المركز الوطني للقياس والتقويم في التعليم العالي
National Center for Assessment in Higher Education

# National Center for Assessment in Higher Education (QIYAS)

## Framework for Assessing Learning Outcomes in Engineering

## (Computer Engineering)

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TABLE OF CONTENTS

# 1. INTRODUCTION, BACKGROUND AND FRAMEWORK STRUCTURE

## 1.1 Introduction

The Ministry of Higher Education in Saudi Arabia has recently requested the National Center for Assessment in Higher Education (QIYAS) to launch an ambitious project to develop a comprehensive framework for assessing Learning Outcomes (LOs) in Engineering Education (Phase 1) and to subsequently prepare a unified engineering qualification exam based on the developed framework (Phase 2). The project covered the following areas of engineering education: Chemical, Civil, Computer, Electrical, Industrial, Mechanical, in addition to Architectural Engineering. In the first phase of this project, a multi-disciplinary team composed of university professors and experts from QIYAS was formed to develop the learning outcomes framework. During the work in this phase, the team interacted with many national and international institutions and experts. The team also reviewed available approaches and methodologies related to the development of frameworks for learning outcomes in engineering education. The review covered experiences from various countries worldwide including North America, Europe, Australia, New Zeeland, Japan, Singapore, China, Korea, Malaysia and South Africa. The review also covered independent and important projects on learning outcomes such as the Accreditation Board for Engineering and Technology (ABET) in the United States [1], Engineers Australia (EA) [2], European Network for Accreditation of Engineering Education (EUR-ACE) [3], The UK Standard for Professional Engineering Competence (UK-SPEC) [4], Conceiving-Designing-Implementing-Operating (CDIO) initiative [5], Tuning-AHELO framework [6] and the National Architectural Accrediting Board (NAAB) [7]. In addition, two workshops were conducted at the QIYAS Center, to review the outcomes of the study. The first workshop was attended by high ranking officials from the Ministry of Higher Education and by several international experts on engineering education and development of learning outcomes. The second workshop was attended by representatives of various local universities who presented their detailed comments on the framework.

## 1.2 Background on Learning Outcomes

The current international trends in education are showing a shift from the traditional teacher-centered approach to a student-centered approach. The teacher-centered approach focuses essentially on the teacher's input. Among the criticisms of this type of approach is that it can be difficult to identify precisely what the student has to be able to do in order to pass the course or program [8]. The alternative student-centered (or outcome-based) approach focuses on what the students are expected to be able to do at the end of the course or program [8]. Statements called learning outcomes are used to express what a learner is expected to know, understand and/or be able to demonstrate after completion of a process of learning [9]. Learning outcomes have strong implications on curriculum design, teaching, learning and assessment, as well as quality assurance. Engineering education is in the forefront of areas that should benefit from the student-centered approach. The Engineering education environment is changing as information and communication technologies are having greater impact, and innovation is becoming increasingly essential. The future role of engineering requires that non-technical skills should be added to the technical dimension of engineering education.

Moreover, in today's competitive environment, the assessment of learning outcomes has become a primary focus for engineering education worldwide. Employers as well as academic accreditation entities push for the incorporation of sound assessment techniques into engineering programs. The outcome-driven assessment process, if carefully designed and implemented, can be useful at different levels; (1) It can provide useful information on whether graduates have acquired the knowledge and skills defined by predetermined educational objectives; (2) It can also convey useful information to faculty and administrators on the effectiveness of the design and delivery of the educational program; (3) It can also develop, in the long term, instruments to obtain comparable information on what students actually learn across different engineering colleges [8 -10].

The assessment of learning outcomes is particularly important to the Kingdom higher educational institutes. The Kingdom has recognized the need to move from a natural resource-based economy to a knowledge-based economy, which puts new priority on the role of universities in general and engineering colleges, in particular. Saudi's young engineering generation will need to acquire new skills and capabilities to meet the current diversification objectives and to be competitive with the best students from anywhere in the world. The proposed assessment framework will ensure that acceptable educational standards are fulfilled by public as well as private universities.

