World Transactions on Engineering and Technology Education
Vol.19, No.3, 2021

Teaching and learning engineering design: creative methods for remote education

Daniela Pusca & Derek O. Northwood

University of Windsor
Windsor, Ontario, Canada

ABSTRACT: The traditional engineering design class was created for integrated lecture-laboratory sessions in a face-to-face environment. With the move towards remote teaching and learning at the University of Windsor, Windsor, Canada, there was a need to make changes related to both, teaching and learning. In this article, the authors discuss issues on *How much change is needed*; *Does tech solve education problems?*; *What is the impact on students' learning?;* and present innovative course design strategies for remote education, based on identified problems and challenges associated with using an e-learning platform. It is the authors' opinion that both teaching and learning should be done creatively, regardless of the environment - face-to-face or remotely. In times of rapid technological changes, instructors and students should be able to use different tools associated with the learning management system (LMS) and also course-related digital tools to achieve the desired student-centred results. The purpose of this article is to present digital tools and new technology that have the potential to transform the teaching and learning experience, regardless of the learning spaces.

INTRODUCTION

To ensure continuous academic success in the context of remote teaching and learning, a rapid shift had to be made to re-think the *why*, *what* and *how* of course design and delivery [1]. The process was possible since a culture of continuous innovation and quality improvement to ensure academic success was already a reality at the University of Windsor, Windsor, Canada. As part of the institutional approach to innovation in teaching and learning excellence and to improve students' teaching and learning experience, several practices have been already implemented, and have proven to be beneficial for student engagement and successful learning.

The face-to-face (F2F) engineering design courses were designed as a hybrid approach to intentionally incorporate digital technologies into the teaching and learning to enhance students' experiences and engagement. The existence of the learning management system (LMS) made possible the implementation of flipped classes, for the purpose of allocating more time for group work and more engagement during class time. This was a great advantage since the students were already familiar with this virtual learning environment.

To provide more flexibility and the capability to quickly change from hybrid to on-line teaching and *vice-versa* as the need arises, the hybrid-flexible (HyFlex) instructional method created by Brian Beatty was considered as the starting point [2]. In the HyFlex course design, students can choose to attend the face-to-face, synchronous class sessions or participate in teaching and learning activities on-line without physically attending class. This approach to course design enables a seamless move from hybrid towards remote life participation (RLP). In RLP, students are expected to be present in the virtual classroom and participate actively for all synchronous activities.

The curriculum is designed in such a way that the learners may have the choice between hybrid or RLP modalities, which may change as needed. Once finalised, this strategy gives the instructor more time in the future to focus on the methods, tools and strategies to enhance student learning and engagement, meanwhile minimising any change required in the course delivery mode. In the quest to re-write the *script* the leading questions for a seamless transition from hybrid to RLP were:

- What is the learning space?
- What should change and what should not?
- How does tech solve education problems?
- Is this scenario designed to quickly translate to evolving circumstances?

The guiding vision to find a solution to the problem can be viewed from a lens of effectivity; namely, *effective learning*. From the students' perspective, *effective* can be described by the following question [3]:

What does the student use, creatively develop and apply in practice and, then, at the end, use in a successful profession [3]?

The move towards hybrid and/or on-line teaching and learning was considered an opportunity to reimagine and re-envision the teaching and learning endeavour, and as a vehicle for positive change [4]. As noted by Chima and Gutman in a recent article:

Advancements in information technology, automation, human interconnectivity, Artificial Intelligence, and the network effects among them, created a new reality where change is much more rapid, continual, and ubiquitous [5].

As a result, both faculty and students must learn to be ready to continually adapt to this *new normal*. The authors will further discuss the course design approach in the context of emerging initiatives (i.e. virtual classroom) and new technological opportunities (i.e. transmedia, virtual reality). They also analyse the role of educational technology (EdTech) to facilitate learning and student engagement by assessing the impact on students' performance.

Instead of assessing the situation based on a deficiency model using questions like *What is wrong?*, the appreciative inquiry (AI) paradigm enabled to shift the attention to what are the elements of the teaching and learning process that allow for better engagement and performance, and that students really care about [6]. It must be noted that change and improvement is not an easy task, and it requires a culture of ongoing learning and professional development [7][8]. As noted by Clemmer, *change can be ignored, resisted, responded to, capitalized upon, and created* [8]. To be successful, the instructor should capitalise on new developments in teaching, learning and technology, and embrace change. As emphasised by Pasricha:

The goal is not to be perfect. The goal is just to be better than before [9].

