

Applying Educational Technological Tools to Promote Effective Student Learning in Engineering Education

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ABSTRACT: *This paper explores specific pedagogical strategies combined with modern technological educational tools to encourage student to participate and engage in dialogues and discussions with lecturer and among themselves in their learning experience. The authors support the notion that active learning pedagogical techniques along with constant students interaction and participation, will stimulate interest in a course far better than passive, lecturer-centered instruction that is based mostly on information transmission and lecturer-centered learning. A number of suggestions and ideas were offered in an effort to promote active student-centered flexible learning environment in a typical classroom situation. Examples are given of some of the many uses to which these teaching and learning (T&L) activities have been put in the context of effective learning in undergraduate engineering courses at Monash University Malaysia (MUM), by drawing experiences/examples primarily from engineering courses that the authors have applied successfully to improve the quality of teaching & student learning. Each of these teaching techniques has its own merit and their applicability in classroom environment depends on the learning/teaching situation such as subject content, availability of new multimedia technology, duration of lecture, level of student knowledge, interaction history of student/lecturer, level of student control, and student behaviours/characters.*

INTRODUCTION

For any universities to remain globally competitive, it's essential for them to change the traditional way of delivering engineering education in order to respond to the rapidly changing conditions in technology and society. This advances in educational and IT technologies along with innovative engineering software and tools has created an entirely new system of teaching and learning (T&L) that shows principles in action as well as improving & enhancing the level of staff/student interactions & participations that enhances communications and student learning experience. For example, today classes in machine shop and mechanical drawing were replaced by sophisticated software systems that teaches computer drawing, solid modelling, tolerancing, and rapid prototyping that give students the ability to apply skills in drawing and visualization, data acquisition and analysis, and information retrieval. Clearly, the shift of this learning pedagogy is from the design of individual components to design of systems, drawing their sources from the most diverse fields of knowledge that requires a new kind of thinking, teaching and learning. These changes in engineering education are essential to meet the needs of our graduates in preparing them for future challenges of the workplace. Additionally, industries have been exerting increasing pressure on universities to pay more attention to the quality of undergraduate teaching programs. The challenge encounter by most universities is to create a favorable environment for these changes that motivates faculty members to improve their teaching and the quality of instruction in their departments; support their efforts to do so by providing the necessary technological resources, educational & IT tools, & infrastructure; and appreciates & rewards their successes in teaching excellency.

The reality is that better T&L techniques do exist but often difficult and time-consuming. However, we can start with how we teach our students. We can improve the course by continuously designing and updating the content and making use of new instructional materials and methods (including applications of instructional technology to reflect the current state of the art). The author (Lee, Nov. 2003) has stated that the application of new pedagogy combined with appropriate use of interactive learning technologies and media in schools has led to the development of active student-centered flexible learning environment in addressing a variety of learning styles. Today trends also see a lot of students starting to make use of emails, Internet and digital libraries to build knowledge and to prepare and submit homework/report, and to perform online chat and discussion with lecturers & classmates. Indeed, societies are getting more wired globally and the access and sharing of information into useful and productive knowledge is becoming instantaneous and ubiquitous. Many institutions have already made use of the improved technology and the growth of both the information and telecommunications industry to deliver flexible learning courses through synchronous and asynchronous instructions, Computer-Based Training (CBT), Computer-Aided Instruction (CAI), interactive multimedia instructions, interactive video and phone conferencing, and Web-Based Training by simply using a computer with special learning programs either in classroom or distance learning environment.

Indeed, we must not only aim to produce quality graduates with a good foundation in basic engineering and science, essential soft skills attributes, but also need to equip them with the essential knowledge and learning process and tools that they can creatively learn, analyze, synthesize new information, problems and tasks on their own. However, managing effective teaching is really the responsibility of the whole engineering faculty working together as a team to plan and deliver quality knowledge and skills to the students that can eventually become lifelong learners. The teaching of this lifelong learning process will eventually better prepare them for the complex challenges of the engineering field as well as enables them to react quickly to any changes in new emerging knowledge and tools. Hence, part of our teaching responsibility is to guide and equip our students with satisfactory levels of technical knowledge and skills, communication & interpersonal skills, and attitudes they will need for success in modern engineering practice in their career in industry. But ultimately, the performance of an individual student in a class depends on a staggering variety of complex factors, many of which are out of the lecturer's control. And the formidable task is to know how to maximize those parameters, which are within our control to create a positive, interactive and participative environment for effective T&L.

