INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN, ICED'07
28 - 31 AUGUST 2007, CITE DES SCIENCES ET DE L'INDUSTRIE, PARIS, FRANCE

DIGITALLY ENHANCING THE PROJECT-BASED APPROACH TO ENGINEERING EDUCATION

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ABSTRACT
Group design projects form a major cornerstone in all design engineering-related courses taught at UOIT's Faculty of Engineering and Applied Science (FEAS). However, there is not a single clear correct solution or answer to a design engineering problem. Conversely, previous experiences revealed that this open-ended nature and the comprehensiveness of design engineering projects, as well as the large number and variety of deliverables required, is often confusing to many undergraduate students at all levels so that some pay more attention on the format than the engineering content or vice versa, all of which are not desired scenarios. Thus, a design project cannot be over-explained, especially not in the context of design process implementation, the usage of design tools, and the necessary engineering documentation and its particular contents. It would be, therefore, particularly beneficial to the students if design projects could be supported with explanatory self-guided step-by step learning modules that would help them to do better on their design projects. The paramount goal of this paper is to raise the awareness of designing and producing a series of Webcasts and offline (or streaming) digital video self-learning instructional units with increasing levels of difficulty that will clearly demonstrate and deliver both basic as well as advanced technical hands-on information on how to prepare design engineering projects. Students will learn how to use advanced computer-aided engineering applications through a variety of intensive hands-on training sessions tailored to fit students' needs and level of expertise. The proposed digital training content is regarded as a cost-effective and efficient approach to the professional development of engineering students.

Keywords: Digital Learning Modules, Project-Based Learning, Design Education

1 PREAMBLE

The growing global awareness of the importance of engineering discovery and innovation in solving the compelling needs of today's world requires significant advances in the design engineering discipline, the foundation of which are the advances achieved in the education of highly capable design engineers.

Creation is the core of all design engineering activities. However, the principal goal of design engineering is not always to invent novel and original solutions, but it is also to achieve optimal solutions in the given conditions. Since ones "motherwit and creativity cannot compensate for defects in methodology, science, and technical knowledge [1]," the role of the educators in the articulation of each instruction form is critical in design engineering education.

2 INTRODUCTION

A basic requirement for registration as a professional engineer in Canada is graduation from a Canadian university in an accredited engineering program or the presentation of equivalent recognized educational qualifications. A system of accreditation for programs in undergraduate engineering education in Canada was established in 1965. It is administered by the Canadian Engineering Accreditation Board (CEAB). Graduation from an accredited engineering program has been accepted by all provincial and territorial professional engineering associations in Canada as fulfilling the academic requirements for licensing [2].

The CEAB criteria specify the minimum content for each program in mathematics, basic sciences, engineering sciences, and engineering design, and also in complementary studies, a category which must include engineering economics, the impact of technology on society, issues in the humanities and social sciences, and oral and written communications. Among the other, according to the CEAB criteria [3]:

> *"The engineering curriculum must culminate in a significant design experience which is based on the knowledge and skills acquired in earlier course work and which preferably gives students an exposure to the concepts of team work and project management. A research project may be interpreted as engineering design provided it can be clearly shown that the elements of design, as noted in the definition, are fulfilled in the completion of the project. Appropriate content requiring the application of computers must be included in the engineering sciences and engineering design components of the curriculum."*

In this context, introducing the basic concepts of design at an early stage of engineering education combined with an emphasis on design throughout the curriculum has been shown to be a preferred method for teaching design to engineering students [4]. In addition, project-based learning has been well established as a methodology for successfully teaching complex materials to students [5].

2.1 UOIT's design strategy

In the fall of 2005, an NSERC-GMCL Chair in Innovative Design Engineering[1] has been endowed at UOIT for a 5-year term (renewable once) with a main objective to substantially contribute towards improving Canada's capacity in design engineering through systematically incorporating specific strategies into the engineering curriculum and intensive collaboration with industry. The crucial impact of the Chair on the training of undergraduate engineering students at UOIT resulted into a successful implementation of the concept of increased integration of design engineering topics into the engineering curriculum. Thereby, instead of covering traditional topics in introductory engineering graphics curricula, such as descriptive geometry and instrument drawing, an intensified incorporation of design activities was executed. As a result, through their gradual introduction to the university-level structured learning environment at UOIT's Faculty of Engineering and Applied Science (FEAS), future engineering graduates are increasingly being engaged in inquiry- and activity-based open-ended design engineering project challenges that require adequate integration of the analytical and design skills acquired.