SETTING THE STAGE: THE SIX DOMAINS OF TEACHING AND LEARNING

In the light of the persistent need for innovation in engineering education, the authors suggest that the following six domains should be the framework of modern teaching and learning (see Figure 1). These domains were considered in the planning and implementation phase of the engineering design course for hybrid and/or on-line teaching and learning, and the implementation phase is discussed in the following section.

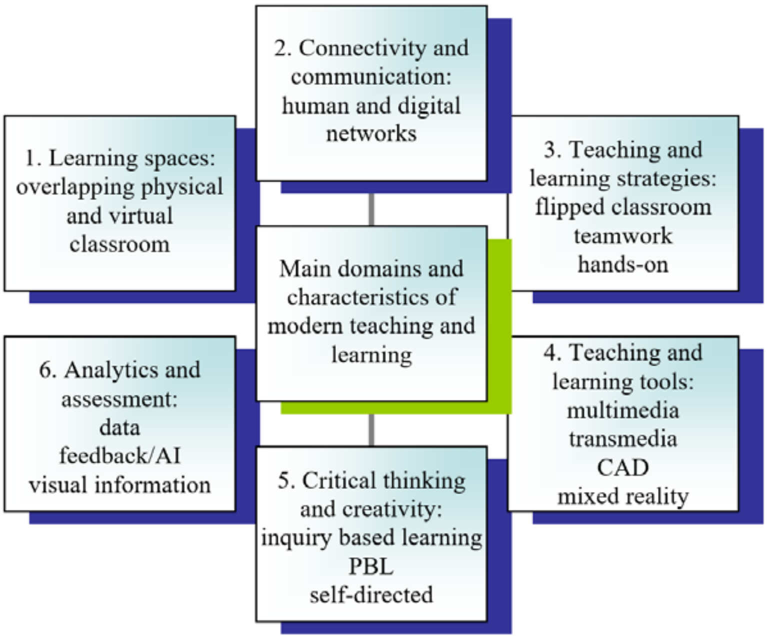

Figure 1: A framework for teaching and learning: six domains for course design.

IMPLEMENTATION

The new approach considered an overlapping physical and virtual classroom as the teaching and learning environment. In this manner, and maintaining a student-centred strategy, not too much change or no change will be required if any of the hybrid or RLP modalities are required for course delivery. As eloquently described by Teske and Horst in this metaphor:

…we might say that with student-centered methodology, the entire classroom is the stage and the scripts are now multiple and various, individualized and collaborative, enveloping comedy and drama with sporadic bouts of absurdity and tragedy [10].

The adopted learning management system (LMS), the Blackboard learn (BL), can be used for connectivity and communication with any device, making teaching and learning accessible and engaging. This platform is designed to provide both the instructor and students with the means for effective teaching and learning:

- Course management tools to build and deliver the course materials and assessment.
- Virtual classroom for digital collaboration and students' engagement.
- Allows for feedback and assessment and provides students' performance reports.
- Has the capability to incorporate creativity, innovation and cutting-edge technologies.

The initial hybrid approach of the engineering design course intentionally incorporated digital technologies to enhance students' experiences and engagement. The real-time classes were recorded for review by all learners. In the new context, considering the possibility of overlapping physical and virtual classroom with RLP, the intent was to minimise the change associated with the course delivery mode, and meanwhile to focus on designing learning activities that allow the use of new technologies. In this manner, the main difference in organising teaching and learning activities consists only in connectivity and communication.

For students in the hybrid category, both F2F interactions and computer interactions were possible. For students in the RLP category only computer interactions were possible. As noted in different studies [11][12], a disadvantage of on-line course delivery is that students may not take on-line classes as seriously as in the traditional course delivery and/or may not perform as well as if they would have done in a hybrid environment. Also, all students can experience technology problems which may impede their learning.

