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How to engage students in the context of outcome-based teaching and learning

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ABSTRACT: In an attempt to improve teaching and learning, the University of Windsor is in the process of implementing learning outcomes and competencies as part of the accreditation process. This article outlines how an outcome-based learning system has been implemented in an Engineering Design course, and the challenges associated with the process - not only for the instructor, but also for the students. It is known that there are pros and cons in regard with the adoption of learning outcomes. By implementing the learning outcomes, the students have a clear statement of what they need to achieve, but some authors argue that it does not engage the learner [1]. In an effort to address this issue, the article explains how several teaching and learning approaches were implemented in the Engineering Design course, including the flipped teaching. The effect of outcomes-based course development on course content, sequence, delivery and assessment are reviewed. By engaging the students in the learning process through in-class activities and blended learning, better results were obtained in regard with the targeted learning outcomes.

INTRODUCTION

In order to implement the outcome-based education approach to the existing models of the engineering programmes, every course has to be re-designed from the classical model, with the focus on the learning process, to the new approach, with the focus on students. In this regard, it is important for the instructors to implement new teaching methods and technologies, in order to achieve the desired learning outcomes and graduate attributes.

In this context, and to not diminish what would otherwise be an open-ended experience for student and teacher alike, a culture of continuous innovation and quality improvement is needed for outcome-based curriculum design [1]. In this new context, institutions are implementing a learner-centred teaching approach [2].

To improve teaching and learning in the context of outcome-based curriculum in Engineering Design classes, a *backward design* approach was used (Figure 1), where 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 [3]. This design process is not linear, and it requires more iteration, in the similar manner as the engineering design process is conducted. The design process of engineering courses should be viewed as an iterative process. It is a continuous process triggered not only by rapid changes in technology, but also by the need of changes regarding the content, methods of delivery and, as a consequence, the role of the instructor and the role of the student as a learner.

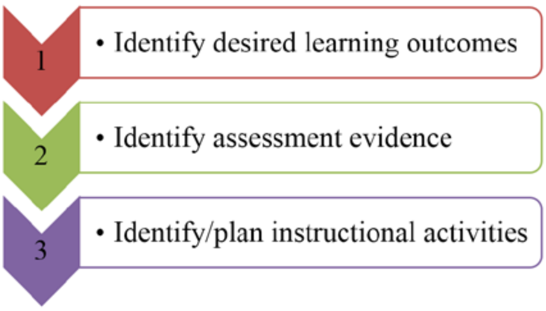

Figure 1: Constructive alignment and backward design approach.

This study is related with the last stage of the course design, instructional activities, concerning teaching and learning activities, and media selection, in the context of student-centred approach. Several authors believe that teaching instructions should consider the wide range of learning styles when designing the course [4-6]. As a result, the instructor must be flexible and incorporate different teaching methods to stimulate student learning since no one teaching style will work for all student audiences, and different teaching strategies complement different learning styles.

STUDENT-CENTRED TEACHING AND LEARNING IN ENGINEERING DESIGN

Given that the main priority was student engagement through active learning, this article explains how the three factors shown in Figure 2 were considered to achieve the desired outcome.

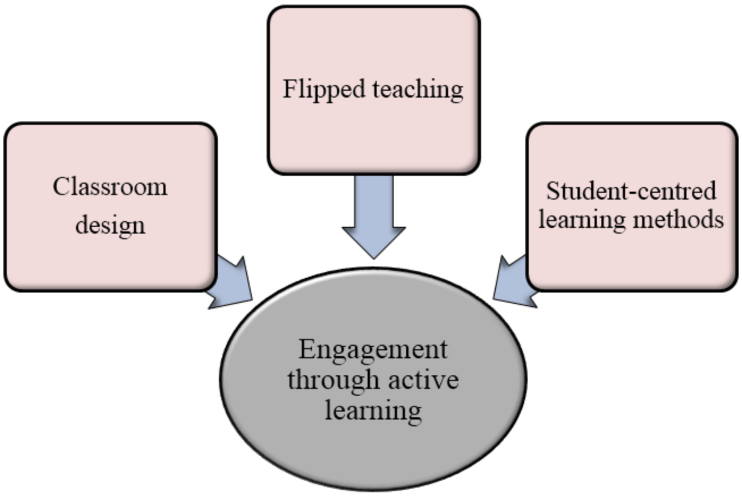

Figure 2: Factors to be considered for active learning.

The Engineering Design course is the introductory engineering design course for first year engineering students. Course activities are aimed at integrating knowledge regarding information-retrieval techniques and problem needs validation, problem identification and formulation, analysis of the problem, and problem solving techniques. Furthermore, the students brainstorm different solutions for the design problems and present their ideas through a variety of visual, written and oral communications. Specifically, they will need to apply what they are taught in visualisation techniques including, but not limited to, sketching, isometric drawing and orthographic projection.