UOIT's engineering curricula are designed with the view that team-based design projects improve motivation and engagement in achieving learning objectives. It is common in all design engineering-based courses at UOIT to have the integration of all the topics covered throughout the course achieved through major team-based design and CAD modelling projects with increasing complexity. Currently, a medium-sized CAD package (e.g., SolidWorks®) is used to support design engineering related courses in years 1 and 2, whereas a full-sized "Product Lifecycle Management" CAD/CAE/CAM package (e.g., Unigraphics NX4®) is utilized in years 3 and 4. Students gain proficiency in feature-based parametric solid modelling, assembly modelling, associative drawing production, rendering and animation, by spending at least 15 hours per term in a guided laboratory CAD training environment. TeamCenter Community® is already in limited use via a multi-university collaborative design research project[2]. Currently, introducing a Product Data Management software package intended for Faculty-wide availability such as TeamCenter Engineering is underway, but the implementation costs are quite high due to the higher bandwidth necessary and the more stringent licensing requirements.

A continuum of design engineering courses that all feature project-based learning is the underlying concept circumscribing the mechanically-oriented program curricula at UOIT which include the following programs: Automotive Engineering, Manufacturing Engineering, and Mechanical Engineering with its three options: Comprehensive, Energy, and Mechatronics.

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[1] More details are available at: http://www.nserc.gc.ca/partners/profile_detail_e.asp?pid=450

[2] More details are available at: http://deseng.ryerson.ca/twiki/bin/view/Ecd/WebHome

For each of the programs, in each of the first three years there is one general course focussing solely on design engineering, each of which features major project-based learning elements. These courses are:

- Year 1: ENGR 3200U: Engineering Graphics and Design [6]
- Year 2: ENGR 2310U: Concurrent Engineering and Design [7]
- Year 3: ENGR 3030U: Computer-Aided Design

In year four, the three general courses above are respectively complemented with a variety of program-specific year 4 capstone design engineering courses, such as:

- ENGR 4080U: Automotive Systems Design,
- ENGR 3395U: Manufacturing Systems Design,
- ENGR 4220U: Mechanical Systems Design,
- ENGR 4230U: Thermofluids and Energy Systems Design, and
- ENGR 4330U: Mechatronic Systems Design.

Senior-level design engineering projects often represent in-depth industry-sponsored realistic engineering design, team or individual, problem solving exercises that reflect the most recent corporate research-related engineering activities. In addition, in year 4, the Design Thesis is the final undergraduate design engineering experience the graduating students have to accomplish.

2.2 UOIT's design objective

The ultimate educational objective of the variety of design engineering projects extending throughout the engineering curricula at UOIT's FEAS is to gradually build engineering design competency (as being described in detail in [8]) by exposing students to engineering design problems with increasing levels of complexity and scope. In general, UOIT's students are expected to work as part of a team to solve a relatively challenging and practical design and build problem within a limited budget by making a broad application of the engineering skills developed by the curriculum. Thereby, students acquire invaluable experience in design research, design problem solving, critical thinking, creative thinking, generation and evaluation of design concepts, design development, design analysis, project planning, teamwork, prototype building, testing and evaluation, fundamental engineering reporting, and communication including the preparation of the final design project plans, design reviews, and technical project reports [6,7,9].

2.3 UOIT's mobile learning environment

Having being recently established, UOIT provides the ideal setting for attaining the above goals by providing a unique opportunity for the creation, prompt adoption, and implementation of advanced and innovative practices in teaching design engineering, without having to go through the burden of modifying or abandoning traditional ones. UOIT is designed and equipped to provide teaching and learning environments that enable the use of information and communication technology hardware and software (e.g. wireless networks and teaching/learning based on laptop and tablet computers).

Each student benefits from the University's mobile learning environment on a campus equipped with state-of-the-art laboratories and fully networked classrooms. This environment offers opportunities for investigating innovative teaching and learning techniques based on these technologies that will not only enrich students' design engineering experience but will also serve as a focal point for multidisciplinary design engineering teams involving students and instructors affiliated with the automotive, manufacturing, mechanical (comprehensive, energy, and mechatronics) engineering programs. The "web-centric" environment around which the University operates utilizes the latest technologies that support traditional face-to-face teaching while expanding Internet-based learning and collaborative learning. In keeping with this vision, teaching and learning at the University is not bound by place or by time because UOIT offers a unique laptop program for all its engineering programs. Every engineering student at UOIT's FEAS has a standard laptop computer that is equipped with a suite of software, including the most recent versions of SolidWorks®, UGS NX4®, NX Nastran 4.1®, MSC.visualNastran 4D®, MATLAB®, Maple®, LabVIEW®, Adobe Acrobat®, Microsoft Project®, and Microsoft Office®. The laptops are connected to a wireless network that enables students to easily work together on group projects [10].

2.4 UOIT's design engineering facilities

To help with the development of design engineering education, as a part of the Design Chair's Action Plan, UOIT established a Centre for Innovative Design Engineering and Research (CIDER). This design engineering and research facility is a powerful resource and a vital focal point for developing design engineering education. The teaching and learning centerpiece of the CIDER is the Design Engineering Commons which includes a Design Laboratory, a Computer Aided Design Laboratory equipped with hardware and software through the PACE[3] program, a Component Design Laboratory, and a Rapid Prototyping and Manufacturing Laboratory which includes 3D scanning equipment. A state-of-the-art virtual reality facility that will be extensively utilized for design engineering education purposes is currently being built at a remote location in the vicinity of the Chair's industrial sponsor's (GMCL) Engineering and Research Centre in Oshawa.

