
14. E-LEARNING FOR EDUCATING 21ST CENTURY ENGINEERS IN INDIA: OPPORTUNITIES AND CHALLENGES*

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Abstract

The Paper discusses major developments in E-Learning on the world scene and its possible impact on Engineering Education in the country, now poised for a rapid expansion. It also brings out the Opportunities opening up for Educating 21st Century Engineers in India and the Challenges Ahead.

1. Introduction

It has been recognized for a long time that engineers are key professionals in any country responsible for its economic progress and prosperity, leading to increased comfort level and satisfaction of its society at large. As a result, *Engineering Education* has attracted world-wide attention since the beginning of the 20th century. In this period, by following the on-going developments/trends in Science & Technology(S&T), *Engineering Education* has steadily moved from its earlier emphasis on curricula for hands-on practice to increasing their science base nowadays, with capabilities in mathematical modeling, analytical techniques, problem solving/design, predetermined outcomes and social/environmental implications. Also, the associated *Teaching-Learning Process* has shifted from its earlier *teacher-centricity* to current *student-centricity*. These changes brought about over a period of 40-50 years recently, have made it necessary to ensure that special attention is devoted to *Educating 21st Century Engineers* on the right lines. As the 21st century is regarded as the *Knowledge Age*

having ever increasing influence of S&T on human activities, shrinking time scale of new developments, high rate of obsolescence in older practices and rapidly growing penetration of Information Technology (IT) in all sectors of world economy, major expectations from *21st Century Engineers* cover:

- a) Good foundation for the basics of mathematics, science & engineering disciplines;
- b) Command over the chosen area of specialization subjects;
- c) Capacity to apply the professional *knowledge* and skills acquired;
- d) Good competence to learn a subject on one's own, without major external help;
- e) Expertise in analysis, design, modeling and simulation of complex systems;
- f) Scaling up, mass production, system operation and maintenance;
- g) Estimation of costs and time factors in

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- engineering assignments;
- h) Ability for rational, logical, orderly and objective thinking;
- i) Skills in personnel management, human relations and management of change; and
- j) Leadership qualities including spirit of tolerance, patience and team work;

These are particularly important in India, because of the emergence of *knowledge* as a key driver for the progress of nations leading to their increasing influence on the world scene and the country has committed itself to become a *Knowledge Society* in the foreseeable future. Besides, the *Engineering Education System* in the country is now becoming more and more demanding to fulfill the above expectations due to:

- Rapid rise in numbers of engineering students/institutions & their spread nationally;
- Continuing shortage of well qualified/ experienced engineering faculty in most cases;
- Steadily increasing cost of state-of-the-art infrastructure at engineering institutions;
- Need to meet the Quality Assessment & Accreditation Standards at all institutions;
- Globalization of employment sector & increasing competitiveness among engineers;

2.0 E-Learning

It is in this context that *Electronic Learning* (or *E-Learning*) is expected to play a crucial role in *Educating 21st Century Engineers* in the country. Important aspects of this are covered in the following *four* Sections:

- i. E-Learning: A Review,
- ii. E-Learning Opportunities: Educating 21st

- Century Engineers,
- iii. Challenges Ahead and
 - iv. Concluding Remarks.

2.1 E-Learning – A Review

2.1.1 E-Learning –Basics

E-Learning is a major development of the 2nd half of the 20th Century, making available a method of technology-based education for the benefit of mankind usable at all levels and by all age groups. It is based on the advances in Communications, Computers and Consumer Electronics being used together in the *Teaching-Learning Process*. It has the capacity to break the barriers between *home and school/college/university*, thereby transforming the world into a *Learning Academy*. In the words of Arthur C. Clarke, the famed space fiction writer, "*E-Learning helps educate all human beings to the limits of their capabilities*". Besides, it has the potential to fulfill the "*Millennium Development Goals of Education for All*" as envisaged by the United Nations General Assembly (UNGA) in the year 2000 and the recently enacted *Right To Education Act* in India. Important characteristics of *E-Learning* are as follows:

- a) Separation of teachers from the students, both in '*Space*' & '*Time*', enabling *Learning Anywhere, Anytime*, all through 24X7;
- b) Enhancement of *Learning* by all the students, as expert/gifted teachers normally assigned to prepare *E-Learning Material (E-LM)* as required;
- c) *E-LM* so prepared helpful to supplement the students' *Learning* by providing them easy access to good *subject knowledge* at all times;
- d) *E-LM* also helpful to serve as supplement to *Classroom Instruction* for improving the quality of *Face to Face Learning (F2FL)* by the students;

- e) *E-Learning* also forms the basis for *Open & Distance Learning (ODL)* capable of leading to high quality of education on a massive scale at all levels;
- f) *Uniform Learning of Any Subject at Any Pace and at Any Level* by all the students facilitated by *E-LM*, as well as by *ODL & F2FL* developments;
- (g) Besides, *Active Learning* by the students facilitated by *E-Interaction* in both *ODL & F2FL* systems; *Passive Learning* also possible in both systems with no interactivity;
- (h) *Teaching-Learning* of two types facilitated in both *ODL & F2FL*: (i) *Synchronous Learning: At the Same Time* (ii) *Asynchronous Learning: At Different Times*;
- (i) *E-Learning* in general, useful for *educating large student groups* at a time in *ODL* and to *enrich students' course work* in *F2FL*;
- (vi) Customizing/Personalizing Learning possible to meet the specific needs of large student groups or individuals, as may be required in practice;
- (vii) Possibility of *easy/quick content updating* at low cost to include new advances by removing obsolescence & to maintain both *ODL & F2FL* at the State of the Art;
- (viii) Enhancing the breadth, depth, uniformity, grasp, consistency & retention of Knowledge Input to the students through well planned *E-LM*;
- (ix) Making the students' Learning more effective/efficient, reducing its cost, improving its affordability and facilitating its easy portability to any location;
- (x) Serving as the heart of *E-Learning*, irrespective of the use of *ODL* or *F2FL* in the education imparted;

2.1.2 E - Learning Material

E-Learning is made possible and its quality/standard enhanced by *E-LM*, having many differences from *Traditional Learning*, such as:

- (i) Well Prepared by subject experts and motivated teachers, for meeting the Learning needs of all the students in specified programmes/courses;
- (ii) No need of well qualified/inspiring teachers in large numbers for *F2FL*, so helpful to reduce mediocrity and enhance the quality level of education;
- (iii) No other teacher needed in the *ODL* system; But in the *F2FL* system, only a guide is required and no highly qualified/experienced teacher necessary;
- (iv) *Active Learning* possible in both *ODL & F2FL* systems, enabling the students not to feel the absence of teachers in the *Teaching-Learning Process*;
- (v) *Learning Flexibility* satisfactory in both *ODL & F2FL* systems for self pacing of studies with *Linear/Non-Linear* and *Just-in-Time* access provided for *E-LM*;

2.1.3 E – Learning Approaches

Several approaches have been developed to provide *E-Learning* and put to use in the field of education worldwide, based on the technological advances taking place in the relevant disciplines. As a result, providing *Education* at all levels has been greatly influenced by the *E-Learning* developments at the *Teaching End* and at the *Learning Ends* in both *ODL and F2FL*. The following three categories of *E-Learning Approaches* are common nowadays:

- (a) *Physical Delivery*;
- (b) *Broadcast Delivery*;
- (c) *Networked Delivery*;

Important features of each of these approaches are summarized in Table 1, including a comparison of their performance and usage.

