Everyday Electrical Engineering: A One-Week Summer Academy Course for High School Students

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***Abstract*—A summer academy is held for grade 9–12 high school students at the University of Toronto, Toronto, ON, Canada, every year. The academy, dubbed the Da Vinci Engineering Enrichment Program (DEEP), is a diverse program that aims to attract domestic and international high school students to engineering and sciences (and possibly recruit them). DEEP also provides them with the opportunity to experience the university setting. This paper discusses the organization of DEEP and presents the details of a DEEP course developed to introduce students to electrical engineering. This course is designed for junior (grades 9 and 10) students and includes lectures, hands-on activities (both in a team and individually), and a field trip. The survey results, collected as both formative and summative feedback, indicate the success of the course. This paper also provides recommendations for future offerings of the course.**

***Index Terms*—Electrical engineering education, high school education, outreach, power engineering, problem-based learning, summer academy.**

I. Introduction

ENROLLMENT in engineering continues to be lower than the demand [1]. In countries such as Canada that rely on immigrant workforce, declining immigration exacerbates this shortfall. Outreach activities, retention efforts, and active recruiting can help reverse this trend [2].

While this situation generally applies to all science, technology, engineering, and mathematics (STEM) fields, this paper focuses on electrical engineering. Among electrical engineering subdisciplines, power engineering is of particular interest, as while for years students had no particular in pursuing studies in power engineering, the smart grid initiative [3] is reversing this trend. The smart grid brings about a number of new concepts that are not present in the traditional power system, which requires updating educational and training programs. The low number of graduates—especially at a time when the existing workforce is retiring—augments this challenge [4].

At the same time, the effort to address the increased demand for power engineering (and engineering in general) by attracting more students translates directly into a more diverse intake of students. This is in contrast to the traditional composition of engineering students who are strong in math and science [5]. To maintain the quality of programs, math and science skills of high school students should be improved [6]. Moreover, it is not sufficient to start recruitment at the university level because many students will have formed a preference for their major at that point; rather, such efforts need to start at earlier stages [7]. Starting earlier has the added benefit of preventing students' developing misconceptions about fundamental concepts in electrical engineering that will be difficult to debunk later [8]. This paper discusses the development of a summer academy course for high school students to address these challenges.

The idea of taking advantage of a summer academy to attract students to engineering and increase retention is not new. In [9], a summer academy for grade 3–10 students with weak math and science abilities is discussed. A six-week math and science summer academy is discussed in [10]. Reference [11] provides an overview of a math-oriented summer academy, and [12] discusses a school-year-long academy. A camp is discussed in [13] that aims to increase enrollment by having students work on a new engineering project each day.

The Da Vinci Engineering Enrichment Program (DEEP) Summer Academy [14] is offered by the Faculty of Applied Science and Engineering at the University of Toronto, Toronto, ON, Canada. DEEP aims to attract students to STEM fields by introducing them to the innovative topics being studied in these fields. The development of a DEEP course is discussed in this paper. The salient features of DEEP and the course are the following.

- The proposed course is inclined toward power engineering. This choice was made due to the recent trend of increased employment opportunities in power engineering.
- DEEP is run in a university setting, as compared to being run in a summer camp or high school. This contributes to the increased excitement and motivation of students.
- DEEP instructors are engineering graduate students. While certainly there is merit in employing full-time instructors, graduate students offer benefits such as having a smaller age gap with participants and being active in research.
- DEEP is a diverse program targeting highly motivated international students in grades 9–12 who excel in math and science. DEEP is not gender- or major-specific.
- Enrollment in DEEP is a social experience. The social aspect is reinforced by after-class experiences in which students take part in extracurricular activities, recreational programming, and day trips.

This paper is organized as follows. After providing a brief overview of the DEEP Summer Academy and its components, the paper discusses the development of different aspects of the proposed course, Everyday Electrical Engineering, in Section III. Sample course activities are explained in

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TABLE I
GENDER BREAKDOWN OF DEEP PARTICIPANTS

	2009	2010	2011
All Students	320	370	404
Male Students	222	281	287
Female Students	98	89	117

Section IV, and Section V discusses the feedback collected from students. Concluding remarks and suggestions for future offerings of the course are presented in Section VI.