Despite many previous studies, there is always room for improvement in conducting T&L in a classroom environment. The aim of this paper is to examine practical pedagogical practices, via the authors teaching observations and experiences that have been used successfully within the context of engineering education at the Monash University Malaysia (MUM) campus. The goal is to create a supporting interacting and positive environment that causes students to take initiative to learn through the process of engagement and participation in the class session to achieve deeper comprehension and understanding of the lectured subject content.

CLASSROOM PERFORMANCE

Through classroom observations and student test records, it is found that motivational influence student learning, and students' motivation will be high when they possess general desire to achieve, have self-confidence & self-esteem, and are patience & persistence. Additionally, our evaluation results also indicated that students can be motivated to learn by the usefulness of the material and learn better when material is related to their own needs and interests, and this result obtained is consistent with the findings in other published works (McKeachie, 1999; Wankat & Oreovicz, 1993; Ramsden & Entwistle, 1981; Glaser, 1984). One can adopt Maslow pyramid model as a first step to develop learning motivation for students (Maslow, 1970) as well as to work with the students to remove the barriers to motivation. Using LECO blocks to experiment on human work behavior, the author (Lee, 1997) has demonstrated that motivation conclusively enhanced the learner productivity and efficiency in performing a work and learning task. Therefore, the certainty is that student needs to be motivated enough to pay attention in

class. Therefore, lecturers need to begin each T&L session by motivating students, expressing positive expectations, and sharing their objectives with them.

The second observation indicates that students generally need more than one exposure to learn effectively especially for new or unfamiliar subject topics and/or to accommodate the needs of students with different levels of prior knowledge and different learning rates. An effective method to overcome this problem is to give the students enough time to learn the material being taught and to rephrase the explanations of many difficult but important points and concepts in the lecture session several times from a different directions/examples or in different words or equations or to present the points using multimedia technology. As was observed in a Lego experiment, the author (Lee, 1997) has shown that effective and increase learning can be achieved by frequent repetition of the same process when presented in different formats. That is, the use of repetition methods in an engaged and participative environment leads to increase learning as it maximize the chances that every student will eventually understand. In our engineering class, we enhance student-learning experiences by developing the same major point in two or three different modes, e.g., mathematically, verbally, and graphically by combining with appropriate multimedia technology tools.

The goal of T&L is to create a supportive and positive environment that causes student to take initiative to learn through the process of engagement and participation in a class session. Table 1 shows some data of student performance using active and standard teaching techniques based on a specific engineering subject over a period of 3 years in a two-hour per week lecture session (Lee, Aug. 2003). The assessment per semester is based on two sets of tests conducted at Week 7 and Week 11 over a period of a 12 weeks semester. The result appears to show that maximum learning occurs when students are fully engaged in the T&L and course content. On the basis of this data, active T&L technique is more effective than traditional methods as far as generating student understanding of the material content is concerned. The longer the students stayed engaged in the lesson (via participating in the relevant learning activities), the more the student learns.

During the period between 2002 and 2003, the author (Lee, Aug. 2003) also carried out a survey on undergraduate engineering students on the improvement of instruction on two engineering courses. The students from this engineering program were asked to identify good classroom teaching practices in which they have a strong preference. The data were collected at the end of each semester period, and some of these generalized statements and preferences expressed by engineering students for good teaching practices are ranked, in decreasing order of importance, as follows:

1. Well-organized, clear and lively lecture presentations by making effective use of interactive computer technologies and software tools.
2. Able to promote active flexible learning by simulating interest, generate enthusiasm and motivation in them.
3. Using well-structured and practical course content that are connected with relevant learning activities.
4. Easy access of e-learning educational tools, web-based resources, library & IT resources to support their work and study.
5. Giving rapid and effective feedback for homework, tests, assignments, lab reports, etc
6. Openness, approachable and accessible to them.
7. Willingness to listen, respect and/or receive their feedback on a regular basis and/or acting upon their suggestions for improving the course and teaching methods.
8. Able to give clear explanation of course goals, expectations, grading and ground rules before course commences.
9. Willing to provide model answers for sample of exam papers, project work, assignments and etc.

This survey result appears to indicate that a majority of the students ranked "Giving well-organized, clear and lively lecture presentations by making effective use of interactive computer technologies and software tools " as the single most important teaching practice.

