



Technology Tools And Approaches to Improve Undergraduate Education

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ABSTRACT

Developments in science and technology have led to improvements not only in consumable goods but also in teaching and learning in the education sector. Although traditional teaching techniques are still in use, the application of hi-tech and advanced teaching and learning methods is increasing every day. These methods have added new dimensions to teaching and learning. This paper reviews different technology tools and approaches that have been applied to improve teaching and learning in undergraduate engineering education. The findings show that a number of methods have great potential for engineering units but have not been tested yet. Simultaneous applications of these technology tools and teaching approaches will significantly improve the efficiency of both teaching and learning.

Indexing terms/Keywords

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INTRODUCTION

Teaching at the undergraduate level mainly involves the transfer of knowledge to students. The knowledge consists of (i) theories about underlying mechanisms, (ii) experimental understanding and (iii) familiarity with some common terms used in a specific profession. Understanding, as well as memorising, is essential to do well in examinations and professional activities. Universities around the world are incorporating different educational tools to facilitate the understanding and memorising of students in undergraduate programs. These tools consist of technology tools, as well as new approaches to teaching. The aim of teaching today is to produce graduates with the capacity to be intellectual leaders in an era that demands flexibility, creativity, experimentation and teamwork across traditional boundaries [1].

Technology plays a significant role in shaping the teaching and learning landscape in higher education. Digital technology is expected to play an increasingly significant role in higher education as members of the millennial and digital generations enter college, bringing with them new approaches to learning and consequent expectations of the classroom instructor [2, 3]. The vast array of technologies with the potential to influence the teaching/learning process includes learning management systems, personal response systems, discussion boards, blogs, wikis, social networking, podcasts and an excess of web-based tools. Technology-enhanced learning is defined as the use of various information technology forms in the teaching and learning process. Technology use in education has kept pace with the exponential growth in its use across all facets of life in much of the world [4]. Learning technologies used by individual faculty and students range from simple information technologies, including word processing, spread sheets and database operations, to purely instructional technologies designed to deliver information to the learner; more complex technology includes computer-assisted instructional packages, multimedia and interactive video used to deliver academic courses and programs online [5]. All these are used to enhance the teaching-learning process and constitute technology-enhanced learning. Course-based use of information technology identified in colleges and universities includes e-mail (34.0% increase in 5 years), Internet resources as part of the syllabus (28% increase in 5 years) and World Wide Web pages for class materials and resources (19% increase in 5 years). The percentage of faculty using technology-enhanced learning for the creation of presentation hand-outs (36.1%) and using multimedia (18.2%), computer simulations/ exercises (15.1%) and CD-ROM-based materials (15.0%) has all increased [6, 7].

The increase in the demand for technology-enhanced learning, together with the rise in its use, creates challenges for faculty, such as determining how to assist faculty in integrating the technology into instruction and how to provide adequate user support [8]. Students need to be equipped to deal with the use of information technology in both the education and the workplace environment. To this end, a substantial number of colleges and universities have a basic computer competency requirement for all undergraduate students [8]. Technology-based teaching-learning strategies include the careful design, selection and use of interactive technologies to engage the learner actively in the learning process. In education program assessments, it is important to evaluate the effectiveness of technology-enhanced learning. An early meta-analysis evaluating the effectiveness of computer-based education across elementary, secondary, higher and adult education programs showed an increase in scores of 10 to 20 percentile points and a reduction of one-third in the time to achieve goals [9].

Different approaches intensify the learning process by highlighting different aspects of teaching methods. These include critical incident analysis, which identifies attributes of workplace problems; module/structure-based teaching, which emphasises strategic engineering education; and mass customisation of courses [1, 10, 11, 12]. Although the aforementioned methods present teaching materials in different ways, they all have similar objectives, such as making students understand, remember and apply the knowledge they have acquired correctly in their chosen profession.