II. DEEP SUMMER ACADEMY

A. Overview

DEEP Summer Academy has been offered by the Faculty of Applied Science and Engineering of the University of Toronto through the Engineering Students Outreach Office since 2003. DEEP targets motivated and bright high school students and has about 5500 alumni worldwide. DEEP is a diverse program: About 1/5 of students come from outside Canada, and about 1/4 are female. In July 2010, out of 370 students, 24.1% were female and 22.0% were from outside Canada—mostly South Korea, US, Turkey, Hong Kong, and Venezuela. The gender breakdown of DEEP students in years 2009–2011 is given in Table I.

DEEP runs over four weeks in the month of July. Each DEEP course is one week long, from Monday through Friday, and a student can participate in one, two, three, or four courses. Regular courses are offered in the first three weeks of DEEP, while design courses are offered in the fourth week. In design courses, students employ the knowledge they gained in their previous DEEP courses to tackle real-world engineering problems. To take a design course, students have to enroll in at least one regular course. Most students stay for all four weeks.

DEEP courses cover STEM fields and business and are categorized into *streams*, e.g., electrical engineering, mechanical engineering, engineering science, robotics, and MBA. Generally, courses are offered either for junior level (grades 9 and 10) or for senior level (grades 11 and 12), but occasionally there are courses that are offered for both levels.[1] Table II shows the courses offered in 2011 in DEEP at the junior level. Each course runs from 9:30 AM to 3:30 PM.

B. Outreach Goals of DEEP

As an outreach activity, DEEP targets pre-university programming. DEEP aims to educate and inspire high school students to pursue careers in STEM fields, and this is reflected by the available DEEP streams. At the same time, DEEP helps enhance the leadership and professional skills of existing undergraduate and graduate students: Select graduate students act as sole-responsibility course instructors, and select undergraduate students act as instructor assistants. This experience is valuable for both groups because sole-responsibility teaching opportunities are rare for graduate students (especially for Master's and junior Ph.D. students). Moreover, the experience gained in teaching a DEEP course is a valuable addition to traditional engineering graduate programs that emphasize research and have almost no teaching proficiency requirement. Involvement in DEEP drastically improves the ability of graduate students in teaching in their area of expertise and gives them the opportunity to share their enthusiasm with peers.

High school students participating in DEEP usually are motivated and strong in math and science; they also form ties with the faculty while in DEEP. The first characteristic makes DEEP alumni good choices from the standpoint of the university. The second characteristic, the formed bond, affects their choice for their university studies. Interaction between students and university staff can enhance the intellectual commitment of students to the university. This fact supports DEEP's aim to recruit its alumni as undergraduate students by giving them a firsthand experience of engineering education.

C. Instructors

Each DEEP course is completely designed and taught by a graduate student. In December of each year, a request for proposals (RFP) is e-mailed to the graduate students in the faculty to solicit offers for courses. The RFP includes four parts: 1) cover letter, résumé, and reference letters; 2) application form; 3) course proposal; and 4) instructor biography. The course proposal includes the course description and outline for all five days of the proposed course. The proposal also identifies an appropriate stream (although streams are confirmed after all proposals are reviewed). The RFP is very thorough and explains the type and characteristics of courses in which DEEP is interested. In particular, proposals much explain how the content covered in each day can be applied to solve real-world problems. The proposals are reviewed, and the authors of the meritorious proposals are invited for interview. The successful candidates will be responsible for designing all aspects of their courses as a paid position.

The instructors participate in a mandatory two-day training. This training is designed to prepare them for teaching high school students and covers the pedagogy of teaching, instructional strategies, undergraduate degree level expectations (UDLE), and safety and emergency protocols. This training helps orient the instructors to teaching an audience of a type they are not used to. Instructors also need to pass workplace hazardous materials information system (WHMIS) training, Canada's national workplace hazard communication standard.

Each activity has to be described in detail on a safety form before it is allowed to run. These forms include a full description of the activity and the required preparation, procedure, diagrams, and materials. These forms are reviewed by a faculty member to ensure that the activities present no hazards to students, instructors, and the institution.

