Student Engagement in the Digital Age: A Review of Effective Teaching within Limited Physical Contact Hours

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CONTEXT
Improved student engagement has long been the goal of educators. Engineering, where the aim is to apply science to solve societal challenges, clearly lends itself well to engage learners through its inherently applied and project-oriented curriculum. The trends for how to achieve this, though, are rapidly evolving. At present many educational institutions are turning to digital and blended learning models, albeit at diverse adoption rates. If education are a zero-sum game, this *may* imply a reduction in physical contact hours (classroom lectures, lab demonstrations, and other face-to-face meetings).

PURPOSE
As global engineering teaching practices shift towards hosting, if not always delivering, a significant fraction of their content online, we raise the question: can student engagement and core engineering graduate attributes be maintained with limited physical contact hours?

APPROACH
A snapshot of the mean contact hours required for a Bachelor's degree in Mechanical Engineering was reviewed from sample plans and degree requirements available from top-ranked Universities around the world. These data were then viewed through the lens of student learning outcomes, tuition costs, and student satisfaction. Studies from the literature of digital learning were then critically compared in this context to determine the most effective practices in a ‘contact hour constrained’ future – e.g. identifying delivery methods which most effectively replace/supplement physical hours as we move to more online and distance learning.

RESULTS
Based on the data and literature reviewed for this paper, it was found that physical contact hours vary significantly between top Universities – from 900 to 1,700 hours during a typical student’s degree program. It was also found that although Universities have significantly different adoption levels, rates, and plans for blended and online teaching, almost all have adopted online Learning Management Systems and have content available online. Based on information in the literature, it is estimated that physical contact time now only makes up <25% of the hours students actually put in towards their Bachelor’s degrees in Engineering. If most of the effort of learning is actually done outside of the classroom/lab, it may be hypothesized that further supplanting contact hours with effective blended learning models may not have negative impacts on student engagement and learning. A summary of the best practices (game-based learning, virtual labs/environments) found in the literature for blended learning in Engineering is presented in the paper.

CONCLUSIONS
Learning efficacy with reduced contact hours will need continuous monitoring if we continue to trade traditional physical contact hours for, or blend with, online teaching. At worst, online and blended teaching techniques provide equal learning outcome and course satisfaction based on today’s literature, but incur additional administration and up-front effort from educators. At best, there is the potential for significant enhancement in student motivation, engagement, and learning outcomes with a long-term return on resource investment for blended and online teaching methods.

KEYWORDS
Physical Contact Hours, Blended Teaching, Online Teaching, Distance Learning.

Introduction

Traditional engineering education has been based on classroom lectures with laboratory exercises of key applied topics. A typical, traditional engineering course might include three hours of lecture and one hour of laboratory each week. In a standard curriculum of four courses per semester, the traditional student has 12-16 hours of physical contact hours, not including scheduled or ad-hoc problem-solving sessions and meetings with instructors. Thus, if obtaining an engineering education demands 40 hours per week, perhaps 50% of it would have been done in the physical presence of paid course staff.

With the advent of learning management platforms, online lectures, virtual labs, and other distance learning modes, it is clear that physical contact hours have the potential to be partially, if not entirely displaced. Even 15 years ago (in 2001), ~90% of public tertiary institutions offered distance education courses (Tallent-Runnels et al., 2006). Today online teaching is almost ubiquitous if learning management systems (e.g. Moodle, Blackboard, and others) are considered.

The trend of 'going digital' is not necessarily detrimental (or beneficial) to learning outcomes if the methods used correspond with the longer term evolution in engineering education; from a 'lecture and rote learning' model to a 'learn-by-doing' model (Froyd, Wankat, & Smith, 2012). A synchronised shift away from traditional physical contact hours and rote learning can be viewed as complementary *or* conflicting, depending on the methods employed and the outcomes desired. Written and oral content delivery, and even online assessments, can relatively easily be scaled-up for online delivery to huge audiences, but this may not necessarily effectively engage students – e.g. from nearly 13,000 students enrolled in Duke's *Bioelectriciy* course in 2012 only ~300 passed the final exam and earned a certificate (Belanger, 2013).