## 1.3 Structure of the Proposed Framework

One of the unique and innovative features of the developed framework is the hierarchy (multi-level) structure used in specifying the learning outcomes as well as the level of comprehensiveness which covers both the discipline and sub-discipline levels. As illustrated in Figure 1, four hierarchy levels are covered in the developed Framework of Engineering Learning Outcomes, namely:

1) **General Skills**, which cover learning outcomes for any higher education graduate (engineering or otherwise). General skills or generic skills also referred to as transferable or soft skills, address the basic competencies that all higher education graduates, including engineering graduates, ought to possess upon their graduation.
2) **Engineering Skills**, which cover learning outcomes for any engineering graduate regardless of his/her general specialty (discipline).
3) **Discipline-level Engineering Skills**, which cover learning outcomes for a given engineering specialty (Chemical Engineering, Civil Engineering, Computer Engineering, Industrial Engineering, Electrical Engineering, Architectural Engineering, and Mechanical Engineering)

4) **Sub-discipline-level Engineering Skills**, which cover learning outcomes for a given engineering specific specialty (Electronics Engineering, Materials Science and Engineering, Thermal and Desalination Engineering, Structural Engineering, Manufacturing systems engineering, Computer Networks, etc.)

In setting up the learning outcomes for General Engineering and for specific disciplines, the four key learning areas namely **Basic Sciences & Engineering Fundamentals**, **Engineering Analysis and Investigation, Engineering Design,** and **Engineering Practice** were considered. The proposed Learning outcomes were formulated using the revised Bloom taxonomy in the cognitive level (Remembering, Understanding, Applying, Analyzing, Evaluating and Creating) given in the Appendix.

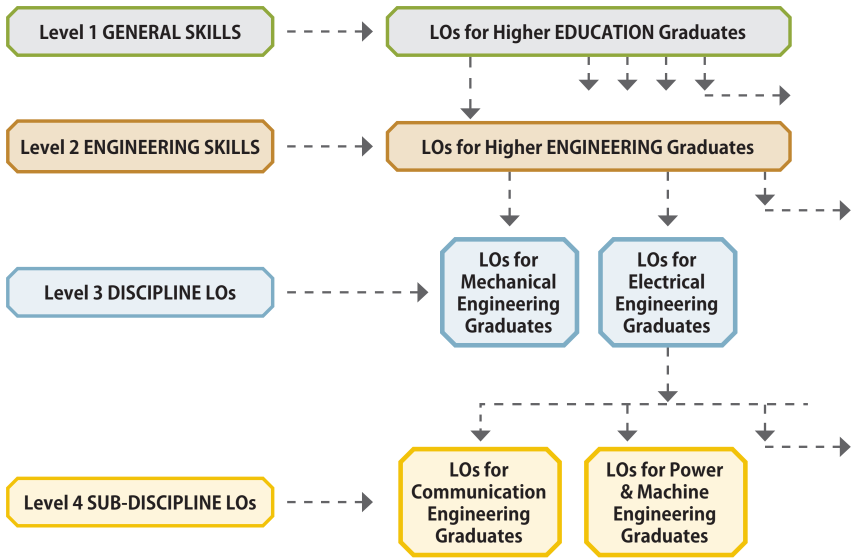


Fig. 1 Hierarchy levels of QIYAS Framework of Engineering Learning Outcomes

# 2. COMPUTER ENGINEERING LEARNING OUTCOMES (CEN)

## 2.1 Discipline Level Learning Outcomes

Computer Engineering **(CEN)** skills initially would cover the fundamental knowledge of computer engineering and ultimately would extend to specialized areas such as, computer architecture, computer network and information engineering. Computer engineering graduates ought to be able to demonstrate their knowledge and understanding in different criteria such as, engineering sciences, engineering analysis and investigation, engineering design and engineering practice.

The following is the list of discipline related abilities, denoted by (DCEN#) and under each ability there is a set of learning outcomes associated with the ability.

### 2.1.1 Engineering Sciences

**DCEN1**. The ability to understand and identify different bases of the number systems and the Boolean Algebraic rules.

***Learning outcomes:***

Graduates who possess this ability should be able to:

1. Explain the number systems and codes and apply their applications to digital systems;
2. Apply Boolean algebra and its application to the design and characterization of digital circuits;
3. Use different rules of the Boolean algebra in order to simplify the Boolean equations which could result in having a cost effective logic design.