3 METHODOLOGICAL APPROACHES

Despite efforts to improve students' performance on design engineering projects as they move from year to year in the program, there are still a number of groups that are performing poorly. The question that needs to be asked is: Is there a way to improve the course delivery so that all groups obtain an acceptable level of performance? Although there will always be individual students who perform poorly in a given course, there should be a way to enhance the present methods of teaching and delivering the material so that no group performs poorly (e.g., below 70%).

To help address the above challenge, the authors have undertaken a systematic study of the core engineering courses within the engineering programs at UOIT. The study's aim was to identify existing problems within the program with regard to teaching design engineering and to determine alternative approaches, such as self accessed digital-learning modules, that would improve the overall abilities of the groups and the quality of their design projects.

Each course was investigated from a design perspective. As the design project is the central element of each of the core design courses, the students' performance on design engineering projects was used as an indicator to determine the level of success of educating the students in design. By implementing this rationale, the grades achieved on the design projects for each course were studied to determine what problems existed in the design training of the students. Potential causes of the perceived problems were then identified. Lastly, proposed remedies to alleviate the problems were determined.

It was decided that the proposed remedies would have to focus on learning contents prepared in a digital form. The reasons for this are many. First, UOIT already relies heavily on digital delivery through its laptop program and its online Learning Management System (LMS) by which course content, including lectures notes, manuals, etc., are delivered to students electronically. Professors at UOIT already use tablet computers to allow them to create real-time hybrid lecture notes that incorporate the best of both slide presentation and chalk board experience that keep interest levels during lectures high. In addition, this approach provides the advantage of these materials being posted on the LMS for later use by the students. Second, the University's mobile learning environment provides students with access to library resources using their wireless laptop anytime, from anywhere. Digital resources and complementary print collections are provided for students in both a physical and virtual environment. In addition, the textbooks selected for most courses feature additional digital resources. Third, although developing the digital content is time consuming, the material can be made available to the students on an on-demand basis for little cost, thus providing ubiquitous access to learning resources. Fourth, the modern student is used to being able to access information at any time from anywhere via the Internet. Having the content available in digital form only reinforces this new paradigm in learning. Finally, the creation of discrete curriculum modules represent an attractive alternative to counter academic and non-academic pressures confronting today's student. In conclusion, the idea of self-contained learning modules in digital form was chosen as the means of conveying additional supportive materials to supplement the face-to-face contact time. A modular structure allows for ease of development, ease of upgrade, and provides flexibility in delivery. What follows is the analysis of each of the core design courses and proposed items for improvement.

[3] Partners for the Advancement of Collaborative Engineering Education (http://www.pacepartners.org/)

4 FIRST YEAR DESIGN ENGINEERING PROJECTS

4.1 A typical project brief

In a first-year design course, student teams are engaged to work collaboratively to provide both reverse engineering and creative design deliverables by using a 3-D solid modelling CAD package. Students have to take an existing design and redesign it to include three independent innovative enhancements to the existing design's functionality. For example: modifying a folding handcart in order to meet three new design requirements, (e.g., to be easily convertible into a chair, a small ladder, and to be equally usable on dry and snow-covered pathways), by applying a structured design process and submission of details of the concept generation and concept selection processes. Using the capabilities of the software, students checked the physical functionality of the proposed design concept and produced a complete set of engineering drawings of their final design, including assembly drawings, detail drawings, and bill of materials, as well as photorealistic renderings and animations. Finally, students had to create a one-page owner's manual/specification/marketing brochure [6].

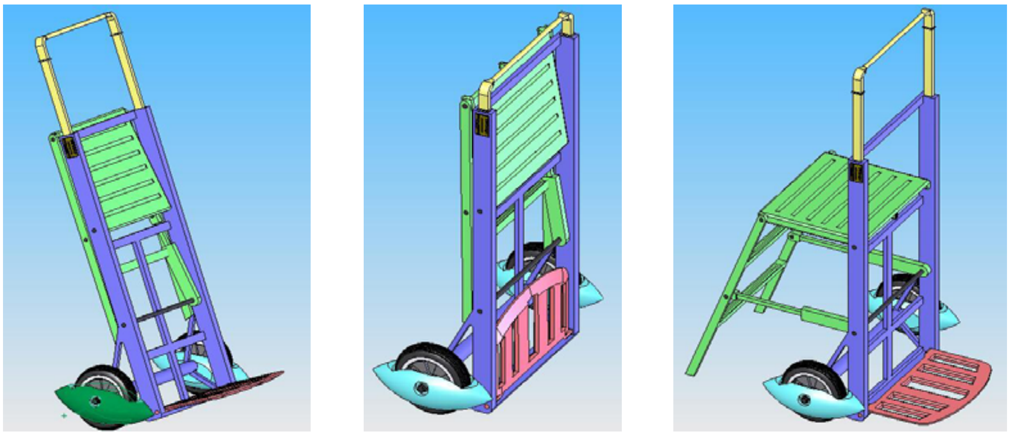

Figure 1: A typical example of a successful first year student design project work

Figures 1 and 2 show examples of a successful design and an unsuccessful design, respectively.

