The evolution of experiential learning in the Faculty of Engineering: From rogue experiment to curricular innovation and beyond

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ABSTRACT

Experiential-based learning in engineering education is nearly synonymous with student-centred, hands-on learning using design projects. The pedagogical model adopted by pioneers of this kind of learning in engineering is one step removed from lecture-based classes. That is, the pencil and paper assignment is simply replaced with a hands-on experience with little or no change in the learning outcomes, methods of assessment, and learner-support strategies. This paper argues that this pedagogical model has outlived its usefulness. Experiential learning ought to be employed as a means to train students in durable mindsets, behaviours, and ways of thinking. Just offering students a hands-on experience is not sufficient. In short, there is a need for a new way to think about experiential education in engineering. This reflective essay maps out the journey of one engineering educator's rogue experiment with experiential education to new ways of thinking about it.

KEYWORDS

experiential learning, engineering design, mindsets, design thinking, coaching

Some years ago, more years than I would like to admit, I came to teach engineering design to first-year students in the Faculty of Engineering at McMaster University. This was no small task, and it was enormously intimidating—I had a class that sometimes exceeded one thousand students. These are students who, only a few short months earlier, had been in high school. There was no support and no guidance. No one knew how to teach a course like this; engineers must learn how to design. Designing is a quintessential ability and universal attribute of an engineer. The course at the time was very unpopular with students and was treated seriously by neither students nor faculty. After experimenting with many small modifications to the course to little effect, I fell upon a very interesting book by a University of Calgary professor of engineering design, Daryl Caswell. He too taught engineering design to a large first-year class and was nationally acclaimed as an educator for this teaching. I devoured the Society for Teaching and Learning in Higher Education (STLHE) Green Guide he authored (Caswell, 2006) and discussed his first-year teaching with him extensively. I quickly adopted his approaches. I found a local community member willing to be a client for my students, and I invited the client to lecture. Students followed a simple set of tools and steps to design for the client. They fabricated solutions for the client. It was a smashing success—newly labelled an instructor of "experiential learning," I achieved the markers of teaching success: student ratings of the course rose remarkably, I earned permanence (i.e., tenure for teaching professors), won an institutional level teaching award, and was promoted to associate professor in the teaching stream. Yet, something was missing. Students still struggled to adopt the design mindset, despite the hands-on learning opportunities.

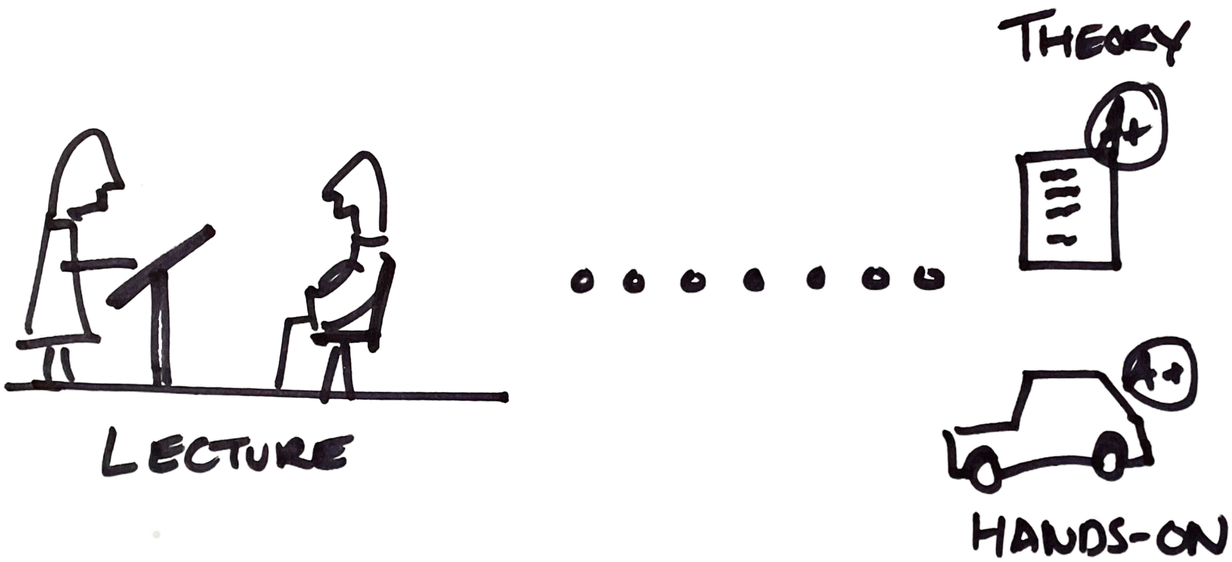
I am trained, like most of my colleagues, as an engineer and engineering researcher. I hold a doctorate in mechanical engineering and have some industrial experience, including a 2-year stint working for a dotcom start-up (albeit not in a leadership role). Although I had gained some experience as a design engineer during co-op terms and as a developer at the start-up, I was by no means a seasoned or accomplished designer. Yet, I was teaching engineering design with some, if not, considerable success. Over a period of years I read many papers and listened to many talks on design pedagogy. This led me to begin questioning the work I was doing. I sought answers to two nagging questions:

- what were students really learning, and
- what did it mean to design and teach design?