**DCEN2**. The ability to understand the fundamentals of engineering sciences including, mathematics, physics, chemistry and the theories of computer engineering. This preparation will be the foundation towards understanding of the specialized areas of computer engineering.

***Learning outcomes***

Graduates who possess this ability should be able to:

1. Explain the structure and properties of different semiconductor materials and their applications. This would help students to gain knowledge towards construction of electrical and electronic components (diode, transistors, VLSI components.. etc);
2. Apply different mathematical description and classification to various signals and systems. This also includes ability to apply different mathematical software packages to different areas of computer engineering disciplines;
3. Express signals in terms of the unit step function, the rectangular pulse, and the unit impulse function for analysis purposes;
4. Apply the basic definitions of the Fourier representation and Laplace Transform and their inverses. This includes understanding of the frequency response, magnitude and phase and ability to identify the modulation and demodulation of AM, PM and FM systems;
5. Represent a control system mathematically by using differential equations and transfer functions. Also be able to use root locus to design compensators to improve steady state error and transient response.

### 2.1.2 Engineering Analysis and Investigation

**DCEN3**. The ability to investigate, analyze and solve computer engineering problems

***Learning outcomes:***

Graduates who possess this ability should be able to:

1. Analyze logic circuits that contain basic memory elements. In addition to being able to design, analyze and implement finite state machines (FSM);
2. Design and analyze synchronous and asynchronous sequential machine;
3. Investigate, implement, analyze the timing problems including clocking, time constrains and propagation delays related to the design and analyses of digital systems;
4. Incorporate Programmable Logic Devices and related technologies during different phases of investigation, analyses and design steps of the logic design;
5. Read datasheets and schematic diagrams in order to investigate, analyze the requirements for selecting the best processor for an embedded system design in terms of cost, processing speed, memory, peripherals, space, power consumption;
6. Investigate how to configure and use timers and serial communication modules as well as being able to design and interface different types of memories to processors;
7. Identify and analyze the tradeoffs of the approaches and techniques related to pipelining (hazards, forwarding, and branch prediction in the computer architecture);
8. Recognize the main categories of memory technologies and the impact of the memory hierarchy on computer performance.

**DCEN4**. The ability to understand and apply the hardware and software tools in the investigation and design of different building blocks of a computer system or related areas.

***Learning outcomes***

Graduates who possess this ability should be able to:

1. Describe the Hardware Description Languages (HDLs) and associated CAD tools and be able to apply them in different phases of investigation and the design of digital systems;
2. Write technically correct and properly documented HDL code for simulation and synthesis of complex digital systems. This could be extended to cover the ability to compare and contrast different PLDs options for realizing complex digital systems;
3. Simulate an open/closed loop system using MATLAB/SIMULINK and being able to apply software packages C/C++ to design the two-position controller;
4. Design FPGA systems together with the use of relevant CAD tools;
5. Test and debug HDL code, containing syntax and/or semantic errors until it satisfies desired specification.

### 2.1.3 Engineering Design

**DCEN5**. The ability to design systems from hardware and/or software point of view which meets the specific needs of the customer while observing the technical, environmental, economical, societal, ethical and safety constraints.

***Learning outcomes***

Graduates who possess this ability should be able to:

1. Design an analogue and digital controller as well as the ability to design and implement cost effective real time digital PID controller plus applying software packages C/C++ to design the two-position controller;

2. Design and implement appropriate method to control a manipulator robot, and also be able to develop obstacles avoidance algorithms, as well as design and control a mobile robot;
3. Optimize the design of multiple logic level circuits using the concepts of logical effort as well as design of major data path components like adders and multipliers;
4. Successfully complete a senior design project in order to achieve experiences in the design, analysis, construction, testing, and evaluation, of their project in the area of their specialty;
5. Apply advanced programming techniques in implementing concurrency and multiplexing.

### 2.1.4 Engineering Practice

**DCEN6**. The ability to understand the electrical datasheets and technical specifications of computer components. In addition, to be able to interpret them appropriately and use them cost effectively towards the design of the hardware and software units.

***Learning outcomes***

Graduates who possess this ability should be able to:

1. Develop an ability to design and conduct engineering experiments, through interpreting datasheets and schematic diagrams and offering best engineering solutions;
2. Discuss, interpret technical data, and to communicate effectively in writing;
3. Communicate effectively with colleagues and contribute towards teamwork activity by exchanging technical information.