The learn-by-doing model, as a philosophy, has the potential for success both inside and outside traditional physical contact hours. As Froyd points out, the 'learn-by-doing' model comes with a few key tenets (Froyd et al., 2012):

1) Emphasizing engineering design

2) Applying educational, learning, and social-behavioural sciences to education

3) The integration of information, computational, and communications technology

In particular, tenet (3) provides a way to align digital learning and the 'learn-by-doing' models. Although educational institutions may not be explicitly seeking such alignment, a thoughtfully developed digital learning environment can graft onto (or perhaps supplant) the traditional physical teaching environment in the shift towards a 'learn-by-doing' model. Without committing to drastic course change, blended learning can be used as enrichment (or a back-up) to traditional contact hours – e.g. recorded lectures. It is also not hard to imagine the myriad ways in which distance learning can give students opportunities to practice engineering design – tenet (1) – particularly when many of today's engineering design tools take the form of software. Thus, *tenet (2) may in fact be the key which determines if digital learning is successful in engineering education*.

When distance learning hours replace physical contact hours it may be difficult to motivate students and maintain their engagement. Unlike physical contact time, the hours students put towards learning is patently less structured and potentially fraught with many more distractions. Digital learning methods must, to some extent, rely more heavily on students' own internal motivation. According a 2011 article by Savage et al., though, engineering students were indeed more likely to be motivated by internal (versus external) factors – e.g. pure interest in the material, taking responsibility for their own learning, and satisfaction in their own achievements (Savage, Birch, & Noussi, 2011). They were less likely to be motivated by positive feedback and were unlikely to read topics outside of their main area of study (Savage et al., 2011). Thus, digital learning methods that are designed to help build intrinsic, internal motivation or those that provide engaging independent learning opportunities may be at least as effective as physical learning modes. The potential pitfall is that digital delivery can provide ‘content overload’. Thus, it is not the solely the *number* of opportunities available, but the *quality* of those opportunities which is crucial to motivation and engagement. Similarly, this logic holds for the *number versus quality* of physical contact hours in any course.

Since the true cost of digital learning methods is still very fluid relative to existing physical contact hours, the questions which most often arises are: Does it provide equivalent learning outcomes? Does digital delivery align better or worse with the ‘learn-by-doing’ model than conventional teaching methods? Are students satisfied with ‘instructor-less’ instruction? These questions have, to some extent, been answered in a number of studies reported in the literature (described below). Not as well explored, however, is if there is minimum number of physical contact hours needed to ensure students have the necessary background knowledge, skill, and motivation needed to become independent, self- learners. The answer to this – and to most of life’s questions – is, ‘it depends’. It depends on the individual students’ background/level, the particular material being taught, the delivery methods, the student/staff ratio, the quality of the staff/students, and a whole host of other factors. Nevertheless, as a starting place for discussion on the questions surrounding blending and supplanting physical contact hours is to compare the amount of physical contact hours taking place in engineering programs around the world along with some of the best practices for digital learning.

Today’s Contact Hours

Given the push towards moving content online, it is of value to take a snapshot of how many physical contact hours are currently offered at top Universities. This assessment should not be considered only for posterity’s sake, but to see if any there is any agreement on number of contact hours required for an engineering degree in general. Aside from the fact that the co-authors teach within mechanical engineering programs, mechanical engineering can be considered as a representative field for engineering due to its wide breadth and the fact that many of the core competencies relate to most engineering degrees. Mechanical engineering is also usually a well-established, reasonably large department within any given engineering faculty.

Based on publically available data from the relevant institutions, Figure 1 gives an estimation of the mean contact hours for a unit of credit (A), the units of credit required for a Bachelor's degree in mechanical engineering (B), and the total number of contact hours a student would have during their degree (C = A x B). It can be seen that there is a relatively wide range in what is required among degrees across the Universities studied, from ~900 contact hours at Harvard University to ~1,700 physical contact hours at the University of Michigan. Note that these data come from information listed on degree requirements and sample course plans (Belanger, 2013; GeorgiaTech, 2015; Harvard, 2015; Imperial College, 2014; MITMECHE, 2016; NUS, 2016; Oxford, 2014; Stanford University, 2016; The University of Tokyo, 2016; The University of Tulsa, 2015; UC Berkeley, 2016; University of Cambridge, 2016; University of Michigan, 2016; UNSW-Australia, 2015). It should also be noted that aside from the co-author’s own institutions, the selected Universities are all in the top 30 according to the QS rankings 2015/16 (QS, 2015a).