The instructor's role is to design the teaching and learning experiences and select the corresponding EdTech given the constraints associated with RLP. This is not an easy task, since some teaching practices are more effective than others, as they relate to the students' level of knowledge and/or their capability to acquire and retain knowledge [13][14]. Also, there are high costs associated with the new cutting-edge EdTech. From a general perspective, the goal is to ensure the relationship between the technology-supported teaching and learning practices, desired educational outcomes and ultimately their impact on graduate attributes, while paying attention to several other factors during the planning and implementation phase, as shown in Figure 2.

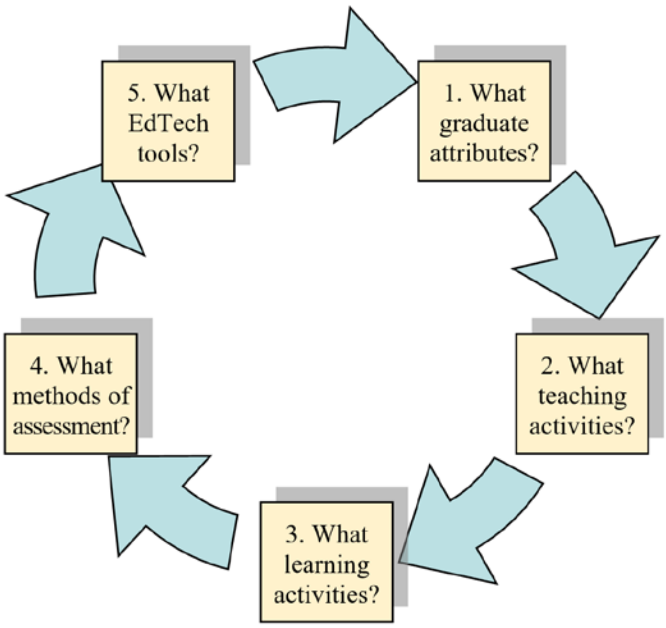

Figure 2: Five *whats* for planning EdTech for engineering design.

Any technology-enhanced learning environment must be instructional, informational, inspirational and involving. The instructional modules should be designed to allow the use of specific teaching and learning tools in a quest to achieve a better teaching and learning experience through engagement, critical thinking and creativity [15][16]. Kuh noted that:

> *Deep approaches to learning are important because students who use these approaches tend to earn higher grades and retain, integrate, and transfer information at higher rates* [13].

For the engineering design class, both synchronous and asynchronous activities were carefully designed to accommodate the RLP and hybrid learner, as needed. Table 1 indicates the implemented EdTech tools for teaching and learning as they relate to learning activities and the corresponding graduate attribute(s). These tools allow for inquiry-based learning, self-directed learning, problem-based learning and different methods of communication in a collaborative virtual environment.

Table 1: EdTech tools for teaching and learning engineering design.

Skills/graduate attributes	Learning activity	EdTech tools for teaching and learning				
		Multimedia	Transmedia	CAD	AR	VR
Graphical communication: Create engineering technical drawings using sketching	• Tutorials and class discussions • Hands-on applications • Drafting portfolio	*	*	*	*	
Use of engineering tools: Ability to create, select, apply, adapt and extend appropriate techniques, resources and modern engineering tools	• Assignments: Create 2D and 3D CAD models • CAD laboratory portfolio	*	*	*		
Design and creativity: Ability to design solutions for open-ended engineering problems	• Teamwork: Case study • Design portfolio		*	*		
Critical thinking: Ability to use knowledge, information and data to effectively solve problems			*			
Communication: Ability to communicate engineering concepts				*		*

NEW TEACHING AND LEARNING TOOLS: THE WAY FORWARD

There are different interpretations as to what differentiates multimedia and transmedia. According to Henry Jenkins, a renowned media analyst:

> *Multimedia and Transmedia assume very different roles for spectators/consumers/readers. In a multimedia application, all the readers need to do is click a mouse and the content comes to them. In a transmedia presentation, students need to actively seek out content through a hunting and gathering process which leads them across multiple media platforms* [17].

Multimedia

This approach used as means of communication: text, audio and visual elements to teach and learn graphical communication skills; and to address diverse learning styles: video recordings, Web sites and recorded life demonstration were employed to explain orthographic projections, section views, auxiliary views and isometric views. The benefits of using multimedia are as follows:

- For the instructor:
  - To teach drafting concepts that would otherwise be too complicated to be explained just by using pencil and paper;
  - To explain the use of CAD software for engineering applications;
- For students:
  - To develop visualisation skills;
  - To understand and develop graphical communication skills;
  - To learn how to use CAD software.