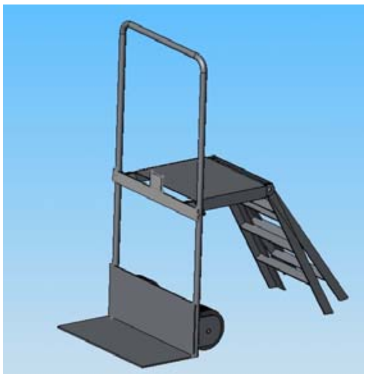

Figure 2: A typical example of an unsuccessful first year student design project work

4.2 Typical problem patterns identified

Although first-year team-based design engineering projects have proven to be feasible and manageable and the majority of first-year engineering students were generally capable of completing rather complex and innovative solid modelling tasks, the authors found that a significant number of students enrolled in year 1 find themselves initially seriously frustrated by the open-endedness of the projects and their non-resemblance to typical high-school assignments. In addition, there seems to be a general lack of students' enthusiasm to grasp the challenging opportunities of design engineering projects that value creativity and immersion into enriched learning experiences beyond the traditional views of engineering.

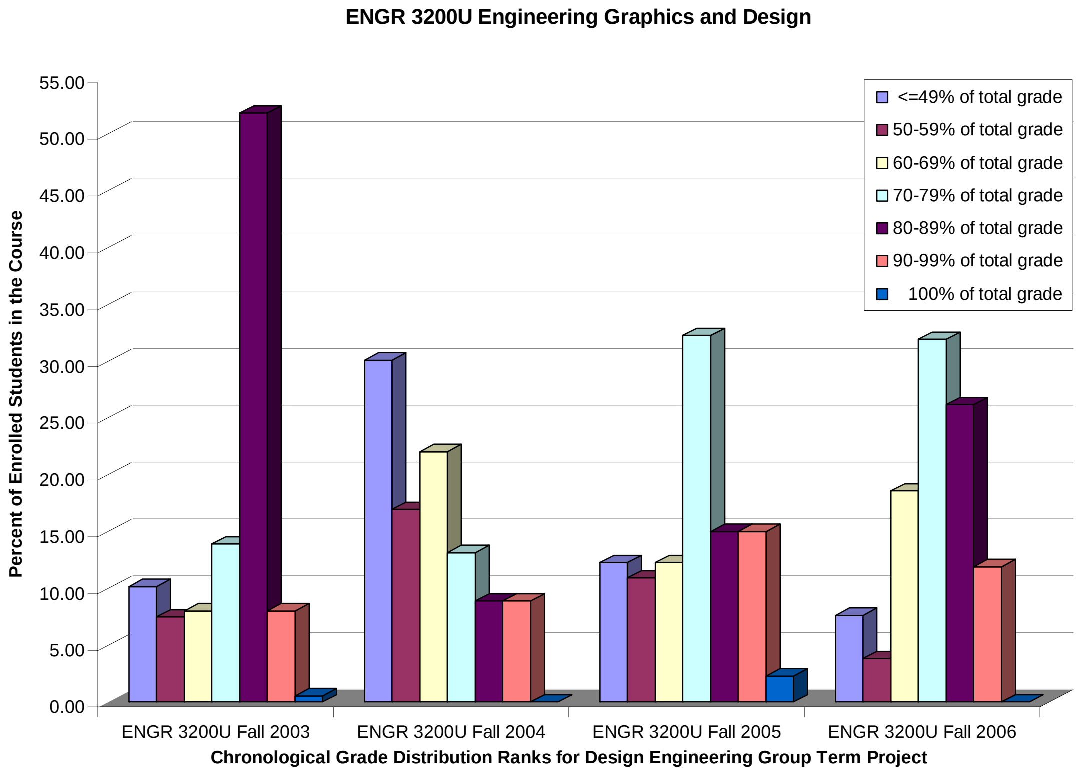

Figure 3: Distribution of design project grades in the first year core design course

Figure 3 depicts the variations of students' performance in first year design engineering projects assigned within the first year core design engineering course over the terms when the course was offered. It is clear that there is a large percentage of students with unsatisfactory grades (<=49%) or those that are performing poorly (below 60%), as well as there is another significant percentage performing at the barely acceptable level (60-69%) on a year to year basis. However, over the years, this critical percentage of marginally performing students is showing a decreasing trend ranging from about 65% in the fall of 2004 to about 11% in the fall of 2006.