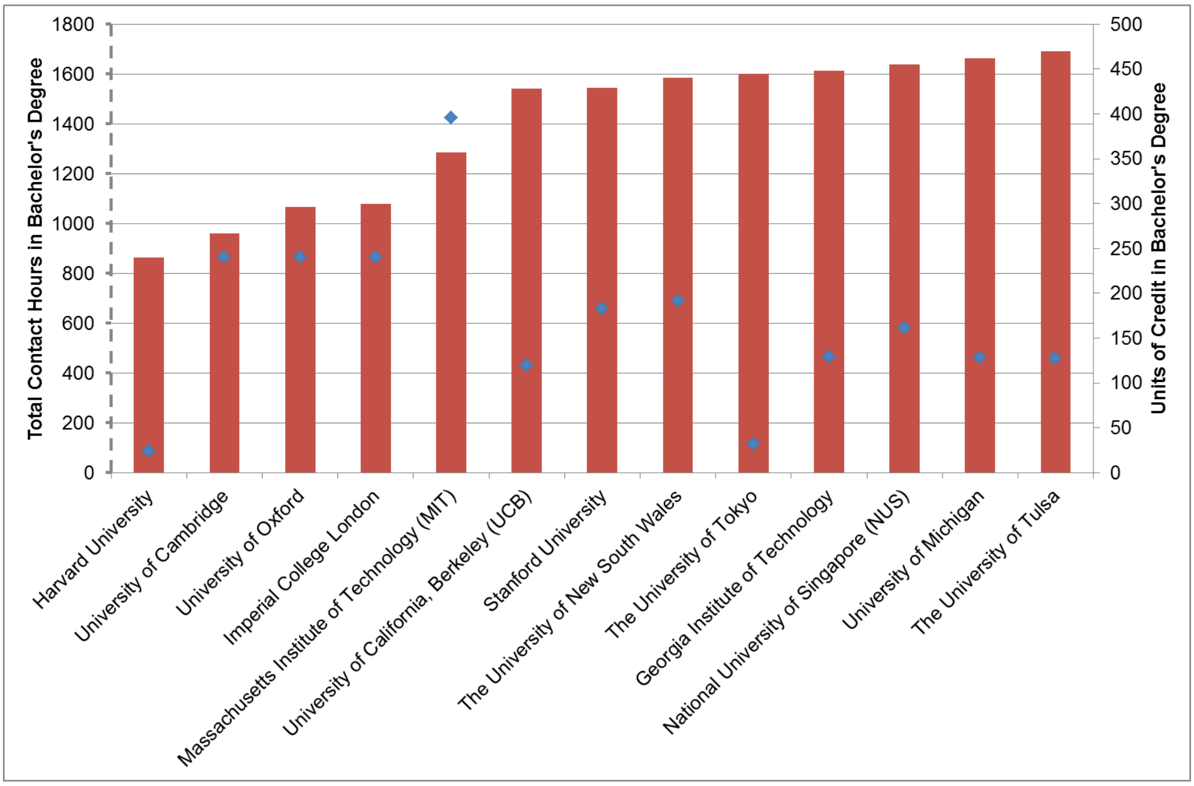

Figure 1. Contact hour comparison for selected Mechanical Engineering degrees (2015/2016) – Physical Contact Hours = Red Bars; Units of Credit = Blue Diamonds, Data from: (Belanger, 2013; GeorgiaTech, 2015; Harvard, 2015; Imperial College, 2014; MITMECHE, 2016; NUS, 2016; Oxford, 2014; Stanford University, 2016; The University of Tokyo, 2016; The University of Tulsa, 2015; UC Berkeley, 2016; University of Cambridge, 2016; University of Michigan, 2016; UNSW-Australia, 2015)