Transmedia

It is defined as presenting a topic of interest across a variety of media formats with an extension of the topic. According to Jenkins:

> *A transmedia story unfolds across multiple media platforms with each new text making a distinctive and valuable contribution to the whole* [18].

Different authors, when discussing transmedia, found that …*transmedia consumers are more involved in the story …resulting in more engagement, intrinsic motivation, and media enjoyment*, and also that …*high engagement and* *media enjoyment …encourage self-regulated learning* [19]. The benefits of using transmedia are reflected in the variety of literacies transmedia environments support:

> *Through immersive, interconnected, and dynamic narratives, transmedia engages multiple literacies, including textual, visual, and media literacies, as well as multiple intelligences. It is highly engaging and allows for important social sharing among collaborators* [20].

The goal was not only to maintain students' attention and interest, but also to instruct, involve and inspire. It was used by the students to better understand a topic presented in the class (i.e. engineering design process) or to analyse a case-study. For teaching and learning purposes, the students were asked to collect information, analyse and communicate their findings with visuals. Transmedia learning allowed students to deep dive into the topic, to gain a different perspective and to reinforce teachable moments. Through transmedia, the following goals were achieved:

- For the instructor:
    - To explain topics like engineering design process, and the design failure and its causes;
- For students:
    - To explore the engineering design process paradigm;
    - To identify and investigate design failures based on real-life case study.

Students were asked to investigate a case of engineering design failure. Each team prepared a presentation to explain what went wrong and why, based on information gathered from different sources - videos, pictures, real-life accounts, and other sources. Also, through transmedia navigation, the students were able to:

- Apply their knowledge by engaging in a design challenge, as part of PBL;
- Develop critical thinking skills when evaluating and integrating the information conveyed across multiple sources.

Students worked in teams to apply what they have learned in graphical communication and engineering design as they define, develop, analyse and implement their design solution. Each project team presented the identified areas of improvement based on the background research performed using different sources of information, how they structured the search for a solution, the possible solutions and analysis, and the final design outcome.

The Benefits of CAD, Augmented Reality (AR) and Virtual Reality (VR) Integration

The reality-virtuality (RV) continuum was first introduced by Milgram and Kishino and describes the science of immersive learning as mixed reality (MR), as illustrated in Figure 3 [21][22]. It is explained as the blending of real and virtual worlds along the RV continuum, which extends from a completely real environment to a completely virtual one. It must be noted that AR and VR technologies do not replace but supplement 2D and 3D CAD-generated models to allow for more immersive learning [23].

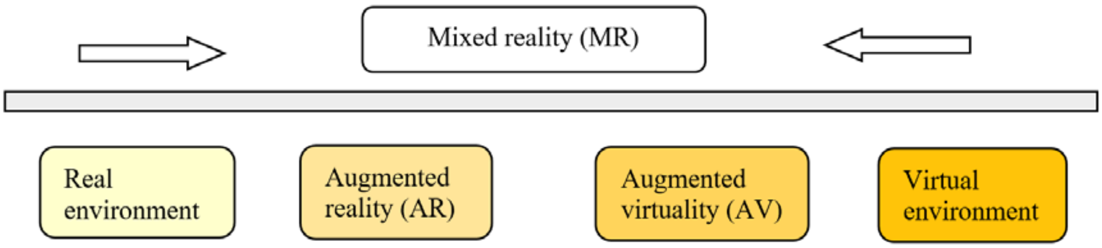

Figure 3: The reality-virtuality continuum: adapted from Figure 1 in Ref. [21].

Not all students have good visualisation skills, hence AR enables them to visualise the objects being described with the orthographic projections in full 3D in a way that was never possible before. Desktop-based augmented reality (AR) as a display technique, which integrates the computer-generated virtual objects into the physical world, was used as a teaching tool to better explain technical drawings concepts. The characteristics associated with AR are:

- The seamless merging of real space and virtual space.
- Integrates the computer-generated virtual objects into the physical world, which become in a sense an equal part of the natural environment.