Based on a review of the literature, there appears to be no perfect educational method that can provide perfect teaching or produce perfect graduates. All the technology tools and education methods aid different aspects of teaching and learning. This paper describes current available technology tools and education methods and the context in which they are used based on the literature. The findings will enable educators to compare the methods and to determine the suitability of their applications in improving teaching and learning.

APPLICATION OF TECHNOLOGY TOOLS

Information and Communication Technologies

The number of students entering higher education is continuing to increase. Thus, universities are looking for new approaches in education [13] and adopting approaches employed in industry to advance educational services [14] and optimize costs. Information and communication technologies have the potential to support the anticipated evolution in the educational sector. They can support educational activities in many ways by providing a wide range of materials in a variety of formats, including audio, video, simulations and animations, and by providing access through the net. The European Commission strongly supports educational material capitalisation and open distance learning transmission and views education as one of the most strategic applications of information and communication technology development [14]. In today's post-industrial, global world, universities have started to adopt new roles and to take new approaches to training students to think critically, solve problems and develop themselves throughout their lives. Expectations from Internet educational applications are very high [14].

Academic institutions generally use technologies because it (i) boosts the visibility of education and allows online registration of students; (ii) creates a complete learning environment combining network-accessible resources, such as



syllabus, objectives, a conceptual map of the course, educational material, references, timetables and forums; (iii) delivers distance, as well as flexible, education; (iv) facilitates international student exchanges; (v) allows reuse and diffusion of educational material on a large scale; (vi) saves money and makes it possible to focus on the improvement rather than the production of educational material; and (vii) facilitates the transmission of information and improves work-flow processes by making online communication tools available to a variety of users, including students, teachers and administrative staff [14].

Web information needs to be updated regularly to ensure that the appropriateness and the accuracy of the data accessed by students, teachers and administrative staff. This is a job that requires a specific set of skills. The institutions should provide rewards (in terms of acknowledgement or financial support and must be able to deal with copyright problems) if teachers are engaged in the production of e-learning material and in the modification of educational strategies [14]. A huge amount of time is required to design and gather good quality educational materials. Although the software design and updating steps remain the responsibility of the teachers, students can be engaged to develop interactive software or multiple-choice questions to save time. After the initial time-consuming effort involved in establishing a web-based teaching program, it provides (i) high-quality and well-structured educational material; (ii) online references that provide details of on every fact; (iii) self-learning tasks that help students take control of the learning process; (iv) support and collaboration with extended work groups, including distant students and experts from industry; and (v) tools, such as simulation, virtual laboratories and remote laboratories [14].

Teachers must be aware of information and communication technologies to optimise the teaching process. Research has found that students are often more informed than teachers about multimedia and Internet possibilities, a finding that is perhaps explained by the generation gap. Thus, training courses are emerging for teachers to keep them updated about current trends. Users expect the following from e-learning tools: (i) accessible when necessary, (ii) ability to provide a self-learning environment, (iii) high-quality and timely tutor support, (iv) encourage group work, (v) assessment tools and (vi) attractive, interactive and technically 100% reliable [14].

Online Games

Games are beneficial for many reasons. For example, the knowledge and skills learned and practiced in games are likely to be transferrable and, with further practice it provides learning more than over required [15]. Games automatise and consolidate knowledge and skills in memory, and they focus on conscious understanding and on the application of new information [16]. Games also provide immediate feedback on actions and decisions and allow trialling [17]. They improve decision-making skills and the ability to deal with increasingly difficult challenges, and success is achieved through trial and error [18]. Success in games that feature levels of increasing difficulty, complexity or pace depends upon the skills learned at previous levels. Therefore, games can be used as educational tools to familiarise the prior knowledge and skills of each learner [16]. The pace of the activities can be adjusted for faster or slower learners to deliver customised instruction [19]. The amusement, contests, virtual atmosphere and instant feedback of games engage players [20] and sustain interest in the game [21]. Thus games can inspire learners who lack attention and lack self-confidence [22]. They can also develop their thinking and strategic skills [21].

