "There are some pedagogical advantages," points out Gilbert. "It allows for more retention and strengthening of the foundation."

At the same time, Gilbert allows that this repetition limits the number of specializations available to graduating students, even though the program has no common first year that might otherwise enable this. "We have to teach a basic foundational program. Our philosophy is: 'maintain the core.' We believe you really should focus on the specialties in graduate school."

When asked how well students of the Lakehead program do in terms of employability after graduation, Gilbert replied: "Ninety-five percent of our electrical engineers get hired within the first two years; so based on that, I think we stand up very well." ■

Contributed by Bruce Van-Lane, Managing Editor, **IEEE Canadian Review**

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› Keith W. Hipel, Continued from page 7

Keith Hipel (front, left) in Japan on Jan 24, 2012, standing with Tottori University students who had visited the University of Waterloo on previous occasions.

The three exchange programs

Tottori University

The first seven students of the Tottori/Waterloo engineering exchange program eagerly landed in Japan in late April of 1988 for their 3A undergraduate academic term. In late July they toured Japan and Asia for one month, worked in Japanese industry from September to mid-December, returned to Tottori University to deliver a presentation–in Japanese–about their work term experience, and then returned to Canada in late December. This is the model followed by the approximately one hundred Waterloo students who have now participated in this exchange program. For its part, Tottori University prefers to send graduate students to study at the University of Waterloo, although recently it started to send undergraduate students and some students on short term visits. The more than 40 Master's students from Tottori University who have studied at Waterloo usually do so for eight months during the Fall (September to December) and Winter (January to April) Academic Terms. As a welcomed spinoff from the exchange program, for about a decade Tottori University has been sending a significant number of students to study English as a Second Language (ESL) at summer programs sponsored by the English Language Institute at Renison University College, which is situated on the west side of the University of Waterloo campus. Former President Masanori Michiue of Tottori University, who visited the University of Waterloo in 1998, fully recognized the great import of international programs and ESL training.

Kyoto University Exchange Program

The charming city of Kyoto, which constitutes the cultural heartland of Japan, is considered to be one of the most treasured and culturally important cities in the world, and is truly the Pearl of the Orient. Kyoto University, or Kyodai, as it is popularly labeled, is now a key part of the cultural scene in Kyoto. The university was established in 1897 as one of the nine great imperial universities and has matured into a relatively large

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> ***"According to our knowledge, every past participant in the three exchange programs is now performing well in his or her chosen career."***

Thus far, every participating exchange student has successfully completed his or her entire academic program at the host university, and for the case of the 100 undergraduate Waterloo students who have studied at Tottori University, each of these students has also obtained valuable work experience in Japan. In addition, many of the graduate students learned new academic concepts at the host university that were directly incorporated into their graduate research theses, which were subsequently completed at their home universities. Virtually every Japanese student has achieved fluency in English by the end of his or her study period in Canada, while each Canadian student has learned to speak reasonably well in Japanese and write Japanese using the two phonetic alphabets called hiragana and katakana, as well as some kanji (Chinese) characters. Moreover, each of the exchange students immersed himself or herself in the culture of the host country, made many friendships, and visited many places in the host country and, in many cases, elsewhere in Asia. According to our knowledge, every past participant in the three exchange programs is now performing well in his or her chosen career.

Faculty members and other researchers have also benefited from the exchange program by executing joint research projects with their foreign colleagues and visiting host universities to deliver invited research seminars and work on collaborative projects. There has been a range of spinoffs from the exchange programs that go well beyond the original purview of the agreements, and valuable academic and social networks are continuing to expand. For example, when the mountain town of Chizu, located near Tottori, requested a Canadian to help build log cabins in the late 1980s, a Canadian school teacher by the name of Ms. Judy App went to Japan to carry out this task and ended up starting an exchange program between her high school in Petrolia and a high school in Chizu.

Experiential Learning at the University of Waterloo

International exchange programs at Waterloo arose as a quiet revolution led at the grass-roots level by individual faculty members–the concept of having an "experiential" international component to engineering education. In many instances, as a consequence of having research connections with foreign universities, Waterloo

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and prestigious university with faculties in most key areas of study including engineering, medicine and law. The university has approximately 14,000 undergraduate students, 9,300 graduate students, 2,800 teachers and a total of 5,400 technical and administrative staff. Like many other Japanese universities, the ratio of students to teachers is excellent – 8.3. Kyoto is ranked as one of the top universities in Asia and among the best in the world.

A preliminary agreement with respect to an official exchange program between the Faculties of Engineering at Waterloo and Kyoto was signed in 1992, and later this was upgraded to an arrangement at the university level. Like Tottori University, almost all of the Kyoto students who study at the University of Waterloo are graduate students who usually visit during the Fall and Winter terms. To date, more than 70 Kyoto graduate students have visited the University of Waterloo where they can take graduate courses for credit or audit, work on research projects under the tutelage of host professors, and improve their spoken and written English language skills via taking appropriate courses from Renison University College and simply submerging themselves in Canadian culture. Beginning in 2009, undergraduate students from Kyoto University came to Waterloo to study in their respective fields of interest. Thus far, mainly Waterloo researchers and graduate students visit Kyoto University.

Tokyo Institute of Technology

The Tokyo Institute of Technology, which is also referred to as Tokyo Tech or Tokodai, traces its roots back to May 26, 1881, when the Government of Japan established what was then called the Tokyo Technical School to educate engineers in order to help Japan to catch up with the industrialized West. Today, Tokyo Tech has 4,860 undergraduate, 3,484 Master's and 1,524 Doctoral students, for a total of almost 10,000 students. These students are ably served by 1,150 teaching and research personnel, plus 560 technical staff. The number of students per faculty members is about 8.6 – an admirable number that Canadian universities should seek to match. Tokyo Tech is Japan's foremost university of science of and technology and is ranked as the best technical university in Asia.

An official exchange program between Tokyo Tech and the University of Waterloo was put in place in late 2006. Under the program, Japanese Master's students spend one or two terms at the University of Waterloo to take courses, carry out research and experience Canadian culture. Researchers from the University of Waterloo have participated in joint research projects involving the two universities. The Tokyo Institute of Technology believes in a better future for humanity through science and technology. Indeed, one can argue that the prosperity and innovation capacity of a given nation is closely linked to the quality and number of engineers that the country graduates and employs [4]. Similar to engineering education in Canada, engineering students at Tokyo Tech take courses in the liberal arts, social sciences and humanities to balance the knowledge they acquire in mathematics, science, engineering sciences and design.

Now boasting the world's largest metropolitan economy, the city of Tokyo began its rise from a fishing village named Edo about 400 years ago. In 1603, Ieyasu Tokugawa, a military dictator, established the Tokugawa Shogunate which lasted until 1868. Rather than using Kyoto as his capital city, Ieyasu established Edo as the capital during this feudalistic period of Japanese history. Ieyasu united Japan just after the brief reigns of Oda Nobunaga and Toyotomi Hideyoshi, who had a much more creative vision for Japan's future. A more enlightening vision for Japan did not emerge until the Meiji Restoration of May 3, 1868, which restored imperial rule in Japan and set it on a purposeful course of modernization and industrialization following the lead of Western nations, but with a distinct Japanese flavor. The city of Edo was renamed Tokyo, meaning Eastern Capital, and it has remained as Japan's capital city. Like the mythical phoenix bird, Japan emerged from the ashes of feudalism to become one of the greatest industrialized nations in the history of civilization. A key supporting pillar of this new Japan was the building of a first-class educational system. ■

Professor Takehiro Inohara and President Kenichi Iga of Tokyo Tech meeting with the author in the President's office on February 1, 2012, to discuss the exchange program.

faculty members founded international exchange programs to benefit not only graduate students and faculty members involved in exciting research projects, but also undergraduate students who would be afforded the opportunity to study and work in foreign countries, and consequently have the opportunity to immerse themselves in the language and culture of the host country.

Currently, the Faculty of Engineering at the University of Waterloo has more than 70 exchange programs with nations around the globe such as Japan, Germany, Singapore, France, and Australia. Indeed, the sponsoring of international exchange programs is the mantra of most major universities around the world as they clamor to enhance their rankings–Waterloo Engineering and other Canadian engineering faculties are now providing in real time this experiential approach to the internationalization of engineering education. This also extends to the university level, where, for example, Waterloo International at the University of Waterloo has more than 320 international agreements in 60 countries with other research and teaching institutions covering joint research, development studies, collaborative academic programs, and student exchange programs. These partnerships presently consist of 150 formal student exchange agreements in 35 countries, including those with which the Faculty of Engineering is connected.

Waterloo's exchange programs can be seen as an evolution of the experiential learning approach pioneered in Canada by the University, beginning with its founding in 1957. At the heart of Waterloo's innovative approach to educating its undergraduate engineering students, and later students from many disciplines, is its co-operative educational program whereby students alternately study for four months at university followed by four months working in industry. Today, almost 16,000 Waterloo students enrolled over three semesters partake of this wonderful opportunity in "experiential learning" in which they are taught at university and trained in industry. Of high importance for Canadian students in general is the fact that most universities and community colleges in Canada have followed the lead of the University of Waterloo and now offer some form of experiential learning.

To look at quantifiable benefits of participation in an exchange program, the results of a survey are presented next. The details of each of the exchange programs with Tottori University, Kyoto University and the Tokyo Institute of Technology are outlined in the sidebar above. Personal success stories of individual Japanese and Canadian students are presented in the sidebars on page 27. Some of this information was

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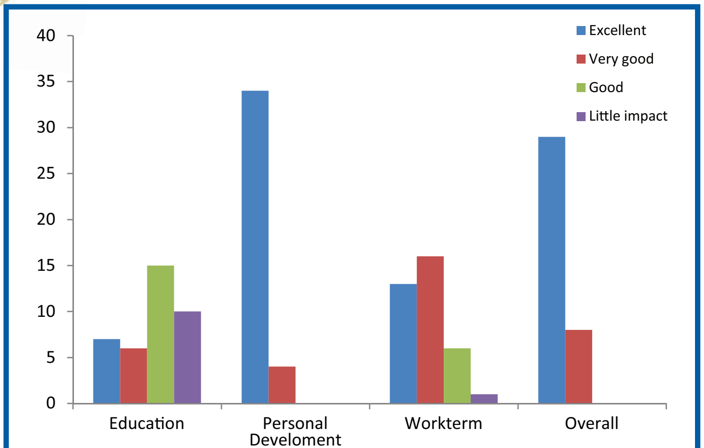

Figure 1. Evaluation of the Waterloo/Tottori exchange program by participating Waterloo students.

1. Background Information

- Personal Information
- Education
- Current Employment
- Other Specific Exchange Program Information (Dates, Department, Club Membership, Travel Information, Employer)

2. Impacts of Exchange Program Participation

- Explain how the exchange program contributed to your education.
- Explain how the exchange program influenced your personal life.
- Explain how the exchange program influenced your career.
- Discuss any return visits.
- Comment on other impacts.

3. Rating Form

Circle your evaluation for each of the queries given below:

Educational Experience at Tottori University:
Little Impact / Good / Very Good / Excellent

Work Term Experience in Japan:
Little Impact / Good / Very Good / Excellent

Personal Development in Japan:
Little Impact / Good / Very Good / Excellent

Overall Evaluation of the Exchange Program:
Little Impact / Good / Very Good / Excellent

Table 1: Exchange Program Questionnaire

Principle	Description
Culture-first	The primary purpose of an exchange program is for the students and academic staff to learn about the culture of a foreign nation. To this end, applicants are required to take pertinent language and cultural courses.
Champion	Both universities involved in an exchange program need to have at least one staff member who is fully dedicated to the successful implementation of the program and to inspiring both the program participants and the staff involved with the program.
Commitment	An exchange program should only accept student applicants who are strongly committed, as demonstrated by applicants writing an explanation of interest in the program, maintaining acceptable grades, and assuming responsibility for most of the necessary preparations.
Friendship	Sincere friendliness and hospitality must be shown to all participants, ensuring that visiting students and researchers feel welcomed and befriended at their host university.
Self-supporting	Although grants and scholarships can be accepted, exchange programs should be designed to operate independently of any external support, with students paying for all of their own direct participation costs.
Universality	An exchange program should be open to all interested students, provided they have a suitable academic background and standing and adhere to the principles of the program. It should be open to any academic staff member as well.
Continuity	An exchange program should be initiated immediately upon receiving authorization and remain in operation continuously every year thereafter.
Equality	Visiting students should pay the same tuition fees and have access to the same facilities as the home students at the host university, as well as receive credit at their home university for courses completed at the host university. Visiting researchers should likewise have access to all of the amenities granted to colleagues at the host university.
Flexibility	Exchange programs should be open to change, actively seeking and embracing opportunities for maturation and expansion.

