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Technology-based activities for transformative teaching and learning

Daniela Pusca & Derek O. Northwood

University of Windsor
Windsor, Ontario, Canada

ABSTRACT: It has been demonstrated by Cavanaugh et al that …*digital technology is restructuring the way our students read and think* [1]. Instructors, when reflecting on what and how we teach, must place equal consideration on how today's students learn. In this article, the authors discuss technology-based teaching and learning tools that have been implemented in design courses at the University of Windsor. The purpose is twofold, namely: 1) to better serve the instructor's objective to create an engaging and stimulating teaching and learning environment; and 2) to meet the students' learning needs, allowing them to achieve the desired competencies in course-specific graduate attributes. To analyse the effectiveness of these new tools in students' teaching and learning experience, the authors used the feedback provided by both the students and teaching assistants. Results indicate the positive impact of the proposed changes not only on student engagement, but also on their visualisation and graphical communication skills, better information retention, ability to adapt knowledge to solve open-ended problems and motivation for further learning.

INTRODUCTION

As Canadian undergraduate engineering programmes move towards an outcomes-based curriculum that requires the implementation of a continuous improvement process, transforming the manner in which teaching and learning is achieved in engineering design courses has become of imperative importance not only for the instructors and the graduate assistants, but also for the students taking these courses. A transformation from traditional teaching methodologies (e.g. lectures and tests) is required to actively engage *digital brains* [1][2]. Since digital technology is affecting our day-to-day life at so many levels, it became essential to transform teaching and learning experiences using technological tools. In this article, the authors discuss how to implement digital technology in order to expand teaching effectiveness and increase students' engagement and learning capacity in engineering design courses.

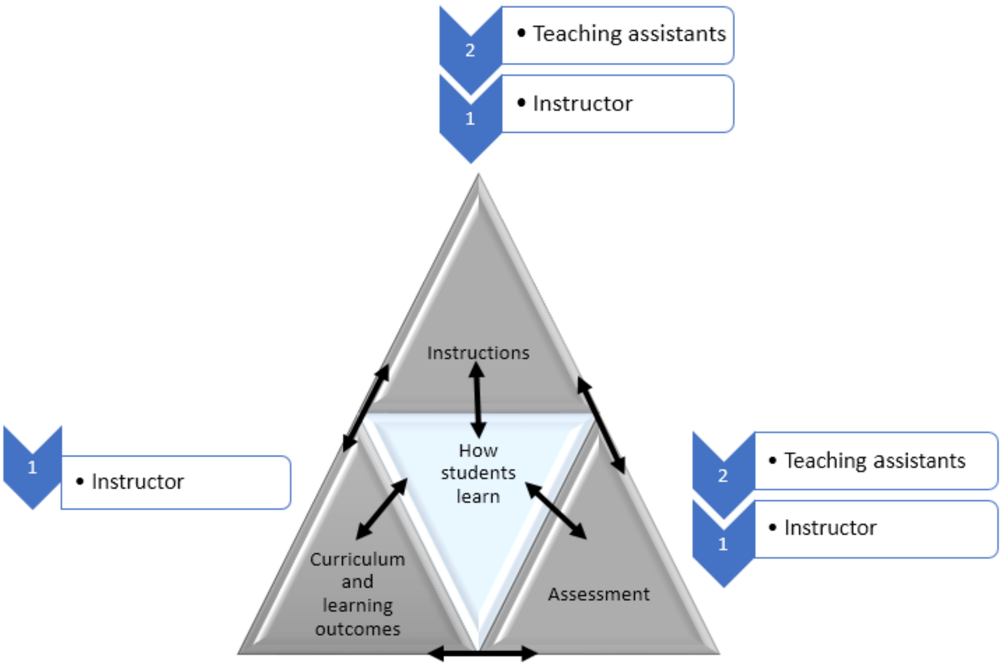

Figure 1: Curriculum-instruction-assessment (CIA) model.

The curriculum-instruction-assessment model shown in Figure 1 was used for understanding how knowledge is transferred from, and among, the instructor, teaching assistants and the students [3][4]. The answer to the question *how people learn* will be different, based on how each part of the model is specifically designed for the course, especially the instructional activities as teaching and learning activities. In the context of outcome-based curriculum in engineering design classes, the learning outcomes are identified first, the evidence of how achievement of the results will be assessed is determined second, and finally, the learning activities and instruction methods are planned, with the main priority being the students' engagement through active learning [5]. This study is concerned with the last stage of the course design, instructional activities and the selection of technology based teaching and learning tools, in the context of a student-centered approach and active learning.