Brain oscillations occur more frequently in more complex games. Such games can improve academic performance by enhancing students' educational, social and computer skills [23]. Thus, games have great potential in education. They make it possible to teach complex new information, which may be difficult to teach using conventional approaches, in a fun and encouraging way. The trial-and-error element improves strategic skills. Thus, academic performance and cooperation are boosted according to the ideologies of the spiral curriculum [15].

Paraskeva et al. [15] laid the foundations of behaviourism theory, which correlates learning and games with relevant stimuli and responses. This approach studies the interaction between the player in a game where the player matches questions and answers. Motivation comes from making a correct match, and then learning occurs [24]. However, this theory is based on drill-and-practice and in-training rather than on understanding [25, 26]. In contrast, games requiring critical thinking build intrinsic motivation by integrating learning and the gaming experience via socio-cognitive learning [27]. This is known as socio-cognitive learning theory. Socio-cognitive learning theory simulates anticipated behaviour of the learning process when that behaviour is reinforced. The simulation takes account of a combination of factors, such as the person's behaviour and the environment where the person displays the self-regulating behaviour [28].

Papert [29, 30] proposed that an active approach to knowledge acquisition and the use of external artefacts help the learning experience via a process called constructionism. Constructionism focuses on the role of external items in the learning process and leads to the creation and connection of different objects, which work as virtual shared artefacts [30].

Paraskeva et al., [15] discussed formulated theories, such as, the activity theory and the socio-cultural theory. Activity theory relates to the effect of tools and culture on human activity [31, 32] and offers a theoretical basis for understanding the influence of games on people. It involves subjects (people or groups), objects (members of a system, rules, learning processes) and tools (games). The tools mediate interactions between the subject and the object. People mediate the activity through mutual customs and anticipation in the game [33]. Thus, there is a cooperative learning atmosphere, where the players interact with the subjects, objects and tools of the game under stated rules and create societies. The interactions throughout the game determine the learning outcome.

Socio-cultural theory involves negotiating an understanding of the learning process. It recognises knowledge as a tool that facilitates activity. This approach is more global and includes players, games and the environment [27]. The most important point from the socio-cultural view is that good games employ players in multiple ways and that the interactions among the different systems form dynamic learning opportunities [33]. These interactions in the game are considered part



of an intricate learning process, which is similar to the daily interactions that take place among children in a playground [15]. Multiplayer games are played against real people anytime and anywhere in the world or against a computer [3]. Such games promote human interactions and lead to the formation of large groups in an extended socio-cultural atmosphere.

On-line Learning

Electronic mail (e-mail) is now the most common way of sharing information and interacting throughout the modern world. Similarly, the Internet is used more often than any other source to retrieve information, communicate and spread information [34]. Many hundreds of thousands of file transfer protocol (FTP) repositories of programs and hypertext transfer protocol (HTTP) web sites are now available. These are searchable by a variety of search engines to find information in an instant. This challenges libraries to merge their collections into these new formats. Networked information transfer has had a dramatic effect on the educational sector, with hundreds of web sites providing educational materials on-line. Some of these are free, whereas others require registration and a fee. Factors that need to be considered from an educational perspective with regard to these on-line materials are (i) the breadth of the materials, (ii) the institutions hosting the material and (iii) the depth of the materials [34].

On-line education systems comprise three main components: clients, servers and the instructor interface. Clients generally obtain information from multiple web servers and the instructor observes the interactions of students with the servers. Servers contain course materials and record the activities of students with the course materials. Course materials, such as the syllabus, lecture notes, notes about assignments and tutorials and other learning materials, can be easily included on servers.