Prestige aside, employers are likely to treat student from Harvard/Cambridge as having a similar competency level as those from Georgia Tech/Michigan (GeorgiaTech, 2015; Harvard, 2015; University of Cambridge, 2016; University of Michigan, 2016). However, the latter provide their students 68-93% more contact hours during their degrees. Since tuition and fees for a four year degree at Harvard is ~175,000 USD, while out-of-state tuition fees at Michigan is ~90,000 USD (QS, 2015b), students actually pay nearly four times as much per contact hour at Harvard. (Note in-state tuition and fees at Michigan = ~56,000 USD). It should be noted that due to their highly selective nature, the staff to student ratio is more than double at Harvard (1 : 9) and at other private schools (e.g. the University of Tulsa ~ 1 : 15), than most large public institutions (1 : 20-30). This means that although contact hours cost more, students are getting more personalised attention during that time. It should also be noted that a mechanical engineering degree from Cambridge/Oxford/Imperial College London cost around 55,000 USD for UK/EU students, whereas international students will pay ~156,000 USD. Each of the UK Universities offer ~1,000 contact hours per degree, so depending on geographic status, the price of each contact hour is roughly 55 USD or 156 USD. A similar fee range is in place at authors' Australian institution, but with more contact hours. Although the selection of Universities should certainly not be based solely on contact hours and fees, it can be seen that the financial value of each contact hour at top ranked Universities varies widely, between 33-204 USD. While the total tuition cost can scale by a factor of three, is seems there's a factor of six difference in the cost of a contact hour. Since the starting salary for most mechanical engineering jobs is in the range of 50,000-100,000 USD/year, it takes one to four years of engineering work to gross the tuition and fees of most four year degrees. This simple payback excludes four years of lost wages and living expenses, which normally exceeds the tuition and fees – effectively more than doubling the real, personal cost of doing the contact hours.

Although there is certainly a sizable variation in the number of hours students devote to their studies, it is reasonable to estimate that a full-time, four year degree would (roughly) equate to 40 hours/week x 40 weeks/year x 4 years = 6,400 hours. It should be noted that a sizable percentage of students take flexible paths toward putting in these hours due to travel, family, work, illness, and many other reasons. Even for these part-time students an estimate of 6,400 hours seems appropriate. It essentially amounts to fewer hours per week spread out over more weeks. In a study by Banks and Faul, it was found that while replacing contact hours with web-based hours did not significantly hurt learning outcomes, it did change student's satisfaction with the course (Banks & Faul, 2007). In particular, students in the early stage of their program were much less satisfied with online and blended teaching methods as compared to more advanced students and students who were working part time (Banks & Faul, 2007).

Thus, at a top University in 2015, students would likely spend between much less than half of their time on physical contact hours and a majority of it on completing assignments, independent study, working in teams, and using web-based and/or distance learning technology. This simple estimate indicates that: 1) the majority of time is spent outside physical contact hours (evident), 2) there is scope for more time to be devoted to digital learning, and 3) better learning outcomes might be achieved in a zero sum game through more 'engaged time' and more 'time on task', rather than more total time.

Digital Learning Trends

Most engineering degree granting institutions have incorporated some form of web-based and/or distance learning technologies as part of their curriculum. Even for institutions which have not yet fully developed their digital learning portfolio (such as those of the co-authors), many of the lectures are recorded and most course content is delivered, and increasingly assessed, through a learning management system (LMS). At the end of 2015, Moodle, Edmodo, and Blackboard had 71, 49, and 20 million users, respectively (Capterra, 2015). Although, an LMS can be used simply as a way to distribute course materials (including recorded lectures), ~51% of users use the LMS 'assessment/testing tools' (Capterra, 2015). Thus, a significant portion of the physical contact time which historically went to conducting, collecting, and distributing feedback on assessments/tests is now web-based.

When done concurrently with physical contact hours, digital learning provides flexibility for students. Dowling et al. did a comparison study of traditional teaching with a blended delivery of the same material (using approximately half as many physical contact hours). It was found that although the blended teaching model had lower mid-term results, the final learning outcomes were slightly (statistically significantly) improved with the blended learning model. Lower mid-term results were proposed to be because it took students time to adjust to the independent learning mode. Dowling also found that certain demographics were more positively correlated with improved learning outcomes from blended learning (e.g. females and younger, full-time students adapted easier to blended learning).

Given the increasing demand for higher education – with 1.4-1.6% year upon year increase since 1970 – we can expect that global tertiary enrolments will more than double by 2050, from 170 million in 2010 to > 320 million by 2050 (British Council, 2012; IES, 2007)). According to a 2012 British Council's report, Transnational Education (TNE) – where the learners are located in a country different from the one where the awarding institution is based – is a huge, growing opportunity where the USA, the UK, and Australia have historically, and are likely to continue to be, the biggest players (British Council, 2012). TNE has traditionally relied on 'bricks-and-mortar' delivery methods, but is expected to increasingly incorporate online and blended learning pedagogies (British Council, 2012). With the potential for per student cost savings and/or teaching quality improvements, the decreased rate of national investment in higher education institutions (Ellen Hazelkorn, 2012), and increasing global competition, the momentum towards online and blended teaching is likely to continue. The authors propose two potential futures for digital learning, shown in Figure 2. In 'scenario A' this takes the form of reduced contact hours and increased digital learning hours. In 'scenario B' physical contact hours are kept relatively constant, but the amount of physical/digital blended hours will increase substantially.