D. Counselors

A number of counselors assist with running each DEEP course. Counselors are volunteer undergraduate students who aid instructors in classes, prepare materials, and monitor and track attendance. They also support students in class, field trips, and excursions. The hours counselors spend in DEEP count toward their professional experience hours.

[1]In the Canadian secondary education system (which is similar to the US system), a high school offers the final four years of K–12 education, i.e., grades 9–12. A student typically graduates from high school at age 17 or 18.

TABLE II
DEEP 2011 JUNIOR-LEVEL COURSES

Stream	Week 1	Week 2	Week 3
Electrical and Computer Engineering	Everyday Electrical Engineering	Circuits: From Discrete Components to Integrated Systems	Microcontrollers: From Theory to Practice
Engineers Change the World	A World of Water	Solar Energy Materials and Cells	Sustainable Transportation
Engineering Science	Eng. Math: Math in Real World	Biophotonics: Looking into Life	Intro to Aerospace
Robotics	Wireless Maze Race	Sensors, Smart Phones, and Robotics	AI and Machine Learning
Mechanical Engineering	It *is* Rocket Science	Orbital Mechanics, Space Robotics	Race and Production Car Eng.
Mini-MBA	Intro to Project Management	Entrepreneurship 101	Manufacturing and Assembly Line
Engineering Leadership	n/a	DEEP Leadership Camp	n/a

E. Students

Students have diverse learning styles and vary in their ability to capture information from different streams [15]. Some students learn best by seeing, some by hearing, and some by doing. In an inclusive learning experience, it is desirable to incorporate all three input modalities to maximize understanding, e.g., presenting a lecture that is accompanied by visuals and hands-on activities [16].

The Felder and Silverman learning style model classifies students as sensing or intuitive, visual or verbal, inductive or deductive, active or reflective, and sequential or global [17]. According to [17], the traditional teaching style for engineering education is geared toward students who are intuitive, auditory, deductive, reflective, and sequential learners. However, not all students fit into this category, and the traditional engineering teaching style does not necessarily result in adequate communication of ideas. DEEP students are from different backgrounds and generally are sensing, visual, active, and global learners. They are very competitive and enjoy displaying their capabilities—even seemingly trivial capabilities such as reading out loud from slides. They are highly motivated and have a variety of interests and abilities. They show initiatives; it is not uncommon to see students adjusting an experiment to try their own hypotheses and make new "discoveries" on their own. As a result, they seek challenge, are vocal, and have high expectations, which sometimes results in their being overly critical of themselves (and others) and being emotionally sensitive.

Admission to DEEP is based on the evaluation of the candidate's academic transcript, teacher nomination, and statement of interest. Among their reasons for wanting to participate in DEEP, students mention learning about engineering, productive use of time, learning about the university environment, learning something practical, career exploration, and being challenged. DEEP is partially funded by the tuition received from students, however bursaries are offered to eligible students.

III. COURSE DESIGN

A. Overview

In this section, the design of one of the DEEP courses will be discussed in detail. This course, titled "Everyday Electrical Engineering," introduces the students to the basics of electrical engineering. The course description posted online reads as follows.

> Almost every aspect of modern life, from your coffee machine to a supercomputer used by NASA, relies on electricity for its energy needs. Electrification was named the number one engineering achievement of the 20th century, and this course introduces you to the foundations of electrical engineering. As the name suggests, this course draws examples from the problems you encounter in your everyday life (such as jump starting your car battery in winter) and combines them with fundamental techniques used in electrical engineering to arrive at solutions. In this course, you will become familiar with electric circuits, electric motors, generators, automatic controllers, and communications; you will even build small-scale working models yourself.

As the first course in the electrical and computer engineering stream, this course is geared toward students from different backgrounds and levels of preparation, and it is inclined toward power engineering to fill a gap that is not covered by the other courses.

This course was offered in 2010 for the first time and was renewed for 2011 due to the positive feedback from students. Twenty students took the course in 2011, of whom 15 were Canadian and five were international; 15 were male and five were female. The course was supported by three DEEP counselors. Students received a 3.5-in floppy disk, used in the last day's computer-related activity, as a souvenir.

