ASEE's 123rd Annual • Conference & Exposition • New Orleans, LA • June 26-29, 2016

New Orleans JAZZED about Engineering Education

Paper ID #15721

Re-design of Engineering Mechanics I (Statics) Using CAP Model

Mr. Khalilullah Mayar, Purdue University, West Lafayette

Khalilullah Mayar is a current Fulbright scholar and a former junior faculty at Kabul Polytechnic University where he taught introduction to engineering, and engineering mechanics courses for a couple of years to undergraduate students. Currently he is pursing a masters in construction management at Purdue University. His research interests includes, engineering education, construction site productivity, and construction operations simulation and modeling.

Re-design of Engineering Mechanics I (Statics) using CAP Model

Re-design of Engineering Mechanics I (Statics) using CAP Model

(A Sophomore Level Course for Engineering Students)

Abstract

Engineering Mechanics I (Statics) is a three credit hour, sophomore level course which mainly deals with the study of objects that are either in the state of rest or uniform motion - under the interaction of various forces acting in two and three dimensional space. " For many engineering disciplines —such as Aerospace, Biological, Chemical, Civil and Mechanical— Statics servers as a prerequisite for more advanced mechanics courses including Dynamics, Fluid Mechanics, and Mechanics of Materials" (Rais-Rohani, Walters, & Vizzini, 2010, p. 1). Learning Statics requires a considerable attention as the course concepts serve as "the building blocks for future courses in engineering, mechanics of solids and design in particular. There is a common disappointment among many educators in the students' abilities to apply the concepts to design/analyze real systems in the subsequent courses" (Condoor, Jayaram, & Boyer, 2008, p. 1).

This paper describes re-design of the Engineering Mechanics I (Statics) course based on the outcome based learning and also student-centered learning theories by integrating the *Content, Assessment and Pedagogy* together in a single model abbreviated as CAP, and utilizing the Backward Design Process. In contrast to the common course design approach, in Backward Design Process, learning outcomes are considered crucial and therefore identified at the beginning of the course design process (Streveler, Pilotte, Smith, & Smith, 2012). In order to make sure the contents are properly aligned with the assessment, the Assessment Worksheet and the Assessment Triangle Method explained by Pellegrino et al (2001) is used where cognition, observation and interpretation are closely aligned to each other. Lastly the pedagogy part of the course design process is essentially aligned in accordance with the Perkins (2009) Making learning whole- seven principles with special emphasize on the “working on the hard parts”, play out of town, and learning from the team principles.

Keywords: *Backward Design Process, Course Design, Outcome Based Learning, Statics.*

I. INTRODUCTION

A. Setting for the Curriculum Project

The specific setting for this curriculum project is outlined as follow:

1. Salient characteristics of the institution or sponsoring organization

As described by Anand (2005), " Engineering Mechanics - Statics is a core course in most of the engineering disciplines, and is generally taught by a civil and/or a mechanical engineering faculty at the nations' ABET accredited colleges and universities" (p.1). The institutional setting for this course is also considered an ABET accredited engineering college that offers undergraduate degree programs for *civil engineering and/or mechanical engineering* students. This course is not designed to be taught in a particular institution, neither is it sponsored by any organization.

2. Salient characteristics of the intended learners of the institution

The specific salient characteristics for the intended learner are explained in the following sub-categories:

a. Learners background in the target domain

As mentioned before, *Statics* is a sophomore level course that is normally offered for second year students in several engineering disciplines including civil engineering and mechanical engineering. The students who get enrolled in this course should have already successfully completed the freshmen-level Math and Physics courses in their relevant disciplines which enable them to do basic algebraic manipulations as well as proper knowledge of the basic Newton Laws.

b. Learners developmental level or age

Statics is the first course in the series of *engineering mechanics courses* which lays a foundations for subsequent courses, i.e., Dynamics, Strength of Materials and other structural design courses. Mastery of the basic concepts and skills from Math and Physics will help students better understand and analyze the concepts of statics and make this foundation solid.

3. Other important contextual issues

Statics is different from the preliminary Newtonian physics in many ways and it's not all about mathematical model solving skills either. It combines both of them and also utilizes critical thinking in order to solve the real world problems. Many of the students enrolled in *Statics* carry along with themselves some misconceptions from the courses they have previously attended. e.g. Uncertainty about the existence of forces among the relatively rigid and unmoving objects (Steif & Dollar, 2005). In this course design module, the author tries to identify those misconceptions and provide the strategies and techniques which can help students to overcome the misconceptions.