Since engineering design is about both creation and design using scientific principles, ideational sketching, 2D graphical representation and 3D modelling are authentic means of communication amongst engineers. In this context, the instructor must be flexible and incorporate the appropriate digital technology to facilitate students' learning and engagement in engineering design classes. Also, in order to select a technological tool in a classroom, it is essential for the faculty member to understand the dynamics of the classroom and the information background of the students. The confidence of the instructor and the practicality of the introduced technological devices, are also factors that need to be considered.

Further, the authors present and discuss the new technology-based teaching and learning tools that have been implemented in design courses at the University of Windsor. The purpose was not only to better serve the instructor's objective to create an engaging and stimulating teaching and learning environment, but also to meet the students' learning needs, allowing them to achieve the desired competencies in course-specific graduate attributes. To do this, the authors have attempted to align the teaching styles with student learning modes [6] by implementing approaches to experiential learning that include digital simulations, augmented reality and other modern concept design techniques, such as fused deposition modelling.

ACTIVE LEARNING THROUGH IMPLEMENTATION OF NEW TECHNOLOGY IN ENGINEERING DESIGN

The challenge for the instructor in the engineering design classes is to find ways to engage students and encourage them to be active and independent learners. Responding to the demand for students' early exposure to the engineering profession, and for the development of their problem-solving and critical thinking skills, problem-based and project-based teaching and learning are used as inductive methods to address all aspects of the engineering design process, as an effective problem-solving algorithm (Figure 2) [7][8].

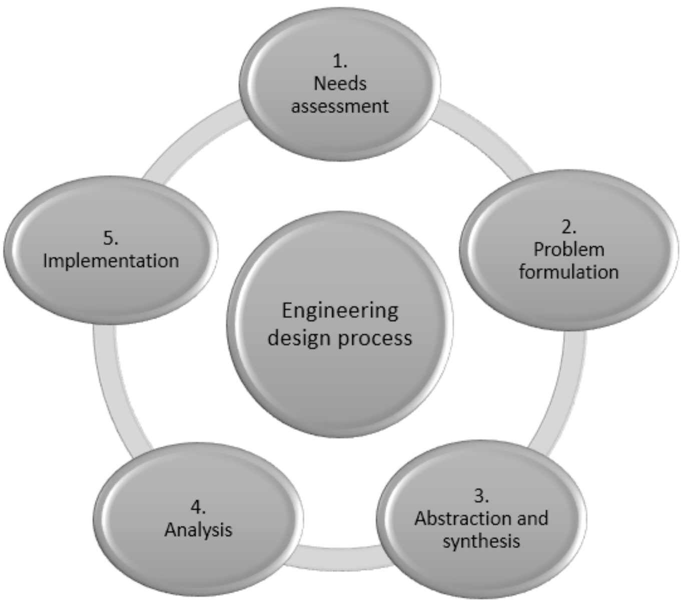

Figure 2: Problem-solving algorithm in engineering design process.

Other specific learning approaches that are used and have strong student-centred components are collaborative learning and experiential learning. In this context, the teacher has the role of facilitator and coach in developing problem-solving skills, promoting positive attitude and group effort, providing the necessary skills for project management and graphical communication of the design solution [9][10]. As noted by Northwood et al in their article on PBL:

> *PBL emphasises learning instead of teaching. Learning is not like pouring water into a glass; learning is an active process of investigation and creation based on learners' interest, curiosity and experiences, and should result in expanded insights, knowledge and skills* [9].

The instructor’s role was to find the appropriate tools and methods not only to motivate students’ learning effort and engage them in the learning process, but also to help them achieve the desired learning outcomes. Since digital technology is a permanent presence in the lives of students [11], every stage of the engineering design process was analysed in order to find ways to modernise it, by identifying the needs areas and integrating specific digital tools. The need to implement these tools was also triggered by other issues, such as:

- To improve students’ spatial abilities and visualisation skills;
- To engage the students in the learning process;
- To provide opportunities for hands-on learning and learning by doing;
- To expose them to a complete design cycle, including prototyping.