B. Lectures and Activities

This course was designed according to concepts of integrated design [18], [19] and was planned as a modular problem-based course [20]. Each day is limited to one major subject, framed at the start by an attention-grabbing statement and an overview of the day's agenda, and at the end by a review of the important discussed topics. Each day starts with the definition of a stimulating real-world problem, which serves to motivate the students. The rest of the day is spent on explaining the theory, methods, and experiments necessary to understand and tackle the problem. Through this approach, students perceive a clear need for the topic. Furthermore, this approach helps students develop the ability to be problem solvers and critical thinkers. The interdisciplinary nature of many jobs requires graduates to combine skills from different disciplines. The lead problem for each day is given in Table III.

Because of the short attention span of high school students [21], a conscious effort is made to keep lectures brief;

TABLE III
LEAD PROBLEMS

Day	Day 1 (Monday)	Day 2 (Tuesday)	Day 3 (Wednesday)	Day 4 (Thursday)	Day 5 (Friday)
Theme	Circuit analysis	Power system of future	How power system works	Electric motors	Digital logic
Topic	Car's dead battery	2003 NA blackout	Field trip	Motors	Computers
Learning Goals	• apply circuit laws to simple circuits • determine parallel and series connections • explain how batteries work	• explain how grid works • explain why the power system is three-phase • understand blackouts • work with a simulation software (PSCAD)	• explain the energy market in Ontario • understand power transactions with neighbor provinces/states	• explain EM energy conversion • explain how and why a motor works • describe motor types	• understand how digital circuits work • understand how a simple computer works

longer lectures are broken into discrete segments filled with short discussions. Wherever possible, active learning strategies [18], [19], e.g., think-pair-shares, discussions, debates, and hands-on activities, are used to engage students. Since this is a summer activity, no quizzes or mandatory homework are used (students immediately react negatively to inclusion of these components). However, optional readings are given to students, and students are observed qualitatively based on their performance in hands-on experiments that are directly linked to lectures. Lectures are run according to the developed instructional plan, which outlines a step-by-step agenda of what to do and ask during class.

IV. Sample Activities

This section discusses sample activities in the Everyday Electrical Engineering course. Different components and their goals and outcomes are also discussed. Although DEEP generally provides all the material requested by instructors, it is desirable to use simple and accessible material so that the students can revisit the experiments at home.

A. Icebreaker

The first class starts with an overview of the course content and policies, such as safety and attendance. Students are asked to share their reasons for enrolling in the course. A note is made of the students' expectations, and these are briefly discussed as to whether they fall within the scope of the course.

In 2010, the course was run after the G20 meeting (in Toronto), so this was used as an entry point by relating the course to this event. The point was made that the elements of G20 security, e.g., closed-circuit TV and cell phone signal jamming, were only possible because of electrical engineering, which underlines its profound applications. Areas of electrical engineering, such as power, control, electronics, communications, and computers, are discussed.

An icebreaker activity follows to help students get acquainted with each other. Inclusion of an icebreaker activity is instrumental in both relieving the stress for students and giving them time to adjust to the new environment. A game known as "truth or lie" is used in this course. In this game, students share three sentences about themselves, two true and one false; other students should then guess which sentence is a lie. The instructor also participates in this activity.

B. Electric Circuits

An overview of circuits, Ohm's law, and series and parallel connection of circuit elements is provided. An analogy is made between electricity flowing in a circuit and an object being passed in a circle. An analogy between different quantities in electrical, mechanical, and heat transfer is also made [22].

The concept of a closed circuit is explored by giving a light bulb, a battery, and one piece of wire to student groups and asking them to turn the light on. Some groups take several tries to succeed, but many succeed eventually. The role of each component in the circuit is discussed, and the importance of having a closed path for the flow of electrons is clarified.

Students also validate Ohm's law by recording voltages and currents for different resistors in the lab and by changing the voltage and recording the change in current for a resistor. In this activity, students learn how to use a breadboard, how to connect voltmeters and ammeters in a circuit (a skill even some undergraduate students do not necessarily master), and how to read the value of a resistor from its colored bands. Students are asked to identify discrepancies between ideal Ohm's law and the results of their own experiment and explain the reasons for these.

