Online Engineering Education: A Comprehensive Review

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Abstract

Development and assessment of synchronous and asynchronous distance learning curricula is an ever growing research due to the new emerging virtual universities. Recent reports confirm the fast growth in online education at an even higher rate than anticipated by educational institutions. The suitability of online learning to engineering disciplines however has been questioned. This paper researches online degree granting institutions and attempts to gain an insight in the growth of online education and its correlation with engineering disciplines. An investigation of educational web sites of 126 educational institutions that offer an Electrical and Computer Engineering degree is used to provide information on whether or not this fast growth in online education is a representative of growth of online engineering disciplines. A comparison of different delivery methods for the online environment is presented as well as a review of different systems for offering electrical, electronics, and digital laboratories via distance learning is presented.

Introduction

Distance learning or distance education is a term used extensively by colleges and universities to describe remote delivery of course contents. It usually refers to off-campus sites, web-facilitated courses, and web-based (online) courses. Development and assessment of synchronous and asynchronous distance learning curricula has gained a large momentum due to the new emerging virtual universities. It has been argued that the ease of transfer of different disciplines from on-campus teaching to online teaching is discipline dependent. In engineering disciplines, laboratory experiments always served as the tool for relating the theoretical world to the real one. Other disciplines on the other hand do not necessarily require extensive hands-on labs. Practical or hands-on experiments delivered in traditional laboratory settings are now delivered through simulation software. Even though simulation is needed to reinforce concepts, practical experiments develop the student's skills in dealing with the real instrumentation. To facilitate online education for engineering disciplines, virtual labs have emerged to give the students the practical experience.

The results of the Sloan survey of online learning[1] show that the growth rate for online enrollment continues to increase from 2003 to 2004. The survey results[1], classified by type of institution, show that the Associates degree granting institutions have the largest number of students taking at least one online course, representing about half of all the students studying online. Associates schools are followed, in order, by Masters, Doctoral/Research, Specialized,

and Baccalaureate institutions with the smallest number[1]. The survey however does not relate the online offered courses to any specific discipline.

This paper attempts to provide a discipline specific review of undergraduate and/or graduate engineering degrees offered online. Different instructional technologies used at different institutions offering online engineering degrees are discussed. A comparison of different delivery methods for the online environment for Electrical and Computer Engineering courses in specific is presented. A review of different systems for offering electrical, electronics, and digital laboratories via distance learning is presented.

Review of Undergraduate and/or Graduate Engineering Degrees Offered Online

The fast and continuous growth of online education coupled with the results of the Sloan-C survey has spurred several questions about distance education;

1. Is this fast growth in online education a representative of all disciplines?
2. Is online education suitable for all disciplines?
3. Would Baccalaureate institutions offering engineering disciplines see more value in online education to their long-term strategy if hands-on experience is resolved?

To attempt to gain more insight in the growth of online education and its correlation with engineering disciplines, the authors investigated educational web sites of 126 educational institutions that offer an Electrical and Computer Engineering degree. These institutions are listed in Table 1[2].

Table 1 A list of investigated educational web sites

1. Air Force Institute of Technology	2. Alfred University
3. Northern Arizona University	4. Arizona State University
5. Auburn University	6. Boston University
7. Boise State University	8. Bradley University
9. Brigham Young University	10. Bucknell University
11. California Institute of Technology	12. California Polytechnic State University - Pomona
13. California Polytechnic State University - San Luis Obispo	14. California State University - Chico
15. California State University - Fullerton, School of Engineering	16. California State University - Los Angeles
17. California State University - Northridge	18. California State University - Sacramento
19. Capitol College	20. Case Western Reserve University
21. Carnegie Mellon University	22. Cedarville College
23. Catholic University	24. Citadel
25. Christian Brothers University	26. Clemson University
27. Clarkson University	28. Colorado School of Mines
29. Cleveland State University	30. Colorado Technical University Online
31. Colorado State University	32. Cooper Union for the Advancement of Science and Art, EE Department
33. Columbia University	34. Dartmouth College, School of Engineering
35. Cornell University	36. Drexel University
37. Devry Institute	38. Ellis College-New York Institute of Technology