On-line teaching offers some capabilities that are difficult or unmanageable in traditional educational teaching. These include (i) accessing and searching for materials, (ii) interacting with students at multiple Institutions, (iii) learning from stored anecdotal knowledge, (iv) on-line laboratories, (v) immediate feedback/ comparison with other students and (vi) immediate reports of class performance to instructor [34]. Each of the capabilities has its own features. Asynchronous (not at the same time, e.g. e-mail) and synchronous (at the same time, e.g. talking on the phone or viewing a shared video presentation) methods are generally used in on-line education systems

E-mail is the most effective and popular asynchronous medium to exchange information promptly. Conferencing systems may be used in a similar way to exchange information, with people reading and responding to information posted in a specific on-line conferencing area [34]. Listservs are the oldest conferencing method. These allow anyone with e-mail to participate. Subscribers to the listserv can send a message to the server, and then the server rebroadcasts the message to everyone in the group via e-mail. Newsgroups are popular conferencing/news systems where information is captured on a server and then forwarded to specified sites for anyone to read. Notes [35] and FirstClass [36] conferencing systems have been very successful in organising knowledge in industries. These systems offer a hierarchical messaging structure where people post information and reply to a posting. The threads of a discussion are placed as indented items in a list under the initial posting. Some engineering colleges use these conferencing systems to deliver course materials [34]. The firstclassse conferencing systems assist discussions among the students on any topic in a course under proper guidance of the instructor and/or teaching assistant. In addition, they allow the instructor to answer a question one at a time, and all the students in the class can see the answer, thereby saving time for both the students and the teachers. Conferencing systems should be easy to use. They should also work on many operating systems, allow threaded discussion, enable figures to be embedded in messages, provide alerts when information is updated and be manageable, cheap and scalable.

Face-to-face synchronous discussions are not effective if a group of students consider a problem that requires continuous instantaneous interaction. However, commercial video conferencing may be a substitute for face-to-face meetings when groups of individuals are unable to meet together. Synchronous methods use several network-enabled modalities including technologies, such as Mbone and CuSeeMe. Mbone allows multicast transmission of video and audio, and CuSeeMe uses reflector sites that accept video and/or audio information and reflect (e.g. bounce) images to recipients. However, these technologies offer much slower frame rates than point-to-point video conferencing systems [34]. Internet Relay Chat (IRC) or similar methods facilitate synchronous text discussions. The use of IRC is entertaining, but it has almost no use for educational purposes. Synchronous sharing of nontext information, including video, audio and simple graphics, may introduce unacceptable delays if network bandwidth is limited. However, the bandwidth of commercial telecommunication carriers that support the Internet is big enough to include video, audio, hypertext, data, graphical information displays and executable files. Engineering students generally engage in activities involving sharing and discussing engineering drawings, simulating theories and sharing big result files. These are of more value than simply watching an instructor present a lecture.

On-line education reduces costs while providing better education with a personal service component. Online conferences, immediate feedback, on-line materials and demonstrations deliver a supported learning atmosphere where the students feel comfortable, and learning becomes easier. Today, almost every student has a computer, and computers have become as commonplace as calculators in engineering education. Thus, it is time to create on-line courses and design teaching to take advantages of network capabilities.

iPods

iPods are an effective learning technology. At present, they are mainly used in the area of performing arts [37]. However, the iPod has very high potential for engineering subjects because of its ability to display and edit movies and images. Simulations and images give a better understanding of engineering facts. This technology has the capacity to develop



creativity amongst students, as well as to aid teaching and learning practices [38]. The iPod, which is capable of combining video, audio, image and text technologies, facilitates greater flexibility in communication with different media [39, 40] and can support lifelong learning processes [41]. The iPod is useful in the class to play music and video, show pictures and, record audio and video [42]. However, it may challenge conventional practices of educators [43]. Instructors obtain a fresh standpoint in their learning and teaching methods, as the iPod adds another level of engagement to the learning experience. This technology enables the students to study their subject in a way that allows them to explore the topic beyond traditional boundaries and to develop a sense of creativity by enabling a more flexible, deeper and personalised approach to learning [37]. The ability to use the device anytime and anywhere allows students to take a more innovative attitude to simplify their own learning. This further promotes a sense of creativity.