## 2.2 Sub-discipline #1: Information Engineering

Information engineering skills include possessing knowledge of the mathematical theory, information technology as well as mastery in related design concepts and operation of variety of high tech devices and systems. Computer information engineering graduates should be able to exploit their fundamental knowledge in computer engineering in order to fully comprehend the different criteria of Information engineering.

### 2.2.1 Engineering Science

**DCEN_S1_1**.The ability to understand the mathematical description and classification of various signals and systems, also having knowledge in mathematical software packages, continuous linear time-invariant systems, convolution and correlation. This is complemented by developing familiarity in Fourier series and transforms, Laplace transform applications to communication systems.

***Learning outcomes***

Graduates who possess this ability should be able to:

1. Develop an understanding of the mathematical software tool for simulation of signals and systems. Students are ought to sketch signals and perform basic time-domain operations on them;
2. Classify signals into periodic/non-periodic, energy/power signals. In addition to be able to perform convolution and correlation for continuous time signals;
3. Determine if a system is linear, time-invariant, causal, memory less and stable. Moreover to be able to describe a linear time-invariant system by its impulse/step response, differential/difference equation, and block diagram.

**DCEN_S1_2**. The ability to understand the probability theory, random variables, descriptive statistics, random sampling, statistical intervals and hypothesis testing for a single sample, stochastic processes, spectral characteristics and applications to systems.

***Learning outcomes***

Graduates who possess this ability should be able to:

1. Explain the basic concepts of probability, joint probability, conditional probability, independence, total probability, and Bayes' rule;
2. Define random variables in terms of their PDF and CDF, and some distributions as well as ability to calculate the mean, variance, and joint moment of two random variables such as the correlation and covariance;
3. Describe the random sampling, data, and develop an understanding of the central limit theorem, as well as being able to explain important properties of point estimators;
4. Construct point estimators using maximum likelihood and be able to construct confidence intervals on mean of a normal distribution for variance known and unknown;
5. Specify confidence intervals on the variance and standard deviation of a normal distribution and being able to test binary hypotheses on the mean of a normal distribution with variance known and unknown;
6. Calculate the mean, variance, autocorrelation and be able to determine if a random process is wide sense stationary, stationary, and ergodic;
7. Develop sufficient knowledge to determine the power spectral density of a stationary random process, such as the additive white Gaussian noise process and to do spectral analysis.

**DCEN_S1_3**. The ability to understand the continuous and discrete systems including Z-transforms.

***Learning outcomes***

Graduates who possess this ability should be able to:

1. Identify the components of control systems in everyday life as well as being able to represent a control system mathematically by using differential equations and transfer function;
2. Simulate and analyze the first and second order systems as well as having the ability to analyze systems in time domain using state space model;
3. Determine the stability of a system represented by a transfer function as well as having the ability to analyze the steady-state error feedback systems;
4. Sketch root locus and use it to find the poles of a closed-loop system. Moreover, be able to use root locus to describe the changes in transient response and stability of a system as system parameters are varied;
5. Represent a control system mathematically by using differential equations and transfer functions. Also to be able to design and evaluate controllers for linear systems in addition to use root locus to design compensators to improve steady-state error and transient response;
6. Explain the steps towards the physical design of compensator and have familiarity towards the digital systems model, determine the steady-state error, and check stability.

**2.2.2 Engineering Analysis and Investigation**

**DCEN_S1_4**. The ability to understand the sampling theorem, periodicity, discrete Fourier transform, z-transform, digital filters, and application in audio and image processing.

***Learning outcomes***

Graduates who possess this ability should be able to:

1. Describe the sampling theorem and the spectra of a periodic signal. In addition to be able to determine the spectrum of a signal using the DFT and the FFT, and explain the difference between the DFT and the FFT;
2. Describe and be able to perform discrete convolution as well as describing a system using difference equation by applying Z-transform;
3. Design digital filters with given frequency response and be able to analyze frequency parameterized filters using the Z-transform;
4. Design, analyze, and implement digital filters in Matlab, and explain how digital methods denoise audio signals together with understanding the smoothing effect of low-pass filters on images.