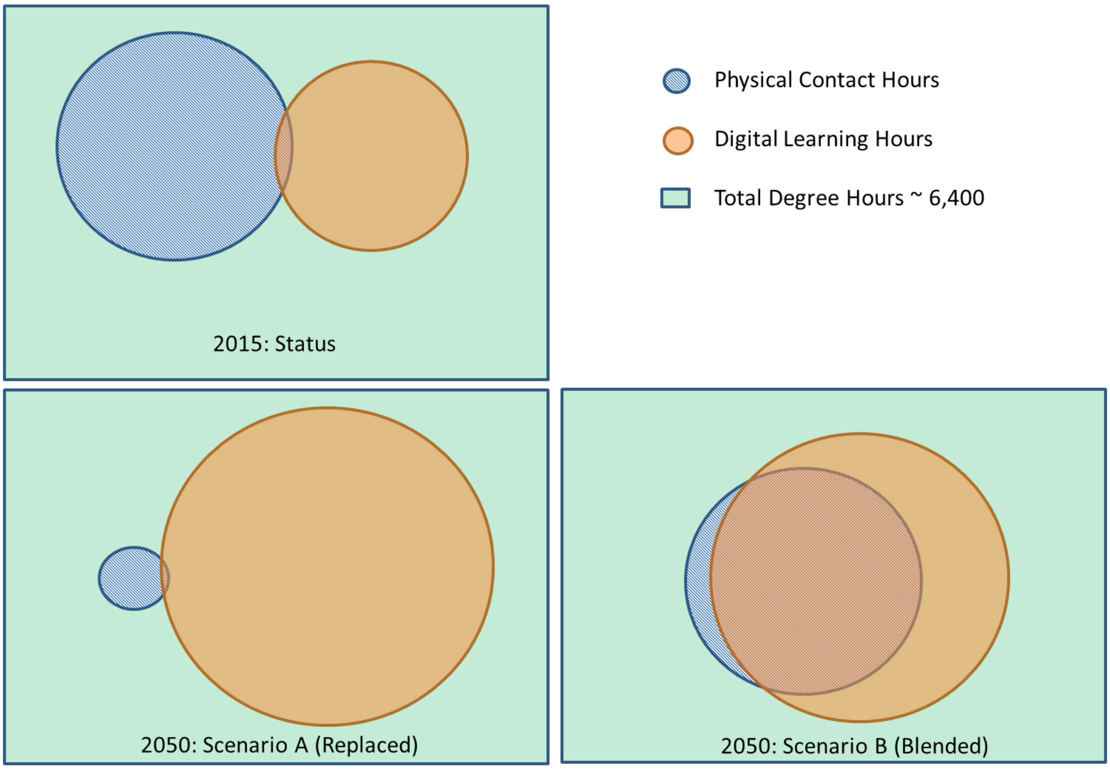

Figure 2: Proposed engineering degree hours: Top Left – 2015 estimate; Bottom Left – 2050 scenario with reduced physical contact hours; Bottom Right – 2050 blended learning scenario

Clearly, this is a spectrum and many Universities may choose a model somewhere between 'A' and 'B'. Will blended learning will be the best-practice model for the future or is it simply a stop-gap/stepping stone for fully web-based degrees with very little (or zero) physical contact hours? To answer this question it is also worth considering which scenario provides the best learning and economic outcomes for institutions and students. In a case study by Tome, it was concluded that online and blended teaching can actually take up more of an educator's time than traditional courses (Tomei, 2006). This is a contentious point, though, since studies have concluded that blended teaching creates more of a workload for instructors, is similar, or is more time efficient (Tallent-Runnels et al., 2006)(DiBiase, 2000). There is some agreement in the literature, however, that digital teaching methods require more up-front time (learning how to interact with the technology) and that more frequent, yet smaller, time inputs are required for both students and instructors (Tallent-Runnels et al., 2006). Literature studies also agree that online and blended teaching methods present trade-offs in effort, time, and learning outcomes which depend heavily on the course content. For example, automated grading and instant feedback to students (particularly for the quantitative assessments of engineering) represents a potential source of time savings for instructors, after the initial start-up cost of making extensive question/response deposits into the LMS' bank are recovered. If designed well, though, online assessments can be used with minor modifications in many subsequent years, giving several years of returns on these initial investments.