Table 1: E-Learning Approaches: A Summary

Approach	Features	Remarks
<p>1. Physical Delivery</p> <p>E-LM having prerecorded Audio/Video presentations distributed from Teaching End by mail/ retail stores for use at Learning Ends in its jurisdictional area;</p>	<p>(a) Audio: Mostly voice - based expert lectures, eminent persons' talks, panel discussions, case studies, printed text updates, language lessons, & E Books in Analog/ Digital Tape/Cassette/CD forms available from Teaching End; Learning Ends with suitable Audio Record Players to support both ODL & F2FL; Possible use for Asynchronous Passive Learning ;</p> <p>(b) Video: Mostly based on visuals & slow/full motion images with voice added, covering various presentations as in the Audio case and also E-LM for experiments/demos/displays, and the like in Analog/Digital Tape/Cassette/CD/ DVD forms available from Teaching End; Learning Ends with suitable Video and Audio Record Players to support both ODL & F2FL; Possible use also for Asynchronous Passive Learning;</p>	<p>(a) In use for many years; Quality/effectiveness reasonably high; But, interactivity at low level or absent; Both Indian & Foreign E-LM available for use at different levels of education;</p> <p>(b) Quite popularly used for many years; Quality /effectiveness better than in the Audio case; Here also, interactivity level very low or absent and both Indian & Foreign E-LM available;</p>
<p>2. Broadcast Delivery</p> <p>Live/Prerecorded E-LM of Audio/ Video presentations broadcast from Teaching End by Radio/ Television (TV) for use at Learning Ends in its jurisdictional area;</p>	<p>(a) Radio: Mostly voice based E-LM with limited text/graphics display to illustrate lecture presentations, either live or in prerecorded form, by AM/FM Radio broadcasts (mostly terrestrial) or Digital Radio broadcasts (mostly satellite based) from Teaching End at pre-fixed timings; Learning Ends spread over large areas (~1000s of sq.km.) with suitable Radio receivers having display panel & facility for interaction with Teachers by landline /satellite/ mobile phone in return path at each location (Interactive Radio) for ODL; Useful also for enriching F2FL at the above locations; Possible use for Asynchronous Active/Passive Learning & Synchronous Active Learning;</p> <p>(b) Television: Mostly based on visuals & full motion images with voice added, covering various presentations as in the Radio case and also E-LM for experiments/ demos/displays, and the like either live or in prerecorded form by TV broadcasts (terrestrial over the air or satellite based direct to home (DTH) / cable connectivity (fiber optic/coaxial)) from Teaching End at pre-fixed timings;</p>	<p>(a) AM/FM Radio in use for many years; But, limited quality and effectiveness; Digital Radio more recent & emerging, with higher quality/effectiveness; No limit on the number of students registered for studies; In both the cases, low level of interactivity;</p> <p>(b) In use for many years; Virtual classrooms formed all over the service area, with no limit on the number of students registered; Also usable at homes; High level of interactivity with voice/ text and the like usable; Superior quality and effective education provided; Although high capital costs involved, cost/student</p>

Approach	Features	Remarks
	<p>Learning Ends spread over large areas (~1000s of sq.km.) with suitable TV receivers having facility for interaction with Teachers by landline/ satellite/ mobile phone in return path (Interactive TV) at each location for ODL; Useful also for enriching F2FL at the above locations; Possible uses similar to those in the case of Radio;</p>	<p>going down as numbers go up; Here, dedicated transponders on satellites and exclusive educational satellites usable;</p>
<p>3. Networked Delivery</p> <p>Live/Prerecorded E-LM of multimedia based presentations broadcast from Teaching End by using internet/web sites, either online or offline for use at Learning Ends worldwide;</p>	<p>(a) Online: Mostly based on digital multimedia E-LM with text/graphics/ diagrams/hand outs/ audio (MPEG) /video for expert lectures and E-Books/Journals broadcast from Teaching End Websites using internet; Each Learning End, at any location worldwide, to have PC, Data Modem, ISP connection & access to telecom network, preferably of broadband type; Interactivity through e-mail at pre-fixed timings (chat session); Supporting both ODL & F2FL with possible use for Asynchronous Active/Passive Learning and also Synchronous Active Learning;</p> <p>(b) Offline: Alternate to Online approach; Downloading of E LM-or Selected Lessons from web-sites at the Teaching End, mostly in Compressed Digital Form by Learning Ends worldwide, having similar configuration as in the earlier case, to support both ODL & F2FL; Useful to reduce telecom costs and avoid Online Learning Delays, if narrow band / dial-up connection made use of; Possible uses for Asynchronous Active/ Passive Learning;</p>	<p>(a) In use since late 1990s and growing rapidly; Highly popular; virtual class rooms or home use with no geographical barriers; E-interactivity giving many useful facilities for good learning; Highly effective; Low cost implementation;</p> <p>(b) In use for many years; Becoming popular now a days; Simplified version of Online approach; Network size generally limited; E-interaction highly effective; Low cost;</p>

