Implementation of high-impact practices in engineering design courses

Daniela Pusca & Derek O. Northwood

University of Windsor
Windsor, Ontario, Canada

ABSTRACT: Teaching and learning practices have an impact on students' performance and their ability to achieve the required graduate attributes. Educational institutions are asked to consider practices that ensure both academic success in university and post-graduation outcomes in the workforce. As part of the institutional approach to innovation in teaching and learning excellence, engineering design courses were redesigned to improve student experience, and also to include more high-impact practices. This article examines the high-impact curricular practices that were implemented in engineering design courses as teaching practices, and how they relate to the desired learning outcomes. Student engagement is considered as a measure of effective learning. Using evidence, the authors argue that experiential learning and high-impact practices lead to greater engagement, better prepare students for future employment, and help to bridge acknowledged gaps between education and practice.

INTRODUCTION

A culture of continuous innovation and quality improvement is needed to ensure both academic success in university and expected post-graduation outcomes in engineering practice. As part of the institutional approach to innovation in teaching and learning excellence, and in an effort to improve students' teaching and learning experience, several high-impact curricular practices have been examined at the University of Windsor. High-impact practices are techniques and designs for teaching and learning that have proven to be beneficial for student engagement and successful learning among students from many backgrounds. The main characteristics of high-impact practices [1-3] are summarised schematically in Figure 1.

Figure 1: Characteristics of a high-impact practice.

Kuh defines high-impact practices as:

> *High impact practices are curricular and co-curricular structures that tend to draw upon high-quality pedagogies and practices in pursuit of 21st Century learning outcomes; they are teaching and learning practices that have been widely tested and have shown to be beneficial ...toward increased rates of retention and student engagement* [1].

Brownell et al suggest that high-impact activities *live up to their name, and lead to a range of positive outcomes for students* [2]. The gains in learning and professional development that result from students' participation in high-impact practices include: *integrating ideas and diverse perspectives, discussing ideas with faculty and peers outside the class, analysing and synthesizing ideas, applying theories.* As Kilgo et al suggest in their study:

> *This finding - that high impact practices have an overall positive effect on student learning and development - has significant practical implications for institutions of higher education. Institutions should strive to provide students with opportunities to engage in high-impact practices, particularly…active and collaborative learning, which are shown to have vast positive impact for student learning and development* [3].

It has been shown that their implementation promotes a deeper student learning and have a positive impact student success. 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* [1].

In this article, the authors examine the benefits of the application of high-impact practices to enhance learning in a first year Engineering Design course at the University of Windsor. The students, diverse in their abilities, motivation and preparedness for university level studies [4], have the opportunity to experience multiple high-impact practices by becoming deeply involved in their learning experience.

INTEGRATING HIGH-IMPACT PRACTICES AT THE UNIVERSITY OF WINDSOR

The National Survey of Student Engagement (NSSE) is a survey mechanism used to measure the level of student participation at universities and colleges in Canada and the United States as it relates to learning and engagement [5]. Data from the NSSE 2017 University of Windsor Summary Report have been used to estimate the effects of participation in six high-impact practices [6].

The NSSE survey was administered to students in the first and fourth year of study to *assesses effective teaching practices and student engagement in educationally purposeful activities* in order to improve students experience in undergraduate studies [5][6]. The survey asked students about their participation in six high-impact practices, namely:

- Courses that included a community-based project or service-learning;
- The formal learning community where students take 2 or more courses together;
- Work with a faculty member on a research project;
- Internship, co-op, field experience, student teaching or clinical placement;
- Study abroad;
- Culminating senior experience (capstone course, senior project, thesis, portfolio).

According to the NSSE Institute, Indiana University [7], and also based on evidence discussed by Gonyea et al [8], it is recommended that all students participate in at least two high-impact practices during their undergraduate studies - one in their first year and one that is connected to their major. Table 1 summarises the survey results regarding students' participation in the six high-impact practices in 2017, compared with 2014.

