Using Certification Exams to Help Formulate Course Objectives in Computer Engineering Technology Program

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Abstract

As information technology advances at an increasing rate, the demand for skilled graduates who can adapt, implement, and maintain the continually-changing technology becomes an important issue. To answer this growing need of industry and to better prepare students for the fast-changing job market, most institutes are moving rapidly to adapt their curriculum to better match the needs of our information-based economy. A new program in Computer Engineering Technology (CpET) was recently approved at IUPUI to be offered by the Department of Electrical and Computer Engineering Technology (ECET). In the design of this new program, we studied and assessed various vendor-sponsored certification programs and professional registration examinations. In this study, we identified skill-sets necessary for several generally recognized job roles in computer networking, programming and telecommunications. We further classified and extracted exam questions into sets of high-level principles and analytical concepts based on these different job roles. In this paper, course objectives developed for each job role from this process and their application to various courses in our CpET program are provided.

I. Introduction

It is generally accepted that the ultimate goal of collegiate education in engineering and technology is to help students mature into skillful and responsible problem-solvers. For years, potential employers of our graduates have expected their new college hires to be technologically conscious and job-ready as well as being capable and efficient problem-solvers. The exponential growth in the telecommunications industry and information technology has created a great demand for skilled graduates who can quickly adapt into this continually-changing technological industry. This demand quickly inspired similar growth in the curricular design supporting the requirements of this changing industry throughout all levels of education. Moreover, corporations today are increasingly dependent on educational institutes to prepare their graduates in readiness and awareness of the fast growing technology in order that the budget in training can be converted into profit.

A new program in Computer Engineering Technology (CpET) was recently approved at IUPUI to be offered by the Department of Electrical and Computer Engineering Technology (ECET). In the design stage of this new program, we studied and assessed various vendor-sponsored certification programs and professional registration examinations in order to better prepare our graduates for the changing technological industry. During this study, we identified skill-sets necessary for several generally recognized job roles in computer networking, programming and telecommunications. Based on the classification of these job roles, we compiled skill-sets necessary for ideal candidates who will perform these job roles. We further classified and extracted exam questions into sets of high-level principles and analytical concepts. From these principles and concepts, course objectives were developed and applied to various courses in our CpET program. In this paper, we give samples of the results obtained during the study and present course objectives applied to the two fundamental courses in our CpET program.

II. Various certification programs

Nowadays, it is interesting to note that more than 50% of the search results returned are somewhat information technology (IT) related when keywords of "certification program" are entered in any search engine on the Internet. Most of these certification programs are sponsored by companies such as Microsoft, Novell, Oracle, Cisco, and Sun. These companies generally create complex products or technologies. To ensure the continuous delivery of these products and technologies and hence the profitability of the company, a supply of knowledgeable, competent individuals who will use their products and technologies becomes the most important part of the overall system. Instead of relying on traditional educational institutes to produce these individuals, most of these companies proactively created their own certification programs that will ensure the continuity of their overall delivery systems to the marketplace. On the other hand, there are some certification programs, such as the Computing Technology Industry Association's (CompTIA's) A+, Network+, i-Net+, Server+, and other credentials, are created by

groups of industry players for everyone's benefit. These types of certifications are usually called vendor neutral to indicate that they stress general knowledge as opposed to detailed knowledge of some particular vendor's proprietary products or technologies.

Below is a sample list of different certification programs that are readily found in most of the publications as well as advisements:

Microsoft Certifications (MCP, MCSA, MCDBA, MCSE, MCSD, MCT, MOUS, MOUS MI)
Novell Certifications (CNA, CNE, MCNE, CNI, CDE)
Oracle Certifications (OCP)
Cisco Career Certifications (CCNA, CCNP, CCIE, CCDA, CCDP)
CompTIA Certifications (A+, Network+, i-Net+, Server+, e-Biz+, IT-Project+, Linux+, and CTT+)
Sun Java Certifications
Chauncey Group Certifications (ATS)
Prosofttraining.com Certifications (CIW, Master CIW)
Red Hat Certifications (RHCE)
LPI Certifications (LPIC)
Sair Linux and GNU Certifications (LCP, LCA, LCE, MLCE)
Security Certifications (ICSA, SANS-GIAC, CISSP, SSCP, and more)