One specific problem that was identified through examining the students' freehand concept sketches included in their projects indicated that problems existed in their visualization and spatial skills. Many of the sketches were sloppy and difficult to understand and poorly conveyed the ideas they were generating. Another major issue was the quality of the engineering drawings. Numerous deficiencies were noted in the poorer performing groups, including: missing assembly and sub-assembly drawings, missing bill of materials, missing part drawings, unnecessary drawings, no templates, missing tolerances, missing units, wrong standard of dimensions, and poor/misuse of the CAD packages built in dimensioning tool. Where tolerancing was included, it was often done incorrectly. The final deficiency was in the student's project management skills. It was clear from the projects that many groups did not adequately manage their time on the project and were rushing at the end to meet the due date.

4.3 Proposed remedial strategies

4.3.1 Mini design projects module

Develop a series of mini design projects that would focus on concept generation using free-hand sketching and the development of CAD models based on the free-hand sketches. Each mini-project would be covered over two weeks of laboratory sessions. The mini projects would be accompanied by online video with voice over featuring sketching using tablet computers as input devices. The video would feature proper sketching techniques and serve as a reference to students of how to do free-hand sketching and to show how freehand sketching ties into concept generation and evaluation and the development of CAD models of a design.

4.3.2 CAD module 1
Create a module that teaches students how to use a medium level 3-D solid modelling CAD package. The module would feature a series of webcasts created using Camtasia® and feature voice over narration. The webcasts would cover all aspects of effectively utilizing 3-D solid modelling and serve to reinforce the concepts introduced in the face-to-face CAD laboratory sessions.

4.3.3 Engineering drawing module
Develop a module that features an online video with voice over that shows the elements of a complete set of engineering drawings. The Engineering Drawing Module would link to online resources showing multiple examples of complete sets of engineering drawings for various projects. The module would also contain a checklist that students can use to ensure that their drawings are complete.

4.3.4 Tolerancing module
Develop a module that specifically addresses tolerancing. Tolerancing is one of the most difficult topics for first year students to master. The module would cover both basic tolerancing and Geometric Dimensioning and Tolerancing (GDT)[4]. The proposed module would contain interactive learning elements where students are given sample parts and assemblies and have to correctly tolerance them before moving on to the next part.

4.3.5 Project planning and management module
In the first two years of offering the course, the project management laboratory was done near the end of the course (after all the CAD laboratories). From 2005 onwards, the project management laboratory was moved to the middle of the course, right at the time the students were starting their group design project. This resulted in the students having better time management for their projects as evident in the reduction in the percentage of students with lower marks in the course for 2005 and 2006 when compared with 2003 and 2004. However, the students would benefit from additional help in this area. The Project Planning and Management Module would feature online resources that would reinforce the concepts introduced during the project management laboratory.

5 SECOND YEAR DESIGN ENGINEERING PROJECTS

5.1 A typical project brief
Typically, the second year core design engineering course is mainly revolving around major group design engineering projects and case studies. For example, one project involved a design of an aircraft main landing gear based on a common landing gear compartment and door design concept that supports interchangeable landing gears, whereas another project involved a design of a bi-axial mold rotating mechanism for single-charge fabrication of integral-skin polyolefin foams. Yet another project involved the design of an autonomous mechanical walking rickshaw pulling mechanism. These projects provide opportunities to student teams to present their finalized design work and working prototypes via in-class presentations. "Meccano 50®[5]" design kits, which consist of a metal (some plastic parts) model construction system made up of strips, plates, girders, wheels and gears, based on the principles of mechanical engineering, were innovatively implemented to support prototype building within the team project based curriculum of this course. In this course, as well, students use a solid modelling CAD package and several additional open-source concurrent engineering-related software packages to enhance their proficiency in concurrent design engineering.

5.2 Typical problem patterns identified
Figure 4 depicts the variations of students' performance in second year design engineering projects. The accomplishment of such "from-start-to-finish" projects normally requires using multiple ways of understanding and applying both basic and engineering sciences through a hands-on, design-build-test-analyze approach involving interdisciplinary methods in a team environment. As a result, sometimes,

[4] GDT refers to a set of symbols used on engineering drawings to specify permissible manufacturing shape variations of a component.
[5] More details are available at: http://www.btinternet.com/~a.esplen/mecc.htm

students become bewildered when presented with a large scale project that emulates the real-world so that their typical response is that they suddenly forget everything they were taught and they then start implementing shortcuts via trial-and-error strategies to solve a given design problem.

5.3 Proposed remedial strategies

5.3.1 How to approach cross-course integrated projects module

According to literature sources, it is apparently a common practice that in higher engineering education undergraduate engineering subjects are taught to significant depth and complexity. However, design engineering is commonly taught in a relatively isolated manner so that integration of these subject areas into a coherent thread is seldom considered. The reasons for this usually reduce to either lack of resources, ignorance of novel technology, or an aging academic environment [11]. To preclude the possibility of this happening in UOIT and to further reinforce the relationship between design and analysis within engineering subjects, the authors have undertaken an initiative to enhance the undergraduate engineering curriculum by developing integrated undergraduate engineering design projects that feature a common project between one of the core design courses and standard analysis courses with a strong linkage to design. For example, cross-course integrated projects were introduced in the third year of the engineering curriculum [9]. The immediate objective of this learning module would be to serve the students as a guide on how to approach integrated design projects. The ultimate objective is to prepare students with relevant workplace engineering skills and improve the product development process through an integrated approach that will beneficially compress future products' time-to-market durations while getting the products right the first time.