From there, I sought top educators, designers, and thinkers in the field. I spent time co-teaching with a nationally recognized creative talent. I also connected with an internationally leading higher education program (i.e., Hasso Plattner Institute of Design at Stanford University) and met many other workers, practitioners, and thinkers who taught and/or practised design in some form. What I discovered in my inquiries radically changed my understanding of what it means to design, teach design, and educate experientially. Ultimately, I revised my approach to experiential education. My understanding of these topics grew into something entirely different than what I first implemented in my first-year, client-based design project course. I offer the reader a glimpse of what I discovered and learned.

Looking back now on how my peers and I taught experiential learning or engineering design courses, I observe that the courses we taught were built on the idea that existing assignment work could be substituted with some sort of hands-on requirement (see Figure 1). This might mean asking students to build a printed circuit board in an analogue circuits course or to virtually design (but not build) a gearbox for a machine design course. It is treated like any other assignment. Students are expected to produce a result which is assessed. In the case of hands-on learning, it would be a physical or visual outcome rather than just numbers, equations, and words on a page. Learning was achieved if students—like in any other assignment—produced what the instructor wanted, the proverbial right answer. As seen in Figure 1, the assessment on the right replaces theoretical learning with hands-on learning, but what happens between lecture and assessment remains largely hidden from instructors. Many instructors have found that students enjoyed and found great value in these hands-on assignments and projects. Some instructors even added a reflection as an assignment at the end of the hands-on exercise or project. It's what Schön (1987) calls *reflection-on-action*. Of course, positive feedback from students strongly encouraged the administration to support these learning experiences. This form of hands-on learning essentially substitutes a paper and pencil assignment with a more tangible experience. Although these new assignments appeared to use experiential learning, the learning outcomes mostly remained unchanged with the primary focus still on learning explicit knowledge, that is, engineering fundamentals.

Figure 1. Lectured-based pedagogical model adapted for hands-on learning



The lecture-based pedagogical model adapted for hands-on learning. The primary difference is the theoretical pencil and paper assignment has been substituted with hands-on work. The student-instructor roles are largely unchanged. Original figure by author.

In an engineering fundamentals course, adding a hands-on experience has unquestionable benefits and costs. In contrast, in a course where the goal is to train a learner in professional abilities like designing, the learning outcomes are orthogonal to those of the engineering fundamentals course. In the engineering fundamentals course the goal is to teach the learner scientifically validated knowledge. These learning outcomes naturally align with Bloom's taxonomy (i.e., the understand-apply-analyze-evaluate-create pyramid) (Anderson & Krathwohl, 2001). However, in an engineering design course, the goal is to teach knowledge derived from practice that represents the best we know in terms of how to think and how to work like an expert design engineer. While in an engineering fundamentals course, experiential learning is a nice-to-have way to give students a visceral experience that complements and reinforces the highly cerebral ways of learning fundamentals, in engineering design, experiential learning is necessary not because it brings experience but because it is the best vehicle we have to achieving its learning outcomes. I argue, the idea of simply substituting one experience (i.e., a written assignment) for a hands-on one and changing little else in the way the instructor approaches learning makes little sense if one is trying to deliver experiential education.

The often unquestioned approach to teaching engineering design can be more clearly perceived with the help of an analogy: a child learning to play a musical instrument, such as piano. Imagine hiring an individual well versed in music theory but with little experience in playing to teach the child. Of course, the child with a strong understanding of music theory can play the piano, but the result will be unskilled and unpleasant to the ear because of the inexpert guidance of the untrained teacher. Thus, I see how my first-year class experienced my experiential learning. Although the opportunity to create and build is novel and exciting, the level of transferrable skill was limited at best and almost non-existent at worst. My learning outcomes included "follow an engineering process" and "apply method *x*," neither of which requires any great intellectual acuity and results in no transferrable (or durable) skill. My cause for concern is that despite any substantial understanding of the pedagogy, expert skill in design, or knowledge of design pedagogy, my teaching was lauded as highly effective because of student experience alone. In engineering design education, it has become common to assess the effectiveness of the learning based on the novelty of the project outcomes and feedback on the experience from students, without including expert knowledge or opinion. This leads to poorly skilled work and no effective assessment of learning. To the untrained eye, the students' work will seem sufficient, but transferrable learning will remain unassessed.