Dale [44] applied three different approaches to embrace the device as a learning technology. The first approach focused on popular music with second-year students studying for a Bachelor of Arts degree in Popular Music. Each student was given an iPod video at the beginning of the academic year and instructed to create collaborative podcasts of popular music bands and to share these with the other students. The second approach involved second-level drama students studying a scenography module where the students recreated a dramatic performance and visualisation. In this case, a sequence of disturbing visual images was transmitted to the audience on a television screen. The iPod transferred extra meaning to the images on the screen. In the third approach, the students recorded a 3–4 minute dance performance on an iPod video in a module named 'Dance, Video, and Technology' for the small screen. It was then compared with a larger screen production of the same performance.

The students considered filmmaking much more deeply and thoroughly when the screen size was different. The device intrinsically motivated them to be creative in their learning processes [45, 46]. The students' self-esteem and confidence were improved by (i) seeing their own creations next to the videos of famous musicians and by (ii) creating their own podcasts on a popular music project. The students wrote their own material, performed and watched their performances on the iPod in the second approach. That was quite a motivating factor as the students felt there were fewer barriers of mega star act and personal material. This motivation was further enhanced by the personal nature of the device itself and the intimate learning experience of using the iPod. These were very special interactions, as the iPod was used in a very personal way. It helped the students to share their conceptions with friends and family, thereby providing additional encouragement.

The implementation of the iPod technology in the curricula is risky because of the continuously growing innovative learning atmosphere [47]. The iPod offers a fresh and innovative perception to teaching and learning practices. It inspires creative learning and motivates the students to become more involved in the subject matter. Time is a crucial factor in establishing a creative learning environment. Institutional support systems are necessary for effective establishment of the iPod as a learning technology. A culture of creativity can be encouraged [48] and creative moments [49] will continue to happen in higher education if properly backed by institutional supports and enough time is given. The perceived novelty and newness of the device may not last. Therefore, its ability to enhance creativity may be short-lived. Longitudinal studies are needed to evaluate the extent of the creativity development using the iPod over the long term [44].

DIFFERENT APPROACHES OF TEACHING

Critical Incident Analysis

The critical incident analysis approach has been tested with nursing students [12]. However, this approach can be applied to any subject where students have to monitor the performance of a system or the health condition of a human being or to correlate effects and causes. Thus, it has significant potential to improve the teaching and learning of engineering subjects. Critical incident analysis assists students to learn from experience and to use knowledge of past incidents [50, 51, 52]. Flanagan [50] defines critical incident as "an observable human activity that is sufficiently complete in itself to permit inferences and predictions to be made about the person performing the act". The observers or participants may make interpretations about the work of nurses in a specific situation. Rimón [51] applied critical incident analysis to examine the emotional role of nurse's while treating patients within a recovery situation. In addition, Norman et al. [53] studied observations of nursing quality using the critical incident technique. In critical incident analysis, reflection assists meaningful experiential learning. The distinction between routine and meaningful learning is important in recognising what constitutes experiential learning [12]. Routine learning takes place by remembering, rehearsing or reciting rules or facts. On the other hand, meaningful learning occurs from understanding and the capability to make sense of things. Students should focus on actual experiences and structured reflections, which are very important in professional life [12]. Critical incident analysis assists the advance of experiential knowledge embedded in professional practice. It can help students to derive meaning from aspects of their practical learning in a quite simple manner by reflecting on stages of education and directing towards real experiences. The recording of a specific incident should be as close as possible to the time of occurrence to avoid losing possible learning aspects. Critical incident analysis incorporates classroom learning with clinical experience, thereby stimulating the cognitive process of professional development, bridging the gap between theory and practice and initiating a self-learning atmosphere [12].

Identification of Attributes of Workplace Problems

Engineering students should learn how to resolve workplace problems because the main duty of practicing engineers is to solve problems. Workplace problems are fundamentally different from those often encounter in the classroom. Thus, a different teaching approach for engineering students is necessary to prepare them for workplace problems. In engineering courses, the nature of workplace problems needs to be understood to better prepare graduates for the workplace.