The course delivery method is basically considered lecture -based with some lab/practical activities inside the classroom. There will be a total of 15 sessions (excluding 2 exam sessions) throughout the semester with each session lasts for 150 minutes. The first 60 minutes of each session is assigned for students to work in teams on physical artifacts that simulate basic *Statics* concepts from the previous class, and the rest of the class is assigned for a highly visualized and interactive type of lecture, and other course activities described in the course (syllabus).

B. Motivations behind selecting this target domain

Many teachers who teach *Statics* are disappointed regarding the inability of their students in applying the learned concepts in analyzing and designing the real world problems in succeeding courses for which *Statics* is considered as a cornerstone (Condoor et al., 2008). Based on the author's experience in teaching the subject topic, students normally struggle learning *Statics,* as most of the time their main focus is on memorizing the mathematical modules and equations used for solving the problems, while they miss grasping the main concepts which *Statics* is really intended for. Moreover the major part of the relevant literature review reveals, that still some instructors teach *Statics* through traditional type of lectures which is less interactive, as well as, the student engagement and the design problems' relevancy to the real world is limited. In addition to this, in many cases, the instructors mainly test students on the accuracy of the mathematical operations used in solving the problems rather than utilizing a specific strategy to measure if the students have actually learned the core concepts of the course. Through this module of course design, the author has strived, first to identify the curricular priorities for the course that match with course objectives and afterwards by using appropriate Outcome Based Learning techniques, the selected contents have been aligned with the assessment and pedagogy parts for yielding better learning outcomes.

II. CONTENT

The contents section for this course is selected in a full compliance with the Backward Design principles by Wiggins & McTighe (2005) as well as using the contents from *Statics* course syllabi from ABET-accredited engineering colleges. In the Backward Design process, first the "Desired results" are identified, followed by determining the "Acceptable evidence" which assures that the intended learners have gained the desired results. At the end having the learning results identified, together with the appropriate evidence for testing it, the final stage is "planning the learning experience" through which instructors plan their instructional activities.

A. Curricular Priorities

According to Wiggins & McTighe (2005) the first stage of Backward Design is identifying the desired results that are organized based on their priorities in the following three categories:

1. Enduring outcomes

As described by Wiggins & McTighe (2005) this portion of the curricular priorities encompasses the content and "big ideas that have enduring value beyond the classroom" as well as "reside in the heart of discipline" and also those that "require uncoverage and offer potential for students engagement". Based on the research findings as explained by Condoor et al. (2008); Steif and Dollar (2005) the main output of learning statics can be briefed in the following couple of points:

- Ability to visualize and interpret the connection between variables they are used. e.g. forces, moments, couples, etc. and what they stand for in reality.
- Development of critical thinking to apply the fundamental concepts and laws of Statics. e.g. forces, moments, couples, static equivalency, equilibrium, free body diagrams, etc. in

analyzing of the similar situation in the subsequent courses as well as to the real life engineering problem solving practices.

The aforementioned statements successfully passes the four filters outlined by Wiggins & McTighe (2005) and therefore can be considered as the enduring outcomes for the Statics course.

2. Important to know

According to Wiggins & McTighe (2005) the *Important to know* part of the *curricular priorities* are the knowledge and skills if the student doesn't know these materials at the end of the course, the learning outcomes are not accomplished. In other words “It specifies the prerequisite knowledge and skills needed by students for them to successfully accomplish key performance" (P.4). Considering this principle and looking at the *Statics* syllabi from some ABET-accredited engineering colleges, i.e., Walla Walla Community College and University of Arizona civil engineering programs. , the *Important to know* part of this course which help students in achieving their main goals for the course can be summarized in the following points:

- Ability to apply basic Math and Physics principles in formulating and solving different engineering problem.
- Ability to identify different type of loads/forces, friction and support systems.
- Understand the meaning of center of gravity, moment of inertia, and virtual work.
- Ability to analyze and interpret finite structures.

3. Good to be familiar with

The knowledge and skills assigned to this portion of *curricular priorities* as explained by Wiggins & McTighe (2005) are those contents that students "should find worth being familiar with". In other words " what do we want students to hear, read, view, research, or otherwise encounter during the course" (P.3). Based on the author's own experience teaching the course, the following points can be included in the *Good to be familiar with* section of the *curricular priorities*:

- Ability to know how different formulas were derived dealing with solving different concepts of the course.
- Ability to use specific methods for analyzing specific type of definite structures.