Turning to the piano learning analogy, the child's parent who is untrained in music will not rely on their own opinion or that of the child to assess the learning and instead will turn to the trained and accomplished person hired for the task, the piano teacher. The value the teacher brings is what Schön (1987) refers to as artistry—the implicit and tacit knowledge accrued through practice and reflection, not through the learning of theory. Thus, in teaching engineering design there is a need for a trained and expert community of educators that together have both experience designing and knowledge of design pedagogy. Adopting hands-on experiences as a substitute for traditional number and equations assignments does not in and of itself help students develop professional-grade abilities of a practitioner any more than a child is likely to learn to play piano well on their own. Minimal learning will happen, but an expert and accomplished teacher will accelerate it. The teacher brings artistry or implicit knowledge to help the learner. It follows, then, that to train engineering students with substantive design engineering skills requires professors with substantial engineering design skills themselves.

This is a challenging proposition for a community of faculty instructors with limited experience of designing and with research mindsets. The thinking researchers are trained in is very different from accomplished and practising design engineers (Cross, 2001). However, there are leading engineering educators who have found ways to deliver durable learning of engineering design skills and mindsets in higher education. For example, Crismond and Adams (2012) propose a low-risk approach. In conventional engineering courses, what happens between lecture and assessment (e.g., assignment or examination) is up to the student. Crismond and Adams advocate that it is in this space where the real learning happens, and where the learning outcomes involve practice, there also ought to be repetition and feedback. This is known as reflection-on-action and is practically implemented via coaching and similar learner support strategies. In the conventional lecture-based pedagogy, instructors typically do not coach students on their thinking or behaviour. How students arrive at an answer is largely up to them. In contrast, reflection-on-action, based on academic research, outlines both skills-oriented learning outcomes, levels of learning, and learner-support approaches to achieving the learning. This approach allows students to maintain a degree of agency on a project, while inserting in the work of designing the expert instructor as a coach to help the learner develop the skills needed for the next project.

To achieve lasting learning, other leading educational institutions have shifted to overarching learning outcomes that are anything but conventional: mindset or mindshifts (Goldman et al., 2012) and ways of thinking. Aiming for this radical new form of pedagogy, instructors and learners need an environment and culture that rewards learning and not just outcomes. In other words, the failures must happen in practice and are not a thing to be avoided. At Stanford University's d.school, in-process prototypes and unfinished work are displayed instead of successful projects to remind students that part of practising means sharing and discussing in-progress, incomplete, and unpretty work with both peers, instructors, and community (Goldman et al., 2012). Educators at MIT in the New Engineering Education Transformation (NEET) program have gone so far as to identify 12 ways for thinking as the ultimate goal of their engineers' education (Crawley et al., 2020).

To illustrate the complexity and challenge of this new kind of education, consider a story from my first-year engineering design course. I was once witness to a group of students who very proudly presented their early (i.e., cardboard and duct tape) prototype to their client. The client picked up the prototype and proceeded to use it in a way that made sense to them. The way the client chose to use the prototype was completely unexpected by the students. The student reaction was that the client had used the prototype not as intended. My reaction as a design engineer was the opposite. This was an "a-ha" moment! The client just taught me something new. My understanding of the client must in some way be flawed. Identifying my flawed understanding might lead to new perspectives and ideas. In contrast, the students viewed it as the client's error and something that needed to be prevented in a future iteration of the design. Although recognizing the a-ha moment (instead of seeing it as a failure) is part of a designer's mindset, it is difficult to teach—and impossible to teach if you have no opportunity to guide or coach students between the lecture and assessment of their work. Not only is there a need for providing students with coaching on their thinking and behaviour as they work, it also necessitates a more sophisticated understanding of learning outcomes than that presented by Bloom's taxonomy, where there is no place for mindset and no place for who the learner becomes.