Students work in groups to encourage and develop personal, teamwork, leadership and task completion skills. Table 1 shows the learning outcomes and the corresponding assessment methods. The graduate attributes developed and assessed are design, use of engineering tools, individual and team work and communication skills.

Table 1: Learning outcomes and assessment methods.

Number	Learning outcome	CEAB Attributes to be developed and assessed [7]	Assessment method
1	Illustrate concepts in graphical form.	Use of engineering tools	Progress tests Mid-term examination Drafting portfolio
2	Apply formal idea generation tools to develop a diverse set of candidate engineering design solutions.	Design Individual and team work	Design portfolio
3	Use models to generate a diverse set of candidate engineering design solutions.	Design Individual and team work	Design portfolio
4	Apply formal multi-criteria decision making tools to select candidate engineering design solutions for further development.	Design Individual and team work	Design portfolio
5	Refine a conceptual design into a detailed design.	Design Individual and team work Use of engineering tools	Design portfolio
6	Relate ideas in a multi-modal manner - visually, textually and orally.	Communication skills	Oral presentation E-portfolio

Note: CEAB Canadian Engineering Accreditation Board

In regard with the learning outcomes, Kenny and Desmarais noted that:

> *Above all, learning outcomes must first and foremost make clear to students what they are expected to learn and must also support student achievement of the expressed learning outcomes by ensuring a curriculum that is increasingly coherent, aligned and integrated. Established outcomes allow faculty, department, programs and the University to both demonstrate and account for student achievement* [8].

To improve the students' learning experience in the context of outcome-based curriculum, it was necessary to re-design the manner the course content was transmitted to the students. This was also triggered by other factors like class size and the learning environment. Other issues that had to be considered in the re-design of the course were:

- Time constraints and, as a consequence, proper selection of content that meets the learning outcomes for the introductory engineering design courses.
- Many first year students do not have any background in engineering graphics.
- Students entering first year engineering are not familiar with the design process used within engineering.
- The need to improve their visualisation skills.
- Graduate attributes in relation to the learning outcomes
- The new model must align with the CEAB criteria, which centres on the active role of students [7].

The classroom design is a very important factor to be considered if the intent is active learning. To facilitate students' engagement, the layout of the classroom has to be changed from the traditional design to a new user-centred design. In this manner, the students are encouraged to work in groups and to collaborate for different assignments, as assigned during class. The user centred design of the classroom in the new Centre for Engineering Innovation at the University of Windsor, Figure 3, was considered the ideal learning space for the students registered in the Engineering Design course, since it facilitates student engagement, student collaborations, and connections between students, teachers and teaching assistants, creating the ideal learning space for flipped teaching.

Figure 3: Class design for active learning.

To overcome the issue with the time constrains, it was decided to use the concept of flipped teaching. In this new context, the lecture content and other related resources - as indicated video tutorials and Internet resources, are made available to the students before the class, using the university learning management system (LMS).

In this manner, the instructor will free up more of class time to engage students in activities that will help them to master the lecture content or to use assessment tools to determine whether or not the students meet the requirements, do not meet the requirements or exceed the requirements related to the specific topic [9].

> *The key is that students are using class time to deepen their understanding and increase their skills at using their new knowledge* [9].

The multitude of approaches that may be used to design the class activities were mapped against the desired learning outcomes. A set of alternative solutions regarding the content of the new course and the manner in which it must be conducted was generated using a morphological chart. Such a chart provides an overview of possible solutions concerning a certain issue to be solved. The morphological chart for the Engineering Design course is presented in Table 2.

The instructor's task is to design the teaching and learning activities as *student-centred*. The student-centred methods chosen to design different learning activities in relation with the learning outcomes are presented in Table 3, and the article will further explain how they were implemented in the Engineering Design course.

Table 2: Morphological chart for teaching and learning activities.

Desired skills	Alternative solutions			
Integration of knowledge	Faculty and students working interactively	Virtual reality resources and augmented reality	Instructional multimedia/ animations	The use of computer tablets
Problem-solving skills	Project-based learning approach	Problem oriented tutorials	Case studies	Feedback - based on progress report
Communications skills	Sketching, isometric and multi-view drawings	CAD packages	Milestone reports and final technical report	Oral presentation and e-portfolio
Teamwork	Exercises and applications	Open-ended team design projects	Design evaluation	Oral presentation
Creativity	The use of creativity stimulation techniques	Proposing alternative solutions for the problem to be solved	Mapping function to form	Oral presentation

Table 3: Student centred activities.