2.1.4 E-Interactivity

This is a recent development in E-Learning, particularly useful for Online/Offline approaches to enable software-based dialogue among Learners present at Learning Ends and the Teachers or the Content at Teaching End for better Learning performance. Major characteristics of E-Interactivity include:

- (a) Stimulation of Learner to Think, Reflect, Analyze, Explore, Discover, Choose, Participate in discussion; Also, Ask/ Answer questions and evaluate;
- (b) Ideal aid for Self-Learning, as it empowers Learners to control Instruction and interrupt Instruction to get context sensitive help;
- (c) Inclusion of Wait Messages during slow access, giving feedback to Learner Responses and encouraging Learners to Learn in depth;
- (d) Benefitting all Learners as it is known that: "The more a Lesson engages Learners, the more readily they will retain its Content";

(e) Providing good help/support to *Learners* to fulfill their aspirations as they attach importance to:

- *What I am told, I forget;*
- *What I see, I remember;*
- *What I do, I know;*

As a result of the above beneficial factors, *E-Interactivity* has received much attention nowadays, leading to software advances for the following three types of *E-Interactivity* of much application value in *Online* and *Offline* approaches to *ODL/F2FL*:

- 1) Learner to Content E-Interactivity;
- 2) Learner to Learner E-Interactivity;
- 3) Learner to Teacher E-Interactivity;

The supporting technologies for *E-Interactivity* are software-based and this method is superior in many respects to the method of phone connection in the return path for *Interactivity* referred to under 2(a), (b) (*Broadcast Delivery*) in Table 1. They include:

- *Web Pages*
- *Chat Rooms*
- *E-Mail*
- *Threaded Discussion*
- *Streaming Audio/Video-Live, Real Presenter*
- *Desktop Conferencing*

The development of these supporting technologies has greatly benefitted *E-Interactivity* in *Online/Offline E-Learning*, making it the next best possibility to *F2F Interaction*, some examples of which are listed below:

- (i) E-mail interactions among students and faculty on the lectures presented;
- (ii) Small group discussions & collaborative Learning among students;

(iii) Access to rich resources available worldwide on the Web;

(iv) Classes with a mix of students in traditional and workplace settings;

(v) Programmes/Classes with a global perspective and for globalization;

2.1.5 E-Learning in India- Recent Developments

E-Learning has been pursued in India in a limited way at different levels of *Education* since the 1970s. Major developments in this are as follows:

- (a) Early Years- Audio courses-Physically delivered; Occasional Radio broadcasts, with phone-based interactivity in some cases; Coursework/Counseling emphasized;
- (b) 1975-Satellite *Instructional TV* Experiment(SITE) conducted for one year by ISRO with *Teaching End* at 2 locations and 2400 *Learning Ends* located at different locations in India with many of them providing *phone-based interactivity*; *Educational* developments mainly emphasized here;
- (c) 1980s-Video courses-Physically delivered; Occasional *TV* broadcasts, with *phone-based interactivity* in some cases; Coursework/Counseling mainly emphasized here;
- (d) 1990s-Indira Gandhi National Open University(IGNOU) using mostly Satellite *TV* broadcasts with *phone-based interactivity* for offering Programmes/ Coursework by *ODL*; A few other Open Universities also engaged in such programmes;
- (e) 2000s-EDUSAT launched by ISRO and made available with *phone-based interactivity* for taking up *ODL* at different levels including programmes by IGNOU;

Many technological Universities also using this facility for enrichment courses to provide *F2FL*; IGNOU launching *Multimedia-based Online/Offline Programmes/ Courses with E-Interactivity* to supplement *ODL* activities; MHRD (Govt. of India) initiatives in *E-LM* development for UG/PG Programmes in *Engineering* by associating competent faculty members from IITs & other leading institutions under the *National Programme on Technology Enhanced Learning (NPTEL)*; *Online/Offline Learning* becoming popular based on easy and low-cost internet access and the widespread availability of *E-Books/Journals* in the country from Indian/International sources;