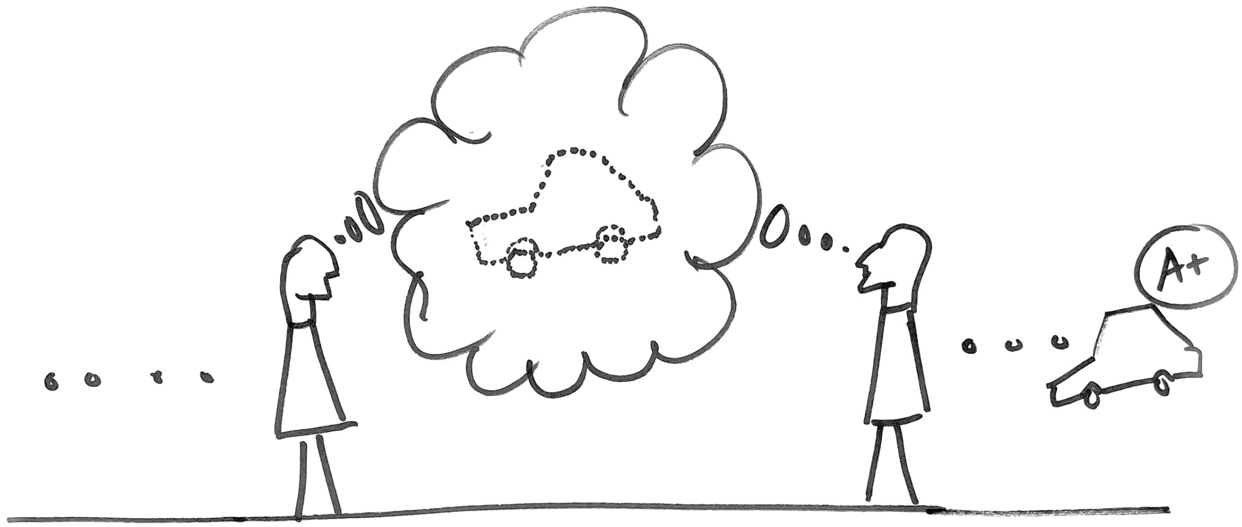
My first success in teaching first-year students engineering design was by teaching students a few tools and steps and thereby scaffolding their "doing." I paid no attention to their thinking, behaving, or working. If they produced a "good" design outcome, they did well. Today, I insert my skill as an educator and designer into the gap between lecture and assessment. I aim not only to help students achieve a design outcome but to grow the skills, abilities, and mindsets which they take with them when they leave university. I now think of teaching in terms of scaffolding the learning (i.e., thinking and working with others) rather than the doing:

- I engage students as partners in conversations about the learning outcomes of the course and continue to remind them of the learning outcomes throughout the course.
- Those learning outcomes have evolved from doing-oriented outcomes like “follow the engineering design process” to durable skills, abilities, and mindsets/mindshifts/ways of thinking.
- When designing my courses, classes, and lessons I pay great creative attention to culture, environment, and community in addition to activities for students. This ensures the learning experience reflect my values and leverage every possible opportunity to support the learning outcomes.
- I provide active support for student learning as it happens. In part, that means teaching students to make their thinking, feeling, doing, and working with others visible to the instructor.
- I model a growth mindset by investing time into growing my design and educational knowledge and skills.
- There are no long lectures. The content aspects of my courses are minimal. Students are learning by practising, which begins almost immediately at the start of a course.
- To help identify learning problems, I am always observing my students and talking to them.

In Figure 1 where there is a gap between the lecture and assessment is where experiential learning happens. It doesn’t happen in the lecture hall. Our learners deserve the very best pedagogy we can offer in the gap. I struggle with a system that primarily values the lecture and project outcomes and leaves the learning between lecture and the assessment up to the student.

Over the course of this journey, I’ve made progress in answering my two nagging questions. In retrospect, when I initially had success with experiential education, student learning was probably not as strong I was led to believe because I had adopted ideas about what learning should be in experiential setting from a lecture setting. Figure 2 illustrates this new way of teaching. To teach mindsets, behaviours, and ways of thinking—which do not appear on Bloom’s taxonomy—I need to engage students in new ways that expose their thinking-in-progress and their work-in-progress. It opens up the opportunity for coaching the student on their skills and mindsets as well as giving the instructor insight into the learning problems faced by the student. The relationship between the instructor or coach and learner is active, reflective, and ultimately intellectually engaging for both.

Figure 2. Evolved pedagogical model for experiential learning



The evolved pedagogical model for experiential learning changes not only the nature of the work students are assigned but the relationship between the instructor and students. In this new model, the instructor engages with students on their work. Students expose their in-progress thinking and work, allowing the instructor to coach the student on their mindsets, behaviours, and ways of thinking in addition to guiding the outcome of the work. Original figure by author.

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Robert Vladimir Fleisig *is an associate professor in the teaching-stream in the Walter G. Booth School of Engineering Practice and Technology at McMaster University. His current scholarly interests reside in reimagining university teaching for teaching-oriented faculty from the perspective of a design thinker. In 2018 he was awarded the prestigious Ontario Confederation of University Faculty Associations' (OCUFA) teaching award and named a fellow of the Canadian Engineering Education Association (CEEA) in 2022. He is currently a co-editor for the International Journal for Students as Partners and program lead for the Master of Engineering Design program.*

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