Table 1: Student participation in high-impact practices at the University of Windsor: 2017 and 2014 NSSE surveys [6].

	High-impact practice	First Year		Final Year	
		2017	2014	2017	2014
1	Service learning/community based learning	47%	39%	58%	52%
2	Learning communities	9%	10%	19%	17%
3	Undergraduate research	4%	5%	22%	22%
4	Internship	-	-	43%	43%
5	Diversity/global learning	-	-	6%	6%
6	Capstone courses and projects	-	-	30%	30%
	Participated in at least one	50%	44%	80%	78%
	Participated in two or more	7%	8%	51%	50%

First-year respondents were only asked about their experiences in the first three high-impact practices, while final year respondents were asked about all six opportunities. In 2017, 50% of first-year and 80% of final year students said they participated in at least one high-impact practice during their undergraduate programme of study. This measure of participation has increased from the previous survey administered in 2014, particularly for first-year students, from 44% to 50%.

To further explore the use of high-impact practices, the entire list of high-impact practices (Table 2), which are a key part of the NSSE model, was considered for analysis. Based on information in Table 1 and Table 2, it appears that:

- There is room for improvement regarding students experiences in the three high-impact practices already implemented for first year students: service learning/community based learning, learning communities, and undergraduate research, as highlighted in Table 2.
- There is the possibility for adoption and implementation of other high-impact practices for the first year students. The new opportunities are further analysed for their suitability in the first year Engineering Design course (Table 2).

Table 2: High-impact practices as per NSSE model [7] and new opportunities for first year courses.

	High-impact practices	Areas of improvement for first year experiences	New opportunities for first year experiences
1	First-year experiences/seminars		*
2	Common intellectual experiences		*
3	Learning communities (2 in Table 1)	*	
4	Writing-intensive courses		*
5	Collaborative assignments and projects		*
6	Undergraduate research (3 in Table 1)	*	
7	Diversity/global learning		*
8	Service learning/community based learning (1 in Table 1)	*	
9	Internships	N/A	N/A
10	Capstone courses and projects	N/A	N/A
11	ePortfolios		*

HIGH-IMPACT PRACTICES: THE WAY FORWARD

The instructor's role is to decide if specific characteristics makes a practice *high impact*, and to translate these high-impact practices into teaching practices in the context of an outcome-based curriculum. The goal is to ensure the relationship between high-impact practices and educational outcomes. Their impact on learning outcomes and ultimately on graduate attributes is greater if the faculty take time to design these experiences, while paying attention to several factors during planning and implementation phase, as shown in Figure 2. This is not an easy task, since some teaching practices are more effective than others [1][4], and others might be beneficial for students at certain levels.

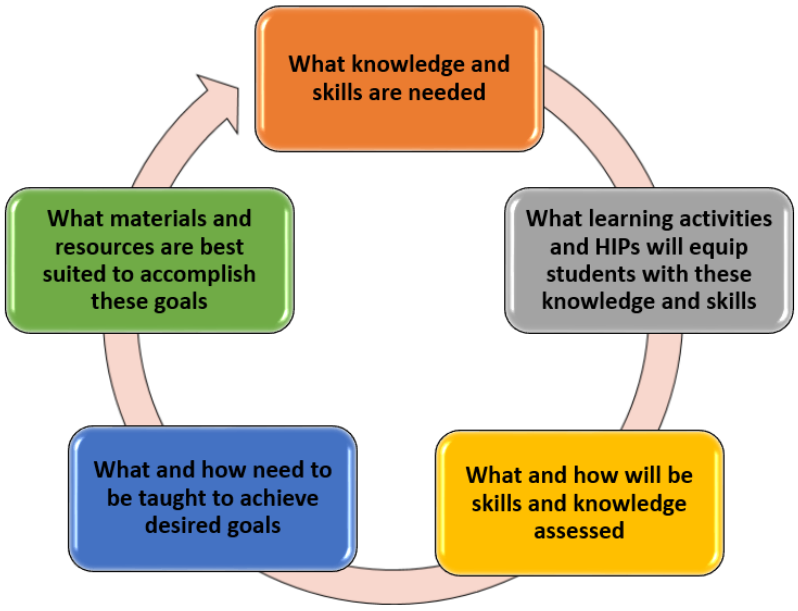

Figure 2: Factors to consider when planning high-impact practices.