Jonassen et al. [11] performed qualitative research to identify the parameters of everyday problems solved by practicing engineers and to ascertain the difference between workplace and classroom problems.

The parameters of a problem are specified in a problem statement (a story problem or a word problem) commonly faced in engineering programs [11]. These problems have understandable correct solutions, which are attained by preferred procedures where rules and principles are applied in a predictive and prescriptive procedure [54]. In story problems, students learn to translate relationships of unknowns into equations based on the given problem and then solve the equations to calculate the value of the unknowns. Story problems involve memorising, practicing and familiarising to find answers to different aspects of the problem [55]. Students must develop a sufficient theoretical background and apply this theory to solve workplace problems, which are complex and ill structured. The goals in such problems are vaguely defined, constraints are unstated, there may be multiple solutions, and there may be no appropriate solution path. The students must take decisions and articulate personal thoughts about the problem and then defend their decision [11]. It is commonly assumed that the skills involved in solving well-structured (classroom) problems are transferable to solving ill-structured workplace problems. However, some researchers suggest that the skills to solve classroom problems do not enable graduates to solve complex ill-structured workplace problems [56, 57].

Jonassen et al. [11] identified the following issues that need attention to improve the ability of students to solve complex ill-structured workplace problems: (i) workplace transfer, (ii) problem-based learning, (iii) problem-based learning environments, (iv) complex, ill-structured problems, (v) varieties of problems and (vi) more meaningful collaboration.

The goal of engineering programs should be to foster workplace transfer. In the traditional concept of transfer, students learn to solve similar word problems embedded in a different background. Bransford & Schwartz [58] proposed that preparation for future learning in work situations in engineering programs should include an ability to solve problems and to learn independently and collaboratively

Problem-based learning programs can complement traditional courses by including complex problems that students learn to solve alone or in a group where they explore the knowledge they need to solve the problems. Many engineering programs in different universities, such as Aalborg University in Denmark, McMaster University in Canada, Monash University in Australia, Manchester University in England, Glasgow University in Scotland, Eindhoven University in the Netherlands and Republic Polytechnic in Singapore, utilise problem-based learning [11]. Problem-based learning has also been implemented extremely successfully in many engineering programs, such as biomedical engineering [58], chemical engineering [59], software engineering [60], thermal physics [61], design processes [62] and aerospace engineering [63].

Online problem-based learning programs are available for students in narrative forms that depict problem-solving experiences and related cases. These offer resources to generate solutions, deliver cognitive tools for representing problem elements and feature communication tools to support collaboration [64]. For those who do not have problem-based learning programs, can design, develop and implement problem-based learning environments with marginal support [65].

Problem-based learning programs are one of the most significant educational advances in the history of education. However, such programs are not able to fully accommodate workplace problems in learning. Thus, more classrooms and all problem-based learning programs should take steps to ensure that students are exposed to workplace problems throughout their studies. For example, students can obtain experience of such problems via internships. Although such experiences are generally believed to be invaluable to the academic and professional development of engineering students, there are limitations of internship experiences because interns are often employed in nonessential and nonprofessional tasks for safety or productivity reasons.

Engineering students should solve as many different kinds of problems as possible. Problems in design are the most complex and ill structured [57]. Therefore, design experiences should be included in engineering courses. Vaguely defined goals, unspoken constraints, multiple solutions, multiple solution paths, multiple or unknown criteria for evaluating solutions are generally found in design problems. These help to develop different kinds of cognitive skills [57], such as decision making, troubleshooting and systems analysis, thereby aiding the design of products, processes, systems and methodologies.

Graduate engineering students should be able to function in multidisciplinary teams and to learn in a collaborative atmosphere, such as that found in engineering classrooms [66]. However, most of the time, teams in the classroom are formed based on convenience rather than on the skill or the roles of the participants. When participating in team-related activities, some students may experience bias or marginalisation (underrepresented students), and the activities may not stimulate a sense of ownership among the group [67]. These problems should be avoided to establish meaningful collaboration [67].