C. Photovoltaic Energy

After a review of the August 2003 North American blackout [23], students are asked to get into groups and discuss the ways in which electricity affects modern life. A distinction is made between grid- and battery-supplied electricity. Students produce a list of items that did not exist when there was no electricity. They also discuss alternate sources of electricity, such as wind, sun, hydro, and chemical energy.

Students construct a simple photovoltaic (PV) system and use an ammeter to learn how the intensity and wavelength of light affect generation of electricity. Parallel/series connections of cells to increase current/voltage are discussed, and the effect of temperature on the efficiency of a PV cell is studied.

D. Batteryless Flashlight

The principles of operation of a generator and the concepts of magnetic and electric fields are explained. Students then build a batteryless flashlight, also known as shake-a-gen [24], consisting of a winding, a magnet, and a 35-mm film canister. The winding is wound on the film canister, and a magnet is put inside, as shown in Fig. 1. Shaking the canister induces a voltage in the winding. Generating enough voltage needs: 1) a strong magnet (neodymium); 2) a high number of turns (500 turns) with a very thin wire (30 gauge); and 3) a low-voltage and low-current LED (red, green, or yellow). The faster the assembly is shaken, the brighter the LED shines. Students experiment with different strengths of the magnetic field by changing the number

Fig. 1. Shake-a-gen.

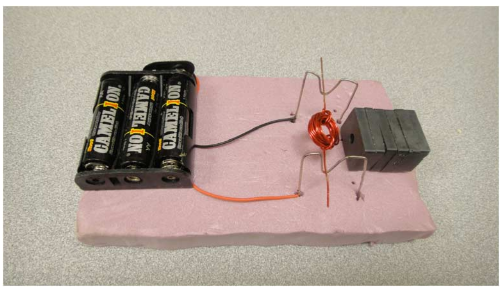

Fig. 2. Motor.

of magnets inside the canister. If the magnet is removed from the assembly, the assembly can be used to detect strong magnetic fields—for instance, that from a microwave.

E. Electric Motor

Electric motors are abundant in modern life. Students are asked to identify electric motors, e.g., in the kitchen, in a utility room, and in a car. The list might include a fan, a blender, a can opener, a washer, a vacuum cleaner, a drill, a power window, a windshield wiper, and a CD player. A motor is introduced to students as the "inverse" machine of a generator. While a generator converts mechanical energy to electrical energy, a motor converts electrical energy to mechanical energy. Both motors and generators use a magnetic field as the conversion medium. In an electric motor, the direction of the electromagnetic field flips when similar poles are facing each other. This is necessary for a continuous movement of the rotating part. Students need a magnet, a pair of paper clips, a piece of Styrofoam (as the platform), and some batteries to set up this experiment, as shown in Fig. 2. Students expand this activity by changing the position of the magnets and the number of batteries.

F. Morse Code Transmitter

A brief history of communication—mentioning smoke signals, mail, pigeon post, signal lamps, telegraph, radio, TV, the Internet, and cell phones—reviews the timeline of transmission of signals over a distance. Students are asked to identify the important factors in a communication technology, e.g., speed, reliability, ease, and speed of encoding/decoding, communication medium, and error detection and correction. The example of credit card validation is mentioned, and the anatomy of a credit card number is explained.

Students build a simple Morse system using a buzzer and a pair of switches made with cardboard paper and paper fasteners.

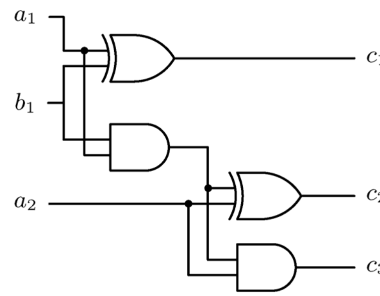

Fig. 3. Digital adder with $\overline{c_3c_2c_1} = \overline{a_2a_1} + b_1$.

Although Morse code is no longer used, it is still popular among amateur radio operators. Students learn the Morse code for the distress signal, SOS: • • • — — — • ••.

G. Digital Adder

Students are introduced to digital electronics. The difference between digital and analog signals is explained. It is mentioned that digital signals use two discrete states, that is, two voltage levels: a LOW level (close to 0 V) and a HIGH level (close to the supply voltage). The advantages and disadvantages of digital electronics are also explained: Their immunity to noise, energy consumption, price, and quantization error.