**DCEN_S1_5**. The ability to understand the probability theory, Markov chains, stochastic processes, Poisson and Exponential processes, Queuing Systems, as well as computer simulation, event-driven simulation, simulation languages and software simulation

***Learning outcomes***

Graduates who possess this ability should be able to:

1. Explain the real life phenomena through standard distribution functions, and be capable of characterizing the phenomena which evolve with respect to time in a probabilistic manner;
2. Acquire skills in characterizing features of a queuing system and analyzing queuing models together with establishing a strong foundation on concepts of computer simulation and mathematical modeling;
3. Recognize the techniques of random number generation and randomness testing and being able to design simulation models for various case studies like traffic flow in networks;

4. Apply simulation tools and impart knowledge on building simulation systems.

**DCEN_S1_6**. The ability to understand the concept of artificial intelligence, knowledge representation, artificial neural networks, fuzzy theory and logic, Genetic algorithms, Particle swarm optimization, and selected applications to signals and systems.

***Learning outcomes***

Graduates who possess this ability should be able to:

1. Analyze problem parameters and come-up with appropriate solution using Fuzzy logic;
2. Explain the practical aspects of artificial intelligence, and being capable of explaining the knowledge representation and reasoning;
3. Apply intelligent methods, including search heuristics, knowledge representation, planning and reasoning;
4. Apply application examples to signals and systems including speech processing and mobile robot navigation.

**2.2.3 Engineering Design**

**DCEN_S1_7**. The ability to understand the Pulse Modulation, Baseband Transmission, Pass band, Digital Transmission, Spread spectrum systems, CDMA, Introduction to Error-Control Coding.

***Learning outcomes***

Graduates who possess this ability should be able to:

1. Model various digital communication systems in block diagrams, including the transmitter and receiver and explain the function of each sub-block;
2. Design a pulse code modulation (PCM) system and a digital communication system;

3. Use Gram-Schmidt procedure to perform signal space analysis and geometric representation of signals;
4. Design matched filters and correlation receivers for optimal detection in AWGN;
5. Design coherent detectors for different modulated signals and evaluate their bit error rate performance in AWGN;
6. Explain the trade-off between various digital modulation schemes in terms of required bandwidth, bandwidth efficiency, and required transmitted power;
7. Express the Code Division Multiple Access (CDMA) concepts and operation of RAKE receiver;
8. Perform channel coding and decoding using linear block codes to improve the digital communication system performance.

**DCEN_S1_8**. The ability to understand the principle of robotics, robot arm kinematics, inverse kinematics, trajectory planning, applications of mobile robots (modeling and control), autonomous mobile robots (navigation and localization). In addition, acquiring knowledge in computer vision, vision-based control, and other robotic devices for experiments, plus Internet and Web Robotics and its future trends is required.

***Learning outcomes***

Graduates who possess this ability should be able to:

1. Explain the practical aspects of robotics, and the robot arm kinematics (forward and inverse kinematics);
2. Define mathematical modeling using differential equation, multivariable calculus and control of robots;
3. Explain different methods for path planning;
4. Design and implement appropriate method to control a manipulator robot, also design and implement of obstacles avoidance algorithms;

5. Implement algorithm for localization and navigation of mobile robot in structured and unstructured environment;
6. Analyze an industrial problem related to robots and solve it;
7. Explain advantages and drawbacks of internet based robotics (tele-operations)

### 2.2.4 Engineering Practice

**DCEN_S1_9**.The ability to gain practical experiences in the digital control techniques. This is achieved through completing experiments in the areas such as, liquid level process, DC- motor, PC controlled temperature system, control of temperature process and complete simulation through MATLAB/Simulink packages.

***Learning outcomes***

Graduates who possess this ability should be able to:

1. Express the concepts of modeling and identification of processes including analyzes of the real time step response;
2. Design an analogue and digital controller;
3. Simulate an open / closed loop system using appropriate and contemporary software packages.

**DCEN_S1_10**. The ability to gain engineering practice in the areas such as image enhancement in both spatial and spectral domains, digital filter design, image restoration and image compression.