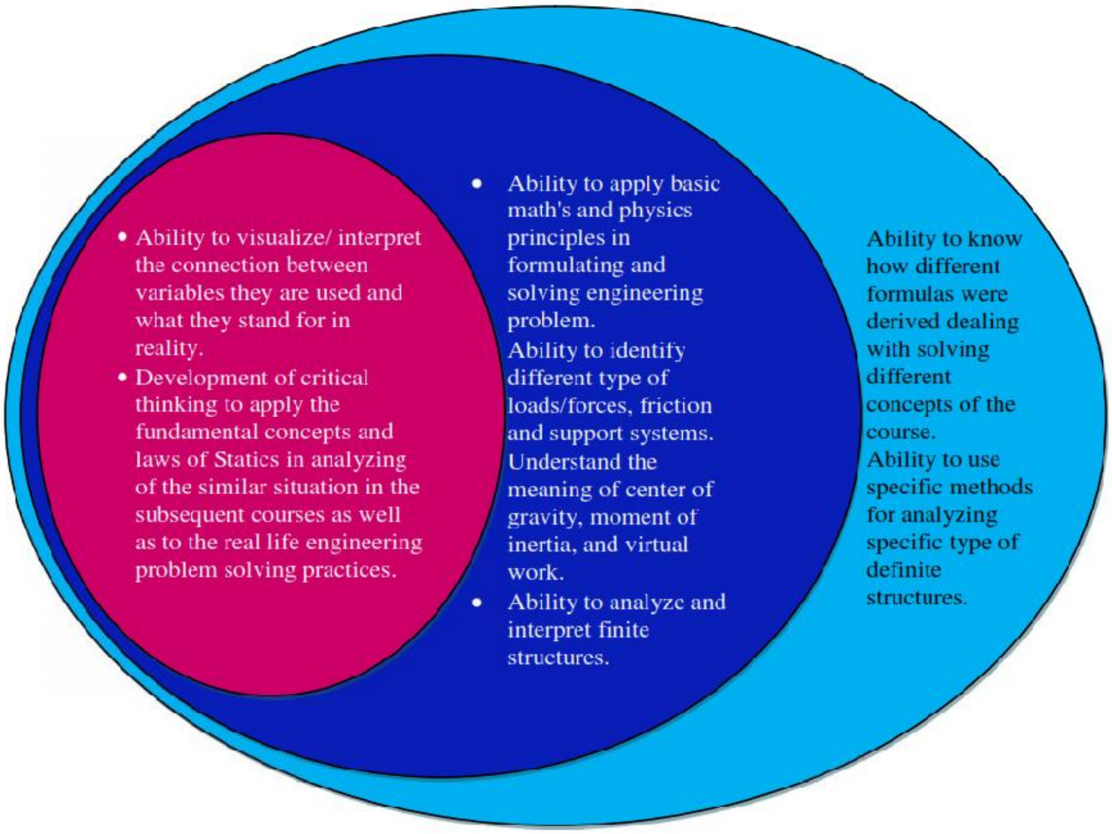

Figure 1. Three nested rings used by Wiggins & McTighe (2005) for describing curricular priorities

B. Concept map

Concept maps are the graphical representation of how the concepts/ideas in a target domain are interconnected to each other. Considering the above three different stages of curricular priorities for the course, the author has come up with the following concept map for *Statics*:

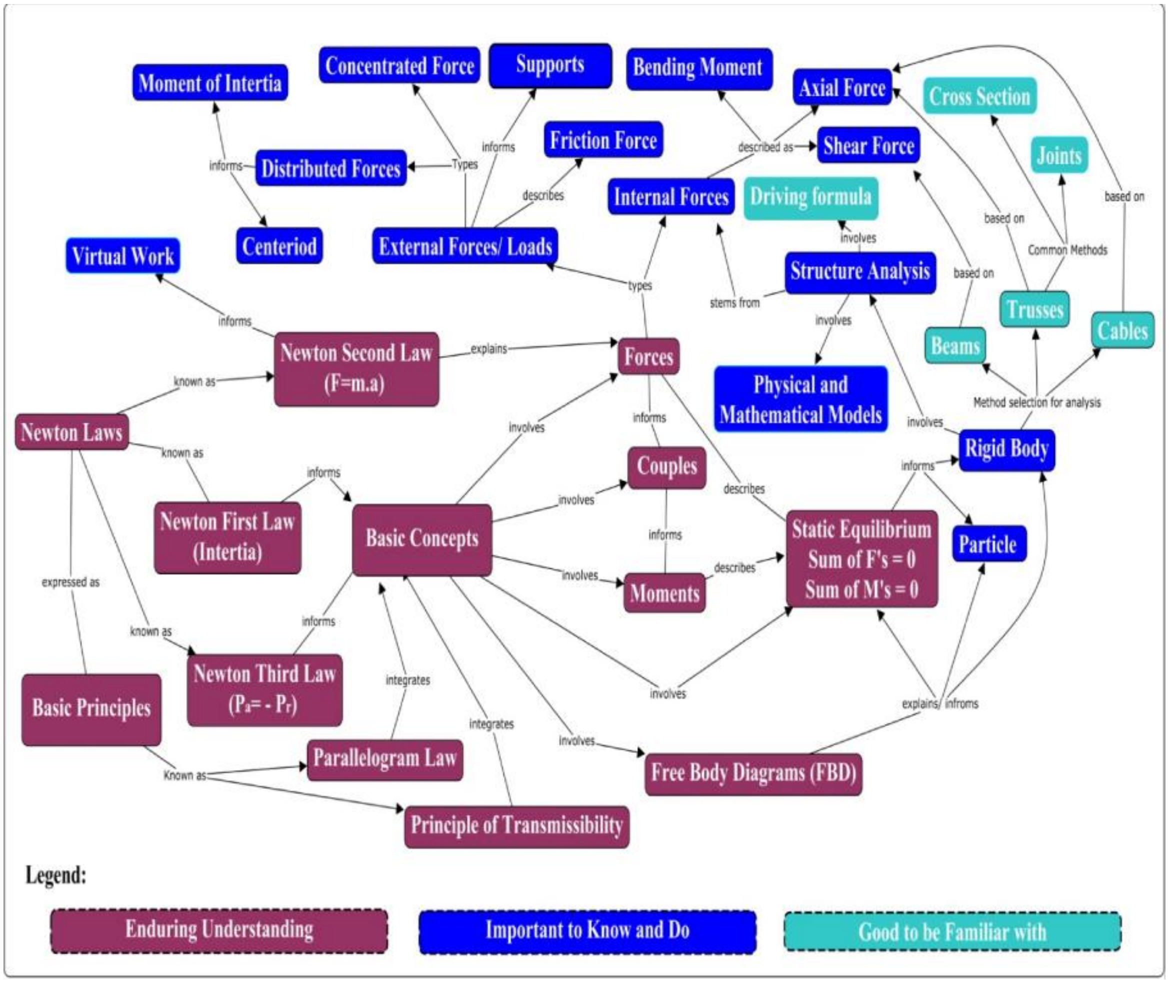

Figure 2. Concept map for the curricular priorities of *Statics*

1. Concept map description

The concepts/contents encompassed by the above drawn concept map have been grouped into three parts: *Enduring Understanding*, *Important to Know and Do*, and *Good to be Familiar with*. Each concept's connection with another one is explained by using vectors along with appropriate notations describing the relationship between them. *Enduring Understanding* concepts colored in purple are laying as a main stem in the center of the map, with *Important to Know* and *Good to be familiar with* respectively in blue and sky blue colors, as the branches .

2. Concept map alignment with curricular priorities

The concept map alignment with curricular priorities is described in the following table:

Table 1. Concept map alignment with curricular priorities

Curricular Priorities		Contents from Concept Map
Enduring outcomes	Ability to visualize and interpret the connection between variables they are used and what they stand for in reality.	Forces Couple Moment Static Equivalency Equilibrium
	Development of critical thinking to apply the fundamental concepts and laws of Statics in analyzing of the similar situation in the subsequent courses as well as to the real life engineering problem solving practices.	Newton Laws • Inertia • F=m.a • Pa = - Pr Other principles • Parallelogram law • Principle of transmissibility Free Body Diagrams
Important to know	Ability to apply basic math's and physic's principles in formulating and solving different engineering problem.	Free Body Diagrams Mathematical Models Principles of physics
	Ability to identify different type of loads/forces, friction and support systems.	Internal Forces/Effects • Axial Force • Shear Force • Bending Moment External Forces/Effects • Concentrated Force • Distributed Forces • Friction Supports/Connections • Roller Support • Pinned Support • Fixed Support
	Understand the meaning of center of gravity, moment of inertia, and virtual work.	Center of gravity Moment of Inertia Virtual work
	Ability to analyze and interpret finite structures.	Understanding the concept of Structure Analysis in Rigid bodies.

Good to be familiar with	Ability to know how different formulas were derived dealing with solving different concepts of the course.	For instance formulas used for finding centroid's, moment of inertia's, statics equivalency, virtual work, etc.
	Ability to use specific methods for analyzing specific type of definite structures.	For instance: Mathematical equations selection used in *section* and *joints* methods for analyzing structures. e.g. beams, trusses, frames, cables. etc.