It is noted in some of the publications that the total population of individuals in the United States today with computer certifications numbers about 6.5 million. And, this trend is expected to grow in a significant manner. By the year 2010, that number is expected to jump to over 20 million. This trend has been largely accelerated by the serious investment from some major IT companies such as Microsoft, Novell, Oracle, Cisco, and others. On the other hand, for individuals, certification can mean increases in pay or better jobs elsewhere. It is generally recognized that a certification can boost an individual's starting employment opportunity. Most salary surveys show that certified technical staffs earn at least 12 to 20 percent more than their uncertified counterparts. It is somewhat understood that a certification provides a better chance for an individual to get into the door of employment. However, the longevity of the employment still depends on the true knowledge and skills possessed by the individuals.

All certification programs have some certain common elements. These include the characteristics of:

- Identifying individuals who have demonstrated their knowledge and understanding of a particular technology or product.
- Defining a particular course of study, this may include supplementary materials. Such study materials can include classroom training, self-study materials, courseware, computer-based study materials, and privately-published or trade books. Eventually, such a course of study leads to a series of one or more tests aimed at examining an individual's knowledge of the subject matter. Most such tests are computer-based and are widely available through

nationwide (and global) testing centers.

- Certifying those who pass a prescribed test or series of tests for as long as the certification period lasts. When new products or technologies replace old ones, currently certified individuals must often recertify to keep their certifications current. Otherwise, such certifications lapse and become worthless.
- Offers tests in a monitored environment, for a fee, to would-be certificants. Each time an individual takes a certification test (whether he or she passes or fails), a test-taker must pay a fee. Some programs also limit the number of tries at a test within a given time period, but all such programs permit individuals to retake tests as many times as necessary to pass.
- Maintains the individual's certification status so it can be verified by current or potential employers.

Understanding the nature of the certification programs and their common characteristics helps us in defining the goals and hence developing the objectives for courses that will be offered in the program. In fact, certification is generally regarded as a valuable program for vendors and organizations, as an important credential for individuals to add to their resumes, and an important checkbox for employers to add to their list of requirements for current and prospective employees. Numerous sample exams from vendors as well as third party organizations could be easily accessed from the Internet. All kinds of study guides and related books populate bookstores. In this study, we have consulted books and sample exams from various publishers and vendors [1 - 15] in searching for a mechanism to develop appropriate course objectives. Naturally, a matrix of objectives mapping out all the details from various certification exams would be the first thing comes into our consideration. However, after a preliminary lengthy list of course objectives was generated from the initial period of this study, it is apparent to us that it is somewhat difficult to present the all the objectives from various certification programs in its entirety concisely in a matrix form. Moreover, the goal of this project is to assess common certification exams and subsequently to extract sets of high-level principles and analytical concepts so that they can serve as guidelines in formulating course objectives for suitable courses in our Computer Engineering Technology program. There is no intention of endorsing any existing certification program in the process of carrying out this project. In fact, simply adapting an existing certification program to teach courses in the program is not advisable. The mission of technology education generally does not limit itself to the narrower goals of various certification programs. This is one of the fundamental reasons inspired the starting of this project. Therefore, during the process of this project, a list of job roles was first identified among related industries. The skill-sets and characteristics of the ideal candidates for these job roles were then developed to serve as high-level principles and analytical concepts in preparing course objectives in our program.

III. Job roles identified from various certification programs

Numerous job titles can be found in the IT environment. However, if the desire is to use the existing certification programs to derive related job roles, they can be generally identified and described as follows:

- PC Technician — Individual who handles basic technical support for IT infrastructures or provides help desk functions and services. This individual typically covers everything from standard hardware and commodity software to supporting custom in-house applications and services. A common certification for PC technicians is the A+ from CompTIA.

- Network Administrator — Individual who supports IT infrastructures by installing, configuring, and managing desktop and server machines. This person is also usually responsible for installing, configuring, and maintaining common network services, including file, print, fax, and Internet access. More senior network administrators may also manage custom or enterprise-level applications and services, including accounting systems, Enterprise Resource Planning (ERP) systems, and database environments. Some common certifications in this job role include credentials such as Microsoft's MCSE or Novell's CNE and MCNE.