5.3.2 Customer requirements and engineering specifications module

This module will cover how to generate customer requirements, interpret them, and generate engineering specifications. It will cover topics like Total Quality Management and House of Quality.

5.3.3 Prototyping and testing module

This module will cover how to create prototypes using rapid prototyping technologies. In addition the module will cover how to structure and conduct a proper prototype testing regime.

5.3.4 • Standardization and regulations module

The Standards and Regulations Module will connect to online resources for standards and regulations. Numerous examples illustrating there appropriate application in design will be included.

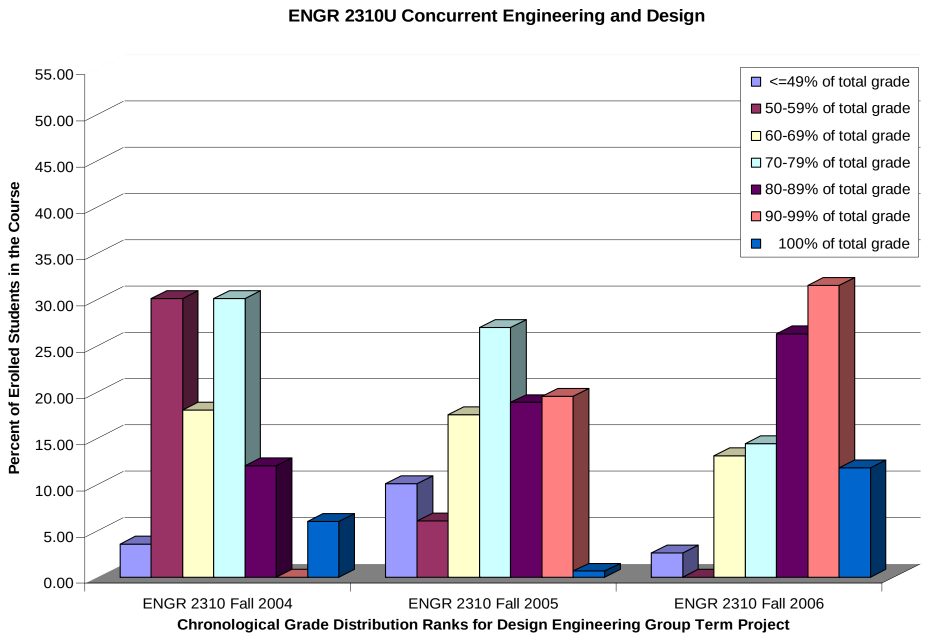

Figure 4: Distribution of design project grades in the second year core design course

6 THIRD YEAR DESIGN ENGINEERING PROJECTS

6.1 A typical project brief

As indicated above, in the third-year design course, the students work on a design project that is a common (or integrated) project with the course Kinematics and Dynamics of Machines. The students have to complete engineering design, including all engineering analysis, of a mechanism to perform some desired task. A typical project was the design of a mechanism to service conveyor belts delivering different sized wheels. Requirements included a complete set of engineering drawings, FEA and engineering analysis, motion simulation of the mechanism, construction of a proof-of-concept prototype using LEGO Mindstorms®[6] design kits, and a maintenance manual.

6.2 Typical problem patterns identified

Figure 5 depicts the variations of students' performance in third year design engineering projects. A major problem identified was the misuse (or abuse) of Finite Element Analysis (FEA) software. Too often groups performed FEA analysis with no regard for boundary conditions and without performing manual calculations to verify that the results obtained were reasonable. This is a serious problem because, when used incorrectly, FEA packages can lead to completely meaningless results.

6.3 Proposed remedial strategies

6.3.1 CAD module 2

Create a module that teaches students how to use a high level 3-D solid modelling CAD package. The module would feature a series of webcasts and using voice over narration. The webcasts would cover all aspects of effectively utilizing advanced 3-D solid modelling features.

6.3.2 FEA module

Create a module that teaches students how to properly use FEA, including how to properly choose boundary conditions and what engineering calculations are required to verify the results obtained. The module would feature a series of webcasts using voice over narration. The module would also connect to additional online resources including solved FEA examples that included the supporting engineering calculations. The module, in essence, would be an online course on FEA.