Student-centred learning methods: inductive teaching methods	How it was implemented
1. Case-based teaching	Students study cases that reflect all of the teaching points the instructor wishes to convey
2. Inquiry-based learning	Exercises/applications solved during lecture time
3. Discovery learning	Applications during lecture time: examination and analysis of given models to discover design concepts
4. Project-based learning	Involves assignments that call for students to design a product

As noted by different authors, learning outcomes promote a learner-centred approach to curriculum planning [8][10]. Prince and Felder stated in regard with the learning outcomes:

> *They are all learner-centred (aka student-centered), meaning that they impose more responsibility on students for their own learning than the traditional lecture-based deductive approach does... 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)* [10].

Student-centred methods have repeatedly been shown to be in general more effective than the traditional teacher-centred approach to instruction for achieving the desired learning outcomes.

Case-based learning was used to teach the students different strategies used to develop concepts: design by accident, creativity stimulation techniques and morphological charts [11]. Students were given handouts with different articles, each representing a solution for a given design problem, and were asked to work in groups of four to identify what creativity stimulation technique applies for each of the given situations [11]:

- The development of Velcro, by Georges de Mestral, as a classic example of *bionics* leading to a successful design.
- The redesign of a toaster that lead to a new product on the market - the toaster oven, as an example of *checklisting*.
- The design of the computer printer as an *inversion* of the typewriter design.

In inquiry-based learning, students are presented with a question to be answered or a statement to be interpreted. The desired learning outcome is accomplished in the process of responding to that challenge. It was used to improve the students' visualisation skills and to explain modeling using sweeping operation.

For example, using circular sweep (a 2D profile is swept to create a 3D object), the students were asked to match the objects with the profiles used to generate them, as shown in Figure 4.

In the case of discovery learning, the learning process takes place not through instruction, but through *examination and analysis*. This method was used to teach multi-views and visualisation. In this case, the challenge was to match the given surface letter from a pictorial drawing with the corresponding surface from the multi-view drawing, as shown in Figure 5. The desired learning associated with this challenge was to be able to develop mental 3D images of objects given the 2D projections, and also to be able to create the multi-views of an object, given 3D pictorial drawing.

Project-based learning involves assignments that call for students to work in groups to design a product, and to present their work as a design portfolio, summarising what was done to achieve the final design. In project-based learning students apply previously acquired knowledge. As part of the design process, they brainstorm different solutions for the design problem and communicate their ideas through sketches. In this regard, they need to recall and apply what they were taught in visualisation techniques, sketching, isometric drawing and orthographic projection, during the first part of the lectures. Design evaluation using criterion functions must be performed by each team of 5-7 students, and the final outcome is communicated using graphical communication techniques.

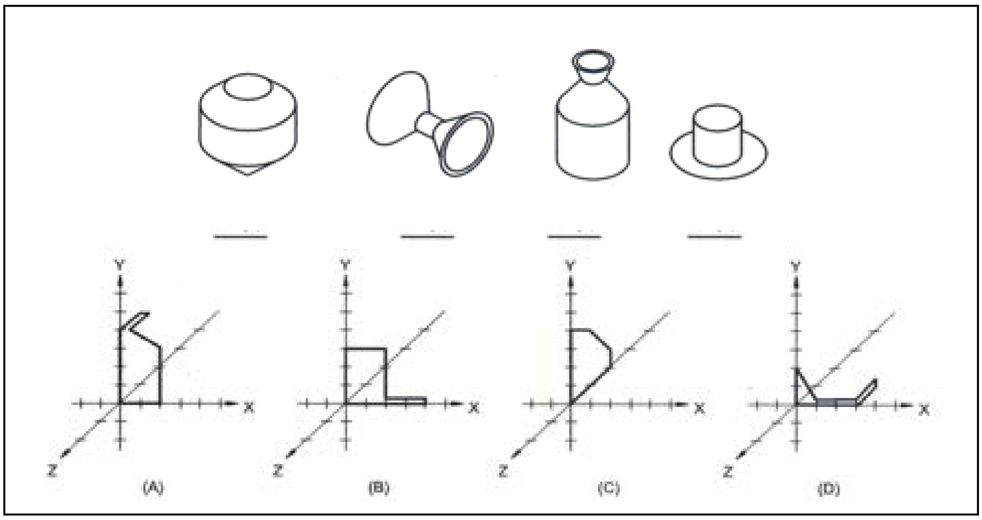

Figure 4: Inquiry-based learning using circular sweep [12].

