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

(Architectural Engineering)

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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.

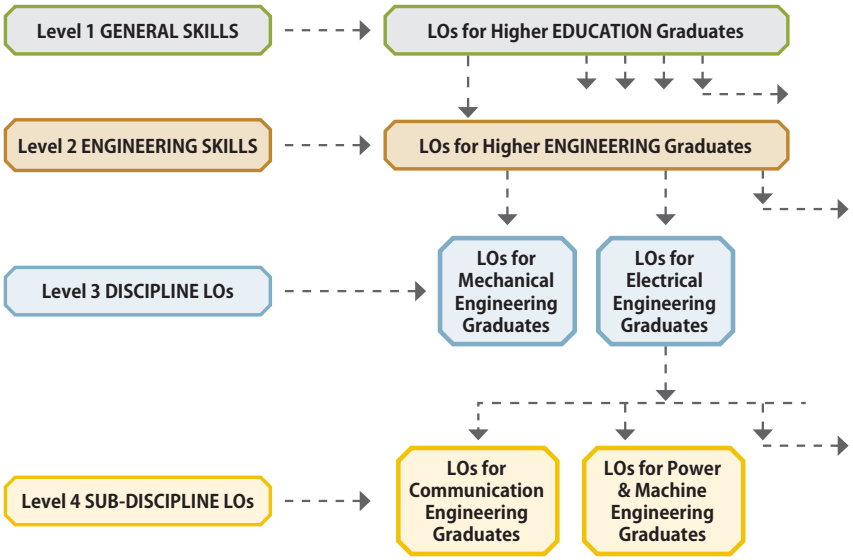

Fig. 1 Hierarchy levels of QIYAS Framework of Engineering Learning Outcomes

2. ARCHITECTURAL ENGINEERING LEARNING OUTCOMES (ARE)

2.1 Discipline Level Learning Outcomes

Architectural Engineering **(ARE)** skills include the understanding, knowledge and application of various architectural engineering subject areas, namely, architectural design, working drawings, environmental studies and control, building sciences and technologies, structural engineering, theory and history of architecture, building systems, electromechanical engineering and project management. Architectural engineering graduates should be able to build on their acquired skills pertaining to basic and engineering sciences, engineering analysis, engineering design, investigation and practice skills, and consequently acquire architectural engineering discipline-level skills.

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

2.1.1 Engineering Science

DARE1. Ability to apply fundamentals of the engineering sciences in the architectural projects.

Learning outcomes

Graduates who possess this ability should be able to:

1. Identify the basic scientific characteristics of building materials and technology and advanced technical tools that can be used in architectural engineering projects
2. Apply the principles of structural mechanics and structural systems to a wide range of practical structural problems.

DARE2. Ability to identify the influence of engineering solutions in economic, environmental, and social settings

Learning outcomes

Graduates who possess this ability should be able to:

1. Discuss the effect of building structures on the physical characteristics of the environment.
2. Explain the fundamental principles that govern the construction of buildings.

2.1.2 Engineering Analysis

DARE3. Ability to identify, analyze, and solve architectural engineering problems.

Learning outcomes

Graduates who possess this ability should be able to:

1. Illustrate abstract ideas to test design alternatives using evaluation criteria and standards.
2. Discuss the research methodologies and approaches to identify form, systems, architectural development and their influence on the social context.
3. Describe the principles used for the appropriate selection of building components and construction materials, based on their performance and interaction with environment.
4. Apply proper solutions for building envelope and systems in relation to performance, durability, thermal and moisture protection, aesthetics, energy efficiency and material resources.

DARE4. Ability to analyze building systems, components, structures and process to meet desired needs in the high performance projects.

Learning outcomes

Graduates who possess this ability should be able to:

1. Analyse the proper environmental systems for application in integrated projects as embodied energy, passive and active cooling techniques, using appropriate assessment tools for performance evaluation.
2. Describe the various buildings systems.

2.1.3 Engineering Design

DARE5. Ability to design innovative designs, conducts experiments and interprets data.

Learning outcomes

Graduates who possess this ability should be able to:

1. Explain with appropriate and different presentation techniques, using both traditional and digital techniques, to satisfy the project objectives and functions during the programming and design process.
2. Develop clear drawings; write specifications to identify the appropriate components, building materials and systems for building design.
3. Apply architectural design criteria and principles in the building design process.

DARE6. Ability to generate and develop concept of system designs that meet realistic challenges such as economic, environmental conditions, social behavior, political constraints, safety, and sustainability requirements.