Table 1: Average test results shown by 3 types of teaching techniques: 2001, using traditional methods, and year 2000 and 2002, using active T&L methods, but for 2002 students were given e-notes and WebCT access.

Summary of Assessment Data for Materials Engineering		
Year	1st Semester Test	2nd semester Test
By active T&L methods (2000)	55.7 (30 students)	57.3 (47 students)
By traditional T&L methods (2001)	50.4 (57 students)	52.3 (37 students)
By active T&L methods (2002) Plus with e-notes and WebCT	68.5 (73 students)	67.1 (52 students)

SUPPORT LEARNING TOOLS FOR ENGINEERING LEARNING CYCLE

The authors (Senanayake & Lee, 2002) supported the use of active, student-centered flexible learning approaches, as a significant step in this direction to increase students' potential for improved academic performance and simultaneously provides important knowledge and skills to prepare them in the workforce. Hence, the need for more efficient and effective T&L techniques is inevitable in the above-mentioned engineering context. At Monash University, we use three different types of instructional tools for delivering the engineering T&L process and this approach that consisted of Simple Collaboration (SC), Mixed Collaboration (MC), Case-based Collaboration (CC) and Enhancement Collaboration (EC) are emphasized as follows:

SC: is designed for self-placed, individualized instruction or for supplementing other forms of live or remote instruction. One example is designing and creating an appropriate e-learning program (e.g. simulations) built right into the computer for supporting and enhancing T&L. Students are obliged to work in groups and have online discussions and e-mail communications. On the other hand, they are given links for previous modeled developed by former students in order to obtain improved models in each and every year.

MC: is a subset of SC and often represents self-contained, complete modules or tutorials of instruction. In this mixed collaboration, lecturer involvement is more than the simple collaboration. Lecturer provides the proper guidance at this stage to optimize the design such a way that students have to revise their design. Here, students are not forced to go for specific components rather a very general design. Then, students may use some virtual instrumentation tools to verify the design optimization before they go for actual construction. Therefore, lecturer may also use different assessment tools to verify the students' design and ask for the redesign based on the proposed lecturer's design.

CC: is to analyze different applications and cases available and to reuse, if possible, some components already built previously. This leads to fast learning and provides more time for students to come up with new or improved products rather than building the same product, which has been designed and built by previously batch of students. In order to explore wide range applications, students are provided with application-based simulators and prototypes that allow them to adjust, input values and view the result in a visually oriented yet quantitatively correct and appropriate animation or images.

EC: is to share the experiences to enhance the existing product by upgrading and improving the problem definition with new requirements and constraints, which satisfy the real world applications. This sharing of experiences is purely based on the information feedback from students, staff and customers in case of a marketable product.

Engineering Learning Cycle

Hence, we propose a model for an efficient and effective T&L method that relies on five aspects; i.e., they are conceptualization, modeling, design, application and product. Figure 1 shows how this learning cycle is structured, with the five key elements described as follows:

Conceptualization: This case defines the conceptualization of engineering subject in consideration. Basically, analytical solutions for the problems presented are given at this stage. Lecturers and students use various assessment tools under SC to enhance the idea presented.

Modeling: is primarily concerned the use of existing or revised models for the engineering context. When we consider the normal classroom, the tendency is the use of existing models. If the problem presented is new for students, revising the existing model is required. This enhances the engineering knowledge base by introducing revised/new models to existing models. The academics can still use the traditional assessment tools for this purpose, but the use of MC provides a better understanding of the model suggested for the problem domain.

Design: This revises the model with actual parameters in order to design the model in the said domain and it may be one of the viable solutions for the real world problem in consideration. But, still, it may not be the best solutions as it considers only in engineering perspective. MC plays an essential role in the design of existing models while CC provides a better platform to design new models.

Application: The recent trend is applying some automation strategies for the viable solutions to obtain the best possible solution. In this context, most of the solutions given for real world problems will look into the optimization strategies by interacting with other multidisciplinary field in a interdisciplinary environment such as management, business, IT, nano-technology or biomedical engineering, etc. for example, students from different disciplinary fields can work together to develop new solutions or innovative processes. However, the efficient tool that we can use before undergoing any implementation is the use of CC, which provides the actual behavior of the solution in the real world constraint. Depending on the degree of optimality, we can certainly decide whether we go for the best solution.