- Internetworking Professional — Individual who manages complex network infrastructures that are most likely TCP/IP-based, plus related routing, name services, security structures, and more. This person's task typically involves complex collections of work that require expertise in wide and local area networks. The interoperatabilty among the Internet, company's own intranet, and an extranet are all in this job role. Some common certifications in this job role include credentials such as Cisco's CCNA, CCNP, and CCIE.

- Programmer — Programmer creates in-house systems, helps making sites interactive, and customizes and deploys complex software such as database or ERP systems. This individual takes the software building blocks that make up most modern IT environments, put those pieces together, and tailor them to suit the unique information processing needs in modern organizations. In this job role, programs such as the MCSD, Sun's Java credentials, and Oracle or CIW Master Enterprise Developer certifications come into play.

- Security Professional — Individual who supports IT and business infrastructures by analyzing and evaluating networks and systems from a security perspective. This person is usually responsible for eliciting, defining, documenting, deploying, and administering an organization or company's security policy. Typically, the individual in this job role works with routers, firewalls, gateways, and intrusion detection systems, performs security audits, responds to virus infestations. Common certifications in this category include the SANS-GIAC, CISSP, and ICSA.

IV. Ideal skill-sets for identified job roles

For each of the five job roles identified in the previous section, a list of potential ideal skill-sets and characteristics for the job candidate is compiled as follows:

An Ideal PC Technician

1. Understands PC hardware, including motherboards, CPUs, RAM, interface cards, hard disks and various removable media, keyboards, mice, and display devices, including installation, troubleshooting, and repair.
2. Understands device drivers, including how to locate, download, install, troubleshoot, and replace them. Also understands how drivers work with software, including DMA and IRQs, and how to detect and resolve hardware conflicts.
3. Understands PC operating systems, including DOS, multiple versions of Windows (3.x, 9x, NT, Windows 2000, and Windows XP), along with familiarity with Linux, MacOS, and other typical desktop operating systems. Knows how to install, configure, patch, upgrade, and troubleshoot operating system software and services.
4. Understands PC applications, including common productivity applications, email, graphics, Web browsers, and other everyday software components. Is able to install, configure, and upgrade such software.
5. Possesses usable customer support skills, including listening, replicating problems, providing solutions, and strong people skills.

An Ideal Network Administrator

1. Understands basic principles of networking, including cabling, NICs, and networking hardware of all kinds.
2. Understands common networking protocols, including TCP/IP, IPX/SPX, NetBEUI, NetBIOS, AppleTalk, and other protocols as needed.
3. Understands one or more network operating systems (NetWare, Linux/Unix, Windows NT, or Windows 2000). Knows how to design, configure, install, maintain, and troubleshoot server and desktop installations.
4. Understands key network services, including name and directory services, file and print services, distributed applications, email, news, HTTP, DNS (and possibly WINS), DHCP, plus other services as required. Knows how to install, configure, maintain, update, and troubleshoot such services.
5. Interacts intelligently with ISPs or long-haul communications providers and works with VPNs, encryption, authentication, and security services to establish safe, usable connections with the Internet and external service providers.
6. Works with users to provide appropriate network services, technical training, technical support, capacity planning, and needs analysis to make sure that applications and services delivered meet user and organizational requirements.

An Ideal Internetworking Professional

1. Thoroughly understands networking, including cabling, NICs, routers, gateways, switches, hubs, and other local and wide area networking hardware and connections. Must know how to install, configure, upgrade, maintain, and troubleshoot all networking and internetworking elements.
2. Understands how to specify, procure, install, configure, maintain, and troubleshoot remote network services for access to service providers, private networks, VPNs, and other internetwork connections. Must understand technologies from POTS to ATM, including ISDN; X.25; frame relay; T1, T3, and so on; E1, E3, and so on; cable modems; and more. Must be able to manage ISPs and long-haul communications providers, including specification, procurement, installation, configuration, maintenance, updates, and troubleshooting.
3. Understands key internetworking services, including directory and name services, DNS (possibly also WINS), and DHCP, and how these services interact with switches, routers, and other key elements of internetworking infrastructure.
4. Understands routing protocols, services, and management, including interior and exterior routing protocols, RIP, OSPF, EGP, BGP, and other routing protocols and services as required.
5. Understands network security and integrity principles, practices, and services, including such things as authentication, security hardware, Kerberos v5, PKI, intrusion detection systems, and more. Knows how to specify, procure, install, configure, maintain, upgrade, and troubleshoot related hardware and software elements.
6. Works with users to provide appropriate network services, technical training, technical support, capacity planning, and needs analysis to make sure that applications and services delivered meet user and organizational requirements.