To improve teaching and learning in the context of outcome-based curriculum in Engineering Design classes, a *backward design* approach is used [9][10]. As indicated by Pusca and Northwood, *…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 [11]. As a result, planning and implementing high-impact practices is the last step in this iterative design process. Design thinking was used as a human-centred, open-ended problem-based approach to solve the challenges associated with the implementation of high-impact practices in the context of outcome-based curriculum [12].

The suitability of the design thinking paradigm as an adaptive use of engineering design methods and tools to solve complex problems was demonstrated by the authors through empirical research conducted in the context of curriculum development [13-16]. Teaching and learning activities were designed as *student-centred*, using inductive teaching methods, such as case-based teaching, inquiry-based learning, discovery learning and project-based learning. Student engagement is considered as a strong argument for the high-impact practices. Russel at al also mentioned that [17]:

> *Engaging in classroom-based problem solving under expert guidance was effective because students received needed help at the precise moment they were struggling with problems.*

Based on the high-impact practices detailed in Table 2, and in the context of outcome-based curriculum, a list of corresponding high-impact activities as they apply to Engineering Design is presented in Table 3. The multitude of approaches selected as class activities have been mapped against the desired learning outcomes, and are related to the corresponding assessment methods.

Table 3: Teaching and learning activities involving high-impact practices.

	High-impact practices	Implemented activity in Engineering Design	Learning outcome	Assessment method
1	First-year experiences/seminars	• Case-base teaching and class discussions • Problem oriented tutorials • Guest lectures	- Oral communication - Written communication - Critical thinking skills	Assignments
2	Common intellectual experiences	• Group assignments • Exercises/applications solved during class • Examination and analysis of given models to discover design concepts • Prepare engineering drawings by applying drafting concepts • Open-ended team design projects	- Design - Creativity - Critical thinking - Problem solving - Analysis and synthesis	Progress tests Mid-term examination Drafting portfolio Design portfolio
3	Learning communities	• Project-based learning approach	- Problem solving - Creativity - Teamwork	Design portfolio
4	Writing-intensive courses	• Prepare milestone reports • Prepare final project	- Critical thinking - Compose engineering-based written communications	Design portfolio
5	Collaborative assignments and projects	• Creating a poster • Developing a group presentation	- Compose engineering-based written communications - Deliver engineering-based oral communications	Presentation
6	Undergraduate research	• Research a topic or a design problem	- Deliver engineering-based oral communications	Presentation
7	Diversity/global learning	• Design for variety	- Critical thinking skills	Milestone reports
8	Service learning/ community-based learning	• Project-based learning approach	- Problem-solving skills - Creativity - Design - Teamwork	Design portfolio
9	Internships	N/A		
10	Capstone courses and projects	N/A		
11	ePortfolios	• Creating a digital presentation • Retrospective reflection	- Communications skills - Creativity - Analysis and synthesis	ePortfolio

The high-impact practices implemented in Engineering Design courses have positive effects on students learning, by providing the desired learning outcomes, as indicated in Table 3. As shown in Figure 3, some high-impact activities are targeting a larger number of learning outcomes, such as common intellectual experiences, learning communities, service learning/community-based learning and ePortfolios. Other high-impact practices include first-year experiences/ seminars, writing-intensive courses, collaborative assignments and projects, undergraduate research and diversity/ global learning - have narrower positive effects on student learning, since they are associated with one or two learning outcomes.