Product: We strongly believe that teaching specialized subjects repeatedly leads the invention of a product for the real world phenomena. Methods used in the product will enhance and retain in the general engineering knowledge base for future use. Therefore, students are forced to provide good description of the product by providing proper documentation such as user manual, technical specification and technical manual. In order to decide whether it's a good product, students are encouraged to collect the data about the product and similar products, to analyze, to synthesis and to evaluate the product and later stage to formulate a improved problem with new requirements and constraints to come up with new engineering context.

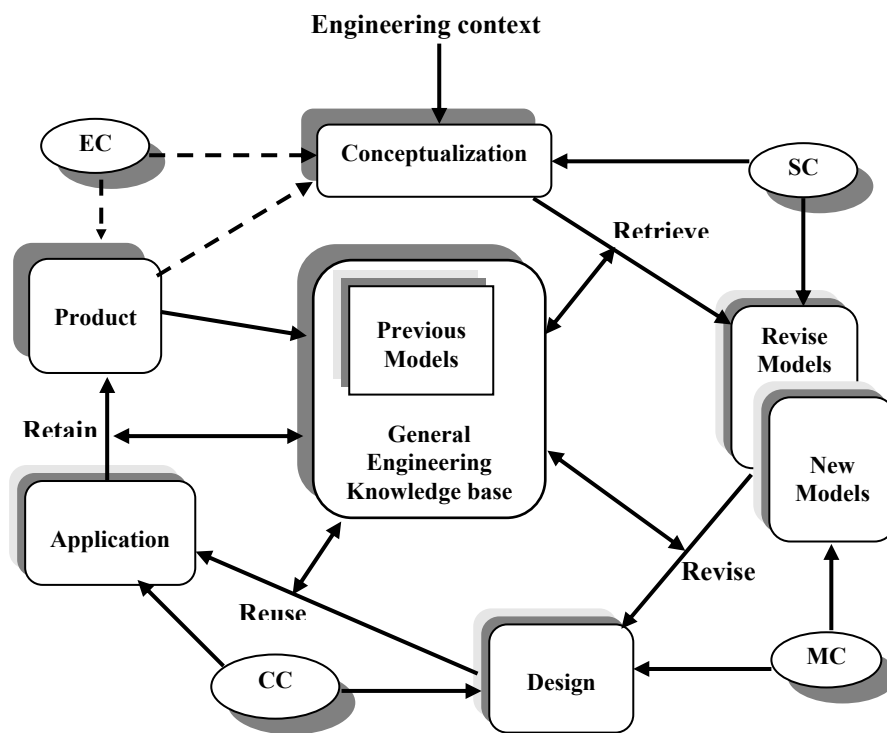


Figure 1: Engineering Learning Cycle

SELECTED APPLICATION OF INTERACTIVE TEACHING ENVIRONMENT

The discussion thus far reveals that lectures are a problem when students are encouraged to be passive in a classroom environment. Good lectures require a lot of creativity and new ideas that are interfaced with interactive educational tools to keep the lectures interesting. For example, the combined approaches to the T&L activities with the aid of modern technological educational tools can provide an answer to the learning problems facing today students. Additionally, the availability and interactive capability of a wide range of resources can provide students with greater opportunities for flexible study and independent learning, and solve case-based problems based on engineering methodology through the use of multimedia interactive software programs. We communicate the information of the subject matter to the students by simultaneously focusing and interacting with the students to motivate and get their attention. And where there is no involvement or participation, there is no real learning. That is, students that are listening and not talking may or may not be involved. If they are talking, chances are they are actively engaging you and are unlikely in the passive mode.

Our experiences have indicated that most students relate better to actual case histories or some specific application stories where they not only possess some good ideas and theories, but also become part of this active learning process by actually using their existing background knowledge to participate and experiencing the content of the subject topic. We do find that a number of students are not interested in accumulating information that does not relate to real-life applications. For example, we can select some very recent incidence of bridge failures when covering fracture and failure of engineering structures, or draw examples from the sinking of Titanic when covering engineering materials behavior. This is because theoretical principles do not mean much to the students unless relevant and practical illustrations of their application are given to explain the course content so that they can see the big picture in the context of an engineering education. Drawing examples from everyday experiences, even if they cannot be demonstrated in class, will help students to visualize or re-experience them and hence reinforce their learning. We can also substitute metaphors and analogies when the use of a live demonstration or visual

aids is not practical so as to provide students with a mental image to digest the materials that reinforce their understanding, retention and recall. For example, to understand the elastic behavior of ropes, have you ever thrown yourself over a cliff with a bungee rope? What happens?