Table 2: Principles for a successful Exchange Program

presented earlier in an IEEE journal paper [1] and a Japanese journal in engineering education [2].

Survey Findings

Starting in July 1999, each of the Canadian and Japanese students who had participated in the Tottori and Kyoto exchange programs were mailed a questionnaire. Table I provides an overview of the contents of the questionnaire sent to the Waterloo students who studied at Tottori University followed by a work term in Japanese industry. A similar form was forwarded to the Japanese exchange students, who were mainly Master's students from Tottori and Kyoto Universities; that form did not include the question related to any work term experience because these students did not work while in Canada. Subsequent to completing the background information in Part I, each student was requested to respond in writing to the questions put forward in the second section. In the third part, each student simply circled his or her evaluation of each query. The main information from all three parts was tabulated in a spreadsheet while graphical output was produced for the third component listed in Table 1.

Figure 1 is a graph of the ratings for each of the four queries listed at the bottom of Table 1. These ratings were determined from questionnaires returned by thirty-eight University of Waterloo undergraduate students in engineering who studied for the first semester of their third year at Tottori University, followed by a four -month job experience in Japanese industry. As displayed in the bar graph, a large majority of students rated the overall exchange program as being excellent. In actual fact, all of the respondents evaluated the program as excellent or else very good. A somewhat surprising result is the exchange students' assessment of their personal development while in Japan, for which 90% of the respondents thought they had undergone significant personal development. As shown in the Figure, a majority of students evaluated their work term experience to be in the very good and excellent categories. Moreover, since engineering programs at Japanese and Canadian universities provide a similar set of courses within a given discipline or subject area, it is not unexpected that the educational experience of Waterloo students in Japan is not rated as highly as the other three categories of queries.

The Tottori and Kyoto Master's students, almost all of whom spent two semesters studying at the University of Waterloo, also gave very high ratings for the overall category and for their personal development. All of the Tottori students who responded to the questionnaire rated their educational experience at the University of Waterloo in the excellent or very good categories, while 83% of the Kyoto students did likewise. Perhaps, the Japanese Master's students were impressed by the inclusion of the latest research results in graduate courses taught at Waterloo as well as the freedom of thought expressed when discussing original research ideas with others.

Designing Successful Exchange Programs

There are fundamental principles that should not only be embedded in the basic design of an exchange agreement, but are also reflected in the practical implementation and improvement of the program as it evolves over time, to meet the changing requirements of students, academic staff, and even local communities. Through many years of "experiential learning" on designing and running exchange programs, the author and his colleagues have found that adherence to these principles ensures the continued success and long-term sustainability of a specific exchange program. Table 2 lists the nine key ideas that contribute to having a rewarding exchange program, along with brief explanations, for which detailed discussions can be found in [1].

The Cultural Aspects of Design

While studying, working and living in Japan, our Canadian students are in a unique position to appreciate first hand how Japanese society and culture are

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and Technology Education

Student profiles

SNAPSHOTS OF THE LIVES of former graduates show the long-lasting impact–both personal and professional–of having participated in the exchange program.

BRIAN WONG, President of a software consulting company, Dezlang Systems Inc. in Thornhill, Ontario, participated in the exchange program in Japan in 1988. The impact on him: "My life was forever influenced [by the culture] in terms of honesty, independence, generosity, balance, and respecting others."

MICHELE BRISTOW, who graduated from Systems Design Engineering at the University of Waterloo in 2006, studied at Tottori University from April to August of 2004 and remained as an employee of Tokyo-based Ark Information Systems during the fall of 2004. While based in Tokyo, she used the opportunity to travel throughout Japan, Malaysia and Singapore. All exchange students are encouraged to travel extensively while in other parts of the world as part of their experiential learning. Michele just completed her Ph.D thesis (on Sept. 5, 3013) in Systems Design Engineering at Waterloo on the topic of an integrative and adaptive approach to policy analysis within a system of systems engineering framework. Having experienced Japan as an undergraduate Michele has kept her connections, returning on a number of occasions to carry out doctoral research.

For **BRYAN MARK** his exchange trip in 1994 permanently changed his life. After completing his degree in Systems Design Engineering at Waterloo, he returned to Tokyo and now lives there with his wife and daughter. He stated that the exchange experience "provided more of a cultural education than a pure technical [one]."

KAZUO UEZEMI and **TOMOO AOKI** were Master's students from Tottori University when they studied at the University of Waterloo from September 1991 to April 1992. Having completed their degrees, Kazuo has since worked on projects in Southeast Asia, Pacific Island Nations and the Black Sea, and currently works frequently in Afghanistan where he assists in designing and rehabilitating airport facilities under the sponsorship of the Japan International Cooperation Agency (JICA). Tomoo has been involved with challenging projects in Iran, India and Vietnam. He is currently engaged with the restoration of Ha Long Bay (descending dragon bay) in Vietman, a designated UNESCO Heritage Site

KEISUKE SATO studied at the University of Waterloo from September 2000 to April 2001, after which he returned to Tottori University to complete his Master's degree. Keisuke is a Professional Engineer in the area of Comprehensive Technical Management and Civil Engineering and works in regional economic planning. Like his colleagues, Keisuke also has an adventurous and inquisitive outlook on life, perhaps inspired by his experiences as an exchange student, and he is now completing a PhD on a part-time basis at Kobe University while he holds his full time job.

KEI FUKUYAMA was a member of the first group of Tottori Exchange students to study at the University of Waterloo from September 1988 to April 1989. Upon completing his Master's degree at Tottori University, he returned again to the University of Waterloo to register full time as a PhD student in the Department of Systems Design Engineering where he successfully defended his doctoral thesis on December 19, 1994. Returning to Japan, Kei is now a Full Professor in Social Systems Engineering at Tottori University and is a strong proponent of the exchange program that his university has with the University of Waterloo. ■

Kei Fukuyama (left), a former exchange program student and now Full Professor at Tottori University join the author (centre) and Vice-President H. Noda (right).

"designed" or structured and how the Japanese people thrive within this fascinating culture that has withstood the test of time. Likewise, of course, Japanese students who come to Canada will see how our relatively young culture is structured and how it is quickly evolving. The discussion in this section concentrates on the design and characteristics of Japanese culture and what we can learn from it to improve our own Canadian society.

Japanese people have great respect for education and hold teachers, or sensei, in high esteem, as noted earlier. For the three Japanese universities referenced in this article, the ratio of students to faculty members is about eight to one. Why do many universities in Canada, and especially those located in the Province of Ontario, have ratios of close to 30 to one? Why do many Canadian universities receive significantly less funding per student than similar institutions in Japan and the United States? Since the economic well-being of a nation is correlated with how well its citizens are educated, especially in fields like engineering, science and mathematics [3], [4], why don't Canadians value education much higher than they do? Universities located in the Province of Ontario, for example, receive the lowest funding found in any political jurisdiction in Canada and the United States, even though Ontario's economy is highly dependent on both traditional and "high tech" industry. Unfortunately, the recent Drummond report commissioned by the Ontario Government [4], devalues post secondary education even more by recommending that less money per student be given to universities. The story gets even worse at the federal level in Canada, where the National Research Council is being downgraded and research funding from granting agencies, such as the Natural Sciences and Engineering Research Council (NSERC), is low compared to other industrialized nations. In reality, this means that post secondary education, research and innovation are not a high priority for Canadian society–our actions reflect our true values. Do we Canadians need a shift in our value system, at least at the societal level? In essence, it is our values that dictate how we design and fund our educational system for both teaching and research. ■ ‹ Back to beginning

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› Monique Frize, Continued from page 8

2. Celebrate success stories of women engineers (posters, websites, Web 2.0 – Facebook, YouTube, chats) to change the introverted style of engineering, showcase careers, life of an engineer. Alumni network could do job shadowing to introduce students (Grades 10-12) to engineering and its potentialities, and thereby attract young people to engineering.

END RESULTS: A pool of materials that can be used for brand image in the media; students, especially girls and young women, get excited, interested, and engaged in engineering; they learn about the field and career opportunities of an engineer and what engineers do.

TOP PRIORITY RECOMMENDATION 2

Enhance the knowledge of engineering of teachers and counselors, and parents.

STRATEGY: 1. Develop a professional development event for teachers/counselors to enhance their knowledge of engineering. Students in teacher training programs should be learning about engineering - a prime time to get future educators interested in this - therefore partnership should include Faculties of Education. Licensing bodies for teachers of the provinces and territories should add an engineering module as they determine the required additional course offerings for teachers to maintain their licences.

2. Prepare hands-on classroom activities teachers can easily carry out, and partner with existing successful outreach programs like SHAD Valley's summer internships for grade 10 and 11 high school girls, Actua, Engineers-in-the-Classroom, and Professional Education Associations special programming;

3. Outreach and role modelling in Grades 3-5, Grades 6-8, Grades 9-12 (avoid gaps); add a mentoring component for older students. A Canada-wide approach ensuring that we are not missing groups (i.e. French Canada, non-Quebec female students).

4. Create resources for parents that promote engineering as a great career for their daughters with specifics about the nature of engineering careers, outlining the steps required to get into an engineering program and providing activities and tips for how parents can encourage their daughters to consider careers in engineering.

Full review and promotion of best practices catalogued in a central depository i.e. a list serve that sends new ideas to those registered.

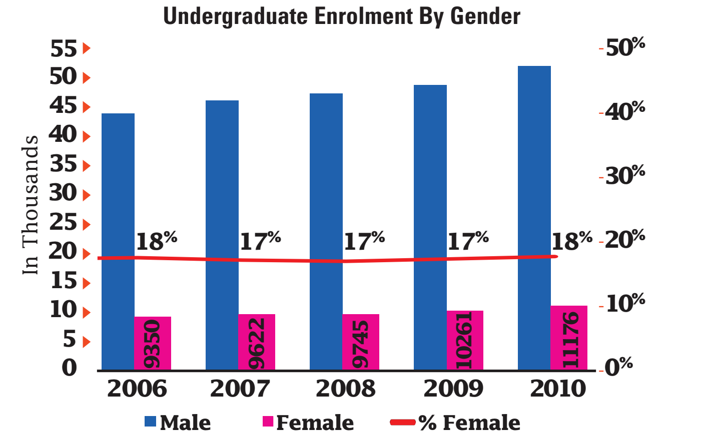
TOP PRIORITY RECOMMENDATION 3

Enhance the image and the structure of engineering programs

We need to attract a more diverse group of students, with the aim of achieving 25% in undergraduate enrolment of women students by 2016 and 30% by 2020.

STRATEGY: **1.** The process should include broad, creative thinkers and decision-makers including women advocacy groups. We need to reconstruct engineering programs to incorporate:

- The new accreditation attributes established by the Canadian Engineering Accreditation Board (CEAB); new student learning profiles; a better understanding of the expectations of new generations of engineering students; a diversity of curriculum including elements of other subject areas (arts, humanities, social sciences, business, leadership); different approaches to teaching and applications of engineering – on the national and international scene.
- Adjusting the accreditation process to incorporate women's values, diversity and sustainable development.
- Launching a pilot program within leading universities (2013-2014) aimed at supporting women's values and needs, diversity, and sustainable development.



Credit: *Canadian Engineers for Tomorrow: Trends in Engineering Enrolment and Degrees Awarded 2006-2010*, pg. 4, Engineers Canada; Oct. 2011

Support for WIE from IEEE

A force for positive change, IEEE encourages young women to enter electrical engineering and provides support for female professionals. For the latter, IEEE Women in Engineering (WIE) confers achievement awards, organizes conferences and networking events, and supports the formation of new WIE Affinity Groups. To attract girls in junior-high and high schools to this career choice, the IEEE Student-Teacher and Research Engineer/Scientist (STAR) Program was developed. Outreach elements include classroom activities, humanitarian projects, competitions, mentoring and teacher training.