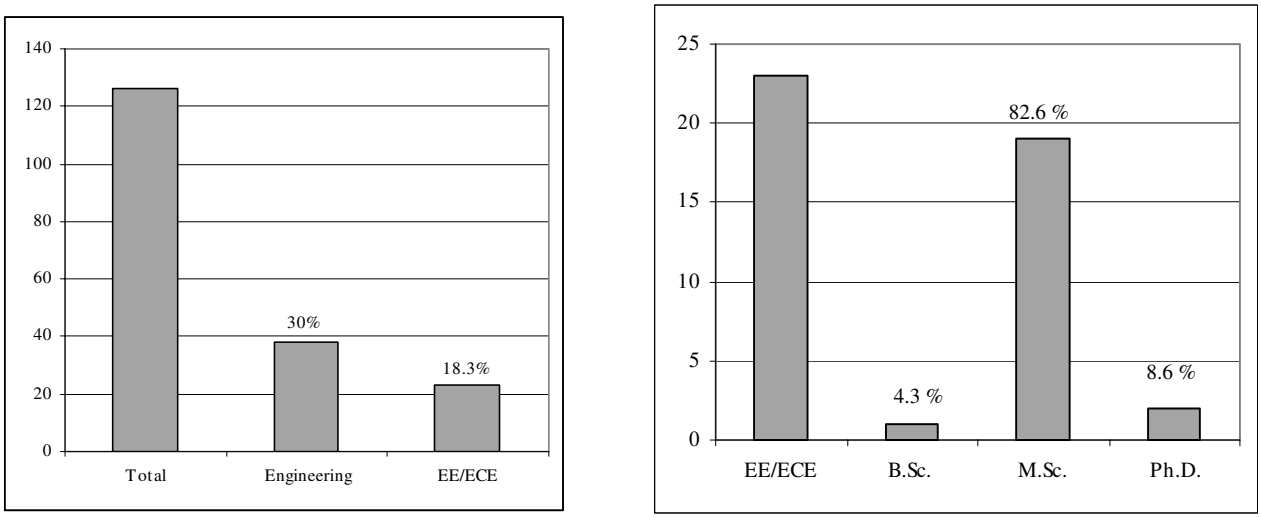
39. Duke University	40. Fairfield University
41. Embry-Riddle Aeronautical University	42. Florida A&M University
43. FairLeigh Dickinson University	44. Florida Institute of Technology
45. Florida Atlantic University	46. Florida State University
47. Florida International University	48. George Mason University
49. Gannon University	50. Georgia Institute of Technology
51. George Washington University	52. Harvey Mudd College, Engineering Department
53. GMI Engineering & Management Institute (Kettering University)	54. Illinois Northern University
55. Illinois Institute of Technology	56. Indiana University / Purdue University - Fort Wayne, Engineering Department
57. Indiana University / Purdue University - Indianapolis	58. Johns Hopkins University
59. Iowa State	60. Kennedy Western University
61. Kansas State University	62. Lamar University
63. Kettering University	64. Louisiana State University
65. Lehigh University	66. Manhattan College
67. Louisiana Tech. University	68. Marquette University
69. Mankato State University	70. Mercer University
71. Massachusetts Institute of Technology	72. Michigan Technological University
73. Michigan State University	74. Mississippi State University
75. Milwaukee School of Engineering	76. Morgan State University
77. Montana State University	78. National Technological University
79. National Technical University	80. New Mexico State University
81. New Jersey Institute of Technology	82. North Carolina State University
83. New Mexico Tech	84. Northeastern University
85. North Dakota State University	86. Ohio Northern University
87. Northwestern University	88. Ohio University
89. Ohio State University	90. Oklahoma State University
91. Oklahoma Christian University	92. Oregon Graduate Institute
93. Old Dominion University	94. Pennsylvania State University
95. Oregon State University	96. Polytechnic University
97. Portland State University	98. Purdue University
99. Princeton University	100. Youngstown State University
101. Rensselaer Polytechnic Institute	102. Rowan University
103. Walden University	104. Wayne State University
105. Worcester Polytechnic Institute	106. Wright State University
107. Wilkes University	108. Wichita State University
109. Western Michigan University	110. West Virginia University
111. University of Illinois-Urbana Champagne	112. University of Delaware
113. University of Florida	114. University of Idaho
115. University of South Carolina	116. University of Southern California
117. University of Massachusetts Amherst	118. University of North Dakota
119. University of Colorado at Boulder	120. University of Maryland-University college
121. Texas Tech University	122. University of Michigan Dearborn
123. University of Missouri-Rolla	124. University of Washington
125. University of Cincinnati	126. University of Norwestern

The investigation relied on the classification established by the Sloan-C report[1] for defining an online course. According to the report an online course is a course that has 80+% of its content

delivered online and typically has no face-to-face meetings[1]. In addition, our investigation concentrated on complete degrees offered online as opposed to course offerings online.

The results of the investigation are shown in Figure 1. Universities offering online engineering degrees constituted thirty percent (30%), or 38 universities, of the total number of investigated universities. Sixty percent (60 %), or 23 universities out of those 38 offered Electrical and/or Computer Engineering (EE/CE/ECE) disciplines. Figure 1(a) relates the number of engineering disciplines and the EE/CE/ECE majors offered online to the total number of investigated universities.