Since a digital circuit is constructed from logic gates, an overview of binary arithmetics, boolean logic, and different gates is provided. With the help of the students, the instructor writes the truth table for a two-bit adder. Students construct a two-bit digital adder in the lab. A digital adder is found in the arithmetic and logic unit (ALU) of a microprocessor. LEDs are used to represent bits. Fig. 3 shows the adder circuit.

H. Field Trip

A field trip to Ontario's Independent Electricity System Operator (IESO) is arranged for students. The role of IESO in regulating the electricity market, auctioning electricity, and overseeing the relations between wholesaler and buyers is explained.

Students visit the control room, dubbed the "viewing gallery," where they are introduced to transmission and generation planning, integration of renewable energy resources, and a showcase of the organization's educational activities [25].

I. Computer Simulation

For students to understand the role and importance of simulation and digital modeling in engineering [26], a number of simulation-based activities developed in Java in [27] are included in the course. Students also simulate simple circuits using the industry-standard PSCAD/EMTDC software [28].

V. Formative and Summative Evaluation

A. Solicited Formative Feedback for the Course

Since final, end-of-course evaluation forms reach the instructor only after the end of the course, a class's final feedback is of no benefit to that particular class, only serving to improve the course for future classes. To remedy this, midcourse feedback was solicited in 2011. The feedback forms are distributed

TABLE IV
STUDENT FEEDBACK REGARDING THE COURSE

	Average (out of 5)	
	2010	2011
This course has met my overall expectations	4.55	4.10
Course material goes above and beyond high school	4.33	3.60
The course includes many hands-on activities	4.72	4.55
Classrooms and labs are appropriate for this course	4.55	4.40
Overall, I am enjoying this course	4.72	4.25

TABLE V
STUDENT FEEDBACK ON THE PERFORMANCE OF THE INSTRUCTOR

	Average (out of 5)	
	2010	2011
Instructor's knowledge of the subject	4.72	4.35
Organized presentation of the material	4.27	4.25
Instructor's interest level	4.72	4.80
Overall rating of the instructor as a teacher	4.64	4.70

TABLE VI
DEEP PROGRAM ASSESSMENT

Number of Students Who...	2008	2009	2010
Applied to U of T	13	30	16
Applied to Engineering	8	17	3
Received Admission	8	13	2
Accepted Offer	5	9	1

on Wednesday (this being a Monday-to-Friday, one-week-long course).

The midcourse feedback is designed to be shorter than the final feedback. The questions and some representative answers are as follows

1) What have you liked most so far this week?: Many students (7 out of 20) specifically identified the IESO field trip as their favorite, mentioning it was "one of a kind" and "a great experience." They also liked the discussions on electric power generation and transmission. Students liked the circuit lab, working with breadboards, and electrical components. Interestingly, "teacher, peers, and how everything is running smoothly" was mentioned by one of students as a favorite part.

2) What have you liked least so far this week?: About half of students mentioned they "liked everything so far" and could not think of any improvements. Two students were concerned that the results of the photovoltaic energy lab did not match what they expected (which shows students were critical of their results). A student wrote that some of the information given during the IESO field trip overlapped with the background knowledge they discussed in class.

3) What do you want to learn that you haven't yet learned this week?: From the answers of students, it seems that overall students want to know how everyday technology works. For example, they mentioned batteries, fluorescent lightbulbs, and wireless transmission. Students are also interested in programming and microprocessors.

B. Solicited Summative Feedback for the Course

An evaluation form is distributed to students. The form has two sections. In the first section, students are asked to rate various aspects of the course and performance of the instructor. The results are shown in Tables IV and V, respectively. The average column is calculated by using a numerical value from 1 for strongly disagree (or very poor) to 5 for strongly agree (or very good).

The second section of the questionnaire contains long-answer questions. Questions and answers are discussed in the following.

1) What was your favorite part of the course?: Students were pleased with the hands-on experiments, and some specifically mentioned their favorite activity. Interestingly, each activity was mentioned by at least one student.