Targeting both genders equally, the pre-university division of IEEE's Educational Activities Department offers many helpful resources, including the TryEngineering.org and TryComputing.org portals. The Teacher In-Service Program (TISP) is particularly active in Canada, with "champions" in most sections organizing teacher workshops to demonstrate design-oriented lesson plans, and in some instances leading classroom activities themselves. Vancouver Section's WIE Affinity Group has for several years worked with a local mixed gender secondary school in developing classroom presentations and organizing field trips that are led by female engineering professionals and graduate students. Since the Section's WIE Group is represented on the TISP Canada committee, the feedback from students and "lessons learned" are shared with other TISP champions.

Conclusion: Although several of the 1992 CCWE recommendations have been put in practice by schools and universities, and some have been implemented in workplaces and in the professional associations such as IEEE, the workshop participants still found 25 new ones that need to be in place if we are to finally see gender balance in engineering. Action on all recommendations would help increase women's participation in the field of electrical engineering. We need all of society to be involved: parents, educators, deans, engineers (women and men) if we are to succeed! ■

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and Technology Education

The trend towards abstraction in engineering education

240V shock), had changed and mended the tire on their bike, would have taken apart a clock and might even have taken off the cylinder head of their, or their parents' car. Today none of these things is likely, although equivalent students might have keyboard skills and might have added more RAM chips to their laptop. There are two basic reasons for this – modern attitudes to safety, and the increased complexity and miniaturization of everyday devices, leading to the black-box syndrome. The modern student cannot (almost literally) learn much from opening the back of a digital watch, or clicking together Lego, or opening the bonnet of the family car to reveal a plastic filter cover embossed with the maker's name. No gear wheels, spark plugs or even nuts and bolts, are easily visible. All the engineering, both clever and mundane, is hidden within a 'black box'. This paucity of practical experience of engineering must diminish the almost subliminal store of knowledge and understanding which the student brings to the beginning of his or her studies. He has every excuse for not knowing how a Hard Drive recorder or an iPod nano works – they have no visible working or moving parts. Realization of this inevitable restricted level of engineering experience dictates that educators must make substantial efforts to provide an engineering context – almost an explanation of what engineering is about – to first-year students." [5]

Experiments and practical understanding is particularly valuable in engineering areas where the theoretical understanding is incomplete. An example of this is fluid dynamics where the theory of vortices is still under development. A friend, who investigated flying wings, told me that his experiments included repeated constructions of paper airplanes in order to get a fuller understanding of how air behaves when objects move through it [3]. New airframe designs are similarly tested in wind tunnels following the approximate theoretical calculations. New designs involving fluid flow can behave in surprising ways as witnessed by the Tacoma Bridge disaster in 1940 [4].

There is even a further trend of abstraction that might be a concern. That is, how the theoretical concepts are implemented in practice. One can look back to say the start of the previous century. At that time engineering students would be educated in performing calculations using paper and pencil, logarithms, slide rules and simple mechanical calculators. They would find the formulas required in for example "The Engineers Manual" by Ralph Hudson [3]. They would learn and understand each step of a calculation in detail and when a result was arrived at they would have some experience in knowing whether this was reasonable or not. When calculating with a slide rule it was especially easy to be off by one or more powers of 10. The calculations were tedious but the engineering students would gain valuable experience in the process. More sophisticated mechanical calculators made the number crunching easier, but the students would still have the detailed knowledge of the calculations.

The introduction of electronic computing machines enabled the calculations to be automated in the form of algorithms for a given engineering calculation. The students would be educated in implementing the calculations at a detailed level using assembler languages or simple higher level languages such as Fortran. Implementing algorithms in these languages required that the engineering students were quite familiar with the details of the calculations. Soon, however, a trend towards greater abstractions arose in the form of subroutines. The advantage was that the cost of programming a calculation used by many engineers would be amortized over many uses. It seemed reasonable, for example, that a deep understanding of linear equation solving (say) was no longer needed as part of the engineering curriculum.

> ***"Practical understanding of the environmental, economic and physical constraints of a design is very important for arriving at a good compromise."***

As computers evolved and became more and more powerful, the software tools evolved and became more and more sophisticated. Whereas an engineering calculation formerly would require many man hours of programming, it would now be executed at a still higher level of abstraction where a few commands would suffice for quite complex calculations. As a reflection of this trend towards further abstraction engineering, textbooks now frequently have the title "Engineering subject X using high-level programming language Y" and the education consists of learning to solve problems from X using the tools from Y. The underlying principles in the calculations can be omitted.

Computer simulations have also tended to supplant physical demonstrations with special purpose equipment. Engineering schools would commission sophisticated experimental set-ups that the students could work with and show how a given theoretical concept played out in practice. Unfortunately the maintenance of such equipment was expensive and it was often felt that computer simulations would provide an alternative. The physical apparatus was therefore often relegated to the dustbin.

Computer simulations are, however, required in many instances by necessity. Many systems are now so complex that it is very difficult to access the details of the system for an individual engineer. It is impossible for a design engineer of a modern computer chip to be able to view and inspect every logical gate of the design. Only through the use of sophisticated computer software can such chips be designed. However, understanding of the underlying details through simpler actual experiments is still necessary in engineering education so that a fuller understanding of the fundamental principles underlying the systems can be appreciated.

Practical engineering can be viewed as practical optimization. That is, a successful engineering design is the result of compromises of factors such as cost, time and the ease of implementation in finding at least an approximate optimal solution of the given engineering problem. Practical understanding of the environmental, economic and physical constraints of a design is very important for arriving at a good compromise. This understanding does not come from reading about the constraints, but from practical experience. ■

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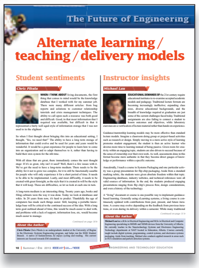
› Chris Pikula, Continued from page 10



Complexity is a difficult thing to measure, especially about what we ourselves create. Working through stages, building our magnus opus, creating a detailed analysis of a finished product, all of these things are more complex to outsiders than to those who create them. It can be intimidating to new users of such information, and thus careful measures need to be in place that topics have ways to be approached. It is utterly expected that eventually such a document would grow in scope such that no one person had a solid grasp of the contents. Trimming or forking of such documents would be expected in time, and would likely provide an interesting upgrade path for technology revisions.

How useful is an empty document? How useful is it to start such a thing? These were just a couple of the questions that I was asked when I talked about such a thing at my university. The first few sets of students that implement a living document have a much different experience than the following ones. Incorporating such an adjustment into a education program tends to create headaches, as institutions need to be able to teach certain skills, and a class that continually adjusts is hard to adapt a program to. The largest difficulty comes in that to teach such a class an educator needs to continually adapt far more than for a class that could be taught in similar ways for several years. This requires more time and effort than a normal class, so it would need to be seen that this practice can be valuable, and well worth the additional time. A bit of a chicken and an egg problem.

When looking at these issues, what comes up again and again is that there would be a great deal that would need to be planned out ahead of time. However once it is in place, then things should just work, in theory. This is a rationalization that I have seen repeatedly. Many work-hours are spent rolling up a system and implementing it, but very rarely is there work done to help set up a self-organizing, clear and implementable style. This could be anything, from making sure that in your wiki that articles are never more than five pages long, to having standards for information revision and deletion. The creation of styles is usually put off, as it can be difficult to know what you need before you have information, but once your living document has such a style, it can be very difficult to alter it. To pull an example from programming, I've seen two coders work on a project, each who had specific ideas on how to name their variables. When the time came to join their work, they each wanted the other to conform to their style, as to not need to redo much of their work. Imagine needing to redo several years worth of work from a living document! So it's utterly important that a plan is made ahead of time, or else the long term prospects of the document would be a tangled knot.

Living documents

Pros

- ☑ Many previous examples
- ☑ Creativity is encouraged
- ☑ Allow specialized and valuable work

Cons

- ☒ Cheating
- ☒ Too much information
- ☒ Hard to Evaluate with low student - teacher ratios
- ☒ Hard to prevent 'slacking'
- ☒ Hard to present
- ☒ Need to have a 'changeover'

So we can see that there are challenges with creating such knowledge archives. Some might say that this means that we shouldn't, but that's not the correct attitude to take. Every successful company implements similar works, so why shouldn't students be exposed to them, to get used to adapting to them, to gain the ability of how to contribute to something that will be worked on long after they are done. Living documents could be the students first encounter with a work-force knowledge base.

One of the first, and best outcomes of a implemented living document would be that it would allow for students to learn in separate ways. A good deal of time is spent in classes trying to teach students the same material over and over. This is unavoidable, as people learn in several different ways, and can have great difficulty learning in a way that isn't what they are suited for. A way of having a multitude of previous work would be that the separate learning styles could be seen and the new student could find the methods that work best for them.

As a student we see a great deal of concern and issue around the problems of cheating and academic conduct. The first, and largest concern is that Engineering is taught in many different ways by many different people. This diversity is important, as without it, we would all find similar solutions to problems. Certain problems have specific solutions, but the methods of implementation vary everywhere.

The ability for a student to have a small section that they need to become an expert in, for them to keep pace and connected with other contributors and to help deliver a large finalized revision would be a better example of work-force experience than anything I've ever experienced in my time as a student. This makes the transition from student to professional easier, and would make the student more competitive when it came to future opportunities.

An interesting use of a generational course like this would be to have it taught not once, but twice to students. The largest use would be in having the students who took the course previously become the leaders, where the new students would be brought into the organizational structure. This would provide an enormous positive impact to the students, as the ability to communicate information and to experience both sides of the worker-management schizm would provide an experience that could not be gained in any other fashion.

It would be interesting to have such a class become required, one where a work environment was the norm, and skills weren't taught and regurgitated, but where the skills were acquired through the need to implement and incorporate solutions. It's the reason we are all working anyways, right? ■

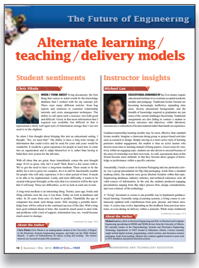
‹ Back to beginning

OPINION

by Doug Houseman

THE KEY TO NEXT GENERATION EDUCATION includes a complete environment, use of real tools and real problems to be solved. This means not only material from prior classes and students but a strong input of industry issues and problems along with the solution sets for each. Moving away from canned problem sets to real world problems not only helps accelerate the learning but prepares students for tackling problems in the real world. It also helps keep them interested - because these are not academic issues, but rather the real situations that they will walk into in the real world.

› Michael Lau, Continued from page 10



courses do use eLearning systems, it is important to note that its use does not necessarily make a course "alive." Rather, eLearning systems enhance the structure of guidance-based learning by providing interaction and evolution that would have been impractical to implement otherwise.

For example, contrast a standard course website, with a syllabus, lecture documents, and announcements, to a living guidance-based course using a typical eLearning system that includes: discussion forums for students to ask questions; student instant access to feedback, instructors, and course material; student examination of previous projects or material to gain insight into possible successes and failures; and instructor revision of course material. The former is relatively static with one-way communication; the latter teems with activity and interaction, constantly refreshed with new material. This online interaction would then connect with offline classroom activities, forming a positive feedback loop between them.

In light of all these advantages, there are significant challenges. The first is the most universal: technological illiteracy. William Gibson's popular quote "The future is already here—it's just not very evenly distributed" is very apt. People from a wide variety of socio-economic backgrounds enter post-secondary education, including ones who may have had limited access to computers and internet in their past. For others, technological illiteracy may be as subtle as knowing how to use a search engine, but not knowing how to navigate discussion forums or submit assignments online. Training and support structures are necessary to eliminate this barrier to success.

The second challenge is the mode of learning for both the student and instructor. Moving to a new learning model may be jarring at first; nearly every secondary school – and many post-secondary courses– still use the standard lecture format. Adapting to a new style of learning may be very detrimental to a student's success. For the instructor, making a course "live" through day to day maintenance of course material and feedback is just one of the many challenges he or she faces. In the classroom, there is increased pressure on an instructor's teaching performance, breadth of knowledge, and even time in and out of the classroom. Support structures may reduce pressures on both students and instructors in the short term, but the real long-term solution may lie in an institutional change to accommodate these learning models.

The last challenge, and perhaps the most important, is that of time management. Guidance-based courses, focused on open-ended activities, will naturally take up more class time for both the student and instructor. Therefore, the quality of these activities will be impacted if time allocations do not allow for meaningful work to occur. Activities outside the classroom are also a factor: how much time is expected for research, forum discussions, and so forth when a typical student has other commitments outside of their academic careers?

