Making Online Industrial Engineering Technology Education a Reality: An Assessment of the Tools and Technologies that Facilitate Remote Lab Instruction

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Abstract

Making an industrial engineering technology (IET) degree program available to everyone, everywhere is only achievable through a distance education model of online instruction and labs. Traditional on-campus IET programs are limited to those students who are able to physically get to campus during the times when courses and labs are scheduled. With demand for highly trained industrial engineers growing, IET degree programs must expand their reach to everyone, including those who are unable to attend on-campus courses due to physical distance, disability, or professional reasons.

We present a comprehensive assessment of a wide scope of simulation tools and remote access technologies and evaluate their ability to meet all lab objectives in a 4-year ATMAE accredited undergraduate Industrial Engineering Technology (IET) degree program. Each tool and technology is individually appraised on its ability to provide the distance education IET student with a hands-on lab experience comparable to that of the face-to-face student.

Keywords

Distance education, engineering, virtual labs, remote access labs, learning tools

Introduction

While online undergraduate education is nothing new and growing rapidly in many disciplines, it presents unique challenges to IET programs with hands-on lab requirement. Hands-on labs are a critical part of any engineering program as they allow students to apply theoretical learning to practical implementation and they are required by many accreditation bodies. Nedic et al. states that practical experiences is "One of the most important factors in forming the engineering graduate qualities" and that "The professional engineering community expects engineering graduates to develop practical skills during their undergraduate educational experience."[1] These sentiments are echoed by Bochichio and Longo who emphasize that practical laboratory experience is important in "validating analytical concepts, introducing students to professional practices and to the uncertainties involved in non-ideal situations, developing skills with instrumentation, and developing social and teamwork sills in a technical environment."[2]

The goal of this paper is to provide an assessment of the remote lab access technologies and lab simulation tools used to meet all lab objectives of an ATMAE accredited IET degree program through distance education. Additionally we provide details on the costs, licensing requirements, and technology requirements of each remote access technology and lab simulation tool used in our assessment.

Significance of study

While studies have shown the effectiveness of online education is on par with that of traditional face-to-face education, and in some respects more effective[1], it is the challenge of providing quality hands-on lab experience from a distance that has hampered the migration of engineering education to online. In their assessment of the status of online engineering education Bourne et al 2005 found very few undergraduate online engineering programs.[3] A more recent study conducted by pickard et al. of accredited Industrial Engineering Technology programs found fourteen accredited undergraduate IET programs, of which none were identified as including online practical lab components.[4]

This paper provides engineering educators with the information to make knowledgeable decisions on selecting the remote access technologies and simulation tools available to migrate the traditional on-campus engineering laboratory environment to a blended or fully distance environment. This will allow colleges and universities to maximize the return on their investment of lab equipment used in engineering programs by making the equipment accessible 24/7 and to expand engineering education to students unable to attend on campus classes due to work schedules, distance, disability, or other special circumstance.

Assessment of lab objectives

All lab objectives by course in an ATMAE accredited IET degree program offered at East Carolina University are listed in Table 1. Graduate students assigned to this case study project used currently available remote access technologies and simulation tools within the college to evaluate the ability of each objective to be completed in a distance education environment.

Table 1. Courses and course lab objectives from the ATMAE accredited IET degree program. For each lab objective the simulation tools and remote access technologies used to complete all labs meeting those objectives area listed using a numeric code. The key for the numeric codes is at the bottom of the table.

Course and Objectives	**Simulator Code**	**Remote Access Code**
ITEC 2054/2055 - Electricity/Electronics Fundamentals		
• Have a working knowledge of numerous meter both analog and digital	1	1,2
• Know semiconductor principles, and be able to test and determine the effectiveness of numerous semiconductors, to include transistors, diodes, FETs and thyristors	1	1,2
ITEC 2090/2091 – Electro Mechanical Systems		
• Explain and demonstrate the theory and functional characteristics of both DC and AC electric motors	2	1,2
• Understand and demonstrate the function and application of variable frequency drives	2	1,2