Learning outcomes

Graduates who possess this ability should be able to:

1. Examine different ideas and concepts to select the appropriate alternatives in architectural and urban design projects.
2. Apply environmental and building systems to design a comprehensive functional sustainable project, using the natural recourses available in the site.
3. Identify the characteristics of both natural and man-made systems and their potential use to design a comprehensive project.
4. Apply the cultural and traditional understanding of the local indigenous, regional and national settings in the design process of projects.
5. Utilize the impacts of building construction and development operations to achieve designs of energy efficiency, zero carbon, and climatically adapted.
6. Apply the design of systems and facilities, which allow integrated independent and use by individuals of special needs.
7. Design a comprehensive project that expresses critical thinking and investigative

skills, accessibly, life safety, using the new techniques of environmental control and structural systems in buildings.

2.1.4 Engineering Practice

DARE7. Ability to work collaboratively with teams of architects and engineers of different disciplines involved in the development process of buildings and the built environment.

Learning outcomes

Graduates who possess this ability should be able to:

1. Abstract ideas to explain information, show respect to different points of view, and test alternatives and options to select the appropriate solutions.
2. Describe the architect engineer's skills and techniques required to work in collaboration with other disciplines in the building design, construction, and operation stages.

DARE8. Ability to illustrate the architect engineer's professional and ethical responsibility in the engineering development to satisfy the market's needs

Learning outcomes

Graduates who possess this ability should be able to:

1. Illustrate the values, diverse needs, behavioral pattern, cultures, and physical abilities and the implication of diversification on the architect's responsibilities.
2. Apply knowledge about the role of the architectural engineer, considering the profession laws and legislations.

DARE9. Ability to apply visual and verbal communication skills in the design and delivery processes of the projects.

Learning outcomes

Graduates who possess this ability should be able to:

1. Use appropriate presentational techniques to illustrate essential elements and ideas in the design process.
2. Illustrate technical drawings and models to identify accessibility and appropriate systems and building materials for projects design.

DARE10. Ability to recognize the engagement and need for life-long learning in the design and building process

Learning outcomes

Graduates who possess this ability should be able to:

1. Apply the principles and systems of safety and requirements at the early design process.
2. Identify the extent the built environment is designed and adapted to natural environment to satisfy human behaviour.

DARE11. Ability to apply knowledge about the significance of contemporary architectural principles and the historical development of the built environment.

Learning outcomes

Graduates who possess this ability should be able to:

1. Describe the responsibility in architectural design and practice regarding political, social and cultural issues, respecting the natural and historic resources to improve the quality of life.

DARE12. Ability to use modern tools, skills and techniques that are necessary to engineering practice.

Learning outcomes

Graduates who possess this ability should be able to:

1. Identify the responsibility of the architect to reconcile the needs of the community in terms of building codes, accessibility laws and environmental regulations.
2. Explain the methods and criteria for the selection of consultants, assembling teams and methods of project delivery.
3. Discuss the principles of time and risk management, arbitration and mediation, and recognition of trends, which influence practice.
4. Describe the building techniques and systems and skills architectural engineers use through design stages and construction process of building, considering both environmental and social context.
5. Illustrate the fundamentals costs of building and financial feasibility such as operational costs, project funding and financing during the design and construction processes.

DARE13. The ability to manage architectural engineering projects and understand the complications that can face the building processes.

Learning outcomes

Graduates who possess this ability should be able to:

1. Develop project work plan and detailed schedule of deliverables through all the design stages.
2. Monitor project schedule during the building construction.
3. Perform detailed cost and control budget expenditures.
4. Recognize the property development process and contractual issues.
5. Deal with all unexpected problems and risks.
6. Control and organize the relation between the project designer, the contractor, and the developer, and the building user through the building process.

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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 Recognizing 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 Interpreting Exemplifying Classifying Summarizing Inferring Comparing Explaining	Associate, Contrast, Describe, Differentiate, Discuss, Distinguish, Estimate, Extend, Interpret, Predict, Summarize
Applying	Carry out or use a procedure in a given situation Executing 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 Differentiating Organizing Attributing	Analyze, Arrange, Classify, Compare, Connect, Divide, Explain, Infer, Order, Select, Separate
Evaluating	Make judgments based on criteria and standards Checking 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 Generating Planning Producing	Combine, Compose, Design, Formulate, Generalize, Integrate, Invent, Modify, Plan, Create, Prepare, Rearrange, Rewrite, Substitute

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