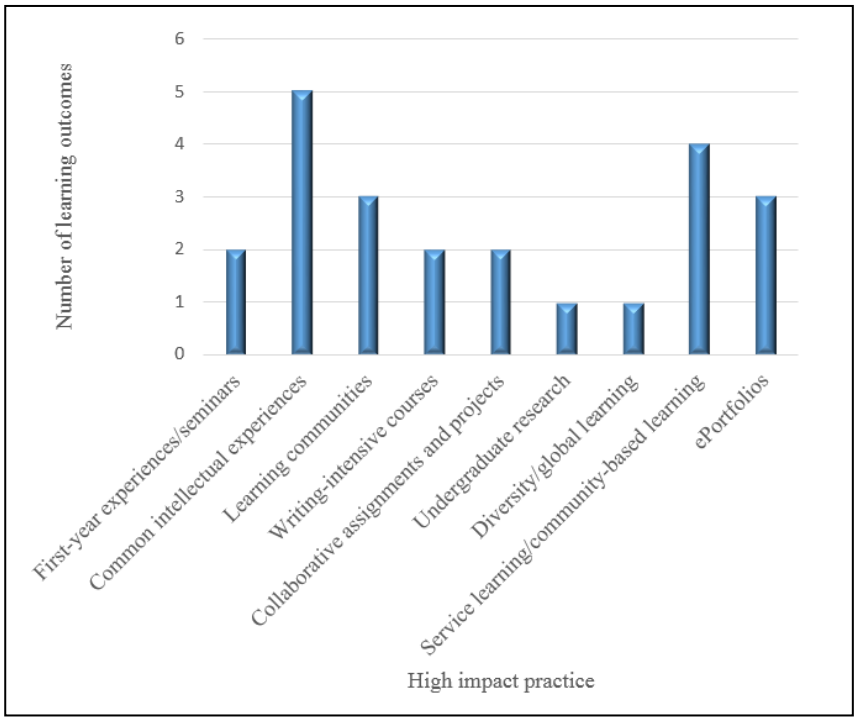

Figure 3: Relationship between the adopted high-impact practices and the targeted number of learning outcomes.

- First year seminars and experiences provide students with opportunities of interaction between themselves and the instructor. Students study assigned cases and reflect on the teaching points the instructor wishes to convey, prepare assignments and participate in class discussion. To enhance students' experience, directed learning consists of case studies that may serve as a model for future work; for example, case histories describing how a problem was solved and the consequences of the decisions that were made. Short lectures by guest speakers emphasise the importance of application of standards and statutory regulations [11].
- Regarding common intellectual experiences, the specific characteristics associated with the proposed high-impact activities are (Figure 1): interaction with faculty and peers, experiences with diversity, structured opportunities to reflect and integrate learning, and opportunities to discover relevance of learning through real-world applications.
- Classroom learning community allows for cooperative learning techniques and group learning activities as integrated pedagogical approaches. The instructor's role is to interact in a way that motivates students [18]. Graduate assistants 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.
- Writing-intensive courses: as part of the proposed activities, students are encouraged to produce and revise various forms of writing [19].
- Collaborative assignments and projects: as part of collaborative learning, students work in groups to research a topic, create a poster and develop a group presentation [20]. The two characteristics associated with this high-impact activity are interaction with peers and exposure to diverse ideas.
- Undergraduate research: students work in groups to research assigned design related issues. This activity target skills, such as inquiry and analysis, reading and understanding primary literature, communication and teamwork.
- Diversity/global learning: students explore cultures, traditions and climate to design for variety, in order to meet customers' needs and expectations. This activity allows for work on real world applications, and it also challenges students' way of thinking [21].
- Service learning/community-based learning: activities are designed as experiential learning opportunities to involve students in solving real world open-ended problems, using the same methods and techniques as engineering professionals. At the University of Windsor the guiding vision is that students will develop:

  …an ability to design solutions for complex, open-ended engineering problems and to design systems, components or processes that meet specified needs with appropriate attention to health and safety risks, applicable standards, economic, environmental, cultural and societal considerations [16].