Best Practices

It appears that for the near future blended learning with both synchronous and asynchronous delivery of web-based hours is the current trend. Numerous studies have shown that blended learning provides a diverse range of pedagogical options and enables different learners to engage with the types of content which suit them the best (Case & Light, 2011). In a 2003 study by Graff, a set of 50 students were grouped according to the cognitive learning styles (e.g. holistic versus analytical and verbalisers versus imagers). It was found that analytics were able to recall content well when it is presented in a long (11 page) format relative to holistic learners, since they can break information into parts more easily. Imagers were able to recall information from a short format (2-page) much better than verbalisers (Graff, 2003). This indicates that if multiple forms of delivery (including traditional physical contact hours) for content can be developed in a blended learning scenario it may be possible to best cater for all learning types.

Another key aspect of blended learning models which could help foster student engagement is nurturing team, group, and collaborative learning. A few studies have shown that online team-based design can work (Bourne, Harris, & Mayadas, 2005), and that it even may be effective across department, institution, and even international boundaries. However, blending online team building with some physical contact time may provide the best results in terms of learning outcomes, collaboration, and perceived quality of instructional variables (Lim, Doo Hun; Yoon, 2008). Since the author's own institution (UNSW-Australia) and many other institutions emphasise group work as a key graduate attribute, it is highly likely that best practice will include ample opportunities for online and blended collaborative learning. Studies also indicate that blended learning provides extensive opportunities for social interaction, personal agency, and flexibility (Demirer & Sahin, 2013). There are a few simple blended resources and techniques which can be considered as 'low-hanging fruit' to provide more opportunities for students to engage with the course content outside of the classroom. These, as a rule, require very little in the way of time and resource to provide into an existing course, examples include:

- Background information to refresh/cover assumed knowledge
- Online assessments/tests to provide rapid, personalised feedback
- Forums to facilitate peer-learning/peer-assessment
- Reading/videos to supplement learning styles not captured in traditional lecture

In the longer term, when significant resources are available to develop them, the following techniques show potential to play a big role in blended and/or online teaching.

- Remote (using physical assets) /virtual (simulated) laboratories
- Augmented and virtual worlds (potentially in 3D)
- Mobile learning to allow greater flexibility and social interaction
- Game-based learning
- 'Smart' technologies to guide student through misconceptions and difficult concepts

Based on a review of the literature for these concepts (Al-Qahtani & Higgins, 2013; Banks & Faul, 2007; Borrego, Foster, & Froyd, 2014; Bourne et al., 2005; Christie & Jurado, 2009; Demirer & Sahin, 2013; Hoffman, Vargas, & Santos, 2008; Kwak, Menezes, & Sherwood, 2015; Laurillard, 2007; Tallent-Runnels et al., 2006), particularly the longer-term concepts, it is clear that educators are only in the initial stages of studying these pedagogies. It is clear that the vast majority of work done on these issues (to date) is exploratory and empirical, rather than systematic and generally applicable across disciplines. The overall efficacy of digital learning, a ratio of gross cohort learning per unit of input resources, will need to be continuously monitored and studied as we blend with (or trade for) traditional physical contact hours going forward.

Conclusions

This study reveals that physical contact hours at top Universities are only 15-25% of the hours students put in towards a degree, but it is likely that this fraction will change. The efficiency in terms of learning outcomes divided by input effort will need continuous monitoring as we move to trade traditional physical contact hours for, or blend them with, digital hours. At present, the literature reveals that, at worst, online and blended teaching techniques provide equal learning outcome and course satisfaction, but incur some additional administration and up-front effort, compared with traditionally delivered lectures and laboratories. At best, there is potential for significant enhancement in student motivation, engagement, and learning outcomes with a long-term return on resource investment in applying (and developing) the blended and online teaching methods. We also propose two potential future scenarios – one where blended learning becomes dominant and one where physical contact hours are replaced by online teaching. The digital age has certainly displaced many of societies' paradigms for information delivery – e.g. film-based photography, newspapers, and physical book/music/video stores. However, it seems to have blended well with numerous conventional technologies to make them 'smarter' and more engaging – e.g. phones, watches, televisions, and cars. At this stage in engineering education, it appears the blended, 'smarter', learning model is coming to the forefront, but it is not clear yet whether physical contact hours will eventually be displaced in favour of online teaching hours.

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