It allows users to turn 2D views into interactive 3D models on a tablet, desktop or smartphone, as shown in Figure 4. A marker is used to interact with the augmented reality models, which will be rendered in real time on the device's screen. The user can manipulate the 3D object to better analyse and understand the relations between the 2D and 2D models.

Figure 4: Examples of AR and VR applications for teaching and learning.

The desktop VR or the Window on a World (WoW) use the computer monitor to display the virtual world. It enabled the students to present their CAD-generated models in a virtual environment, as a method to communicate their solutions. VR offers greater opportunities for enhancing a user's ability to conceptualise, manipulate and understand design models.

ASSESSMENT OF STUDENTS' PERFORMANCE

The effectiveness of the course design and of the implementation of new EdTech is reflected by the students' performance, in both the hybrid and RLP approach as shown in Figure 5. Different assessments methods were used to measure specific graduate attributes: assignments, progress tests, drafting portfolio, CAD portfolio, design portfolio and virtual presentations.

The RLP approach led to good results regarding communication, critical thinking, engineering design and the use of engineering tools. It has to be noted that 15% of the students did not feel comfortable with the virtual teaching and learning environment and decided to drop the course; 16% performed below 60% and did not meet the course requirements, 31% received grades between 60%-79.9% and met the requirements, while 39% exceeded the requirements with grades of 80% and higher. Since it was the first time that this course was offered in a virtual environment, future offerings will allow for a more detailed assessment and analysis.

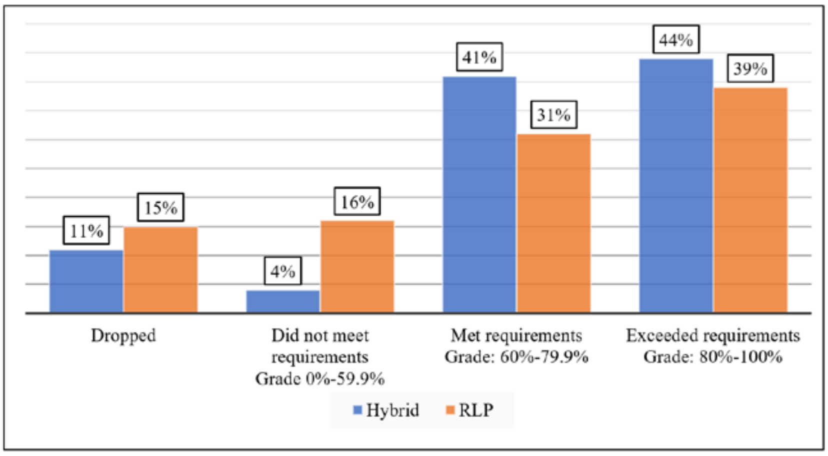

Figure 5: Assessment results for the hybrid and RLP course delivery mode.

These results were compared with the previous hybrid course offering, when similar teaching and learning and assessment methods were employed. As expected, in RLP the percentage of students that did not meet the course requirements or dropped the course is higher and the percentage of students that met or exceeded the course requirements is lower than in the hybrid approach.

CONCLUSIONS

The design and implementation of EdTech tools had the potential to transform the teaching and learning experience for all participants in the educational process - faculty, teaching assistants and students, regardless of the learning spaces: hybrid or RLP. As a result of these new experiences, the students became more familiar with the use of multimedia, transmedia, and were more engaged and more interested in the process with the implementation of AR and VR.

There is a continuous need to monitor technology evolution, to set future goals, and to encourage an ongoing culture to bring the needed change in teaching and learning. This requires co-operation between all parties involved, an open mind, and willingness to embrace change, and to learn and adapt to new technological developments. But, as noted by Albert Einstein:

> *It has become appallingly obvious that our technology has exceeded our humanity* [24].