• Write, debug, test and run programs on a PLC	3	1,2
• Interface, program, collect and analyze data from PLCs	3	1,2
IENG 4024/4025 – Electromechanical Systems Integration		
• Describe and apply semiconductor principles and be able to evaluate the effectiveness of a variety of semiconductors, to include transistors, diodes, FETs and thyristors and how these devices are used	1	1,2
IENG 3020/3021 – Robotics in Computer Integrated Manufacturing		
• Demonstrate how to program and operate an industrial robot to perform a given task assignment	4	1,2
• Work on a team project to design, create, and evaluate as automated robot according to a given set of performance parameters	13	1,2
IENG 2076/2077 – Introduction to Computer Numerical Control (CNC)		
• Explain and apply common formats and codes for manual CNC programming	5,6,7	1,2
• Create and run a CNC program	5,6,7	1,2
• Troubleshoot a manual CNC program	5,6,7	1,2
• Perform set-up procedures on a CNC machine	6,7	1,2
• Make a part to print specifications	6,7	1,2
• Explain and demonstrate height compensation, cutter compensation and tooling offset	5,6,7	1,2
ITEC 2080/2081 – Thermal and Fluid Systems		
• Demonstrate the knowledge of the basic refrigeration and heat pump cycles	8	1,2
IENG 2020/2021 - Materials Processing Technology		
• Specify and interpret results of basic materials tests and associated engineering forces	9	1,2
• Identify strengths and limitations of basic manufacturing processes	10	1,2
DESN 2034/2035 – Engineering Graphics 1		
• Prepare technical drawings utilizing sketching and CAD	11	1,2
• Apply technical graphics principles to graphically oriented disciplines	11,12	1,2
• Communicate graphically using sketches and CAD	11,12	1,2
DESN 2036/2037 – Computer Aided Design and Drafting		
• Draw geometric shapes and constructions in both 2D and 3D CAD systems	11,12	1,2
• Create drawings of different disciplines and dimension and annotate drawings in CAD	11,12	1,2
• Create, plot and print CAD drawings based on accepted industry standards and conventions	11,12	1,2
• Demonstrate disk management including storage, copying, deleting, moving, and creation of files	11,12	1,2

Codes for simulator tools:	7 = Denford CNC Lathe
1 = National instruments multiSim 14.0	8= Delmar/Cengage HVAC Simulator
2 = Automation Studio v6	9 = Autodesk Simulation Mechanical
3 = Allen Bradley, Logix PRO PLC simulator	10 = Flex Sim
4 = Melfa RG series robot simulator	11 = Autodesk AutoCAD

5 = Denford CNC Simplified 6 = Denford CNC Milling	12 = Autodesk Inventor 13 = Kit robot and downloading the appropriate programming software
Codes for remote access solutions: 1 = Physical PCs with RDP using Horizon View 2 = Virtual PCs with VMs using NDG Netlab+	

The distance education technologies used to meet the listed course objectives are divided into two categories; remote access labs and lab simulators. While each technology is intended to provide students with the fundamental hands-on skills required to meet lab objectives, they differ in approach. Simulators place students in simulated environment while remote access technologies provide students with access to real physical equipment over a distance. Following are details on the costs, licensing requirements, and technology requirements of each remote access technology and lab simulation tool used in our assessment.

VMware Horizon 6

VMware Horizon 6 provides students with remote desktop access to virtual or physical PCs that are connected to lab equipment in the engineering lab.[5] Once connected to these PCs they have access to all of the software, tools, and utilities just as if they were physically in the laboratory.

Students must download and install the VMware View Client on their home computers. Once downloaded, the students run through a client setup wizard in which they input the required configurations to connect to a VMware Horizon Connection Server located on campus. The VMware Horizon Connection Server acts as a broker for the student client connections by authenticating and directing the clients to the requested desktop and/or application. The connection server not only performs authentication but also manages the student connections and performs authorization functions to ensure students can only access the resources they are authorized to access.

The requirements for the VMWare Connection are Window Server 2008 with at least 4GB of RAM. The supported virtual desktops on VMware Horizon 6 is limited to Microsoft windows. The VMware Horizon client can be installed on all current major mobile and desktop operating VMware Horizon also supports access the remote desktops over HTTP through Chrome, Internet Explorer, Safari, Firefox, Microsoft Edge, and Safari. The standard edition of VMWare Horizon 6 with 10 concurrent use licenses and production level 24-hour support runs approximately $3,125 annually.

NDG NetLab+

NetLab+ also provides remote desktop access to virtual or physical PCs, however, unlike the VMWare Horizon, Netlab+ is a standalone appliance that has a graphic user interface (GUI) that students can access through a Web browser.[6] Just as with the VMWare Horizon solution, the PCs are connected to lab equipment in the engineering lab. Once connected to these PCs they have access to all of the software, tools, and utilities just as if they were in the laboratory physically.

NetLab+ has two editions; Academy and Professional, each priced at $9,995.00 and $19,995.00 respectively. The differences between the two editions are the number of concurrent users and the number of equipment PODs that are supported. The pricing includes NETLAB+ appliances, software and first year maintenance and support. Annual maintenance support after the first year is $2,395.00 for the Academic edition and $8,985.00 for the professional edition.