- ePortfolios: this activity is normally considered as a culminating senior experience, but it was implemented at the first-year level since it enable students to electronically collect their work as they progress through the course, reflect upon their personal and academic growth, and share selected artefacts with others [22][23]. It requires investment of time and dedication, and provides opportunities for students to reflect and make connections between various educational experiences. For the Engineering and Design course, *a hybrid portfolio was designed, a combination of developmental and showcase portfolio* [22]. The purpose of this portfolio is to achieve three goals: to demonstrate the advancement of certain skills and discipline specific graduates attributes, to showcase the best engineering design related work to be shown to potential employers and to gain co-op placement [23], and to be used as a building block for the engineering programme e-portfolio. The success regarding e-portfolio implementation *is dependent on the quality of training provided to the students* [24].

This high-impact learning can also be viewed from a lens of effectivity, namely *effective learning*. From the students' perspective, *effective* can be described by the following question [25]:

> *What does the student use, creatively develop and apply in practice and, then, at the end, use in a successful profession?*

High-impact practices, and the associated high-impact learning, mirror what in the theatre world parlance is known as *breaking the fourth wall* [26]. In our student-centred, high-impact methodology, the students are the *audience*.

> Breaking the fourth wall *is a theatre idiom where the actors on stage acknowledge the audience's presence. This first famously occurred in the 1904 play* Peter Pan *when the title character asks the audience to* clap if you believe in fairies*.*

As eloquently described by Teske and Horst in a playful metaphor:

> *…we might say that with student-centred 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* [27].

CONCLUSIONS

The design and implementation of high-impact activities allows all participants in the educational process - faculty, teaching assistants and students to communicate in a constructive and synergistic manner and has the potential to transform the teaching and learning experience. As a result, the students gain confidence in their work and their knowledge, and gain specific graduate skills regarding communication, critical thinking, design, problem solving, analysis and synthesis, creativity and teamwork.

In summary, the authors have given the students the tools they need to become critical, yet creative, thinkers. At the same time, since learning is about constant growth and development, not only in our students, but in ourselves as educators, the education *system* benefits [28].

REFERENCES

1. Kuh, G.D., High-impact Educational Practices: what they are, who has Access to them, and why they matter. Association of American Colleges and Universities (AAC&U), Washington, DC (2008).
2. Brownell, J.E. and Swaner, L.E., High-impact practices: applying the learning outcomes literature to the development of successful campus programs. *Peer Review*, 11, **2**, 26-30 (2009), 22 February 2018, http://link.galegroup.com.ezproxy.uwindsor.ca/apps/doc/A205051358/AONE?u=wind05901&sid=AONE&xid=4d726005
3. Kilgo, C.A., Ezell Sheets, J.K. and Pascarella, E.T., The link between high-impact practices and student learning: some longitudinal evidence, *High Educ.* 69, 509-525 (2015), 22 February 2018, DOI 10.1007/s10734-014-9788-z, https://link-springer-com.ledproxy2.uwindsor.ca/content/pdf/10.1007%2Fs10734-014-9788-z.pdf
4. Marton, F. and Saljo, R., On qualitative differences in learning: i-outcome and process. *British J. of Educational Psychology*, 46, **1**, 4-11 (1976).
5. National Survey of Student Engagement, 21 February 2018, https://en.wikipedia.org/wiki/National_Survey_of_Student_Engagement#NSSE_Survey-_Outcomes
6. NSSE 2017 Summary Report, University of Windsor (2017), 21 February 18, http://web2.uwindsor.ca/general/info/pdf/reports/NSSE_2017_Report.pdf
7. High Impact Practices, 21 February 18, http://nsse.indiana.edu/html/high_impact_practices.cfm
8. Gonyea, R.M., Kinzie, J., Kuh, G.D. and Laird, T.N., High-Impact Activities: what they are, why they work, and who benefits. Association of American Colleges and Universities (AAC&U), Washington, D.C., (2008)
9. Pusca, D., Stagner, J. and Bowers, R.J., Outcome-based design approach for engineering design. *Inter. J. of Design Educ*., 9, **3**, 27-34 (2015).