- (f) *2010s*-Further consolidation of *E-Learning* based on continuing developments in educational infrastructure like nationwide *broadband telecom network* for internet and easy availability of *E-LM*, both for *Satellite TV* broadcast with DTH service and Internet based digital *Multimedia Courses*;

2.2 E - Learning Opportunities: Educating 21st Century Engineers

2.2.1 Opportunities

As seen from the review on *E-Learning* presented in the previous section, major developments of interest in the field of *Education* at all levels include, *Digital Multimedia-based E-LM, Interactive TV & Online/Offline based ODL/F2FL* with/without *E-Interactivity*. But, *Education* being a social process and not a technological one, the *teachers* have to play a central role in *Learning* to develop students' interests in exploration/innovation and serving them as *role model*. This calls for the availability of *good/motivated teachers* in adequate numbers at *primary and secondary levels of Education* for providing personal attention, guidance and mentoring, as the *Learners* normally belong to the very young age group. But, the situation is somewhat different at *Higher Education*

Institutions (HEIs). Here, the *Learners* normally belong to the senior/mature age group and technology can be used to advantage to support their *Learning*. Hence, *E-LM, ODL/F2FL* and other developments are more usable at *HEIs* and the *teachers* need to be only *guides to students* in the *Learning Process*. As *Engineering Education* is a specialized sector of *HEIs* and it is facing a multitude of difficulties in *Educating 21st Century Engineers*, the opportunities brought forth by *E-Learning* can be of much benefit here. Today, *ODL* with *Online/Offline* approaches & *E-Interactivity* has found acceptance in this respect, as it can be used to support both *formal and non-formal* types of *E-Learning*. Also, *Satellite-based Interactive TV* with DTH service and *phone-based interactivity* finds good use for both the above types of *E-Learning*. The *ODL* developments discussed earlier have also benefitted *Open Universities and Virtual Universities* to a great extent. In the latter class of *Online/Offline HEIs*, the same network is also usable for facilitating all the *studentship functions online*, like *admission, registration, coursework, library, testing, assessment, awards and related administration*. In addition, *ODL-based non-formal* programmes providing the *Learners* with *Lifelong Learning, Skill Development & Knowledge Enrichment* activities have also opened up new opportunities in recent years. Besides, *F2FL* advances, largely similar to those for *ODL*, have found good use for educational enrichment in *Educating 21st Century Engineers* by supplementing their normal class-room instruction. In all these cases, the difficulty of getting well qualified, experienced, motivated and inspiring teachers in large numbers in India can be taken care by the use of *E-Learning* technologies.

2.2.2 Educating 21st Century Engineers

A few major objectives of *E-Learning* in *Educating 21st Century Engineers* cover:

- (a) Preparing a good foundation for the *students* and develop their competencies in *Basic Sciences & Engineering*

- Sciences*, as required;
- (b) Ensuring that the *students* gain confidence and command over their chosen areas of *Engineering discipline* and the *specialization subjects*;
 - (c) Strengthening of skills among the *students* for *Analytical, Problem Solving, Modeling, Simulation, Design, Experimental, Observational & related activities*;
 - (d) Inculcating a professional attitude & leadership qualities among the *students* and good capacity for *life-long learning & rational/logical/orderly/objective thinking*;
 - (e) Giving the *students* a proper perspective of the impact of S&T on human society, like *energy, environment, climate change, sustainable development & related issues*;

As *E-LM* is at the centre stage of *ODL/F2FL*, special attention is called for in the planning and design of *E-LM* to meet the above and related objectives of *Educating 21st Century Engineers*. A typical Chapter/Lesson of an *E-LM* for this purpose may contain the following:

- Historical developments and significance of the topic;
- Concepts and principles underlying technical aspects of the topic;
- Topic-related qualitative and quantitative issues;
- Physical/Mathematical formulation and required analytical approaches/ techniques;
- Modeling, simulation, design & related issues and results;
- Experimental set-up, verification, observations, results & report preparation;
- Some practical applications relating to the

topic;