***Learning outcomes***

Graduates who possess this ability should be able to:

1. Identify the fundamental units of an image processing system by recognizing the basic relation between the human visual system and image processing;
2. Classify images into binary, gray-scale, color and multi-spectral images, and describe the image geometry and algebra, convolution, and basic spatial operations;
3. Explain the 2-D Fourier including implied symmetry, phase, circular convolution, and filtering and being able to apply low-pass, high-pass, and band-pass filtering, including ideal and non-ideal filters;
4. Classify the image processing applications into restoration, enhancement and compression;
5. Apply adaptive contrast enhancement to digital images and being able to explain the concepts of image sharpening and smoothing in both spatial domain and spectral domain;
6. Design Wiener and power spectrum equalization filters for image restoration in addition to explaining the basics of image compression and decompression.

## 2.3 Sub-discipline #2: Computer Architecture

Computer architecture skills deal with the detailed knowledge of building blocks of the computer system both from hardware as well as software point of view. Computer engineering graduates who are specialized in the areas of computer architecture ought to have knowledge and skills in the design, analysis, implementation and hands on experiences in the hardware and software aspects of computer engineering in general and computer architecture in particular. These can be summarized under the following themes:

**2.3.1 Engineering Sciences**

**DCEN_S2_1**. The ability to design fundamental aspects of digital systems and gain appropriate hardware and software experiences through attending laboratory sessions:

***Learning outcomes***

Graduates who possess this ability should be able to:

1. Design and analyze the combinational and sequential circuits;
2. Choose appropriate VHDL constructs to describe combinational and sequential logic circuits and by constructing VHDL test benches to verify functionality of VHDL designs;
3. Write small programs and fragments of assembly language code to demonstrate an understanding of machine level operations;
4. Interface and program input/output devices such as semiconductor memory and keypad and LCD module to the Processor. Use appropriate hardware or software tools to troubleshoot any faults;

**DCEN_S2_2**. The ability to apply the knowledge and skills of advanced engineering sciences in relation to computer architecture in order to fulfill the highly demanding expectations of the graduates.

***Learning outcomes***

Graduates who possess this ability should be able to:

1. Describe how to build logic gates in MOS. This includes estimating circuit delays using MOS delay models and includes the different CMOS circuits styles and tradeoffs between them;
2. Optimize the design of multiple logic level circuits using the concepts of logical efforts. Moreover to demonstrate having knowledge in applying concepts of timing, clocking, timing constrains, clock skew, jitter, and propagation delays;
3. Apply artificial intelligence techniques, including search heuristics, knowledge representation, planning and reasoning. In addition, demonstrate ability to implement solutions for planning problems such as determining a sequence of actions for a robot.

### 2.3.2 Engineering Analysis and Investigation

**DCEN_S2_3**. The ability to use simulation tools to evaluate the suitability of the design aspects of computer architecture and related areas.

***Learning outcomes***

Graduates who possess this ability should be able to:

1. Use simulation tools to test a complete design process and selected procedures from requirements analysis to final realization;
2. Apply the mathematical software tools for simulation of signals and systems and be able to verify that it fulfills the design criteria;

3. Design, analyze and implement digital filters in Matlab;
4. Simulate a digital communication system using Matlab and study its performance in presence of noise.

### 2.3.3 Engineering Design

**DCEN_S2_4**. The ability to design hardware components and building blocks of the computer systems. These designs and constructions must satisfy the hardware and software specifications as well as meeting the safety regulations and being cost effective especially once graduates enter into the job market

***Learning outcomes***

Graduates who possess this ability should be able to:

1. Validate their design procedures through performing practical experiments in the labs;
2. Satisfy the client's expectations once they enter into the job market since this is one of the most important aspects of the engineering services that one can offer to the community. In particular, provision of after sale services is of the highest importance that one has to provide;
3. Use the contemporary design techniques, together with the high-tech laboratory equipment and components in their design. This provides knowledge and preparation as how to use the most up-to-date facilities and prepares them for an easy start once they enter into the job market

### 2.3.4 Engineering Practice

**DCEN_S2_5**. The ability to participate in teamwork activity and multidisciplinary program and contribute towards critical thinking by getting involved in debating dialogues.