REFERENCES

1. Pusca, D. and Northwood, D.O., The *why*, *what* and *how* of teaching: an engineering design perspective. *Global J. of Engng. Educ*., 19, **2**, 106-111 (2017).
2. Beatty, B.J., *Hybrid-Flexible Course Design. (1st Edn)*, EdTech Books (2019), 15 Apr. 2021, https://edtechbooks.org/hyflex
3. Ilkovičová, L., Ilkovič, J. and Špaček, R., Ways of rationality and effectivity in architectural education. *World Trans. on Engng. and Technol. Educ*., 15, **4**, 331-337 (2017).
4. Pusca, D. and Northwood, D.O., The impact of positive change in higher education. *World Trans. on Engng. and Technol. Educ*., 18, **4**, 427-432 (2020).
5. Chima, A. and Gutman, R., What It Takes to Lead Through an Era of Exponential Change. Harvard Business Review, O (29 Oct. 2020), 20 Apr. 2021, https://hbr.org/2020/10/what-it-takes-to-lead-through-an-era-of-exponential-change
6. He, Y. and Oxendine, S.D., Leading positive change in higher education through appreciative enquiry: a phenomenological exploration of the strategic planning process. *J. of Higher Educ. Policy and Manage*., 41, **3**, 219-232 (2019)
7. Kotter, J.P., Accelerate: Building Strategic Agility for a Faster-moving World. Brighton, Massachusetts, USA: Harvard Business Review Press (2014).
8. Clemmer, J., Change management deciphering the oxymoron. *HR Professional*, 24, **3**, 70 (2007).
9. Pasricha, N., Rid your brain of the weight of tiny choices. *Toronto Star*, 15 August, E7 (2017).
10. Teske, P.R.J. and Horstman, T., Transmedia in the classroom: breaking the fourth wall. *Proc. 16th Inter. Academic MindTrek Conf.*, Tampere, Finland, 5-9 (2012)
11. Hudson, J.M. and Bruckman, A.S., IRC Français: the creation of an Internet-based SLA community. *Computer Assisted Language Learning*, 15, **2**, 109-134 (2002).
12. Kirkpatrick, G., Online *chat* facilities as pedagogic tools. *Active Learning in Higher Educ*., 6, **2**, 145-159 (2005).
13. Kuh, G.D., *High-impact Educational Practices: What they are, Who has Access to them, and Why they Matter.* Washington, D.C.: Association of American Colleges and Universities (AAC&U) (2008).
14. Marton, F., Saljo, R., On qualitative differences in learning: I-outcome and process. *British J. of Educational Psychology*, 46, **1**, 4-11 (1976).
15. Šuligoj, V. and Ferk Savec, V., The relationship of students' attitudes to technology and their creative ability. *World Trans. on Engng. and Technol. Educ*., 16, **3**, 243-248 (2018).
16. Avsec, S. and Jermanand, J., Self-efficacy, creativity and proactive behaviour for innovative science and technology education. *World Trans. on Engng. and Technol. Educ*., 18, **4**, 369-374 (2020).
17. Jenkins, H., Transmedia Education; the 7 Principles Revised (2010), 20 Apr. 2021, http://henryjenkins.org/blog/2010/06/transmedia_education_the_7_pri.html
18. Jenkins, H., *Convergence Culture: Where Old and New Media Collide*. New York: New York University Press (2006).
19. Pietschmann, D., Volkel, S. and Ohler, P., Limitations of transmedia storytelling for children: a cognitive developmental analysis. *Inter. J. of Communic*., 8, 2259-2282 (2014).
20. Herr-Stephenson, B., Alper, M. and Reilly, E. (2013), T is for Transmedia: Learning Through Transmedia Play (Rep.), 22 April 2022, http://joanganzcooneycenter.org/wpcontent/uploads/2013/03/t_is_for_transmedia.pdf
21. Milgram, P. and Kishino, F., A taxonomy of mixed reality visual displays. *IEICE Trans. Inf. Syst.*, 12, **12**, 1321-1329 (1994).
22. Milgram, P., Drascic, D., Grodski, J.J., Restogi, A., Zhai, S. and Zhou, C., Merging real and virtual worlds. *Proc. IMAGINA'95*, Monte Carlo (1995).
23. Tan, S., The rise of immersive learning. *J. of Appied Learning and Teaching*, 2, **2**, 91-94 (2019).
24. Szczerba, R.J., 20 Great Technology Quotes to Inspire, Amaze, and Amuse, 28 Apr. 2021, https://www.forbes.com/sites/robertszczerba/2015/02/09/20-great-technology-quotes-to-inspire-amaze-and-amuse/?sh=5a3609e116a6