Guidance-based educational models offer many benefits over traditional models. However, there are significant challenges to overcome before they can be effectively put into practice. Further consultation into structural changes within educational institutions must be explored in order to avoid serious implementation issues in the future. ■

‹ Back to beginning

OPINION

by David G. Michelson

EVERY STUDENT ENTERS a degree program or an engineering course with his or her own unique set of experiences, expectations and abilities. No single mode of delivery will satisfy every student. Group application exercises and exposure to industry practice are extremely motivating but their impact is diminished if the students are lacking in the fundamental knowledge and problem solving skills that are associated with the subject matter.

Student time is limited so efficiency must be considered when selecting the mechanisms for imparting fundamental knowledge and problem solving skills. The nature of the material must also be assessed. In some disciplines, reading assignments are sufficient to impart the basic knowledge required. In engineering, the students themselves are requesting that adequate lecture time be allocated to rapidly and efficiently explain concepts and share problem solving strategies. When this is followed up with group application exercises and exposure to industry practice, success is inevitable.

Acknowledgements

Our most sincere thanks to our contributors for the careful reflection and imagination their pieces reflect; we simply could not have done it without you. The complete list of those assisting extends well beyond those who have shared their thoughts in writing. The *IEEE Canadian Review* gratefully acknowledges the many others who participated in phone interviews—the information and views they offered often being quoted, and their perspectives helping to refine the scope of the report. Still others directed us to sources we could not have connected with otherwise. Our gratitude on all of these counts to Wahab Almuhtadi of Algonquin College; Shawn Dearn of the Association of Canadian Community Colleges; Peter DeVita of DeVita Associates, Professional Engineers Ontario (PEO) President 2000-2001, Emerging Disciplines Task Force Chair; Allan Gilbert of Lakehead University; Roger Jones, Councillor-At-Large 2013-2014, Emerging Disciplines Task Force, PEO; and, Dennis Peters of Memorial University of Newfoundland, Chair 2013 Canadian Heads of Electrical and Computer Engineering. A special note of appreciation to Ron Britton of the University of Manitoba, Canadian Engineering Education Association President 2012, who was extraordinarily helpful in suggesting additional contributors and very generous with his time on the phone.

The idea of having a Special Focus on this theme was conceived of in 2011 by then Editor-in-Chief, Amir Aghdam and Managing Editor, Wahab Hamou-Lhadj, both of Concordia University. Over the following year, the editorial team, led by current Editor-in-Chief Wahab Hamou-Lhadj, Associate Editor Maike Luiken, and current Managing Editor Bruce Van-Lane, developed the concept of seeking multiple contributors for a series of pre-defined topics, framed to give as complete a picture as possible of current and upcoming issues.

This Special Focus is bound into the Summer 2013 issue (No. 70) of the *IEEE Canadian Review*, and also printed as a standalone document. Inquiries about obtaining hard copies can be directed to vanlane@ieee.org; comments/feedback can also be directed to this e-mail address. Electronic versions can be downloaded free-of-charge from the magazine's web site at http://www.ieee.ca/canrev/

Bruce Van-Lane, Managing Editor

By **Terrance Malkinson**

Engineering Management: What's New in the Literature?

THE US PRESIDENT'S Office of Science and Technology Policy has recently released a policy memorandum on increasing public access to the results of federally funded scientific research. Federal agencies with over $100 million in annual research and development expenditures are required to develop a plan for increasing public access to both printed and digital scientific publications. A number of mandatory key elements are included in the memorandum. The document is available at: http://www.whitehouse.gov/sites/default/files/microsites/ostp/ostp_public_access_memo_2013.pdf

3-D PRINTING is a technology in which a three-dimensional solid object of any shape is created from a digital model. Compared to traditional machining techniques which generally cut and drill, removing materials (subtractive); 3-D printing is an additive process, where successive layers of raw material are brought together to form an object. Applications are believed to be substantial. Jeroen P.J. DeJong and Erik DeBruljn discuss many aspects of the technology and its benefits and how it fits into the trend of open-source innovation with collaborative online communities. ["Innovation Lessons From 3-D Printing." MIT Sloan Management Review. 54(2):43-52. Winter, 2013. www.sloanreview.mit.edu].

SOME BELIEVE that innovation and new technology development might be slowing. This is discussed in "Has the Ideas Machine Broken Down?" [The Economist. Volume 406: Number: 8818. pp. 21-24. January 12-18, 2013 www.economist.com] and also in another article in the same issue [pg. 11] "The Great Innovation Debate". The articles examine innovation historically, its environment, and accomplishments, presenting arguments on both sides. The article concludes with the interesting suggestion that "institutions have become too rigid to accommodate truly revolutionary changes."

TIMOTHY MACK, President of the World Future Society, discusses how we may need to modify our methods of forecasting to include change while not discarding the wisdom of the past in an article in The Futurist ["Foresight as Dialogue" 47(2):46-50. March-April, 2013. www.wfs.org]. He discusses a number of forecasting "Rules of the Road" that provide a path between inclusiveness and adaptation; and discretion and convention.Ramez Naam discusses how the world's most critical challenges could be met by encouraging innovation in another article in the same issue of The Futurist ["How Innovation Could Save the Planet". pp. 24-31] Interesting graphs are provided on food production, oil production, and the plummeting cost of solar energy. The author introduces his article discussing the "best of times" and the "worst of times", and then discusses ideas as a resource expander, resource preserver and waste reducer; ideas that will stretch the limit; challenges ahead for innovation; and finally directions toward a wealthier, and cleaner future. An inset reviews the authors' recent book A Better World Is Just a Series of Innovations Away.

THE COVER STORY of the January 2013 issue of Scientific American [308(1), www.scientificamerican.com] is titled "The Future in 50, 100, and 150 years." A series of articles by futuristic thinkers provide realistic visions of scientific and technological milestones that are envisioned for the world. The Economist published its inset "Technology Quarterly" in the 1 December 2012 issue [Volume 405, Number 8813, www.economist.com]. This 24-page inset provides snapshots of emerging and forecasted technological developments. Discussions focus on computer 3-D printing, medical add-ons for smartphones (Star Trek's "tricorder"), detecting oil spills in the arctic, indoor personal navigation technology, eye tracking, a profile of the drone father, Abe Karem, and many other brief articles of interest.

THE SPOTLIGHT FOCUS in the January-February issue of Harvard Business Review[91(1-2):57-64, www.hbr.org] discusses "The Future of Knowledge Work." Three articles: "Redesigning Knowledge Work" (pp. 58-64), "The Third Wave of Virtual Work" (pp. 66-73), and "Making Star Teams out of Star Players" (pp.74-78) focus on the management, future and motivation of knowledge workers. In today's world real success is dependent on effective management of both professional and technical employees. Christine Porath and Christine Pearson discuss the high cost of rudeness at work in a second article in the same issue of Harvard Business Review ["The Price of Incivility." 91(1-2):114-121]. The authors discuss the rise and types of rudeness on the job. Based on 14 years of interviews with more than 14,000 people in the United States and Canada, they have tracked the prevalence, types, causes, costs, and cures of incivility at work. They go on to provide strategies to counter rudeness.

IMPORTANT LESSONS learned with regard to archiving of data emerge from two reports in the December 2012 issue of IEEE Spectrum [49(12), www.spectrum.ieee.org]. The cover story "Finding the Source of the Pioneer Anomaly" [pp. 38-54] describes the challenges associated with finding, reconstituting old (40-year) data stored on obsolete recording media, and then analyzing the information to solve an important scientific question of why the two pioneer spacecraft launched in 1972 slowed unexpectedly. The second article "Forever Flash" [pp. 11-12] describes a new technology that will allow flash memory to last longer by healing itself. Technology used in USB devices wears out after being recorded and erased about 10,000 times. The lessons learned from these reports are stated eloquently at the end of the Pioneer Satellite article ""Every experiment needs a clear plan in place to ensure that a record of the original observations is still available and readable even decades into the future" [pg. 62].

MORE THAN fifty short articles — categorized under the headings of business and economics, energy, environment and resources, food and agriculture, habitats, health and medicine, information society, science and technology, and world affairs — provide valuable insights important to personal and career success in the annual Outlook feature published byThe World Future Society. Authoritative forecasts designed to provoke thought and inspire action for building a better future today [The Futurist, 46(6): magazine insert, November-December 2012.www.wfs.org]. ■

SPACE MAPPING

Have You Ever Wondered About The Engineer's Mysterious "Feel" For A Problem?

by **John Bandler**

Eureka Moment

"Come and look at this," Steve Chen said in 1993.

I still see him in the doorway, beckoning me, and I remember where his computer stood and how it was oriented as I leaned towards its screen seconds later for my first glimpse at the results of a novel approach to automated design, a technique that I believe encapsulates the engineer's mysterious "feel" for a problem—an issue that had dogged my 30-year immersion in the art and science of optimization for computer-oriented engineering design.

Why had this concept taken so long to reveal itself?

Back-Story

I recall two rebukes in the 1960s during my undergraduate years at Imperial College, London, that were influential in my brush with the engineer's feel for a problem. At issue were my write-ups of laboratory experiments. In the first case, a teacher asserted that if my experimental results didn't fit accepted theory, it was my duty as an engineer to make them fit. The second rebuke concerned my plots of measured triode valve characteristics. Apparently I took the instrument manufacturers' stated error bounds too seriously: the tolerance spreads that I had estimated for my voltage-current characteristics were deemed too broad and hence (statistically) unreasonable.

These "practical observations" surely disoriented me. Later, designing and constructing stable, broadband tunnel-diode (negative resistance) amplifiers as per my Ph.D. requirements proved troublesome: my waveguide designs largely ignored possible machining and fabrication tolerances, and uncertainties due to mounting effects and mechanical pressure for the devices under test. I also ignored model uncertainties, particularly in the fragile tunnel diodes. I then spent months experimentally wrestling stable amplification from my experimental amplifiers.

It didn't occur to me to try to explain what the display on my even then ancient spectrum analyzer confronted me with—in retrospect, chaos. Had I changed the course of my research towards a theory that predicted what I observed, who knows what discoveries I might have made? Someone else invented chaos theory.

I rubbed shoulders with circuit theory "synthesis" purists and "nuts-and-bolts" engineers, most of whom objected to the use of digital computers for solutions to electrical engineering design problems—other than in narrowly interpreted analysis studies (solution validation). In the 1960s and 1970s, academics and others in positions of influence deemed computer-aided design and optimization as "not engineering," to be taken seriously only because these activities would hurt engineering students. Engineers who scribbled on the backs of envelopes thereby demonstrated their "feel" for a problem (and hence their expertise) while those who preferred "closed-form" solutions demonstrated their agility in the realm of mathematics.

While I became attracted in my undergraduate years to methodologies for design that accounted for manufacturing tolerances and statistical uncertainties, I did not initiate research in this area until 1970. I introduced post-production tuning into the so-called "design centering" and tolerance assignment problem [1] and went on to advance yield-driven design and design with tolerances. A key paper (Bandler, Liu and Tromp [2]) further embodies uncertainties in component modeling, in manufacturing and in so-called parasitic effects. All this started more than fifteen years before implementation of these features in commercial microwave CAD software. The microwave community at large saw no need for this technology, until championed by Robert Pucel of Raytheon in the 1980s. My paper with Steve Chen [3] encapsulates the state of the art.

In the late 1970s I formed collaborations with Radek Biernacki (now with Agilent Technologies) and mathematician Kaj Madsen of the Technical University of Denmark. Radek joined me for two years as a postdoctoral fellow and introduced me to analog fault diagnosis, and Kaj, who spent a sabbatical summer with me, led me to his robust nonlinear optimization algorithms.

The Debut of OSA

I formed my company Optimization Systems Associates (OSA) in 1983. OSA's first major assignment was to reengineer the inhouse simulation and optimization software for the flagship product line of the aerospace technology company ComDev (Cambridge, Ontario): microwave multiplexer (waveguide) hardware for communication satellite applications [4], [5].

EEsof Inc. of Westlake Village, California, commissioned me in the mid 1980s to develop new optimization tools for their recently released circuit simulation tool Touchstone.

Meanwhile, in 1985, Robert Pucel of Raytheon Research Division in Lexington, Massachusetts, asked me to do a feasibility study for yield-driven circuit design. Following its success, he invited OSA to contribute to Raytheon's initiative towards the Microwave and Millimeter Wave Monolithic Integrated Circuits (MIMIC) Program. This brought OSA together with software vendor Compact Software of Patterson, New Jersey. Encouraged by Bob Pucel, one of Compact's immediate aims was to avail itself of a yield-driven design capability.