Figure 1(b) relates the number of EE/CE/ECE Baccalaureate, Masters, and Doctoral degrees offered online to the total number of EE/CE/ECE degrees offered online. Only one university, out of the
23 universities found here to be offering online EE/CE/ECE disciplines, is offering a Baccalaureate degree. The majority, 19 universities (82.6%), are offering Masters Degrees online.



(a) (b)

Figure 1 The results of the investigation

The result of our investigation definitely validates the high growth rate in online education as 65% of the investigated universities offer online degrees or programs. However, only 46% of these universities are offering engineering degrees online with less than 1% offering a B.Sc. in EE/CE/ECE, 15% offering Masters in EE/CE/ECE, and 1.5% offering EE/CE/ECE Doctorate Degree.

Online Course Delivery Systems

Research has proven that even with the availability of well-prepared students and highly skilled faculty, a lecture-based, traditional teaching delivery method can be a detriment factor in students' success and retention. It has been proven that a higher success rate is achieved with a shift from traditional teaching to web-facilitated learning. The curriculum must also have an emphasis on inquiry-based, hands-on approaches to learning. Blending multimedia and communication technologies into the delivery system is therefore a must.

A distance learning management system (DLMS) is the platform used by most institutions for the delivery and tracking of blended learning, i.e., online and traditional learning. A robust DLMS should provide a seamless integration for educational, administrative and supervisory tasks. As with any online system, a DLMS system must offer security by selectively limiting and controlling access to online content. It must also be scalable to meet future growth in the volume of instruction and/or the size of the student body. The system must be user-friendly to facilitate the distance learning experience. It also should be built on an open architecture that supports content from different sources and is interoperable with different platforms.

Several platforms, listed in Table 2, are available in the market and an excellent review of some of the features offered by these platforms and others can be found on the instructional technology site of Marshall University[3].

Table 2 Distance Learning Management Systems (DLMS)

DLMS	Company
Angel™	CyberLearning Labs, Inc.
WebCT™	WebCT, Inc.
Blackboard™	Blackboard Inc.
Desire2Learn	Desire2Learn Inc.
Embanet™	Embanet corporation
eCollege.com™	eCollege
IntraLearn™	IntraLearn Software Corporation
Symposium™	Centra Software
Convene™	Learning Technology Partners (LTP),

The most popular DLMS systems are Blackboard™, WebCT™, Desire2Learn™ and Angel™. The Angel platform is gaining a large popularity due to its open and flexible architecture and ease of use despite that it does not contain as much features as the two leading LMS. The different DLMS systems provide several multimedia capabilities such as:

- Different text formats: PDF, DOC, HTML, XML, and PPT.
- Different Graphic formats: JPEG, TIFF, BMP.
- Streaming Audio: MP3, WMA.
- Streaming Video and animation: AVI, MPEG, WMV, Flash, and Shockwave.

Blackboard Inc. provides a comprehensive comparison of some of the DLMS capabilities across the leading solutions available in the market today: Blackboard Academic Suite™, WebCT Vista™, WebCT Campus Edition™, Desire2Learn™ and CyberLearing Lab's ANGEL™. The capabilities are divided into four categories[5]:

- Instruction, Communication and Assessment
- Connections, Personalization and e-Commerce
- Collection, Sharing and Discovery
- Administrative

Some of these capabilities that are of most interest to the educator and that are common among all five platforms are[5]:

- Course Creation Wizard
- Course Import / Export
- Spell Check
- Equation Editor
- Audio / Video
- Adaptive Release Quizzes
- Adaptive Release By Date
- Adaptive Release By Grade
- Upload Existing Syllabus
- Has Learning Unit / Module feature
- Discussion Board
- Chat
- Email
- Students Can Submit Assignments Online
- Download Assignments
- Questions Can Contain Images
- Questions can contain Audio / Video / Other Media
- Time Limit Option on the Test
- Instructors Can Require Proctored Exams
- Can Display Test All at Once or One Question at a Time
- Instructors Can Override Automated Scoring
- Create Pools of Questions (Test Banks)
- Include individual Questions from Test Banks

According to a recent report by the National Centre for Educational Statistics[6] (NCES) different delivery methods were used by different institutions. A summary of the report findings are presented in Table 3 below.

Table 3 Primary Technology for instructional delivery for distance education courses[6] 2000–2001.

Delivery method	Public 2-year	Public 4-year	Private 4-year
Synchronous Web Courses	40%	55%	35%
Asynchronous Web Courses	95%	87%	86%
One Way Audio	10%	11%	12%
One Way live Video	9%	13%	4%
One Way prerecorded Video	57%	40%	24%
Two-way video with two-way audio	60%	80%	22%

The report results' are indicative that the preferred delivery method for online education is asynchronous web-based instruction[6]. The vast majority of these institutions (90%) reported that they use asynchronous web-based as a primary mode of instructional delivery.