Table 1 provides an overview of the digital tools that were implemented, in relation to teaching and learning activities and applicability to the engineering design process. Digital technology enables engineering educators to respond to a variety of learning styles and allows for demonstration and better presentation of difficult concepts.

During class time, which is designed as an integrated lecture-laboratory environment [5], students work in groups to find solutions for the design problems, and present their ideas in a multi-modal manner-visually, textually and orally. To accomplish this, students are first introduced to the fundamentals of sketching, isometric and orthographic drawings, and dimensioning. They need to apply visualisation, modelling and graphics techniques to design appropriate project reports, enhancing in this manner their competencies not only in technical communication skills, but also in the use of engineering tools and teamwork.

Table 1: Morphological chart for technology-based activities.

Digital tools	What	Instructor	Students’ competencies	Application in engineering design process
Mobile devices (iOS and Android devices)	Digital sketching Augmented reality	Integration of knowledge: • Sketching • Isometric drawings • Multi-view drawings	Visualisation skills/spatial abilities Teamwork	Abstraction and synthesis phase
PC computers	CAD packages (CATIA V5) Cloud computing	Integration of knowledge: • Solid modelling • Generative drafting • Animation	Use of engineering tools Graphical communication skills Teamwork	Analysis Implementation
3D printer	Fused deposition modelling	Integration of knowledge: • Prototyping • Additive manufacturing	Use of engineering tools Physical model	Implementation

The use of mobile devices, like tablets and cell phones, was triggered by the availability of user-friendly applications for engineering design classes, and also because of their mobility and convenience. These devices are used in the process of teaching and learning to develop three important competencies: freehand sketching, view generation and visualisation skills. Lenovo Think Pad tablets (Figure 3) are used together with traditional paper and pencil in producing ideational sketches.

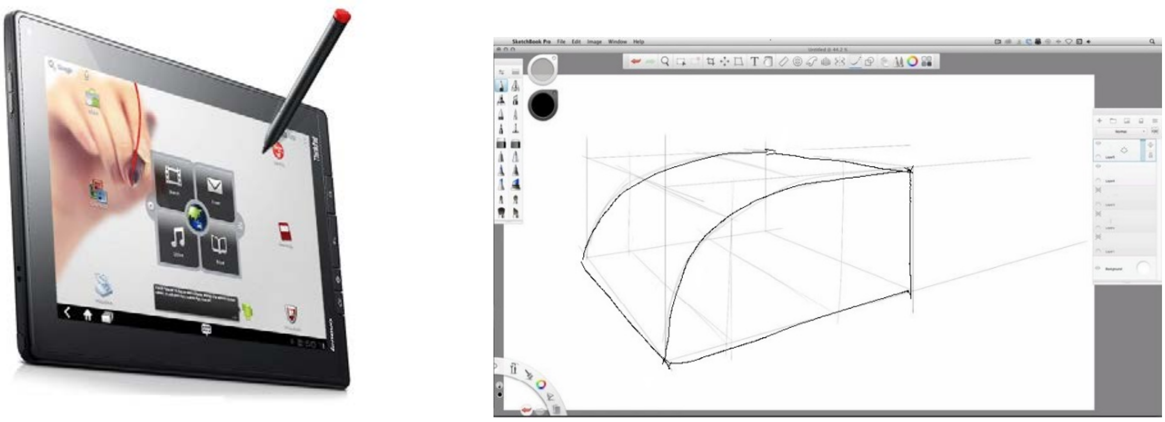

Figure 3: Tablet and digital sketch of a two-point perspective using SketchBook Pro.

A professional grade drawing and sketching mobile application, SketchBook Pro, was installed on the tablets. Its user friendliness and simplicity were deciding factors in choosing this software. Students tested the software through a self-learning process following instructions provided by teaching assistants, and also made available through the learning management system on the course Web site. They used the application for digital sketching of their design ideas or concepts, during abstraction and synthesis phase of the design process. At this stage, each design team was required to brainstorm and explore different design alternatives. The advantage associated with the digital sketching was not only that it provides an experience similar to the use of paper and pencil, but also the convenience of file storage in Dropbox, in order to access the ideation sketches on any device and to share them with the other members of the design team or to make them available to the teaching assistants and instructor for review. By implementing digital sketching, the faculty (academic staff) was able to stimulate students, to capture their attention and to create a positive attitude towards the sketching tasks.