I asked Radek Biernacki to rejoin my group. With Q.J. Zhang, Steve Chen, Monique Renault, and others, we reengineered the immense SuperCompact Fortran code and contributed to Compact Software's Microwave Harmonica (for harmonic balance simulation). OSA introduced yield-driven design, engines for (statistical) simulation and optimization, and entirely new documentation to Compact Software's premier products.

Our involvement with Compact Software and Raytheon ended in 1989.

OSA Goes Solo

OSA initiated its own commercial optimization-oriented software products in 1988 [6].

Meanwhile, Ansoft Corporation, Hewlett-Packard, Sonnet Software and others offered simulators that solved Maxwell's equations to validate complex microwave structures.

I had frequently spoken of driving electromagnetic solvers in an optimization loop. So I asked both Ansoft Corporation and Hewlett-Packard to send OSA their simulators, without charge because OSA was a shoe-string company and because I believed we offered value to them. Ansoft was unresponsive; Hewlett-Packard representatives openly ridiculed me: surely I knew that their "full-wave" electromagnetic simulator might take, if not hours, perhaps days or weeks on a useful structure to complete a frequency sweep for just a single set of design parameters?

After Jim Rautio, founder and president of Sonnet Software, freely availed us of his flagship electromagnetic simulator "***em***," OSA benchmarked 1992 with "Empipe." Empipe [6] could incorporate, on-the-fly, simulations by Sonnet's ***em*** into OSA's user-friendly optimization system OSA90, providing RF and microwave designers for the first time not only electromagnetics-based optimization but also yield-driven electromagnetic optimization for structures with arbitrary geometries, albeit for modest sized problems.

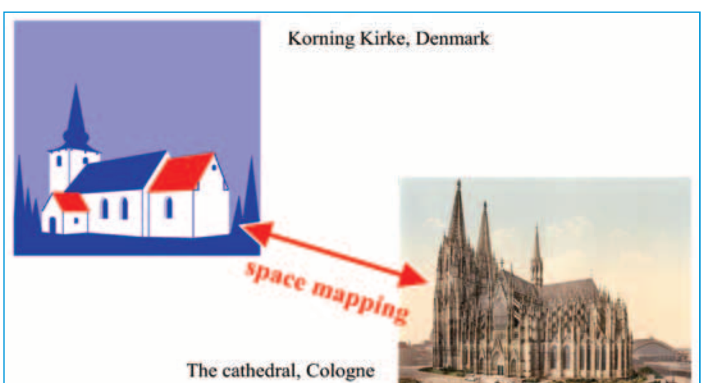


Fig. 1. In the summer of 1993, in the outskirts of Copenhagen, space mapping is conceived as an association of models. [Cologne Cathedral from The Photochrom Print Collection, Library of Congress; Korning Kirke courtesy Asbjorn Lonvig.]

It still took weeks before Hewlett-Packard agreed to send us their electromagnetic simulator "HFSS" (high frequency structure simulator) free of charge. And once Ansoft got wind of our success with HFSS, they promptly sent us their own "Maxwell Eminence" simulator.

The era abounded with challenges and surprises [7]. In Dan Swanson's words, "[OSA90 is] the first commercially successful optimization scheme which included a field-solver inside the optimization loop" [8].

Then, on November 20, 1997, after mutual visits and demonstrations in Dundas, Ontario, in Santa Rosa, California, and elsewhere, Hewlett-Packard acquired OSA. Weeks later, Steve Chen and Radek Biernacki, OSA's principal contributors of the time, relocated to Santa Rosa.

The Birth of "Space Mapping"

In 1993 Salvador Talisa of Westinghouse Corporation challenged us with the design of a certain high-temperature superconducting (HTS) filter [9]. I asked graduate student Peter Grobelny to see what OSA's Empipe could achieve with Sonnet's ***em***.

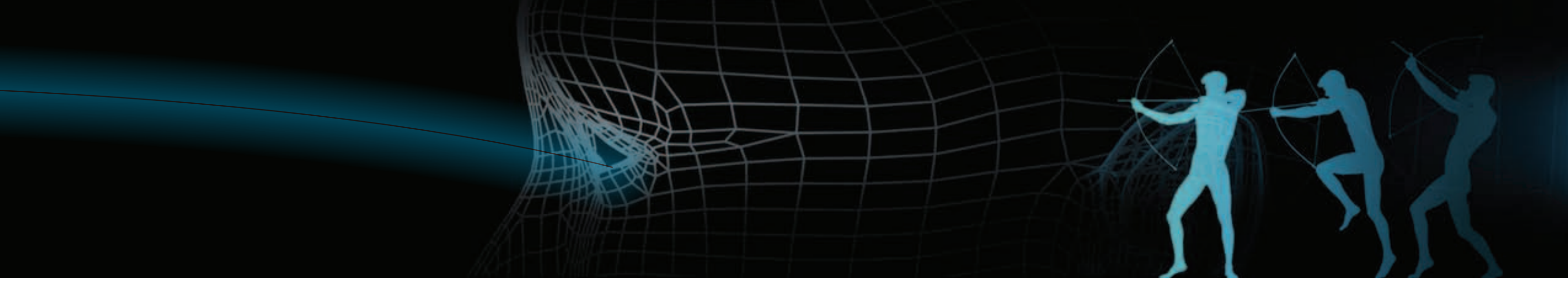
Bad news. It took some two weeks of CPU time on our Sun SPARCstation 1 for a full evaluation of just the starting point (the initial design) along with the six perturbed points (sets of parameter values) for approximating the first-order derivatives with respect to the filter's six design variables. I estimated up to two years of CPU time for a formal optimization using the conventional approaches embodied in OSA's software—a result dramatically at odds with what a skilled engineer might have achieved via an experience-tested "feel" for the problem.

That summer (1993), I spent a week in discussions with Kaj Madsen, both in Denmark and at a conference in Sweden. I recall my obsession—and, not surprisingly, his startled skepticism—while we strolled in a forest with the notion of "model," the recognition of "real" objects (churches, houses) on the horizon and "mapping" them to an element of a possible "library" of preconceived images (models) in one's brain. More specifically, extracting certain essential features of the objects that allowed them to be recognized (by virtually anyone), named, and manipulated in an as yet indefinable way. A question was, how could one associate these "fuzzy" features with a related "model" so as to drive a design optimization of the object without expending too much computational effort on the object itself. The process seemed at once obvious and hidden; iteration was surely required, as well as scaling, shifting, rotating, twisting, and elimination of detail. See Fig. 1.

I was searching not for mathematics but for the engineer's "feel."

On my return flight from Frankfurt to Toronto I jotted down my ideas. Back in Canada, I handed my notes to my collaborator Steve Chen to see if he could make sense of what I had written. Two weeks or so later, after I had all but forgotten about my scribbling, Steve asked me to look at his computer monitor. I saw an equal-ripple response. Nothing unusual: equal-ripple responses from optimized filters were customary. The astounding difference here, he pointed out, was that he had produced this response not by a fast equivalent circuit model within our own OSA90, but by Sonnet Software's ***em***—in just three simulations, driven by OSA90. My notes, Steve Chen said, were correct, apart from some redundancies in notation.

Space mapping was born.



In effect, by cleverly exploiting an underlying surrogate, the electromagnetic simulator was taken out of the classical optimization loop: the engineer's mysterious "feel" was emerging.

Radek Biernacki should be credited with coining the expression "space mapping." (Memory has a habit of playing tricks, so I checked this recently with him.)

In the following sections, I attempt to explain and illustrate the many faces of space mapping.

The Essence of Space Mapping

The sketch in the sidebar to the right roughly follows our so-called "aggressive space mapping" (ASM) approach, published in 1995—particularly when fine model data is frugally exploited [10]. The key to ASM was our utilization of Broyden's famous "rank-one update" for estimating the Jacobian involved in the numerical solution of the relevant nonlinear equations [11]. It was Kaj Madsen who first realized a space mapping iteration update as a classical quasi-Newton process.

Most researchers who subsequently confirmed our space mapping methodology (and published their results) exploited the "aggressive" approach—ASM.

Why didn't mathematicians advance this generic formulation? Simple. They stayed away from the messy engineering side of the modeling coin. So long as only localized information is exploited by their algorithms—function values, first-order derivatives, and possibly second-order derivatives—only a "conventional" attack is feasible. Put another way, the "**parameterized model**" that drives the conventional mathematical optimization process is limited by its generic assumptions (linear, quadratic, i.e., local modeling of functions). For engineering design, space mapping is underpinned by a "quasi-global" formulation: a well-conceived, parameterized model based on engineering knowledge, that represents—hence, is "physics-based"—expensive "fine" model behavior relatively well. An appropriate algorithm can then yield excellent designs after only a handful of fine model evaluations. Under certain circumstances, between two and four such simulations may suffice, unlike the tens, hundreds or even thousands required by conventional optimization, even if exact gradients (first-order sensitivities) are available.

Then why didn't the design experts explicitly formulate space mapping in a manner widely understandable? They often used it and continue to do so. (In fact, at about the same time as we published our work, Tony Pavio of Texas Instruments did utilize a bona fide space mapping process to solve filter design problems [12], [13]). Simple, also. Engineers stayed away from the increasingly sophisticated nature of the (by then canned) solution techniques. For example, the basis of aggressive space mapping is the formal solution of nonlinear equations [10].

I offer here a simplistic explanation. To formulate the space mapping concept, you need a comfortable foot in the domains of both engineering and mathematics; not one simulator (model), but **two** simulators (models) are concurrently harnessed, ones that must be coupled and interact intelligently on-the-fly off each other. One simulator, the nonlinear, physics-based, quasi-global "coarse" model drives the also nonlinear, high-fidelity physics-based "fine" model.

A Space Mapping Methodology

Preliminaries

Study a discipline/conduct experiments/become an expert.

Develop a library or resource of fast, parameterized coarse models (surrogates) and inexpensive ways of invoking them.

The Specific Problem

Focus on the device under test/the real-life situation/the fine model/the expensive-to-compute system (there are many labels: validation, high fidelity, …).

Select a representative (reference) coarse model, preferably capable of meeting your design specifications ("implicit space mapping" exploiting preassigned parameters and "output space mapping" that corrects or shifts responses can aid in this process).

The First Iteration

Optimize your fast coarse model until your specifications are optimally exceeded (if possible).

Assign the resulting parameter values to the fine model.

Expedite (simulate, run) the fine model.

If the specifications are met (implying that your coarse and fine models are sufficiently aligned), **STOP**.

Subsequent Iterations

BEGIN: to better match the observed behavior of the fine model use available fine model data (generate more, if necessary, but frugally) to augment/update your coarse model with a mapping. We call this step **parameter extraction** (a surrogate update, a training process).

Optimize your mapped (space-mapping-augmented) coarse model until your specifications are optimally exceeded (by this step they preferably should be).

Assign the resulting parameter values to the fine model.

Expedite (simulate, run) the fine model.

If the specifications are met (implying that your coarse and fine models are sufficiently aligned), **STOP**.

If a specified number of iterations (or other stopping criteria) are reached, **STOP**.

Go to **BEGIN**.

The process can fail ("intuition" often fails); remedies are discussed in the literature. You may consider "implicit space mapping" (see a later section) to improve the coarse model.

A comment (for advanced readers). In the original or "input" space mapping methodology, an explicit re-optimization of the mapped coarse model is averted by assuming that the initial coarse model optimally satisfies the design specifications, and that any manipulation or mapping of the input parameters would not improve the situation. In this case, the aim of the space mapping optimization process is to predict a set of fine model design parameters such that the fine model response matches the already satisfactory (target) coarse model response.

In the field of engineering, parameterized, physics-based coarse models abound, covering every conceivable variation from super-fast analytical or empirical to slower, coarse-mesh numerical.

When an engineer explains a clever design methodology based on tradition or experience, it often seems impossible to escape from the jargon of the specialty in question. But that mental flexibility is exactly what is needed to explain the space mapping concept and make it accessible. In fact, hand-waving can illustrate the concept—no "expertise" needed. Following the public unveiling of the space mapping concept in 1994, it has often reappeared in different guises.