10. Northwood, D.O., Learning outcomes - some reflections on their value and potential drawbacks. *World Trans. On Engng. and Technol. Educ.*, 11, **3**, 137-142 (2013).
11. Pusca, D. and Northwood, D.O., How to engage students in the context of outcome-based teaching and learning. *World Trans. on Engng. and Technol. Educ.*, 13, **3**, 268-273 (2015).
12. Pusca, D. and Northwood, D.O., Design thinking and its application to problem solving. *Global J. of Engng. Educ.*, 20, **1**, 48-53 (2018).
13. Pusca, D., Engineering design process as a method used in reforming the engineering and design course. *Design Principles and Practices: an Inter. J.*, 4, **2**, 437-452 (2010).
14. Pusca, D., Bowers, R.J. and Northwood, D.O., Hands-on experiences in engineering classes: the need, the implementation and the results. *World Trans. on Engng. and Technol. Educ.*, 15, **1**, 12-18 (2017).
15. Pusca, D. and Northwood, D.O., Technology-based activities for transformative teaching and learning. *World Trans. on Engng. and Technol. Educ.*, 14, **1**, 77-82 (2016).
16. 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).
17. Russell, J., Andersland, M. S., Van Horne, S., Gikonyo, J. and Sloan, L., Large lecture transformation: improving student engagement and performance through in-class practice in an electrical circuits course. *ASEE, Adv. in Engng. Educ.*, 6, **2** (2017), 25 Feb 2018, http://advances.asee.org/wp-content/uploads/vol06/issue02/Papers/AEE-21-Russell.pdf
18. McDermott, K.J., Göl, Ö. and Nafalski, A., Considerations on experience-based learning. *Global J. of Engng. Educ.*, 6, **1**, 71-78 (2002).
19. Brown, N., Updating assessment styles: website development rather than report writing for project based learning courses, *ASEE, Adv. in Engng. Educ.*, 6, **2** (2017), 26 Feb 2018, http://advances.asee.org/wp-content/uploads/vol06/issue02/Papers/AEE-21-Brown.pdf
20. Pusca, D. and Tam, E., Engineering and design: first year learning and development. *Review of Manage. and Economic Engng.*, 8, **1A (31)**, 99-108 (2009).
21. Riemer, M.J., English and communication skills for the global engineer. *Global J. of Engng. Educ.*, 6, **1**, 91-100 (2002).
22. Pusca, D. and Eiliat, H., Integrating e-portfolios into engineering design courses. *Proc. 9th Inter. Technol., Educ. and Develop. Conf., INTED*, ISBN 978-84-606-5763-7, 4733-4740, IATED, Madrid, Spain (2015).
23. Johrendt, J., Singh, P., Hector, S., Watters, M., Salinitri, G., Benzinger, K., Jaekel, A. and Northwood, D.O., *The Co-op Portfolio: an Essential Tool for Assessment and Student Development in Co-operative Engineering Programs.* Engineering Education: an Australian Perspective, 291-305 (2011).
24. Smith, E. and Mills, J., E-portfolios and first year students - do we assume too much? Engineering the Curriculum. *Proc. of 20th Annual Conf. for the Australasian Association for Engng. Educ.*, University of Adelaide, 400-404 (2009).
25. 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).
26. About 4th Wall Theatre Company, 26 February 2018, https://4thwallkids.com/about-4th-wall/
27. 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).
28. Couros, G., Innovation is a Process, not a Product (16 January 2018), March 01 2018, https://georgecouros.ca/blog/archives/6999