Module/Structure-based Teaching

With the advancements in technology, the increase in the availability of learning materials and the interdisciplinary nature of courses, it is time to rethink the way engineering is taught. Many courses in engineering are frustrating because the material is difficult and boring due to the lack of proper teaching methods. Students drop out of these courses or fail in exams. Mechanical design is one of several essential courses for students of mechanical engineering. A mechanical engineering degree cannot be completed without a proper understanding of mechanical design. There is a widespread belief that the dropout rates for these courses and the high failure rate on exams are due to the insufficient talent and attention of students. However, brighter students often leave because of disinterest [68, 69, 70]. These problems can be avoided through a cooperative learning approach, which supports students in areas such as intrinsic motivation, higher-



level reasoning, academic and social support, social development and self-esteem [71]. The best learning is achieved when (i) students build on and relate to past experiences, (ii) the content is relevant to them, (iii) there is a chance for direct 'hands-on' experience, and (iv) students can construct their own knowledge in collaboration with other students and faculty to communicate effectively [72]. Module- or structure-based teaching combines almost all these elements, with the modules based on questions from students that relate to practical applications of the subject matter [73]. This article describes a module-based approach to teaching mechanical design to increase students' interest in engineering and to raise their awareness of the connection between engineering and practical issues.

Module-based teaching consists of several components of varying length within a course unit. Each module is based on an interesting question that provides a background for understanding and applying specific mechanical design knowledge. The module question and background deliver an appropriate framework for exploration of the subject matter. Each component of the course unit emphasises a smaller and more specific question through explorations. The explorations can be based on practical experience, in-class and out-of-class exercises and laboratory activities. The final component of the course unit is project based, intended for assessment of student learning of mechanical design and scientific thinking skills. Teaching engineering in the context of practical problems has been suggested as a way to motivate and interest students. Using module-based teaching, it is possible to make the content easier for the students to absorb and to highlight the interdisciplinary nature of mechanical design.

A general technique to solve complex problem is 'Divide and Conquer', in which a complex problem is divided into two or more simple problems and solved separately [74]. It seems that this strategy works in teaching and learning. In module/structure-based teaching, the unit is divided into several topics, and each topic focuses on different aspects of the unit. This encourages student concentration. It also allows the teacher to teach the student in a focused and comprehensive way. In addition, in the tutorials, the students are divided into smaller groups, which facilitates greater interactions between the teachers and the students. Thus, it is easy for teachers to follow up on the progress of the learning of individual students and to put more effort into students who are lagging behind. Pramanik and Islam [10] found that the module/structured-based teaching approach improves student learning and satisfaction in mechanical design courses. Learning and satisfaction can be further improved by introducing assessments on each topic, adding subsidiary knowledge of the topic and teaching solutions to practical-based problems. This teaching method can be applied to other units to improve student learning and satisfaction.

Emphasis on Strategic Engineering Education

Schaefer et al. [1] described the term 'strategic engineering' as follows: (i) the advance of strategies for understanding engineering education as required in 2020 and (ii) the development of new strategic role models capable of including different scientific fields. Strategic engineering will equip the engineers of the future with the knowledge, skills and attitude to tackle intricate multidisciplinary problems facing society [1]. It is essential to develop educational programmes that incorporate different disciplines, involve students in the enjoyment of learning, motivate students for positive societal advancement and make future leaders [1].

Strategic engineering education nurtures design as the basis for adding value to the economy where design transforms technology/intellectual capital into economy/wealth [1]. This transformation integrates engineering, business scope, customer demands, academia and industry. As design is at the core of engineering, it plays a dominant role in the engineering curricula of various universities [75, 76]. A design-centric curriculum, including business, people and development, requires reconceptualisation of the current educational standard where scholarship is an integral component [1].