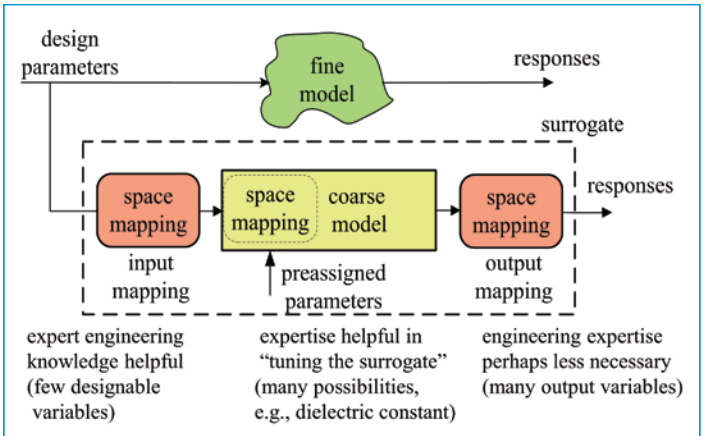


Fig. 2. The evolution of the space mapping concept from 1994 to 2004.

The Original Input Space Mapping

In our 1994 paper [14], we first proposed space mapping as a simple way to mate the efficiency of circuit optimization with the accuracy of electromagnetic solvers. The approach was conservative, the forerunner of later work in enhancing model libraries: several fine model simulations were necessary for developing a serviceable mapping upfront. The aggressive space mapping methodology [10] followed later.

Input space mapping can be expressed as

$$\boldsymbol{x}_c = \boldsymbol{P}(\boldsymbol{x}_f)$$

where $\boldsymbol{x}_c$ and $\boldsymbol{x}_f$ are vectors that represent, respectively, the coarse and fine model (input) design parameters. The mapping is expected to be near-linear in the case of well-matched models.

As a traditional first step, conventional optimization is carried out using the coarse model. The resulting solution is denoted $\boldsymbol{x}_c^*$.

Once a mapping is established, an inverse determines the fine model solution as the image of $\boldsymbol{x}_c^*$, namely,

$$\boldsymbol{P}^{-1}(\boldsymbol{x}_c^*)$$

The required parameter extraction step in effect calibrates the coarse model against the fine model to minimize differences and off-sets between them, and permits an update of the mapping. In general, to make the overall process desirable, the coarse model should be significantly faster (a hundred or more times) and much cheaper to execute than the fine model.

Space Mapping: The Experts' First Impressions

Vittorio Rizzoli is world-renowned in nonlinear systems and microwave electromagnetics. When I faced him across his huge desk in his office in Villa Griffone (University of Bologna, Italy), the space mapping concept had not yet been announced. I asked him to listen for a moment while I sketched my idea with a few words accompanied by some hand waving. Then I waited. For a moment his stare was blank. Seconds later a look of amazement swept across his face, a look that said, "Of course!" I'm not sure whether he pounded his desk.

In 1994, in a hall of the San Diego Convention Center that overlooked the harbor, former EEsof cofounder Bill Childs was one of many who had gathered around me in my "open-forum" (poster) presentation—my first publication of space mapping. He waited until the crowd had thinned before protesting that I was concealing the key to my algorithm. Pointing at the simple formula that mapped $\boldsymbol{x}_f$ to $\boldsymbol{x}_c$ I assured him that I had divulged absolutely everything. Unconvinced, he threatened to bring his concerns to the attention of the conference's technical program committee.

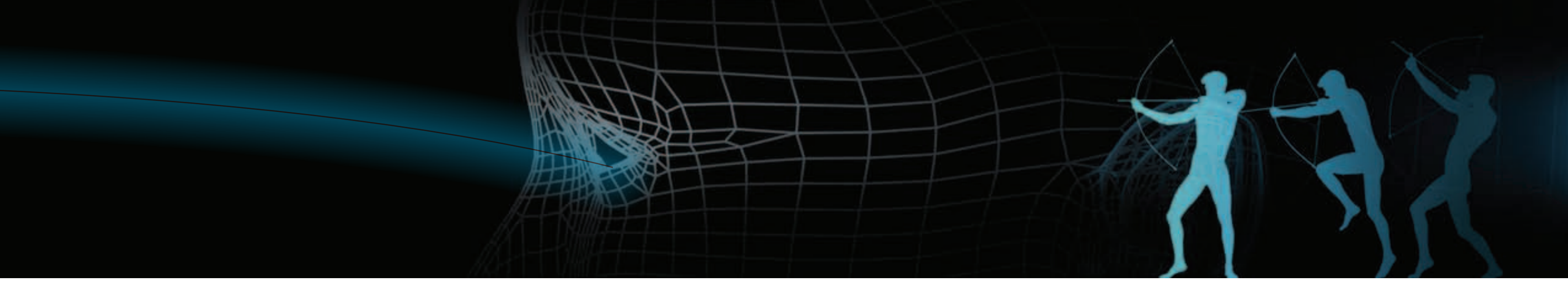
(Ironically, I had toyed with the idea of keeping space mapping secret; exploiting the process in OSA's software to possible huge advantage: other vendors might have taken years to catch up.)

After the session, I found Ralph Levy—a respected consultant in the microwave filter business—relaxing in an armchair. Knowing that he hadn't visited my poster presentation, I sketched the space mapping concept by hand-waving, as I had done with Vittorio. His eyes lit up almost immediately. "I get it!" he said and instantly recalled designing a filter in which he aligned (calibrated) his circuit response against that of an electromagnetic simulation at a certain frequency point and found that his updated filter model then readily facilitated a good solution.

A noteworthy item in the history of OSA is OSA's failure in 1995 to win a contract under the MAFET (Microwave and Analog Front-End Technology) Program from DARPA (the US Defense Advanced Research Projects Agency). The title of our ambitious proposal was "Space mapping techniques for intelligent, automated, direct optimization-driven electromagnetic design of microwave and millimeter-wave circuits."

The OSA90/hope user's manual was updated to include a very early space mapping option [15].

Rice University professor and mathematician John Dennis and I first met in 2000 in Lyngby, Denmark, at the First International Workshop on Surrogate Modelling and Space Mapping, co-organized by Kaj Madsen and myself [16]. He and his team had already explored algorithms for the management of surrogates for optimal design. The space mapping concept proved new to them. Following the workshop, he wrote, "The idea of a space map is very appealing. I had not heard of it before, but it seems to have proved its worth in electrical



engineering. John Bandler, an electrical engineer and entrepreneur from McMaster University in Ontario, seems to have originated the idea, and he has a stable of graduate students applying it in several variations" [17].

The Evolution of Space Mapping

An early industrial enthusiast of space mapping was Jan Snel of Philips Semiconductors, who engaged me in 1998 to instruct him and his colleagues in the art. In turn, Jan inspired academic research in The Netherlands in this area [18], [19], [20], [21].

The space mapping approach has evolved over the past twenty years into a space mapping technology. The half-way point is demarcated by a review of the state of the art [22] and a paper that reviews implicit and output space mapping [23]. These papers are co-authored with some of my important collaborators of the time; they already introduce illustrative examples of an everyday nature—the so-called "cheese-cutting" and "wedge-cutting" problems. These examples, which I conceived while attending an opera in Copenhagen for a seminar to Kaj Madsen's students the next day, are launching pads for explanations that anyone should be able to grasp.

The space mapping concept can be layered with, augmented by, and reinvented in conjunction with other modeling schemes, parametric or otherwise, including artificial neural networks—neuro-space mapping [24]. The drive to automate and make the processes more robust continues (my colleague Slawek Koziel, now with Reykjavik University, Iceland) [25], [26], [27].

Space mapping optimization belongs to the arena of surrogate-driven optimization methods [28], [29]. Space mapping is distinguished by the effective utilization of enhanced (mapped) quasi-global coarse models that harness the essential features of the fine model in the domain of interest. Vicente offers an overview [30].

By 2003, my group offered several variations of space mapping, e.g., input (the original form), implicit (using preassigned parameters), output (employing direct manipulation of responses, etc.). See Fig. 2 on page opposite. Each form enjoys advantages and disadvantages, and can be used in concert.

In the input (original) space mapping process, a typical problem has relatively few designable (optimizable) variables. Here, expert engineering knowledge is helpful. Implicit space mapping exploits preassigned parameters—those many possible parameters of a real structure that are usually predetermined and fixed ahead of formal optimization. In the coarse model, however, they are free to be used to improve the alignment between the coarse and fine models. Many possible preassigned parameters suggest themselves; popular in electromagnetics-based design is the dielectric constant, which can be decomposed and directed to aid in independently "tuning" various sections of a structure. Thus, expertise for "tuning the surrogate" is helpful. Engineering expertise is perhaps least necessary in executing output space mapping, since the technique consists of shifting or manipulating the coarse model responses directly at the response level. Many output variables are usually involved, and a robust mathematical platform is desirable.

The invasive (expertise required) tuning space mapping process exploits tuning ports and simulator-based models [31]. The surrogate is a tuning model based directly on the fine model.

Space mapping and its spin-offs continue to flourish in various engineering practices, for example, neural-based space mapping for large-signal statistical modeling of nonlinear devices [32], [33]. Recent technical reviews can be found in *IEEE Microwave Magazine* [34], [35], [36].

The essential difference—oversimplified here for the sake of discussion—is that space mapping arises out of an understanding of the "feel"

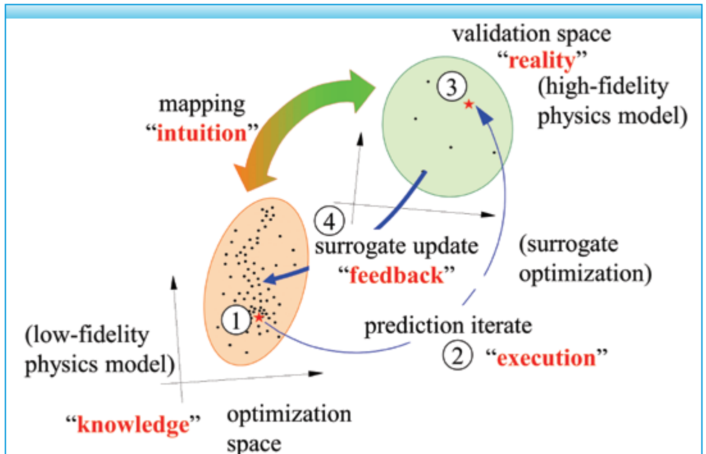
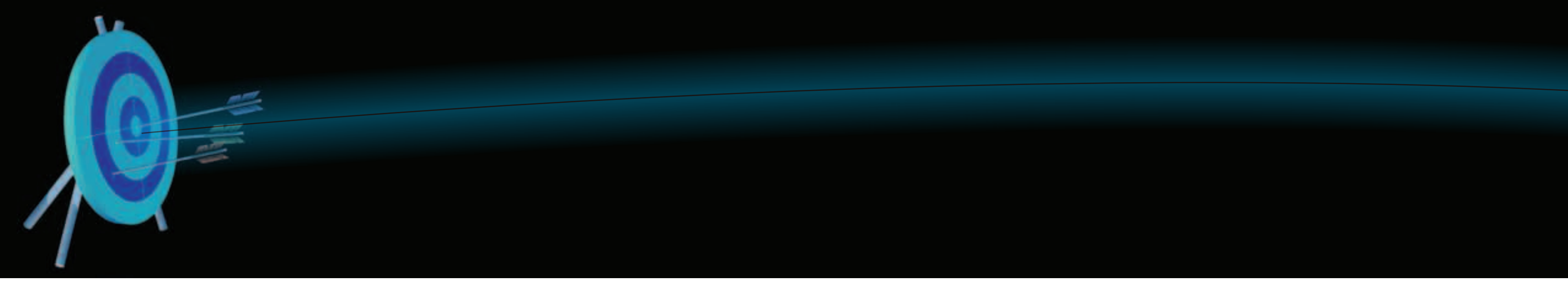


Fig. 3. The space mapping concept as it has evolved over the years (Bandler *et al.* 1994-)

that an experienced engineer has for a complex engineering design problem, while the generic surrogate-based approach arises from the "feel" that a mathematician has for a generic optimization problem. Confusion sets in when words like surrogate, model, and simulation are tossed around arbitrarily and interchangeably to mean almost any representation of anything. One thing is for sure: surrogates, models, and simulations imply underlying knowledge, nowadays typically the physics embodied in a simulator. How this knowledge is **cognitively manipulated**—from the "inside" or from the "outside"—depends on whether the designer is oriented towards engineering or mathematics (or perhaps both).