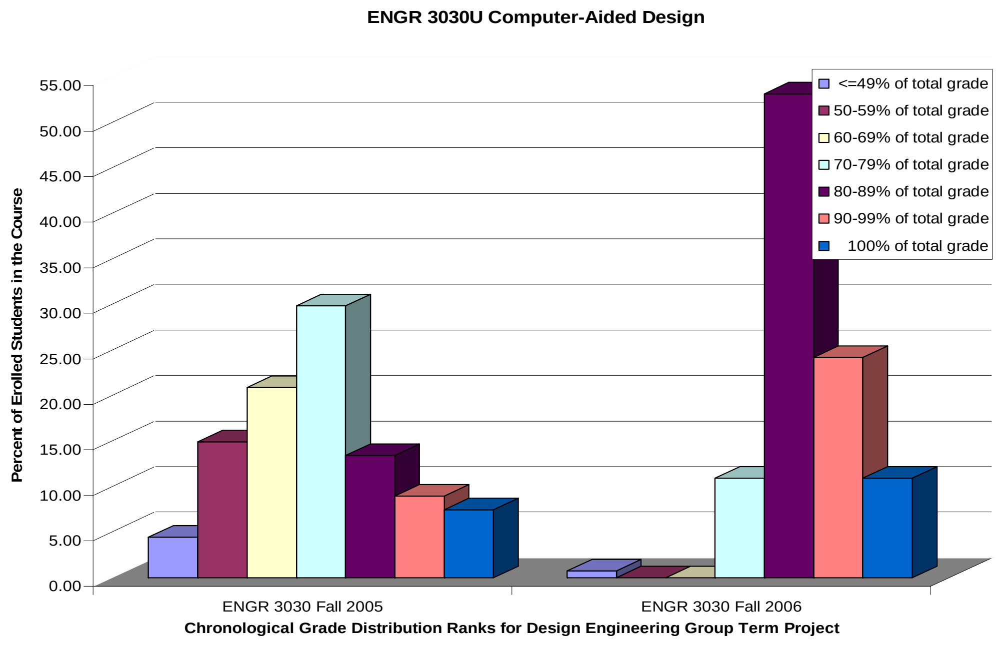

Figure 5: Distribution of design project grades in the third year core design course

[6] More details are available at: http://www.lego.com/eng/education/mindstorms/default.asp

7 THE FRAMEWORK OF DESIGN ENGINEERING EDUCATION MODULES

The ultimate goal of the project is to more effectively prepare graduating engineers for the real-world. These modules will form the core of the curriculum and serve as exemplary, "hands-on-minds-on" model lessons that enrich the learning experience of the entire range of students. Eventually, successful students should gain proficiency in: (i) applying principles of mathematics, science, and engineering science to solve problems, (ii) demonstrating the ability to understand and design a useful product in the context of solving a design problem, (iii) working effectively as part of a team, and (iv) communicating effectively design contents. The framework of modules will be hosted on a web site at UOIT allowing students unrestricted access to them at any time. Although certain modules are targeted for students within certain years of the program, the idea of the framework is to allow students to use it as reference source that they can access anytime during the duration of their program.

7.1 Completed modules

To date the following modules have been completed:

- CAD Module 1
- Mini Design Projects Module
- CAD Module 2
- How to Approach Cross-Course Integrated Projects Module

CAD Module 1 consists of a series of webcasts created in Camtasia that explain step-by-step the use of SolidWorks®. The Mini Design Projects Module was selected as the next module to be developed. As stated before, the module focuses on concept generation using free-hand sketching and the development of CAD models based on the free-hand sketches. The ability to spatially-visualize is critical for an engineer to be good designer and it is a skill that student must master early if they are to succeed. CAD Module 2 is similar to CAD Module 1 in its format, but it concerned with UGS NX4®. Cross-Course Integrated Projects have currently been implemented between the Computer-Aided-Design and Kinematics and Dynamics of Machines courses in the third year of the programs. The hope is that this idea will be broadened to other years and courses in the programs.

7.2 Modules under development

At the time of writing, the following modules were under development:

- Engineering Drawing Module
- Project Planning and Management Module
- Customer Requirements and Engineering Specifications Module

7.3 Future modules

At the time of writing, the following initial modules needed to still be developed:

- Tolerancing Module
- Prototyping and Testing Module
- Standardization and Regulations Module
- FEA Module

The above list of modules is in the planned order that they will be developed. The Engineering Drawing Module and the Project Planning and Management Module were determined to be the most critical based on the results of the various projects in terms of how often mistakes in these areas were being made.

7.4 Envisioned framework evolution

The idea of the framework is that it will always be evolving and expanding. Professors can develop their own modules and incorporate them in the framework. As technologies change, as is the case in CAD, new modules can be developed for the latest CAE tools and old modules can be removed. Other modules will be permanent fixtures of the framework, but will always be updated to keep them relevant. The form that the modules take may change as technology changes. For example, as virtual reality, becomes more cost effective, the modules may incorporate elements that take advantage of the benefits if this technology.