- Emerging trends relating to the topic and future directions for development;
- Set of *Frequently Asked Questions(FAQs)* to test *students' Learning/Understanding*;
- Suggested reading material: text books/ references and other resources;

Such an *E-LM* is invariably of the *digital multimedia* type prepared by *expert/gifted teachers* based on their live presentations in the class-rooms or specially prepared by them for student audiences to support coursework using *ODL/F2FL*. Advanced technologies commonly used here include, *Digital Photography, Video Cameras, High Resolution CCTV, HiFi Audio Systems, Audio/Video Recording, Fiber Optics, Personal Computers(PCs), Displays, Internet, Intranet, Soft-ware & Web Site Designing*. And, serious efforts are made to design each *E-LM* to convey the subject knowledge to the *students* in a clear manner for their easy understanding, by properly mixing of the different media and suitable editing to result into a good presentation. Attempts are also made for the standardization of *E-LM* to assist in their easy replication for large scale usage. These measures can be of much help in introducing *E-Learning for Educating 21st Century Engineers in India* on a massive scale, so necessary nowadays.

2.3 Challenges Ahead

E-Learning technologies have witnessed good progress on the world scene in the last 40-50 years and they constitute the main stay of *Quality, Standard, Effectiveness, Access & Equity* enhancement issues in *Education* worldwide. India has also taken advantage of *E-Learning* to meet the concerns due to the above issues. While commendable progress has been achieved in India in this respect so far, there are many challenges ahead, particularly in respect of *Educating 21st Century Engineers*, which are limiting the future possibilities of *E-Learning* expansion in the country. Some of these

challenges are as follows:

(a) Education not possible alone by technology; Human beings required to drive & meet the various concerns and enhance the characteristics of *Learning*;

(b) Pool of well trained expert/gifted teachers with in-depth *knowledge* needed in adequate numbers. to prepare/use *E-LM* for various *Engineering & related subjects*;

(c) Adequate laboratory facilities & trained support staff to be available to assist, guide, motivate & inspire the *students* in the *Laboratories/workshops*;

(d) Availability of low cost, high standard *E-Learning Resources*, like *E-Books & E-Journals* at the state of the art, covering *Engineering disciplines*;

(e) *Educational Technologies* particularly for *E-Learning* advancing rapidly, needing new R&D initiatives/investments, to be at forefront;

It is expected that the country can benefit from adopting *E-Learning for Educating 21st Century Engineers* by meeting the above challenges in a time bound manner. Some of the achievable gains from this measure include:

- Development of quality *E-LM* capable of replacing mediocre teachers in class rooms;
- Availability of digital multimedia based courses providing high clarity instruction;
- Use of *ODL/F2FL* approaches on a regular basis to handle increasing *student Nos.*;
- *Active, Asynchronous Learning* providing many benefits in *Teaching-Learning*;
- *Online/Offline E-Learning & E-Interactivity* facilitating highly effective *Learning*;
- Each lesson in *E-LM* form, well designed/ made to engage the *E- Learners* fully;
- Exceptionally good enhancement of *Learning & improvement of Grasp*;

- *E-LM* costs steadily going down, as *student numbers* increase;

Thus, *E-Learning for Educating 21st Century Engineers* is expanding at a rapid pace to achieve the above benefits by meeting the various challenges brought out earlier.

2.4 Concluding Remarks

Major developments in *E-Learning* on the world scene have been reviewed in the paper, with particular reference to its implementation in India. As the country is now poised to expand its *Engineering Education System* at a rapid pace and finding shortages in the availability of well qualified/experienced *teachers* with inspirational skills and also in the state-of-the-art *Laboratories/Libraries/Infrastructure* at *HEIs* to meet the expectations of its *students & teachers alike*, the present state of technological progress of *E-Learning* is found to be of considerable benefit for *Educating 21st Century Engineers* in India. The opportunities brought forth by *E-Learning* and the *Challenges Ahead* are also covered here. It is hoped that the Paper will stimulate further developments in this important subject to enable the enhancement of *Quality, Standard, Effectiveness, Access & Equity of Engineering Education* in the country.

3. References

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