Virtual laboratories for distance education

In its infancy, distance education relied on simulation for engineering courses to illustrate the physical phenomena. Java applets, simulation software such as PSpice, Matlab, Simulink, and Multisim were used to provide a virtual prototype of a practical experimentation. However the need to deliver and achieve the same learning and outcome objectives for online learning as those for traditional learning imposed the necessity of providing virtual and real experimentation facilities. The first generation of Remote Labs consisted of simply monitoring remote experimentation setups through dedicated environments which later progressed to virtual labs over the internet [7-10].

The new technology available with National Instruments (NI) LabVIEW® Remote Panels enables a user to quickly and effortlessly publish the front panel of a LabVIEW® program for use in a standard Web browser[11]. Once published, anyone on the Web with the proper permissions can access and control the experiment from the local server[11]. If the LabVIEW® program controls a real-world experiment, demonstration, calculation, etc., LabVIEW® Remote Panels turns the application into a remote laboratory with no additional programming or development time[11].

Collaborative and group work as emphasized by ABET is a key point to provide in virtual labs. Through NI remote panels, only one client can control the Host Server Clients application at a time, but the client can pass control easily among the various clients at run-time. At any time during this process, the operator of the host machine can assume control of the application back from the client currently in control[12].

National Instrument Educational Virtual Instrumentation Suite (NI ELVIS), Figure 2, consists of LabVIEW-based virtual instruments, a multifunction data acquisition device and a custom-designed bench top workstation and prototyping board[12].

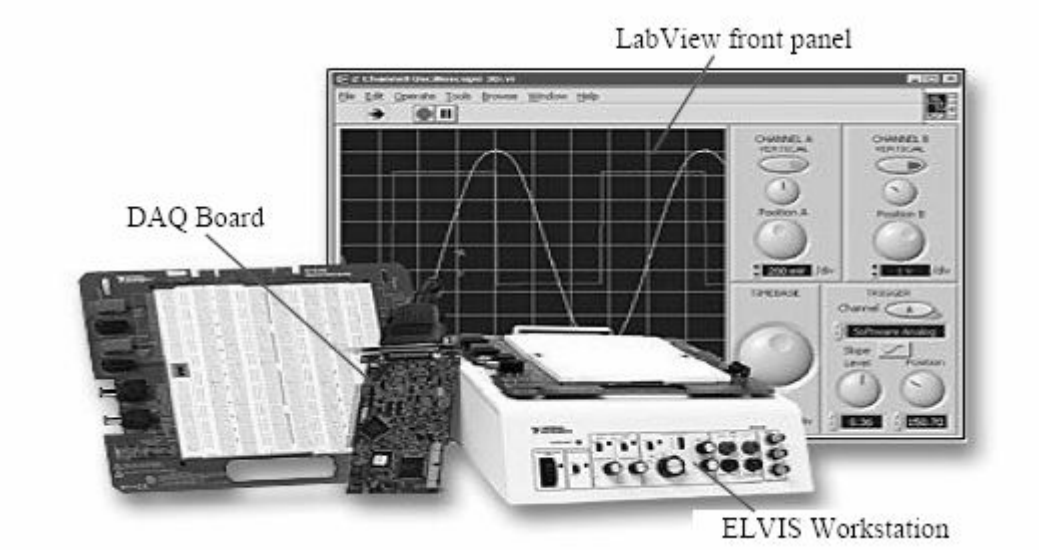


Figure 2. National Instruments Educational Laboratory Virtual Instrumentation Suite[12]

The eTCB(electronics training circuit board), Figure 3, a custom-built trainer board that works in concert with National Instruments' NI ELVIS (Electronics Laboratory Virtual Instrumentation Suite) and a personal computer, is a solution for students who need to perform laboratory experiments, whether at a distance or on campus[13]. This solution offers students the convenience of purchasing a laboratory manual and a custom-built eTCB, which are designed to offer a complete set of laboratory experiments in DC and AC circuit analysis and design courses[13].

Figure 3 *eTCB board interfaced with NI ELVIS workstation*[13]

Conclusion

An investigation of educational web sites of 126 educational institutions that offer an Electrical and Computer Engineering degree was presented. The results are clearly indicative that online education has yet to gain ground in offering basic engineering courses leading to a Baccalaureate degree in engineering. It is the authors' opinion that this is largely impacted by the extensive hands-on nature of engineering courses. However with the evolution and advancement in remote laboratories through NI-ELVIS or similar systems, it is expected that the number of online engineering Baccalaureate degrees will increase. This will be a direct result of labs moving from monitoring remote setups over the internet to a more realistic, interactive participation of students in remotely controlled lab facilities.

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Biography

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