We make use of small group activities in a classroom whenever possible; for example, like holding classroom discussion or case studies for developing students problem solving and decision-making skills. This is useful in assessing the student's ability to synthesize, evaluate and apply the information/concepts learned in lectures and texts. For example, students acquiring the skills and knowledge in engineering and design, require a varying approach to achieving the learning outcomes set at each stage of the process. To illustrate a point, the students can be asked to solve an engineering problem that required them to write an excel least-squares fitting program to work out the best values for the slope and intercept, apply their results to different data sets, and then compare their results with actual data from recommended textbook and comment or present the results obtained. Our class questionnaire survey indicates that 87% of engineering students valued group working of assignments, reports and structured/moderated case studies where they indicated an increase of understanding of learning from the close interactions among themselves and with lecturers. Students commented that through this working together and increased level of support they are able to form friendships, give or receive advice, and received empathy and encouragement in this type of new learning environment. It was observed that the introduction of compulsory group presentations in the course can help to sharpen the students' presentation skills and to give them an opportunity to gain experience in educational learning software/tools, foster teamwork and communication skills, compilation/documentation of solutions effectively, and opportunity to interact with an audience. For example, students working in a team to improve a process are required to recognize, define and formulate the problem and know what constitutes a quality solution. Most students' surveyed feel that the considerable effort expended in preparation for their talks was well worth the investment.

In our lecture materials, occasionally there are a few subject contents that are difficult to cover every single point in a classroom presentation. Hence, we find it beneficial to provide electronic materials to the students in the form of handouts together with step-by-step solutions to problems along with clear explanations when presenting a particularly complicated, complex, or lengthy subject. For example, we took large portions of our notes, including detailed derivations, worked example problems, explanatory paragraphs, and complex flow charts and figures, and placed them in a electronic folder that are accessible by our students. By handing out these notes, we can have enough time to focus on the most critically important & conceptually difficult material in the lecture notes, and other learning exercises (e.g., methodological points) that we chose to do in classroom that would reinforce the students' understanding of these points, without decreasing content coverage in the syllabus. We used shockwave & flash movies, adobe acrobat files, digitized photographs or video segments to explain a point more clearly. We found that this technique helps to improve the student learning experience and understanding of difficult concepts or solving their on-line problems of the week. Students can also access supporting information of the university's electronic journals or resources to do their assignments and reports. For example, dislocation motions in three-dimensional crystal planes can be shown using the movies clips to provide the student with understanding, and this can combine with computer-based methods and tools for students to facilitate this understanding with relevant applications. Student response to this method of T&L has largely been favorable. 83% of the students said these methods not only help them better visualize the solutions to the materials problems but better understand how to solve the problems while 17% indicated that it "somewhat" helped in their learning, while no student said it was not helpful.

We believed that the use of modern educational learning tools and web-based technologies are indeed a powerful resource to enhance and support our T&L activities. For example, the increasing ease of use of improved presentational and interactive teaching tools allow us to present almost any amount of material in any amount of time with planned student participations/involvement. This visual aid can be used to facilitate and solicit short questions for class discussion, multiple-choice questions for feedback, and for

providing representations of ideas and processes that are difficult or impossible to represent in a blackboard. When used appropriately, we find it very useful and effective to make use of visual images to describe lecture points in LCD projection. We found that LCD presentations if used in an active sense, does enhance student interest, and improve student performance and learning experience; this helps them to develop the required skills, knowledge and insight in the engineering course. For example, we have provided visual projected LCD representations in our lecture presentations using computer software such as AutoCAD, Lab View, and Shape for students to interact dynamically with 3D color images/animations of complex engineering assemblies, for measurement and automation of mechanical circuit system, and for showing atom crystal structures respectively. Based on student feedback, this representation has allowed them to extend their comprehension, reasoning, and problem solving skills and application of complex 3D object problems more easily beyond what is possible with tradition printed resources. In addition, we also make use of slides, films, transparencies, videotapes, tape recordings, demonstrations, and samples to illustrate the subject matter and/or to show relationships between concepts and ideas. For example, we show videotape on good welding techniques and ask students to answer questions after watching the film as a form of tutorial or assignment. Students often need to see the whole picture to understand and remember how ideas are linked together to form meaningful wholes. Course guides and course maps can provide a helicopter view of the whole picture. We believe that the active use of any instructional methods such as lecture, books, videotape, web-pages, audio-tape, CD-ROM, interactive multi-media, and “whatever” can be used effectively or ineffectively, alone or combined and is also dependent on the subject content, class environment, human learning factors, and other complex & unpredictable events/issues.