***Learning outcomes***

Graduates who possess this ability should be able to:

1. Demonstrate knowledge in written communication skills and being confident in oral presentations. Incorporate multimedia tools and software packages in the oral presentations;
2. Incorporate multidisciplinary programs (such as mechanical engineering, electrical engineering, management, economics, and industrial engineering) in the course of their study. This is particularly relevant to the practical component of their program in general and in the final year project in particular;
3. Demonstrate an active participation in teamwork activities. The outcome of this participation must be evident through improvements in communication skills, meeting the deadlines and exchange of the technical information.

## 2.4 Sub-discipline #3: Computer Networks

Computer networks skills include preserving the knowledge of the design and operation of variety of high tech equipment, devices and systems. Computer networks graduates should be able to utilize their fundamental knowledge in computer engineering in order to understand, analyze and design specialized network devices and systems under different working environment.

### 2.4.1 Engineering Science

**DCEN_ S3_1**. The ability to understand the communication systems including network architecture and the OSI reference model. This is complemented by understanding of the different aspects of transmission criteria and data schemes including multiplexing and spread spectrum.

***Learning outcomes***

Graduates who possess this ability should be able to:

1. Demonstrate an understanding of the OSI model for computer networks protocols as well as being familiar with the fundamentals of data transmission principles, time and frequency representation of signals, relation between data rate and channel bandwidth, and transmission impairments;
2. Identify the characteristics of the various transmission media and also demonstrate an ability to characterize the various data encoding techniques, and assimilate their design principles;
3. Describe the principles and operation of synchronous and asynchronous transmissions, and demonstrate an understanding of the principles of error detection and control;

4. Discuss the operation and architecture of the various multiplexing techniques, and be able to design simple data multiplexing systems. This is complemented by realizing the operation and architecture of spread spectrum techniques.

**DCEN_S3_2**. The ability to understand different network technologies and their applications in different environments. This includes being able to apply routing algorithms and network protocols:

***Learning outcomes***

Graduates who possess this ability should be able to:

1. Demonstrate an understanding of the end to end transmission and comparison between virtual circuit and datagram networks;
2. Apply and evaluate routing algorithms and classify and evaluate congestion control algorithms;
3. Demonstrate how to apply and evaluate Internetworking protocols and ability to describe IP protocol specification and operation.

**DCEN_S3_3**. The ability to identify different network models and categorize different software and hardware tools. Students are expected to be familiar with the web programming. Teamwork activity is highly recommended.

***Learning outcomes***

Graduates who possess this ability should be able to:

1. Demonstrate an understanding of transport protocols behavior and be able to identify networked and non-networked applications;
2. Gain knowledge to design and develop network applications from the elementary socket functions and design secure applications using DNS;
3. Design client-side and server- side web application and being familiar with network protocol analyzer.

**DCEN_S3_4**. The ability to understand computer networks and variety of the data link control (DLC). This is complemented by realizing the LAN and WAN standards.

***Learning outcomes***

Graduates who possess this ability should be able to:

1. Develop an understanding of the basic principle of client/server model which includes the basics of error detection including parity, checksums, and CRC;
2. Describe the concepts of reliable data transfer and how the link layer implements these concepts as well as knowing how to share a channel by using medium access control protocols;
3. Use hubs and bridges to build a LAN, as well as become familiar with Ethernet and Token ring networks. This would include understanding the network layers services (datagram, VC).

### 2.4.2 Engineering Analysis and Investigation

**DCEN_S3_5**. The ability to understand transmission media characteristics and impairments including digital modulation technique, basic shift keying methods and multiplexing technique.

***Learning outcomes***

Graduates who possess this ability should be able to:

1. Identify the characteristics of the transmission media and impairments together with being able to evaluate analog modulation techniques;
2. Demonstrate an understanding of and capability to evaluate digital modulation techniques as well as basic Shift Keying methods such as ASK, PSK, FSK;
3. Realize the operation and principles of multiplexing techniques as well as recognizing the basic modem operation and structure.

**DCEN_S3_6**. The ability to demonstrate an understanding of security concepts, attacks, services, variety of block schemes, public-key cryptography and RSA. This includes observing ethical aspects of the computer systems. At last but not least recognition of protocols and different classes of security levels including firewalls.