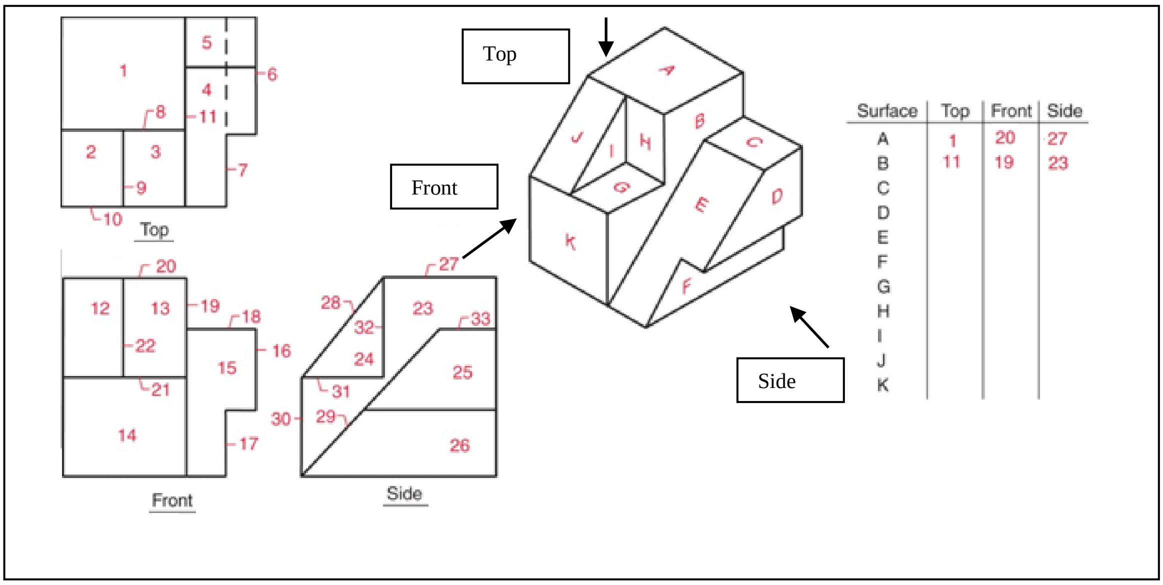

Figure 5: Discovery learning using pictorial drawings and multi-view drawings [12].

To enhance students' experience, directed learning consists of case studies that may serve as a model for future work; case histories, describing how a problem was solved and the consequences of the decisions that were made. Short lectures by guest speakers are meant to emphasise the importance of application of standards and statutory regulations.

These approaches introduce the students to such critical design topics as needs assessment, problem formulation, abstraction and synthesis, patents, engineering liability, engineering ethics and ergonomics. In this context, the instructor's role consists of constructing a knowledge base, developing problem-solving skills, promoting positive attitude and group effort, providing the necessary skills for project management and for graphical communication of the design solution, in the context of the flipped teaching. The role of the faculty is to manage the activities of the teams working on open-ended team design projects.

Teaching assistants' role is also essential in this activity [13]. Since the course is offered to large classes (300-400 students), they act as a link between the instructor and the design teams. Each teaching assistant must be familiar with the course content, have the ability to supervise 5 to 7 design teams, guide the students through the process of developing the skills for self-directed learning, provide feedback and assist the students to access resources needed to solve the design problem.

CONCLUSIONS

The design of such activities allows all factors involved in the educational process - faculty, teaching assistants and students - to communicate in a constructive manner. As a consequence, the students not only gained confidence in their work and their knowledge, but also benefit from the fact that there are no communication barriers between them and the teaching assistants. The assessment results for specific graduate attributes are shown in Figure 6 and reflect the percentage of students that met the expectations (ME), did not meet expectations (DNM) and exceed expectations (EE). The implemented methodology is clearly beneficial from the students' perspective.

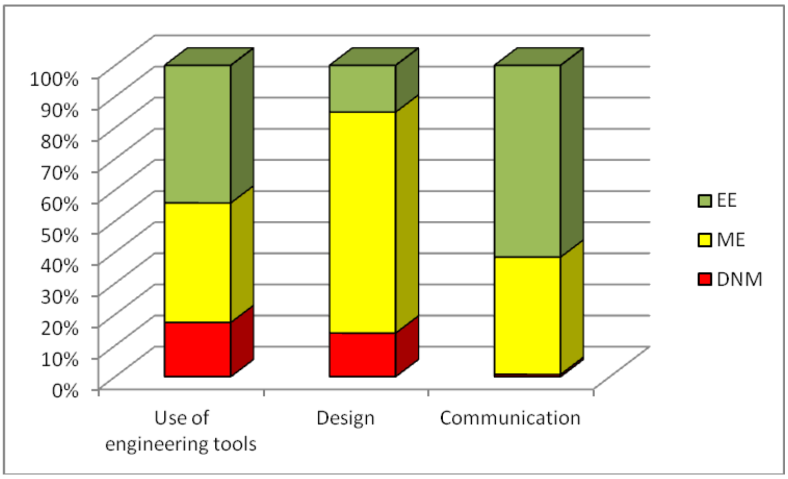

Figure 6: Students' assessment as a measurement for quality of the course re-design.

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