C. How do people learn

Statics as an essential course included in the majority of engineering curricula, dealing with the study of objects in the state of equilibrium under the effect of different forces. But majority of students have difficulties learning this course. As described by Venters, McNair, and Paretti (2013) *Mastery* of *Statics* as the base point in engineering mechanics is considered as a "Conceptual gateway" that paves a new way of thinking about objects and systems which otherwise was not available. In order to students have a good command of engineering problem solving skills in engineering mechanics, as well as, to make appropriate links between the concepts and the relevant real life problems, "They must engage in both procedural and conceptual learning of problem solving" (p.2) Because this is one of the main difference between experts and novices, as the novices contrary to experts, mainly focus on the procedural learning of the problem and have difficulties in linking these concepts to the real life problems. Therefore "Metacognition" can be used as a useful tools in this regard. The "approaches such as writing out problem solution process may promote metacognition" (p.2).

The main part of *the theoretical framework* for this course design which particularly addresses to the enhancement of the linkage between procedures and concepts in statics, is based on three major parts of the "Cognitive Learning Theory: expertise, conceptual and procedural knowledge development, and conceptual change" (P.3). According to Venters et al. (2013) experts have both conceptual and procedural knowledge of the field. Which means that their knowledge has meaningful connections, is interrelated, and is organized into big concepts. This meaningful nature of the knowledge makes easy the "quick retrieval of pertinent information from long term memory" back into the working memory. Moreover based on their working experience, the experts possess procedural knowledge of how to apply the conceptual knowledge in solving the real life problems. Venters et al. (2013) say that yet there is not a common consensus among researchers that either conceptual or procedural knowledge develop first in the novices as well as on their relative importance. But the research proposes that these two types of knowledge are "interlocked" and therefore should expand together for a successful learning process. Additionally Venters et al. (2013) explain that "As novices transition from naive understanding to more robust conceptions, their conceptual knowledge is altered through a process called *conceptual change*" (P.4). It further adds that, this conceptual change which is normally either in the form of "enrichment" where fresh knowledge is added to the present knowledge structures, or in the form of "revision" where the structure of present knowledge is changed, have not been researched in the engineering courses like statics. This theoretical framework helps students make a better mastery of the required skills for problem solving and pave the ways for validating the *Enduring outcomes* of the course design.

1. What difficult concept or misconceptions have been identified?

According to Douglas, Roman, and Streveler (2010) students misconceptions and errors normally originate from one of the four concepts that students are unable to properly understand and apply. Steif outlined these concepts in four conceptual clusters that are deemed essential for the analysis of engineering problems, as follows:

> (C1) Forces are always in equal and opposite pairs acting between bodies, which are usually in contact. (C2) Distinctions must be drawn between a force, a moment due to a force about a point and a couple. Two combinations of forces and couples are statically equivalent to one another if they have the same net force. (C3) The possibilities of forces between bodies that are connected to, or contact, one another can be reduced by virtue of the bodies themselves, the geometry of the connection and/or assumption of friction. (C4) Equilibrium conditions always pertain to the external forces acting directly on a chosen body, and a body is in equilibrium if the summation of forces on it is zero and the summation of moments on it is zero (Douglas et al., 2010, p. 4).

Additionally Douglas et al. (2010) describe that the following ten *common errors* are recognized after several years of students' observation which students normally do while solving problems in Statics:

> (1) Failure to be clear as to which body is being considered for equilibrium. (C4)
> (2) Failure to take advantage of the options of treating a collection of parts as a single body, dismembering a system into individual parts, or dividing a part into two. (C4)
> (3) Leaving a force off the FBD when it should be acting. (C1, C4)
> (4) Drawing a force as acting on the body in the FBD, even though that force is exerted by a part which is also included in the FBD. (C1, C4)
> (5) Failing to account for the mutual (equal and opposite) nature of forces between connected bodies that are separated for analysis. (C4, C1)
> (6) Ignoring a couple that could act between two bodies or falsely presuming its presence. (C2, C3)
> (7) Not allowing for the full range of possible forces between connected bodies, or not sufficiently restricting the possible forces. (C2, C3)
> (8) Presuming a friction force is at the slipping limit, even though equilibrium is maintained with a friction force of lesser magnitude. (C3)
> (9) Failure to impose balance of forces in all directions and moments about all axes. (C4)
> (10) Having a couple contribute to a force summation of improperly accounting for a couple in a moment summation. (C2) (Douglas et al., 2010, p. 4).