National Instruments (NI) MultiSim

MultiSim provides Integrate Circuit Emphasis (SPICE) simulation and design software.[7] It helps students gain a comprehensive understanding of circuit behavior in power, digital and analog classes through a simulated environment where they can design and test electrical circuits.

Installing MultiSim requires Windows XP or newer, at least 256 MB of RAM, and 2GB of storage. Students can purchase a copy of MultiSim for $39.95. However, academic institutions must also purchase a software license for each copy. A one-year license for 25 copies is $5,552.00.

Autodesk AutoCAD Mechanical

AutoCad is a computer aided design and drafting software that is used create 2 dimensional (2D) and 3 dimensional (3D) models.[8] It is designed to meet the needs of various technical professionals from architects to engineers. AutoCad helps students prepare mechanical drawings by using computer aided design (CAD) and helps them to learn to dimension and annotate drawings in a simulated environment. AutoCAD is free for students, educators and academic institutions. AutoCAD requires Windows 7 or newer, at least 2GB of RAM, 6GB of storage, and a DirectX9 or later compliant card for its graphical intensive feature.

AutoDesk Inventor

AutoDeskInventor is a 3D mechanical computer-aided design (CAD) modeling application used to design, visualize and simulate products.[9] It is used to create accurate 3D product prototypes that can run stress tests and simulate a machine's motion to identify any unexpected errors. By using this software, students create, plot, print and mold drawings based on accepted industry standards and conventions. Inventor is free for students, educators, and academic institutions. The educational licenses are available for a three-year term. Inventor requires 64-bit Windows 7 or newer, at least 8GB of RAM, 100GB of storage, and Direct3D 11 or later capable card for its highly graphical intensive features.

Virtual Reality CNC Turning

Virtual Reality CNC Turning is a software package that allows editing and control of CNC files either online (physical machine connected) or offline (no physical CNC machine connect).[10] The features that are available in this package are: 2D and 3D graphical simulation of CNC files, comprehensive tooling features, full offline control of a CNC machine using VR, full online control of a CNC machine, full CNC file editing and context sensitive online help. Virtual Reality CNC Turing requires Windows XP or newer, at least 512MB of RAM, 200MB of storage, an available USB port, and a graphics card that supports OpenGL 3D Acceleration with 128MB RAM.

VR CNC Milling 5

VR CNC Milling 5 is a CNC machine control software that incorporates Denford Printed Circuit Board (PCB) manufacturing software along with its 2D Drawing Exchange Format (DXF) import facilities.[10] It simulates and runs G code programs on both virtual and real CNC machines. Virtual Reality Milling 5 requires Windows XP or newer, at least 512MB of RAM, 200MB of storage, an available USB port, and a graphics card that supports OpenGL 3D Acceleration with 128MB RAM.

LogixPro 500

LogixPro 500 is a Windows based Programmable Logic Control simulator. It allows students to hone and develop their PLC programming skills.[11] Unlike other PLC simulator, LogixPro 500 does not require any PLC hardware. LogixPro 500 is licensed for a single computer at an educational price of $35. LogixPro 500 requires Windows XP or newer. Additional information about software such as download require can be found at their website.

FlexSim

FlexSim is a simulation software that allows students to develop any type of system or process in a 3D world.[12] These processes include manufacturing, packaging and many others. Students are able to import 2D or 3D CAD drawing into the program to use a floorplan for a building. It also comes with a scripting language for those without programming skills to make development easier. FlexSim is available in two editions: Express and Enterprise. The Express edition is free. FlexSim requires Windows Vista or newer, 4GB of RAM, and a graphics card that supports OpenGL 3.1 or higher.

Automation Studio V6

Automation Studio V6 is a broad raging simulation tool that permits simulation of fluid power systems, electromechanical systems, ladder logic and other automation systems. It allows students to create and test automated equipment system designs without having to physically build the system. This allows DE students to learn automation skills without damage to equipment.

Conclusions

Hands on labs are critical to equipping tomorrow's engineers with the practical skills expected by the professional engineering community. Access to real face-to-face lab equipment imposes time and physical limitations for both students and faculty in engineering programs. However, to meet the growing demand from the professional engineering community for knowledgeable and skilled graduates, colleges and universities must extend the reach of their programs to those who are unable to attend traditional on campus courses through distance education. We provided in this paper a comprehensive assessment of simulation tools and remote access technologies that will allow colleges and universities to bring engineering education to everyone, everywhere.

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