An Ideal Programmer

1. Thoroughly understands one or more object-oriented high-level programming languages, such as Java or C++. Should also have knowledge of popular languages such as Visual Basic and C. Should be able to architect, design, implement, test, debug, troubleshoot, and maintain simple and complex systems.
2. Should have some understanding of a scripting languages, such as JavaScript, Perl, or Unix shells. Able to automate routine tasks using such languages and perform arbitrary tasks to manipulate files, parse text input, and translate data among multiple forms and formats.
3. Understands principles, including object-oriented design, distributed programming techniques, client/server software design, implementation, testing, debugging, and maintenance.
4. Understands principles and practices for production software development, including version control, code libraries, source control systems, documentation, code reviews, testing tools and methodology, plus software release management.
5. Understands principles behind interactive Web pages and Web-based applications, including one or more of Java Server Pages, Java servlets, Active Server Pages, ActiveX controls, and more.

An Ideal Security Professional

1. Understands basic principles of computer and network security, including physical, software, and human security requirements and considerations.
2. Is well versed in formulating, analyzing, implementing, updating, and maintaining security policies, practices, and procedures.
3. Understands secure protocols, services, transports, and so forth, including VPNs, encryption, privacy mechanisms, public key infrastructure (PKI), IP Security (IPSec), and so forth.
4. Understands key security services and devices, including screening routers, firewalls, proxy servers, and intrusion detection systems, and how best to install, configure, and deploy such systems and services to implement security policies.
5. Observes and monitors security exploits, news, and events keenly and consistently to keep abreast of recent developments and to forestall the perpetration of successful break-ins or use of vulnerabilities on the systems and networks for which he or she is responsible.
6. Works with users and management to provide appropriate security services, technical training, technical support, and needs analysis to make sure that future growth and technology changes occur within a well-secured network and systems environment.

Considering the breadth of the above skill-sets and their characteristics, we can easily see that it is hard for a BS degree to cover all these topics. However, using these skill-sets as guidelines and developing related objectives for selected courses in a BS program will prove to be a rewarding process.

V. Sample course objectives derived from certification exams

Based on the ideal skill-sets listed in the previous section, some sample certification exams were used to extract and derive course objective for each job role. In this section, we present some working collection of course objectives, key words, and notes extracted from different sample certification exams [3, 5, 7 - 9]. They are listed based on either job roles identified previously or some key characteristics in the skill-sets.

Internetworking Professional Course Objectives:

Student should be able to describe and recognize scalable networks.
Student should know the characteristics of a network that is adaptable to new technologies.
Student should understand each of the three components of a hierarchical model: core, distribution, and access tiers.
Student should understand the benefits of using a hierarchical design. In particular how this relates to scalability, ease of implementation and troubleshooting, predictability, protocol support, and manageability.

Students should understand how to setup a network to maintain most of the traffic within a local workgroup.
Students should be able to identify the advantages/disadvantages of distributed and collapsed backbone architectures.
Students should be able to identify cabling options for WANs.
Students should be able to explain how interconnect methods bridging/switching (layer 2) and routing (layer 3) affect network scalability.
Students should understand how a switch could be used to fix a bandwidth contention on local media.
Students should be able to select proper transports to deal with Quality of Service (QoS).
Students should be able to properly classify characteristics of an ATM network.
Students should understand how a building architecture be designed so that anyone in a building can be in any logical workgroup. Student should be able to extend this concept to a campus.
Students should understand advantages of using DHCP for assigning IP addresses on your network.
Students should be able to give a high-level description of the Hot Standby Router Protocol and how can it be used in a VLAN design.
Students should be able to describe the path to upgrade a legacy FDDI in distributed backbones to an ATM switch.