All the above stated misconception are mainly relevant to the problem solving practices which are located on the *Enduring outcomes* part of the course design.

2. How do people develop as they build more expertise in this area?

One of the most efficient ways by which novices improve their engineering problem solving skills and become experts is Cognitive Apprenticeship. According to Moseley and McCord (2014) the way novices and experts are categorizing problems is different. Novices are normally looking at the physical characteristics/ properties specified in the problem statement in order to categorize the problems into groups. While experts used the information of the circumstances given for the specific problems in order to categorize them. Which means that they use different cognitive strategies for arranging of the problems into groups. In *cognitive apprenticeship* novices learn the cognitive strategies for engineering problem solving used by the experts though an apprenticeship process. Moseley and McCord (2014) explain there are four major parts to designing courses based on the *cognitive apprenticeship model: Content, method, sequencing and sociology.* It further adds*:*

> The area of content focuses on the types of knowledge that one must hold in a content area to be considered an expert. The method category refers to the ways that are used to promote the development of expertise. Sequencing refers to the order in which learning activities should be presented to develop expertise. Finally, sociology refers to the social context of learning environments that promote development of expertise (Moseley & McCord, 2014, p. 3).

As described by Moseley and McCord (2014) one of the most important element of the *cognitive apprenticeship* for transforming the novices into experts in the engineering problem solving process of statics [*enduring outcomes*], is highlighting and making clear for novices, the ways experts use their content knowledge in solving engineering problems in statics.

III. ASSESSMENT

As the second item in Backward design principles by Wiggins & McTighe(2005), assessment is referred to as *acceptable evidences* which assures that the intended learners have gained the desired results from the selected contents as well as assessment is properly aligned with the curricular priorities. This section is further explained by the following components:

A. Learning Objectives

The learning objectives as described by the Anderson, Krathwohl, and Bloom (2001) must be measureable, obtainable, clearly stated, and aligned the curricular priorities. The learning objects for this course encompasses the *Enduring outcomes* and *Important to know* parts from the curricular priorities and they are in full accordance with the ABET - accredited engineering colleges Statics syllabi. e.g. Walla Walla Community College and University of Arizona civil engineering programs. At the end of this course student should develop the following abilities that are referred to as the *Learning objectives*:

LO1. Ability to work to apply basic engineering mechanics principles required for analyzing and solving statics structures.

LO2. Ability to identify an appropriate structural system to studying a given problem and isolate it from its environment.
LO3. Ability to identify and model various types of loading and support conditions that act on structural systems.
LO4. Ability to find out centers of gravity/centroids and moments of inertia using integration methods.
LO5. Ability to model the problem using good free-body diagrams and accurate equilibrium equations.
LO6. Ability to communicate the solutions to all problems in an organized and coherent manner and elucidate the meaning of the solution in the context of the problem. (“Engineering Mechanics(Statics) Syllabus,” 2007, p. 1)

B. Learning objectives alignment with curricular priorities

Learning objectives alignment with the curricular priorities is shown in the following table:

Table 2. Learning objectives alignment with curricular priorities

Curricular Priorities		Learning Objectives
Enduring outcomes	Ability to visualize and interpret the connection between variables they are used and what they stand for in reality.	• LO.1 • LO.5 • LO.6
	Development of critical thinking to apply the fundamental concepts and laws of Statics in analyzing of the similar situation in the subsequent courses as well as to the real life engineering problem solving practices.	• LO.2
Important to know	Ability to apply basic Math and Physics principles in formulating and solving different engineering problem.	• LO.5
	Ability to identify different type of loads/forces, friction and support systems.	• LO.3
	Understand the meaning of center of gravity, moment of inertia, and virtual work.	• LO.4
	Ability to analyze and interpret finite structures.	• LO.2 • LO.6

C. Learning objectives taxonomy

For mapping the course objectives the Author uses the Revised Bloom's Taxonomy developed by Anderson et al. (2001). Where each of the course objective is mapped in a two-dimensional table, with the vertical dimension describing the nature of the knowledge and the horizontal dimension indicating the cognitive aspect of the knowledge:

Table 3. The Revised Bloom's Taxonomy for mapping the learning objectives

Course Objectives		Cognitive Aspect Dimension					
		Remember	Understand	Apply	Analyze	Evaluate	Create
Knowledge nature Dimension	Factual Knowledge			LO.4			
	Conceptual Knowledge		LO.4 LO.6	LO.1 LO.2 LO.3	LO.1 LO.2 LO.3		
	Procedural knowledge		LO.6	LO.1 LO.2 LO.3 LO.4 LO.5			
	Metacognitive Knowledge			LO.1			

D. Assessment Triangle

For better aligning assessment with the course content, an Assessment Triangle is developed for one of the most important learning objectives (LO.1) that belongs to the *enduring outcomes* part of the curricular priorities. According to Pellegrino et al. (2001) the Assessment Triangle consists of three different corners: cognition, observation, and interpretation that should be properly aligned to each other:

LO1. Ability to apply basic engineering mechanics principles required for analyzing and solving statics structures.