Schaefer et al. [1] provided some typical examples that allow innovation at the interface between disciplinary emphasis (e.g. fluid mechanics, materials, heat transfer and manufacturing) and system understanding (e.g. design, manufacturing, life-cycle activities) in engineering. They suggested the following: (a) design procedures for intricate engineered systems-product families and architectures; (b) design and analysis of knowledge and information flows; (c) design, analysis and fabrication of aspects of products that employ ambient intelligence that facilitate automated reconfiguration; (d) quickly reconfigurable business processes, including supply and assessment of chains and e-commerce; (d) user observation methods to analyse customer needs relevant to product design, development and testing; and (e) effective engineering techniques to design smart products. Many more can be added to this list.

Mass Customisation of Courses

Modern engineering courses are largely focused on aspects of analysis, critical thinking, abstraction and synthesis skills [1]. The initial analysis helps to understand the problem, critical thinking allows observing and framing the problem, abstraction identifies the root of the problem, and synthesis solves the problem utilising available data [1]. Customised teaching is necessary to assist learning of these skills. This new method is based on the requirements and quality of each individual student. However, it is almost impossible to customise the teaching for each student when the class size is very big. Mass customisation intends to resolve this issue. According to Williams and Mistree [77], mass customisation of courses relates to students' interests and learning styles where the emphasis is placed on the individual in a group setting. Mass customisation of courses can handle a multidisciplinary design environment where individuals with different backgrounds, knowledge, professional experience and preferred learning styles participate in the creation of new engineering systems [78].

In mass customisation teaching, the information flow is one way, and the teacher inspires the students and offers the necessary support to facilitate learning. Various tools, such as lecture notes, presentations and examples, are used to



customise the course content based on the needs of the individual group. The first step in developing a customised course is to understand the educational needs and goals of each student and then put the students with similar needs and goals in the same groups. At this stage, the students are encouraged to become actively involved and to take control of their learning. Schaefer et al. [1] discussed the mass customisation of a graduate-level course. On the first day of the class, the students identified and prioritised their personal learning goals and needs based on the subject matter of the course. These learning goals and needs, which made the students proactive in their learning, were exploited to tailor the lectures, presentations, examples and feedback [1]. The students were encouraged to use observe-reflect-articulate steps to understand how they learn and therefore to learn better. Observing helps the student to accumulate ideas and evidence from all available relevant sources. Reflection helps to apply existing knowledge and experiences to generate new ideas and to link existing information and knowledge. Articulation generates new conclusions and learning based on the observations and reflections [http://deseng.ryerson.ca/dokuwiki/design:observe_reflect_articulate]. All these steps give students a good understanding of how learning takes place. The students are enabled to deliver customisation at their own level which brings out the process of individual learning of each student. All the activities throughout the semester are targeted to meet the goals and needs, and the lectures and assignments are used to support students' responses. According to students who wrote an essay on how the content covered in class related to their goals each week, the customised course (i) improved their creativity, (ii) permitted them to focus on facts that are most important to them in line with their goals and needs, (iii) provided valuable feedback about the effectiveness of lectures and (iii) provided an opportunity for self-learning [1]. The effectiveness of this teaching approach has been discussed by other authors [79, 80]. Collaboration is very important in mass customised teaching where best practices are provided and students learn from each other. By collaboration, students learn from others and add value to the existing body of knowledge by building on the work done by others. The students' submissions are graded at the end of the semester when the students make their own grading outline based on their learning goals. The lack of continual evaluation is associated with risks. However, by evaluating their own grades, the students obtain the ability of self-evaluation, which paves the way for lifelong learning [1].

CONCLUSIONS

There are a number of methods that have not been tested for engineering courses but have great potential. It is worth pointing out that the technology tools discussed herein need an initial investment of money and time. However, after the initial investment, the technology will make it possible to manage a large number of students at very low cost. In addition, technology tools make educational materials readily available, and they are capable of making scientific facts easy to understand through simulation. All the teaching approaches require a continuous investment of time in terms of preparing the student for every aspect of their profession. The simultaneous application of technology tools and different teaching approaches can be expected to improve both teaching and learning efficiency in a variety of ways.

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