2) What is the one thing you would change about the course?: More than half of the students mentioned they would not change anything about the course. Some students asked for more experiments spread throughout the day. Clearly, students enjoy "building things, " and they want to see more such activities in the course. This can be addressed by adding activities that are of relatively shorter duration. One student mentioned they wanted to learn more about how computers and cell phones work. Another student asked that students should be allowed "on the last day to create their own devices."

3) We are looking for course ideas for next year's DEEP. What topics or subject areas would you like to see offered next year?: Students asked for courses on computers, rockets, plane and vehicle design, and nautical engineering, which further confirms the interest of students in hands-on activities.

C. Overall Assessment of DEEP

The DEEP program (not the individual courses) as a whole tries to estimate the number of students who, after DEEP, plan to pursue engineering. However, there are certain difficulties in tracking the academic status of DEEP alumni. For example, they are not assigned a student number, some come from overseas, and some are still in high school and cannot apply for university. Table VI gives information about the DEEP alumni who applied to the University of Toronto and, more importantly, could be tracked. At the time of writing, data for 2011 is not yet available.

VI. CONCLUSION AND FUTURE PLANS

The course Everyday Electrical Engineering was offered in two consecutive years as a part of the DEEP Summer Academy at the University of Toronto. DEEP was run in a university setting for high school students whose feedback demonstrates that they enjoyed the hands-on activities of the course.

An important challenge in designing this course is the mixed background of students: Some students are familiar with concepts that are completely new to others. Since the mix of students is not known *a priori*, a balanced approach in designing the course should be taken. For example, each activity is accompanied with extra work for the more advanced students. Lectures need to remain short. Including competition-based activities in the course helps provoke students' interest. Students best enjoy activities with moving parts and loud noises. To retain the inclination toward renewable energy, the PV cell activity can be augmented with wind power generation.

Gamification can also be used to enhance the student experience by increasing their engagement. In gamification, game-play elements are used in nongame applications. This is prevalent considering the proliferation of social networking Web sites, such as Facebook, in which posts are scored up through "likes." In the context of this course, one idea is to ask students to watch a video, read a short article, or visit a Web site; they are then asked some questions about those materials and are given points for their correct answers (compare this with a scoring system that deducts marks for wrong answers). Questions are not meant to be difficult, but should rather increase the interest of the students. Therefore, simple but important questions are the most effective, such as the following.

- What is the difference between dc and ac power?
- Why is electrical energy transmitted as ac and not dc?
- How does signal transmission work?