TCP/IP:

Students should be able to describe a TCP/IP system that uses public (IANA assigned) or private IP addresses.
Students should be able to describe a method of address translation if using the internet with a private address system.
Students should be able to design a TCP/IP subnetting plan and select routers for a large campus.
Students should understand how variable-length subnet masks are used and how to combine them with classless routing.
Students should be able to describe hierarchical addressing (area code to local phone company to exact phone).
Students should be able to explain how VLSM (variable length subnet masks) allows the address space to be used more efficiently.
Students should be able to explain how Classless Interdomain Routing (CIDR) allows blocks of class C networks to be advertised and why this reduces the number of routes advertised.
Students should be able to explain how secondary addressing allows multiple IP subnets to exist on the same router pot and why it is inefficient.

CCNA Skills:

Fully understand what tasks are handled at each layer of the OSI 7-layer model, in particular what happens at the network layer.

Understand encapsulation within the layer network framework.
Understand a connectionless verses a connection-oriented protocol. Understand TCP flow control.
Understand TCP/IP. Understand subnet masking, ports.
Understand RIP, how a hardware address is obtained from an IP address.
Understand the major network components such as a switch, router, server, and client.
Understand different types of switch: cut-through and store and forward.
Understand the process of building routing tables.
Know memory types. ROM, RAM and NURAM and how a machine starts up.
Fully understand how a routing protocol works to build up routing tables.
Understand the functionality of a default gateway.
Know how to use command line entry.
High-level overview of how several WAN protocols work.
Familiar with names of the common WAN protocols.
High-level overview of how several LAN protocols work.
Familiar with the names of the common LAN protocols.
Concepts involved in making routing decisions.
Ports on a PC (serial, parallel)
Know how to use UNIX commands such as Telnet, Ping etc.
Basic functions of a bridge, switch and router.
Know how a bridge/switch learns about the network and builds tables.
Spanning tree protocol
Techniques for redundancy
DNS
Connection timeouts
IP Host table
Using script files
IP network masks
Frame relay
Frame relay encapsulation
Understand the concept of a broadcast
Broadcasting routing tables (RIP or IGRP) to establish neighbor adjacencies and how to avoid endless loops.
HDLC, PPP, and SLIP encapsulation.
SNAP (subnetworking access protocol).
RIP (routing information protocol) is an example of an interior gateway protocol (IGP). Know one well such as RIP and have an awareness of others.
Understand how to approach a troubleshooting problem. What level to start at and tools that are available for troubleshooting.

Above are examples of objectives, key words, and notes extracted from some different sample certification exams. This time-consuming process not only requires some detailed knowledge of the material from the person who is developing the list, it also has a tendency to derail itself because of the redundancy or overlapping material in various exams. Using the skill-sets and characteristics described in the previous section as the

anchoring stones, and it is a rather straightforward task to extract various objectives into courses without having to first compile an exhaustive objective list.

VI. Application of the objectives in CpET program

After most of the necessary skill-sets are identified and some objectives have been developed and compiled through sample exams from certification programs, we selected related courses in our CpET program for the implementation of appropriate objectives. The selection of proper objectives for various courses is based on the level and the structure of the course offered in the curriculum. In this section, we use two courses at associate degree level as examples to illustrate the application of these objectives. The courses considered here are: PC systems I (EET 234) and Computer Communications (EET 284). Both courses are required for all students in the department with the goal that all graduates (at the associate degree) will have necessary skill-sets for some certain certification programs. Course objectives for both courses are listed in the following:

EET 234

1. Demonstrate knowledge of, characteristics of individual PC hardware components (hard drives, memory, CD-RW for example) by installing/setting up, listing, comparing and contrasting their characteristics.
2. Install, format and partition hard drives.
3. Change settings in and update system BIOS.
4. Install and configure Windows 98 and Windows XP operating systems.
5. Create a small peer-to-peer network (1) between two systems and (2) among 3-5 systems, including manufacturing the necessary cables and entering the correct settings on each.
6. Compare and contrast different home networking methods.
7. Describe the functions of IRQs and DMA: list specific information on system reserved settings.
8. Describe plug and play including characteristics of the operating system, hardware, and system settings.
9. Describe the operation and characteristics of each system bus and system ports: parallel, serial, USB, AGP, PCI, ISA.
10. Compare and contrast sound and graphics cards.
11. Prepare Visual Basic programs using basic controls (text boxes, list boxes, command buttons, etc.)
12. Install and configure a PCI data acquisition (ADAC) card.
13. Write Visual Basic programs to interface with the ADAC card; write the data to the screen and graph the data.
14. Write data from the ADAC card into an Excel spreadsheet.
15. Research selected course topics and prepare written reports.
16. Work effectively in teams to develop programs.

EET 284

1. Have an overview of data communication systems and their basic underlying characteristics.
2. Analyze signals in the time and frequency domains.
3. Explain the necessity and the concept of modulation in a communication system.
4. Explain the concept of signal-to-noise ratio and its importance to communication systems.
5. State the relationship between bandwidth and information rate for a given communication system.
6. Describe and contrast different types of modulation schemes.
7. Understand the overall concept of computer communications and networking technologies.
8. Describe and explain various types of computer networks, network topologies.
9. Describe the basis of data communications and computer networking, such as: digital signals, serial and parallel transmission, communication modes, digital encoding, and error detection methods used in networking.
10. Describe and explain the function of each layer in the OSI Reference Model.
11. Understand how local area networks are configured and specified.
12. Understand how data is transmitted through interconnected networks from both hardware and software aspects.
13. Describe the TCP/IP protocol used for transporting Internet messages.
14. Understand the usage of data communication media such as twisted-pair cable, coaxial cable, fiber optic cable, and wireless communication.
15. Describe the applications of multiplexer, de-multiplexer, types of multiplexing and multiple accesses, and switching technology.
16. Understand and describe the applications of networking interconnection devices such as repeaters, bridges, routers, and gateways.
17. Explain Internet architecture, TCP/IP, IP, IPv6, and Internet II.
18. Have an overview on some advanced networking technologies.
19. Install and manage a LAN with the available hardware and software.
20. Understand how WAN and special types of interconnected networks are setup.

Both of these courses serve as the introductory courses in specific sequences in the CpET program. For example, EET 284 is the introductory course in the data and network communications sequence. The course goals in EET 284 are to assist students in:

1. Learning the general concepts and the essential building blocks in basic data and computer communications systems.
2. Understanding the hardware issues in computer communications.
3. Understanding the software issues in computer communications.
4. Implementing and administrating basic computer networks.

It is very important to note that the course is not merely designed in a way so that students can be proficient in testing through some certification exams. It is, however, designed with some specific higher-level goals set at the beginning and the proper objectives are then selected to be implemented in the course. The curriculum in our CpET program is

designed under the provision of missions set forth in common technology education.

VII. Conclusion

By no means are we able to say that we have compiled and selected all the related course objectives to prepare our students for the existing certification programs. On the contrary, we have considered the reality in the existing and future job markets and come up with necessary skill-sets to prepare our students for the changing industry. This process of studying, collecting, developing and implementing related course objectives in our CpET program has proved to be challenging and fulfilling. With certification programs proliferating to an extent that causes the traditional educational landscape to be changed in fundamental ways, traditional higher educational institutes have to adapt their curricula to this changing landscape. It is our hope that we are not merely changing course contents to meet specific skill-sets brought forth by particular certification programs. Instead, we should consider the elements and characteristics in this changing industry and identify necessary skill-sets that can be adopted into our existing curriculum.

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Computer engineering core courses. Course Number. Course Title.Â Degree in Computer Engineering and a Second Major in Electrical Engineering. Minor in electrical and computer engineering (ECE). The Minor in ECE is designed to allow students to add another dimension to their Rose-Hulman degree. Advisor ECE Department Head.Â This program will be critical to help developing a more interdisciplinary interaction for students and faculty. The creation of a workgroup within the faculty of both departments will coordinate current courses and resources, create new courses of interest for the field, and develop a showcase testbed education and research laboratory.