A Semi-Technical (Advanced) Explanation

My current thinking about the space mapping concept is depicted by Fig. 3. The validation space ("reality") represents the fine model, for example, an expensive-to-compute, high-fidelity physics model. The optimization space, the only arena in which iterative, conventional optimization is carried out (indicated by the multitude of points), incorporates the coarse (or surrogate) model, for example, the low-fidelity physics or "knowledge" model. There is a prediction or "execution" step, where the results of the mapped coarse or surrogate model are assigned to the fine model for validation. Then, if the specifications are not satisfied, relevant simulation data is transferred back to the optimization space ("feedback"), where the mapping-augmented coarse model or surrogate is updated (enhanced) following an iterative optimization process we term "parameter extraction." The mapping element



itself embodies the "intuition," certainly essential to the so-called "feel" for the problem. It "distorts" the coarse model to align it with the fine model.

Cognitive Analogies

In 2002, while waiting at the Copenhagen airport for a flight to Frankfurt after visiting Kaj Madsen, I picked up a copy of *The International Herald Tribune* for February 21, 2002 [37]. On page 7 I found an article by Sandra Blakeslee reprinted from *The New York Times* entitled "The brain's automatic pilot."

Having just addressed Kaj Madsen's students on everyday interpretations of the space mapping methodology (e.g., the aforementioned "cheese-cutting" problem), I was struck by the analogy. Blakeslee wrote, "[certain brain] circuits are used by the human brain to assess social rewards …" and that "… findings [by neuroscientists] … challenge the notion that people always make conscious choices about what they want and how to obtain it." Notice that notions of intuition, unconscious choice, or "feel" manifest themselves here.

Blakeslee quoted Gregory Berns (Emory University School of Medicine): "… most decisions are made subconsciously with many gradations of awareness." She also quoted P. Read Montague (Baylor College of Medicine): "… how did evolution create a brain that could make … distinctions … [about] … what it must pay conscious attention to?" The implication that (Darwinian?) evolution has **optimized** what humans need to pay attention to and how to respond is intriguing. For example, a child is prone to ensure that his or her slice of birthday cake is no smaller than anyone else's.

Blakeslee continued with "… the brain has evolved to shape itself, starting in infancy, according to what it encounters in the external world" and that "… much of the world is predictable: buildings usually stay in one place, gravity makes objects fall …" The ideas of experience, expertise, or some sort of "feel" manifest themselves here. And there is no mention of any **conscious** technical expertise in the sense of any mastery of the mathematical formulas or dynamical equations that might model these processes.

I add my own nomenclature and interpretation in bold and square brackets, as follows, to expose the analogies with my technical perspective of space mapping. Blakeslee wrote, "As children grow, their brains build internal models [**coarse models, surrogates**] of everything they encounter, gradually learning to identify objects …" Not a few things, but **everything**. Further, "… as new information flows into it [**fine model data**] … the brain automatically compares it [**parameter extraction**] with what it already knows." "… if there is a surprise … the mismatch [**response deviation**] … instantly shifts the brain into a new state [**surrogate update, switch coarse model, start on a new model, …**]." Finally, "Drawing on past experience [**knowledge + intuition**] … a decision [**prediction, execution**] is made …"

The foregoing appears entirely intuitive, based on experience, and the memory and processing power of the brain, whether human or animal—animals walk, hunt, fly, etc., obviously without consciously formulating any dynamical equations.

On page 7 of a recent book [38], Eagleman writes, "The brain runs its show incognito." For example, "In 1862, the Scottish mathematician James Clark Maxwell developed a set of fundamental equations that unified electricity and magnetism. On his deathbed, he coughed up a strange sort of confession, declaring that 'something within him' discovered the famous equation, not he." On page 17 Eagleman writes, "… the mind" [according to Freud] … "was rather like an iceberg, the majority of its mass hidden from sight."

On page 33, "Helmholtz (1821-1894) had begun to entertain the suspicion that the trickle of data moving from the eyes to the brain is really too small to account for the rich experience of vision. He concluded that the brain must make assumptions about the incoming data, and that these assumptions are based on our previous experience."

Previous experience implies an arsenal of physics-based "coarse" models, candidates of which are updated "on-the-fly" by incoming data, and harnessed in a decision-making process. Then "… the brain uses its best guess …"

Eagleman deepens his observations on page 48. He suggests that "We're able to catch baseballs only because we have **deeply wired internal models of physics** [bold is my emphasis]." That "These internal models generate expectations about when and where the ball will land given the effects of gravitational acceleration." He explains that "That the visual cortex is fundamentally a machine whose job is to generate a model of the world." On page 49, he continues with "This unpredicted information adjusts the internal model so there will be less of a mismatch in the future."

Again we see the idea of the development of suitable coarse models and their enhancement, for example, through a parameter extraction process followed by a space mapping update.

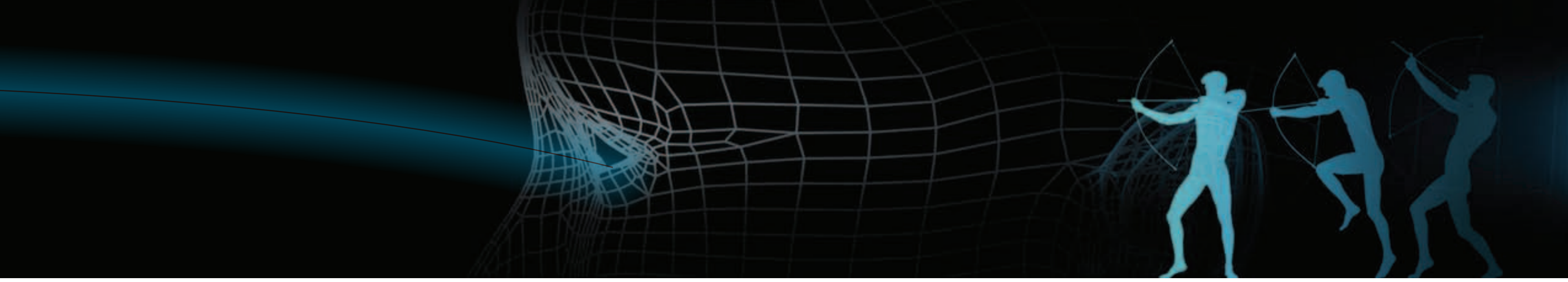
The Grand Design

Hawking and Mlodinow [39] (p. 45-46) write that, "it is pointless to ask whether a model is real, only whether it agrees with observation." "The brain, in other words, builds a mental picture or model." (p. 47). On page 172, they declare that "Our brains interpret the input from our sensory organs by making a model of the outside world … trees … people … other universes …"

How good need a model be? The authors' criteria on this are found on page 51. They write, "A model is a good model if it:

1. Is elegant
2. Contains few arbitrary or adjustable elements
3. Agrees with and explains all existing observations
4. Makes detailed prediction about future observations that can disprove or falsify the model if they are not borne out."

This suggests the notion that the modeling process itself—in the present case the manipulation of a mapped (mapping-augmented) quasi-global coarse model—is a model.



Selecting a Pair of Shoes

After a brief brush with “the grand design” of the universe we turn to the most down-to-earth of activities, that of selecting a pair of shoes that fit. See Fig. 4. This example illustrates everyday common sense formalized as a space mapping process.

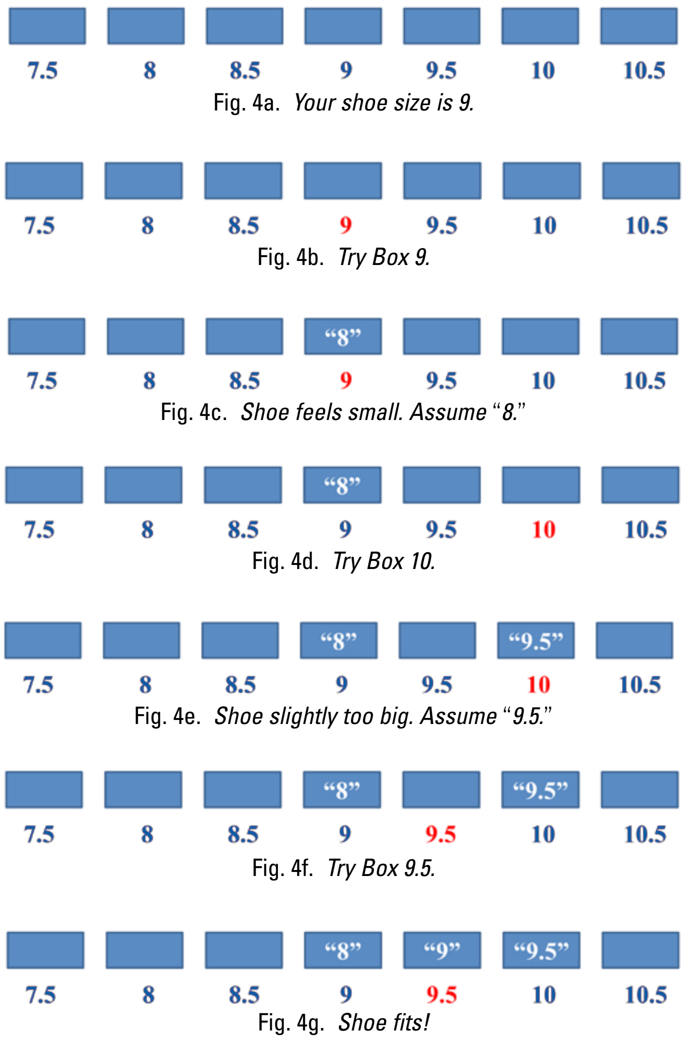


Fig. 4. A “shoe-selection” problem.

You are shopping for shoes in a shop you are unfamiliar with. The shoeboxes of interest are identified by numbers (presumably) representing the sizes of their contents: Box 7.5, Box 8, Box 8.5, etc. Assume for simplicity there is only one available width: normal. Prior knowledge: let your shoe size be “9” and your width normal. Your first attempt would surely be a look into Box 9. You try on a shoe from Box 9; it feels small; perhaps it’s an “8,” a whole size too small. You would likely next select Box 10. You try on a shoe; it feels too roomy; perhaps it’s a “9.5,” half a size too large. Your next, and hopefully final, choice would surely be Box 9.5. If shoes from this box don’t quite fit, you would likely give up this particular line of shoes.

Note that you tried three likely sizes so far; not too frustrating. You made certain assumptions about the labeling of the available selection. The available shoes seemed smaller than your expectations and were not too uniformly graded—if your judgment can be trusted.

We could add shoe widths, for example, and expand this illustration to two dimensions.

Some Applications

A distinguished team at ComDev [40] optimized a 10-channel output multiplexer involving 140 optimization variables. See Fig. 5 on the following page for the optimal responses of the multiplexer, comparing ideal (circuit theory) responses, responses calculated by the electromagnetic simulator HFSS, and subsequent measured responses. Aggressive space mapping was used.

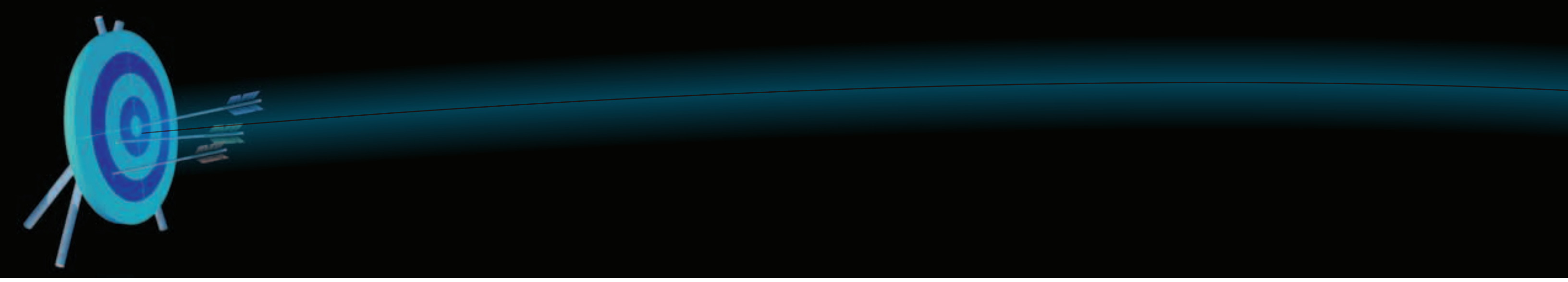
Another illustration is the optimization of a microwave hairpin filter using implicit space mapping and the simulator ***em*** from Sonnet Software as fine model [34].