Interpretation

The teacher can interpret the students' mastery of this skill, as well as anticipate the achievement of this objective by documenting the followings:

- Students can easily apply the basic mechanics principles to the physical artifacts they are working on inside the classroom in groups, first by solving these artifacts problems in their notebooks. They can receive regular feedback from their group fellows, as well as from the teacher on the hard parts.
- Every student can easily apply the basic mechanics principles to the real world problems assigned by the teacher as the required but ungraded class assignments through report writing of the entire application process and then presenting to the class while discussion their Metacognition aspects as well.
- Every student can easily apply the basic mechanics principles to a real world engineering problem; a 3- stage class project done throughout the semester, for which they receive ungraded feedback from the professor at the first two stages, as well as with a final graded feedback. All the processes are reported in a written form which specifically states which principles and how they were applied.

Observation

Working on real world problems of statists structures (i.e., physical artifacts, real world problems visual multimedia representation, etc.) as class activities, class assignment and a multi stage class project independently and in groups.

Assessment Triangle (LO.1)

Cognition

Enhancement of the linkage between procedures and concepts based on the major parts of the Cognitive Learning Theory (Venters, McNair, & Paretti, 2013): expertise, conceptual and procedural knowledge development, and conceptual change.

Figure 3. Assessment triangle for learning objective.1

E. Assessment work sheet for each of the three most important learning objectives

For better alignment of the content and assessment parts together, the Assessment work sheet which was first developed by Shanna Daly in the Content, Assessment and Pedagogy class (Streveler et al., 2012) has been used for the three most important learning objectives (i.e., LO.1, LO.2 and LO.6) that relate to the enduring outcomes part of the curricular priorities.

Table 4. Assessment work sheets for LO.1, LO.2, and LO.6

<table>
<tr><td rowspan="3">LO.1 :
Ability to work to apply basic engineering mechanics principles required for analyzing and solving statics structures.</td><td>General:
Group discussions, written class assignments, 3-stage final project and presentations.</td></tr>
<tr><td>Claim:
• Students will apply the basic mechanics principles to the physical artifacts problems by recording the relevant process in a written form for each specific principle used.
• Students will apply the basic mechanics principles to solving the real world engineering problems in the form of written class assignments where each principle is specified and the appropriate FBD and mathematical models are selected (LO.5 and LO.6) as well as they will be able to orally describe the Metacognition process behind the selected relevant principles.
• Students will be able to present their final 3-stage class projects on a real world engineering problem in front of the class reasoning each principle applied in the project, as well as the Metacognition process behind it.</td></tr>
<tr><td>Task:
• Students work in 2-5 person groups doing hands -on laboratory experiments on physical artifacts (Rais-Rohani et al., 2010), matching it up with the appropriate mechanic principles and writing down their entire application process.
• Students work on the real world engineering problems selected by the professor both inside and outside the classroom in the form of written class assignments. Then presenting it to the relevant groups of students describing every principle used and also the Metacognition process behind the entire problem solving process. Feedback from peers and also the professor is provided.
• Student works in groups on a 3-stage class project of a real world engineering problem selected by them in compliance with the specific criteria determined by the professor (Described in the authentic task part). The first two stages of the project is a detailed ungraded feedback while the final submission is graded. Moreover each group is required to orally present the project to the entire class describing the principles that are used and how they are selected.</td></tr>
</table>