9 SIGNIFICANCE OF THE WORK ACCOMPLISHED

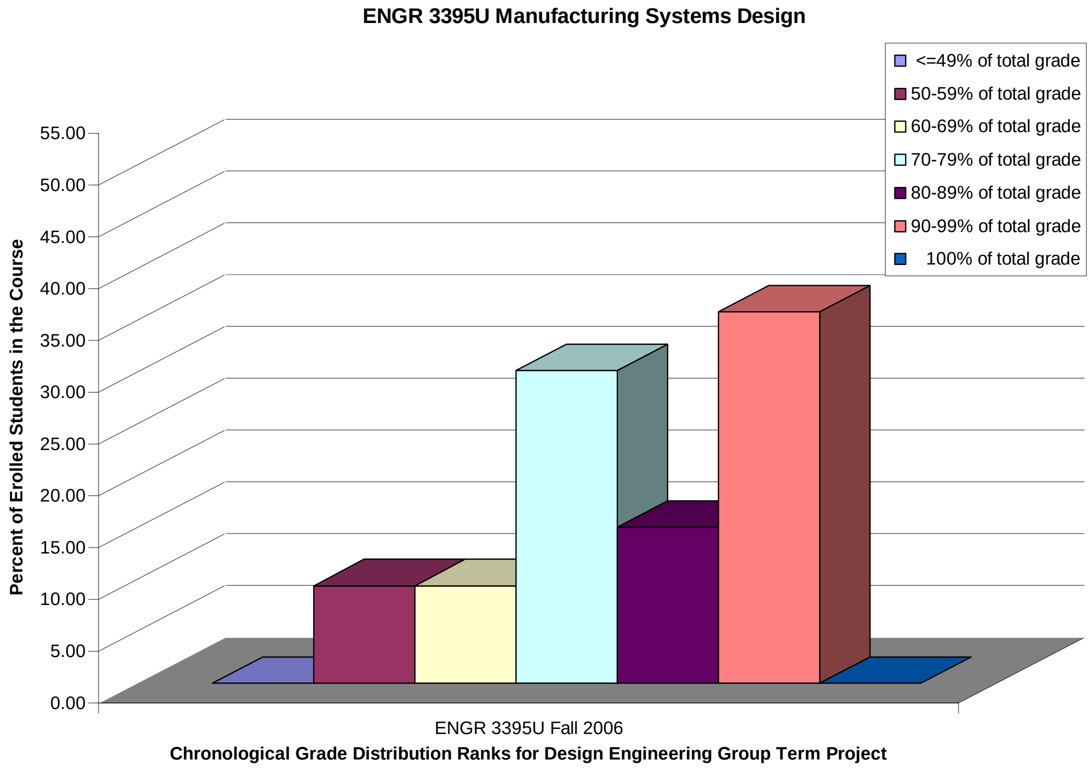

Figure 6: Distribution of design project grades in the fourth year capstone design course

Figure 6 depicts the variations of students' performance in a fourth year capstone design engineering course. The immediate benefits of introducing part of the digital learning modules are already quite obvious: over the years, the critical percentage of marginally performing students on design engineering projects is showing a decreasing trend (Figures 3-5) in all core engineering courses while achieving "only" about 15% of "sub-standard" (<70%) student performance in the graduating year.

10 CONCLUSIONS

A design-intensive undergraduate engineering curriculum has been developed in a brand new entirely laptop-based university around three core design courses, a program-specific capstone design course, and a Design Thesis. These courses were designed to provide a continuum of carefully crafted project-based team and individual design engineering experiences. The significance of the core design courses has been further augmented by implementing integrated cross-course design engineering projects among compatible design courses and those with strong emphasis on engineering analysis. However, not always the actual students' performance in these design projects was considered as being in par with the above-the-average projected quality expectations. In addition, although the benefits of the laptop program are numerous, after four years of its implementation, the preliminary results show that despite having permanent access to such a powerful resource at their fingertips, junior engineering students are not making the most effective use of the tool. To counter this undesired occurrence, this paper explored some novel educational opportunities of assuring that engineering students continue to acquire, retain, and enhance the competences typical for the engineering profession for the betterment of its stature and its relevance. As detailed in the presented paper, the authors have incorporated a specific non-traditional approach to the engineering curriculum which extends and promotes the most advanced concepts of design engineering training into the general engineering educational setting via digital content. As a short term result, the general performance of students in design engineering projects has been notably improved when the students learning process was supported by deliberately produced digital deliverables in the form of instructional videos. The addition of self-learning digital units such as self-paced self-learning and explanatory self-guidance step-by step know-how digital video materials substantially enriched the way the material is being presented thereby enhancing the positive outcomes of this initiative. It has been found that by deliberately supporting the depth of students' learning in a manner suitable to their every day habits, i.e., via providing well-paced design engineering educational experiences in a controlled digital environment commensurate to their level of expertise makes a substantial and desired difference. The completion of this extensive project represents a significant step towards narrowing the existing gap between the mostly theoretical approach in solving design engineering problems typical to fresh engineering graduates and the practical realities of the industrial workplace.

ACKNOWLEDGEMENTS

UOIT's Design Chair budget is financially supported by: Natural Sciences and Engineering Research Council (NSERC) of Canada (cash contribution), General Motors Canada Limited (GMCL) (cash and in-kind contribution), and UOIT (cash and in-kind contribution). The authors would also like to thank the Canadian Design Engineering Network (CDEN) and UOIT for the partial financial support of this work. The authors are also grateful for the hardware and software provided by the PACE program.

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