Redhe and Nilsson [41] applied space mapping to a structural optimization problem involving a finite element vehicle model requiring computing times of the order of 100 hours. For a Saab 9-3 driven straight into a steel barrier at 56 km/h, they report that space mapping cut calculation times by three fourths compared with traditional response surface optimization methods; and penetration of the passenger space was reduced by 32 percent without compromising other crashworthiness parameters.

Further illustrations—too numerous to list here—encompass electromagnetics-based microwave circuit design, active device modeling, device modeling techniques that combine space mapping with artificial neural networks [42]; antenna design; design optimization problems in the fields of electronics, photonics, and magnetic systems [43],[44],[45],[46]; and applications in chemical, civil, mechanical, aerodynamic, aeronautical and aerospace engineering systems.

Ben-Ayed *et al.* [45] and Berbecea *et al.* [46] used output space mapping to address the optimal design of electromagnetic devices. Banda and Herty applied space mapping to the dynamic compressor optimization of gas networks [47]. Lass *et al.* wanted to solve optimal control problems for real-world applications [48]. Marheineke and Pinnau [49] performed a feasibility study for transport processes coming from the fields of fluid dynamics, semiconductors and radiation. Vivier *et al.* exploited output space mapping [50]. Prieß and Slawig [51] applied aggressive space mapping to the optimization of a one-dimensional marine ecosystem model.

Marheineke *et al.* [52] studied space mapping within fluid dynamics. “To control random particle dynamics in a turbulent flow,” the authors write, “we suggest a Monte-Carlo aggressive space mapping algorithm which yields very convincing numerical results.” They say, “we show that space mapping is a very elegant method for our dispersion problem in terms of range of applicability, power and efficiency.” “To the authors’ knowledge this is the first numerical treatment of a stochastic control problem by space mapping.”



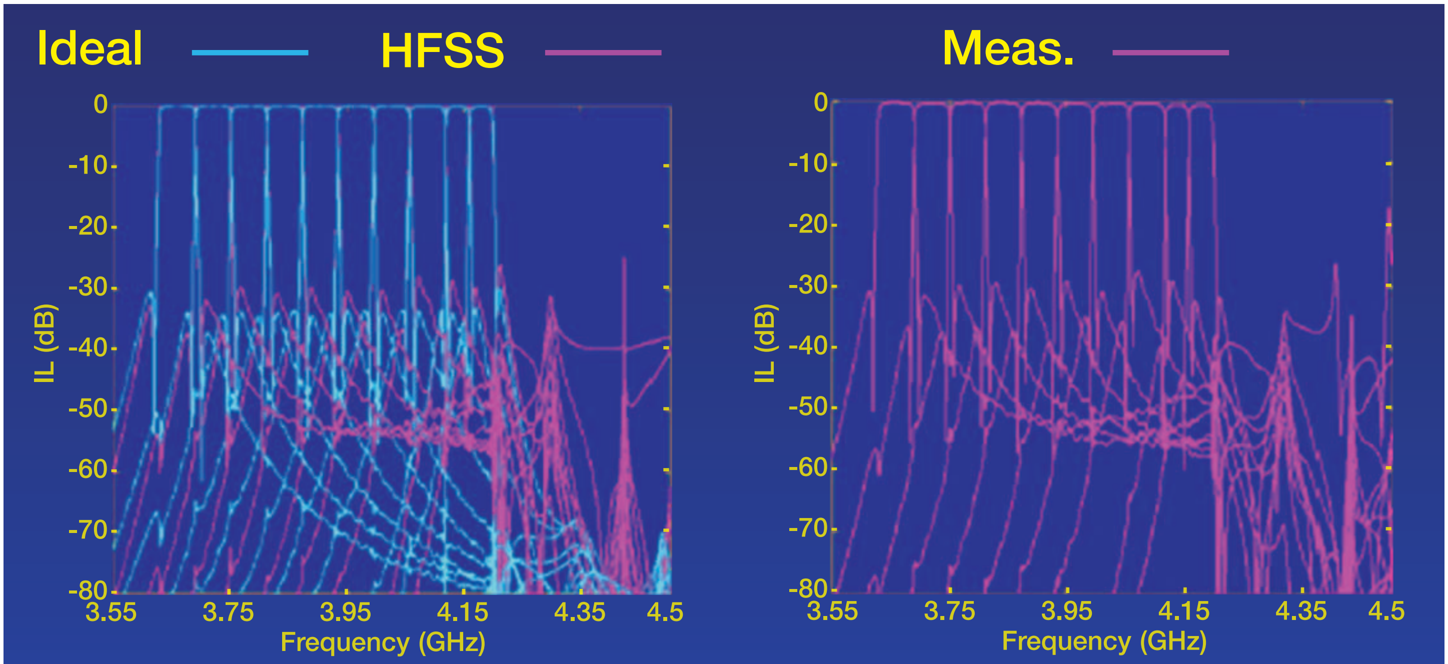


Fig. 5. Aggressive space mapping design optimization of dielectric resonator multiplexers by Ismail *et al.* [40]: a 10-channel output multiplexer, 140 variables.

Less is Always More

In 1967, a senior academic declared that my proposed research into computer-aided design (CAD) had already been fully explored. In 1974, experts predicted that my work in CAD with tolerances would never prove useful; in 1985, Raytheon Research Division hired me to work on CAD with tolerances; in 2004, I received the IEEE Microwave Theory and Techniques Society's Application Award for my work on CAD with tolerances. In 1993, I told Hewlett-Packard representatives that I wanted to link their "HFSS" system to my "OSA" optimization software; they ridiculed me; in 1997, Hewlett-Packard bought my company.

It took me an honors degree in electrical engineering that included feedback control, followed by 30 years of research into optimization techniques and engineering design technology, to stumble across space mapping. Space mapping offers two mathematically-based utilities: (1) optimization "on-the-fly," and (2) "off-line" model enhancement for later use. The key to space mapping optimization "on-the-fly" is to intelligently exploit the information flow between two available simulation levels. The key to "off-line" modeling is to use the fine model to train—to (re)calibrate—a suitably mapped coarse model over a domain of interest.

For topics triggered by this article see, for example, Ramachandran [53] on the notion of mirror neurons, and adaptive control involving a reference model [54].

Psychologist and Nobel laureate Daniel Kahneman [55] describes a System 1 way of thinking that is fast and intuitive and a System 2 that is slow and effortful. "Expert intuition strikes us as magical," he writes, "but it is not. Indeed each of us performs feats of intuitive expertise many times each day." Like selecting a pair of shoes that fit? But Kahneman doesn't separate the concept of a trained fast model (expertise, knowledge) from an "on-the-fly" updating process (space mapping).

In "The essence of space mapping: less is more," my long-time colleague Qingsha Cheng and I listed certain properties of space mapping [56]: "build a thin layer around existing knowledge, minimally complex (usually linear or very simple); for model enhancement, the data required is small (Helmholtz's trickle?); the iteration count is small; manual implementation is often possible; the resulting enhanced model or design can be astonishingly good."

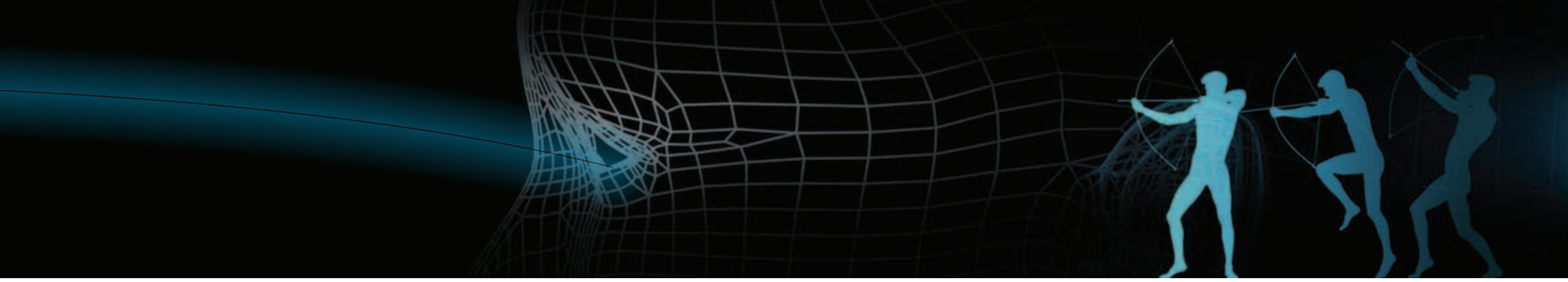
It seems to me that if knowledge can be built into a predictive model, so can "feel" and intuition.

If at First You Don't Succeed

So why does space mapping work? It works, I have often said, because it is a natural mechanism for the brain to relate objects or images with other objects, images, reality, or experience; because "experienced" engineering designers (experts), knowingly or not, routinely employ it to achieve complex designs; because, with virtually no mathematics, simple everyday examples confirm it. This has been amply illustrated over many years with everyday examples that conform to today's understanding of how the human brain itself treats models of "reality."

According to the legend of Robert the Bruce, "If at first you don't succeed, try, try again." But how many times are you willing to try? If you're familiar with a certain process—say, knotting your tie so that it hangs properly—and you don't realize success in one or two tries, you may feel frustrated. If you are an expert, shouldn't you get it right in three tries or less? If it is essential that you learn a new skill, you will usually be willing to keep trying (learning process). Yet, if you require an unexpectedly large number of tries, you may have to overcome your heightening frustration. This is common sense.

Aggressive space mapping efficiently invokes inner loops of conventional optimization—common sense at work—often yielding excellent



results in an acceptable two or three iterations. The aggressive space mapping update/execution process is itself optimization on a higher level—meta-optimization?—a process that uncannily mimics both common sense and the expert's "feel." It surely mirrors an optimal strategy for human survival, honed by evolution, for rapid learning and decision-making under extreme duress.

It is ironic that the very same generic process is as easy to explain to your next-door neighbor as it has proved difficult for an expert to explain to a fellow expert in the next cubicle.

Space mapping facilitates multidisciplinary engineering design and modeling; it offers a quantitative explanation for the engineer's "feel"; it offers everyone "more" for "less"; and by the definitions of Hawking and Mlodinow [39] it may even qualify as "elegant."

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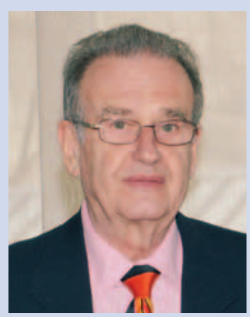
About the Author

John W. Bandler



John Bandler (LFIEEE) is professor emeritus at McMaster University and president of Bandler Corporation. A previous company he founded, Optimization Systems Associates, was acquired by Hewlett-Packard in 1997. John studied at Imperial College of Science and Technology and received his degrees from the University of London.

Based on John's work, advances such as design with tolerances, yield-driven design, and electromagnetic optimization—once academic fantasies—are now taken for granted by microwave engineers. His implementations into major commercial design tools have impacted high-frequency and microwave design initiatives world-wide. John introduced space mapping in 1994. From automotive crashworthiness to magnetic systems, his concept has been adopted into design portfolios across the entire spectrum of engineering, making possible the high-fidelity design of devices and systems at a cost of only a few high-fidelity simulations. John has published more than 480 technical papers, served on editorial and review committees, and been guest editor of several special issues.

John is a Fellow of several societies including the Canadian Academy of Engineering and the Royal Society of Canada. In 2004, the IEEE MTT Society honored him with its Application Award. In 2012, he was honored by the IEEE Canada McNaughton Gold Medal and the Queen Elizabeth II Diamond Jubilee Medal. In 2013, he received the IEEE MTT-S Microwave Career Award "For a career of leadership, meritorious achievement, creativity and outstanding technical contributions in the field of microwave theory and techniques." Active in artistic endeavors, John has written a novel, a screenplay, and several stage plays, three of which have been performed, one of which he directed himself.

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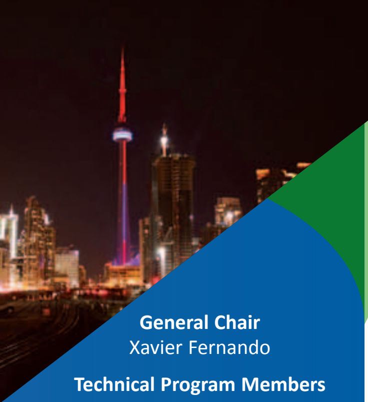

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