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References

[1] Engineers Canada, "Engineering labour market conditions 2009–2018," Sep. 2010 [Online]. Available: http://www.engineerscanada.ca/files/engineering_labour_market_conditions_report_2010.pdf
[2] C. Davis, M. Yeary, and J. Sluss, "Reversing the trend of engineering enrollment declines with innovative outreach, recruiting, and retention programs," *IEEE Trans. Educ.*, 2011, to be published.
[3] U.S. Department of Energy, "Smart grid system report," White Paper, Jul. 2009 [Online]. Available: http://www.smartgrid.gov/sites/default/files/resources/systems_report.pdf
[4] W. Reder, A. Bose, A. Flueck, M. Lauby, D. Niebur, A. Randazzo, D. Ray, G. Reed, P. Sauer, and F. Wayno, "Engineering the future," *IEEE Power Energy Mag.*, vol. 8, no. 4, pp. 27–35, Jul.–Aug. 2010.
[5] C. R. Smaill, G. B. Rowe, E. Godfrey, and R. O. Paton, "An investigation into the understanding and skills of first-year electrical engineering students," *IEEE Trans. Educ.*, vol. 55, no. 1, pp. 29–35, Feb. 2012.
[6] L. J. Shuman, M. Besterfield-Sacre, and J. McGourty, "The ABET "professional skills"—Can they be taught? can they be assessed?," *J. Eng. Educ.*, vol. 94, no. 1, pp. 41–66, Jan. 2005.
[7] G. C. Orsak, "Guest editorial. K–12: Engineering's new frontier," *IEEE Trans. Educ.*, vol. 46, no. 2, pp. 209–210, May 2003.
[8] M. C. Periago and X. Bohigas, "A study of second-year engineering students' alternative conceptions about electric potential, current intensity and Ohm's law," *Eur. J. Eng. Educ.*, vol. 30, no. 1, pp. 71–80, 2005.
[9] K. J. Reid, "The young scholars summer program in electronics and computers," in *Proc. ASEE Annu. Conf.*, St. Louis, MO, Jun. 2000 [Online]. Available: http://soa.asee.org/paper/conference/paper-view.cfm?id=15465
[10] Manitoba Science Academy, "Manitoba Science Academy," Aug. 2011 [Online]. Available: http://www.msawhiteshell.com
[11] Carleton University, "Bright Math Camp," Aug. 2011 [Online]. Available: http://web.ncf.ca/au680/index.htm
[12] University of Waterloo, "Waterloo Unlimited," Aug. 2011 [Online]. Available: http://www.unlimited.uwaterloo.ca/
[13] M. Yilmaz, J. Ren, S. Custer, and J. Coleman, "Hands-on summer camp to attract K–12 students to engineering fields," *IEEE Trans. Educ.*, vol. 53, no. 1, pp. 144–141, Feb. 2010.
[14] University of Toronto, "Da Vinci Engineering Enrichment Program (DEEP) Summer Academy," Aug. 2011 [Online]. Available: http://deepsummeracademy.com
[15] R. M. Felder, "Matters of style," *ASEE Prism*, vol. 6, no. 4, pp. 18–23, Dec. 1996.
[16] A. M. Moll, *Differentiated Instruction Guide for Inclusive Teaching*. Port Chester, NY: Dude, 2003.
[17] R. Felder and L. Silverman, "Learning and teaching styles in engineering education," *Eng. Educ.*, vol. 78, no. 7, pp. 674–681, Jul. 1988.
[18] R. Pregent, *Charting Your Course: How to Prepare Teach More Effectively*. Madison, WI: Magna, 1994.
[19] P. C. Wankat and F. C. Oreovicz, *Teaching Engineering*. New York: McGraw-Hill, 1993.
[20] D. Santos-Marin, J. Alonso-Martinez, J. E.-G. Carrasco, and S. Arnaltes, "Problem-based learning in wind energy using virtual and real setups," *IEEE Trans. Educ.*, vol. 55, no. a, pp. 126–134, Feb. 2011.
[21] J. Sticklen, M. Urban-Lurain, and D. Briedis, "Engagement of millennial students using web-based screen movies to replace traditional lecture in lecture/lab courses," in *Proc. ASEE/IEEE Frontiers Educ. Conf.*, San Antonio, TX, Oct. 2009, pp. M3C-1–M3C-5.
[22] A. Mehrizi-Sani and R. Iravani, "On the educational aspects of potential functions for the system analysis and control," *IEEE Trans. Power Syst.*, vol. 26, no. 2, pp. 878–885, May 2011.
[23] U.S.–Canada Power System Outage Task Force, "Final report on the August 14, 2003 blackout in the United States and Canada: Causes and recommendations," Apr. 2004 [Online]. Available: https://reports.energy.gov/
[24] J. Hare, "The shake-a-gen," *J. Phys. Educ.* vol. 37, no. 5, pp. 436–439, Sep. 2002 [Online]. Available: http://www.creative-science.org.uk/gensimple1.html
[25] Independent Electricity System Operator (IESO), "10 Smart Meter Lane," Aug. 2011 [Online]. Available: http://www.ieso.ca/house
[26] M. Kezunovic, A. Abur, G. Huang, A. Bose, and K. Tomsovic, "The role of digital modeling and simulation in power engineering education," *IEEE Trans. Power Syst.*, vol. 19, no. 1, pp. 64–72, Feb. 2004.
[27] J. E. Tate, T. J. Overbye, J. Sebestik, and G. C. Reese, "Interactive lessons for pre-university power education," *IEEE Trans. Power Syst.*, vol. 23, no. 3, pp. 824–830, Aug. 2008.
[28] *"PSCAD Users Guide,"* Manitoba HVDC Research Centre, Winnipeg, MB, Canada, Feb. 2010 [Online]. Available: https://pscad.com/products/pscad

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