We do find that the use of e-learning educational tools such as WebCT course management system (Web Course Tools) is another powerful resource for constructing and managing the online course environment for effective student learning. The use of this tool has increased the flexibility in course presentation and mode of teaching. As an example, the Materials Engineering course has a WebCT web-site, which is easily accessible to MUM students anytime and anywhere using a password through the Portal integrated with WebCT (Lee, Aug 2003). This web-based resource not only serve to provide online communication and interactive course tools/components to be easily accessed by students with an internet connection anywhere but also has copies of the lecture and tutorial notes and presentations, course information and outline, assignments and quizzes, survey, CD ROM, bookmark, news items, timetables, the practice examination paper, discussion boards, images, links, mail, video animations, audio, and any other information deemed important. This active web tool contains utilities for organizing, designing, tracking, and managing the course materials for continuous improvement through student feedbacks. For example, in the discussion tool students can contribute and share their analysis and views with lecturers and fellow students via course Internet email. Additionally, the students will eventually develop other related skills such as information acquisition and analysis, creation and application of new knowledge, decision-making skills, and other essential engineering skills. Students can attempt the online Quiz section for a specific lecture topic. At the end of each quiz, the score was displayed along with suitable and immediate feedback that explained why the selected answer was incorrect. This ongoing feedback information is stored in the computer database and can be statistically analyzed by the lecturer to study the student preferred learning pattern of the course content and to determine the effectiveness of the questions from semester to semester. It also appeared that student achieved better marks in their overall performance when they were given with continuous improved e-notes and WebCT access (Table 1).

We have also developed several courses that teach computer-based problem solving to students. These courses have employed Mathematica, Matlab, Excel, Pascal, Fortran 90, and C++ to explore applied numerical methods for solving engineering equations. Software such as Matlab interactive system can help students to perform numerical computations and graphics. For example, students can use Matlab to investigate the application of the material described to signal and image analysis or to solve a nonlinear equation to determine how much cooling is required to narrowly fit a cylinder into a hollow hub. Through the students' active participation and taking responsibility in their self-directed learning, the students can

easily study the material and solve the types of problems and issues that can occur by typing the MATLAB commands and using also some of the available files provided in the university computers. This form of teaching proved to be effective and give opportunities for students to participate in guided activities that allow them to try out a new way of doing things.

Where a good discussion and case study is performed in lecture, we can guide students to solve engineering application problems using a systematic interdisciplinary problem-based learning approach (Senanayake & Lee, 2002). This problem-based learning approach forced students to take initiative in their learning in a self-directed and collaborative ways with other students, hence allowing them to practice interpersonal communication and team working skills. additionally, working on relevant topics of real applications (e.g., semester project, thesis work, industrial project or case studies) in collaboration with local industries has allowed group of students to tackle relevant problems and solve real life issues as part of their studies. This learning is then backed up with field trips or practical classes to verify the concepts learnt in this software package. This type of T&L methods allow students to acquire multi-disciplinarians and multi-skilled, and hence to have a wide baseline of knowledge and skills. Hence, we have to be flexible to keep up with new learning tools and techniques to test new ways of looking at T&L that support a positive and challenging interactive environment of engaged, meaningful learning and collaboration that is relevant to real student needs.

CONCLUSIONS

The use modern educational interactive learning tools and web-based technologies are indeed powerful resource to enhance and support quality learning and enrich the students' learning experience. The traditional T&L model is not relevant to real student needs due to today rapidly changing environment. Lectures should focus not only on the material content, in-class activities, or discussion but how to actively engage the students with the material in ways that promote student learning. This will involve a lecturer total commitment in teaching that take full responsibility by actively doing everything to cause the student to learn. The lecture content must be valuable, relevant, and interesting and related to real-world problems that enable students to make the necessary connections between theory and everyday life applications. The challenges for lecturers are to influence students in positive ways and simultaneously be able to flexibly adapt a wide range of learning situations and educational technologies encountered from time to time. To be effective, one must consciously attempt to be flexible, changing plans, actions or goals in response to the changing interests and needs of today students and/or from the many unplanned and unforeseen events that happen during the course of the lecture.

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