The main challenge faced by the students in engineering design class seems to be the capability to visualise 3D objects and create axonometric views based on 2D orthographic projections. To make the learning process faster and more engaging, augmented reality (AR) is used as a visualisation tool [12]. This was possible since the textbook contains embedded markers associated with the 2D application. When scanned by a device (cell phone or computer tablet) with the AR engineering application, it produces a 3D model that will appear on the screen superimposed on top of the marker. By moving the device, the 3D model can be manipulated in real time (Figure 4) [12]. The mix of real life and virtual reality displayed by the applications using the mobile device's camera allows information to be manipulated and seen like never before. The AR engineering application and software in conjunction with the textbook not only creates a highly engaging environment, but also transforms the students' learning experience.

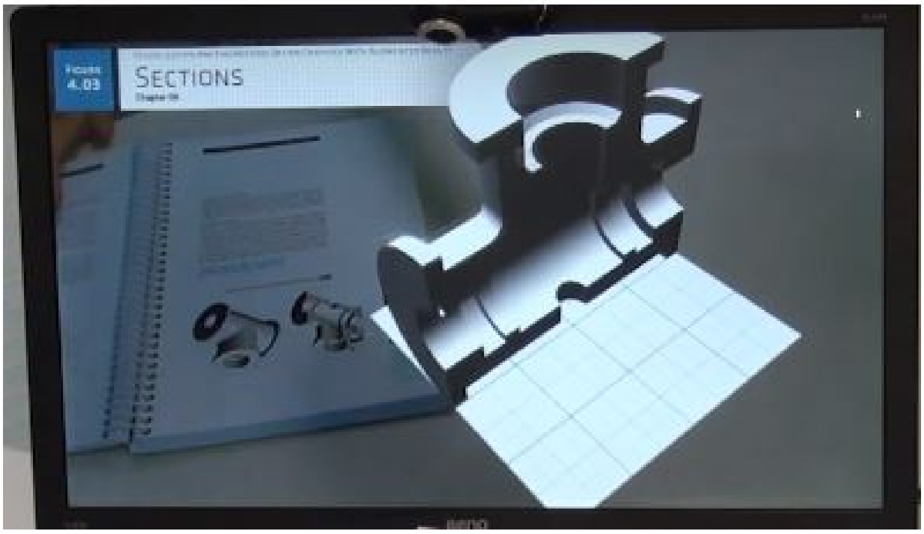

Figure 4: Example of an object rendered in real time on the screen using AR engineering [12].

Preparing the students with visualisation skills through free hand sketching and augmented reality was complemented with the use of PC computers and modelling software. Along with learning the basic drafting and visualisation skills, CATIA V5 software was used to further develop the students' engineering graphical communication skills. Through tutorials and class applications, students developed their capability to use the software for solid modelling, generative drafting and animation. These skills were used during the analysis and implementation phases of the design process. Figure 5 provides a sample of students' work on a project concerning the design of an electric car.

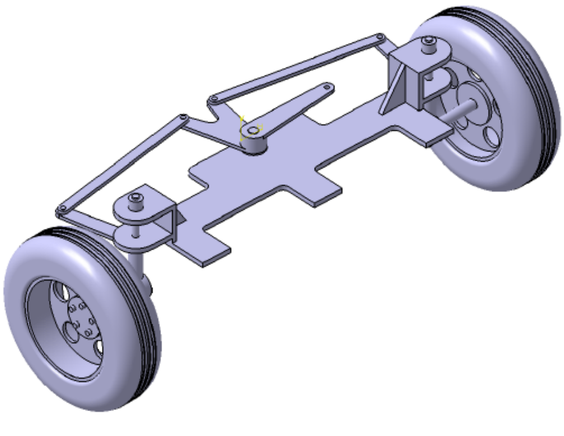

Figure 5: CAD representation for a 3D rear steering linkage mechanism.

3D printing was introduced because it provides several features that improve the teaching and learning experience. The technology allows users to turn the digital file into a three dimensional physical product (Figure 6). For the purpose of the engineering design course, it was used to produce physical models of specific parts/shapes, so that the faculty was able to use them to better explain some difficult to grasp concepts, like orthographic projections, sectioning or the need for auxiliary views. At the same time, the students were also provided with the pictorial representations of the same objects, using a CAD package. This approach enabled more opportunities for interactive class activities. For the students, it provides a great opportunity for hands-on learning and learning by doing. Using fused deposition modelling as prototyping technology, students were able to produce realistic 3D mini-models (Figure 6). Given all these attributes, 3D printing definitely assisted in the fulfilment of a productive educational experience.