***Learning outcomes***

Graduates who possess this ability should be able to:

1. Identify the main security attack types and standard security terminology together with different block schemes;
2. Apply encryption and hash algorithms by hand and/or using calculator as well as being able to assess security vulnerabilities in authentication protocols;
3. Demonstrate capability in implementing the network security applications and protocols and being able to identify how to implement security at different system and network layers;

4. Decide appropriate firewall types and design firewall rules and being confident with the design of security policies based on needs and threats;
5. Recognize the ethical aspects of using computer systems.

**DCEN_S3_7**. The ability to exhibit an understanding of the optical fiber transmission medium, optical components and optical communications: expectations are coverage of different network topologies, bandwidth management, wavelength management, interoperability.

***Learning outcomes***

Graduates who possess this ability should be able to:

1. Identify optical networks architecture, components, and devices as well as being able to recognize the physical concepts upon which the optical components work;
2. Demonstrate familiarity with SDH/SONET networks and being able to identify DWDM network structure, building blocks, interfaces and management strategies;
3. Design and analyze optical networks including demonstrate capability in characterizing the optical technologies to meet desired system requirements.

### 2.4.3 Engineering Design

**DCEN_S3_8**. The ability to understand Peer-to-Peer and server-based networks with Common Transport Protocols and Router configuration together with bridged networks with emphases on performance analysis of LANs, Virtual and Wireless networks.

***Learning outcomes***

Graduates who possess this ability should be able to:

1. Demonstrate capability in applying different components such as switches and

routers to an active network as well as being able to evaluate different routing techniques;
2. Construct and configure virtual and wireless networks plus having confidence in producing access control lists for the routers and packet filtering firewalls;
3. Evaluate and measure QoS performance and exhibiting familiarity with the comparison of the transport layer protocols.

### 2.4.4 Engineering Practice

**DCEN_S3_9**. The ability to put into practice the gained knowledge in broadband networks and switches with different schemes as well as network control and management Protocols in High Speed Networks and SDH/SONET.

***Learning outcomes***

Graduates who possess this ability should be able to:
1. Characterize the high-speed networks and classify high-performance switches;
2. Demonstrate an ability to solve internal blocking in electronic/optical switches and be able to classify routing, congestion, and error control protocols;
3. Analyze management protocols in high-speed networks and evaluate quality of service performance in high-speed networks;
4. Put into practice and demonstrate ability to apply the fault tolerance techniques;
5. Gain hands on experience and practice in the area of high speed networks in the local market as well as being able to identify the standards and migration paths to future technologies

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## Appendix: Revised Bloom's Taxonomy [11]

| Categories | Cognitive Process | Sample Verbs Commonly used for Stating Specific Learning Outcomes |
|---|---|---|
| Remembering | Retrieve relevant knowledge from long-term memory<br>Recognizing<br>Recalling | Collect, Define, Describe, Examine, Identify, Label, List, Name, Quote, Show, Tabulate, Tell |
| Understanding | Construct meaning from instructional messages, including oral, written, and graphic communication<br>Interpreting<br>Exemplifying<br>Classifying<br>Summarizing<br>Inferring<br>Comparing<br>Explaining | Associate, Contrast, Describe, Differentiate, Discuss, Distinguish, Estimate, Extend, Interpret, Predict, Summarize |
| Applying | Carry out or use a procedure in a given situation<br>Executing<br>Implementing | Apply, Calculate, Change, Classify, Complete, Demonstrate, Discover, Examine, Experiment, Illustrate, Modify, Relate, Show, Solve |

| | | |
|---|---|---|
| Analyzing | Break material into its constituent parts and determine how the parts relate to one another and to an overall structure or purpose<br>Differentiating<br>Organizing<br>Attributing | Analyze, Arrange, Classify, Compare, Connect, Divide, Explain, Infer, Order, Select, Separate |
| Evaluating | Make judgments based on criteria and standards<br>Checking<br>Critiquing | Assess, Compare, Conclude, Convince, Decide, Discriminate, Explain, Grade, Judge, Measure, Rank, Recommend, Select, Summarize, Support, Test |
| Creating | Put elements together to form a coherent or functional whole; reorganize elements into a new pattern or structure<br>Generating<br>Planning<br>Producing | Combine, Compose, Design, Formulate, Generalize, Integrate, Invent, Modify, Plan, Create, Prepare, Rearrange, Rewrite, Substitute |

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