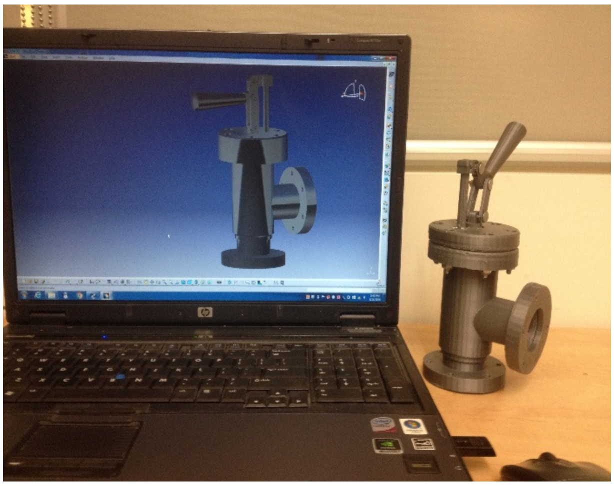

Figure 6: 3D CAD representation and 3D print for a mechanical valve.

By modernising the teaching and learning process of engineering design through the implementation of technology-based activities, a learner-centred approach to curriculum planning was also achieved [6]. The changes that were implemented and the targeted students' attributes are summarised in Table 2. As Prince and Felder stated, this approach imposes more responsibility on students:

The methods almost always involve students discussing questions and solving problems in class (active learning), with much of the work in and out of class being done by students working in groups (collaborative or cooperative learning) [8].

Table 2: Graduate attributes and overview of technology based activities.

What	How	
	Initial course	Transformed course
Concept design	Pencil and paper sketch	Digital sketch and paper, and pencil sketch
Visualisation skills	3D models on a 2D medium	Augmented reality and physical models
Solid modelling and animation	CAD software/no animation	CAD software/animation
Additive manufacturing	N/A	3D printing by FDM

RESULTS AND CONCLUSIONS

For the successful implementation of such activities, faculty members, teaching assistants and students need to communicate and collaborate in a constructive manner. The students not only gained confidence in their work and their knowledge, but also benefited from the fact that there were no communication barriers between them and the teaching assistants. The students were able to constructively experiment with all these tools, within the time constraints associated with the delivery of the one semester course.

The pilot study involved a series of activities of increasing difficulty to demonstrate the efficiency of introducing digital technology for improving students' visualisation skills. In both the pre-test, administered at the beginning of the course before the use of technology-based activities, and post-test at the end of the course, after experimenting with AR and CAD modelling, the students were required to represent:

- Orthographic views based on physical parts;
- Orthographic views and auxiliary views given the isometric view;
- Isometric views of parts given their orthographic views.

For the purpose of the study, in both tests the students were asked to use paper and pencil to sketch the solutions. Table 3 summarises the results as the mean of the scores in pre-test and post-test, out of 100 points. The pre-test results reflect that the participants have difficulties with spatial abilities. The results also show the suitability of integrating technology based activities, reflected by the improved mean scores in the post-test.

Table 3: Data for pre- and post-tests.

Difficulty level	Requirement: model the part	Pre-test score	Post-test score
Level 1	Orthographic views based on physical parts	72.3	88.7
Level 2	Orthographic views and auxiliary views given the isometric view	65.8	76.2
Level 3	Represented by their orthographic views.	48.6	62.3

The total average increase in the mean score is about 14 points; and it is strong evidence that using suitable digital tools and software can enhance students' learning and their spatial abilities.

Who will benefit? The instructor uses the feedback to further improve the course content, delivery methods, and the selection and implementation of engineering tools. Teaching assistants have the opportunity to gain teaching and learning skills by having exposure to new engineering design tools. Also, the teaching assistant's leadership skills, their ability to communicate and manage conflicts are improved by being involved with the project-based activities. Students have an opportunity to become motivated and active participants in the learning process by experimenting with different digital tools, and use these skills to make personal decisions regarding future career paths.

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