	Evidence: Documenting the following: • Ability to identify the appropriate principle to the real world problem (Class room/Lab activities, written class assignment and a final 3-stage project). • Ability to select appropriate FBD and mathematical model (LO.2 and LO.5) for solving the problem. • Ability to communicate the problem solutions in written (LO.6) as well as ability to orally describe the Metacognition process behind it.
LO.2 : Ability to identify an appropriate structural system to studying a given problem and isolate it from its environment.	General: Group discussions, written class assignments, 3-stage final project and presentations.
	Claim: • Students will apply the appropriate free body diagrams and structural schemes to the given engineering problems by identifying the appropriate supports/connections, applied loads and other statically determinate structures related assumptions.
	Task: • As described on the LO.1 part, students work on engineering problems (Class room/Lab activities, written class assignment and a final 3-stage project) and as a part of the problem solving process they select a proper structural system for the given problems by drawing the appropriate free body diagrams, identifying relevant supports/connections, applied loads and other statically determinate structures related assumptions.
	Evidence: • Documenting application of the proper structural system in the classroom room/lab activities, written assignment and a final 3-stage project by drawing the appropriate free body diagrams, identifying the imposed loads and support/connection conditions as well as other statically determinate structures related assumptions relevant to the specific problem.
LO.6 : Ability to communicate the solutions to all problems in an organized and coherent manner and elucidate the meaning of the solution in the context of the problem.	General: Group discussions, written class assignments, 3-stage final project and presentations.
	Claim: • Students can communicate the problems solutions in written form as well as be able to verbally explain both the concepts and procedures utilized in the specific statistically determinate structures problems in a systematic, coherent and precise manner.
	Task: • Students work on the class classroom room/lab activities, written class assignments and a final 3-stage project of engineering problems both

	inside and outside the classroom and present the output in a written report form as well as defending it verbally in front of the peers and the entire class.
	Evidence: • Documenting that students have written systematically and precisely the entire problem solving process for the class/lab activities, written class assignments and a final 3-stage project in specific steps determined by the professor (for the authentic performance task: preliminary design, detailed design and construction stages) as well as presenting and also defending it verbally in front of the peers and the entire class.

F. The most authentic assessment selection

As described by Hansen (2011) the best way to assess the students understanding in a given topic is to give them an opportunity to solve the real world situation problems that are similar or identical to what they were taught in the course. For this course design, the author has selected a 3-stage project as an authentic performance task. Through this project students will work in groups of 2-5 depending on the total number of students in the class, on a wooden truss bridge design project as described by Norman and Thompson (2008) to carry the maximum of load per unit of mass as well as the students will be able to calculate the load carrying ability of their trusses. As stated by Norman and Thompson (2008) every group will be provided with exact amount of materials that are used in the truss construction process (i.e., 200 wooden splits of 5.4"x0.2"x0.04" and a bottle of specific glue). Some of the design constraints explained by Norman and Thompson (2008) are as follows:

- The bridge truss has to be made of "two identical, vertical, two-dimensional (plane) trusses".
- The bridge has to be single spanned with a span of 16" between two supports and a horizontal contact surface underneath.
- The truss height from the level of support shall not exceed 10" and the depth of the truss under the level of supports shall not be more than 4".
- The truss shall be minimum 3.5" wide with cross beams between joints, where it can accommodate the application of a load area of 7"x3" at the center of truss.
- There must be two joints on of truss at the center with 5" spacing where the loads will be applied.
- The truss structure shall be statically determinate with no gusset plates at joints. Joints are formed by over lapping the sticks (over lap must not be more than the width of two sticks).
- Students are allowed to cut, re-split the wooden pieces as per their choice.
- According to Norman and Thompson (2008) the project is consisted of the following three stages:

    - **Preliminary Design Stage:** Each group select one of the three simple truss configuration forms, Pratt, K, and Baltimore for a single span of 16" and select the appropriate type based on a variety of loads applications.

- **Detailed Design Stage**: After the truss type selection, students work on the detailed design of their selected trusses considering the given data by professor on the truss materials strengths for different type of stresses (i.e., sticks and glue). Students do a structure analysis for the stresses and identify the potential weak members that might fail during the load application process as well as they identify the maximum load that the truss can withstand it without collapsing.
- **Construction Stage**: Students take the specified amount of materials and construct their trusses that will be used later on for loads application experiment, as a result of which the actual maximum load and the failure member will be identified. Afterwards the student will compare their previous predications with the actual results and find out the potentials gaps that might exist in the design process.

In compliance with the six criteria's set by Hansen (2011); the selected authentic performance task meets these requirements as explained in the following table:

Table 5. Six important criteria selecting an appropriate authentic performance task

No.	Criteria	Application to the selected task
1	Be realistically contextualized.	It represents a real word bridge design problem.
2	Require judgment and innovation.	Students are free to select the appropriate configuration type for the truss, number of members, joints and some other features of the bridge.
3	Ask the student to "do" the subject.	Students not only do the design problem by producing the design drawings and reports, but also practically do the construction of the truss bridge and apply specific loads on it.
4	Replicate key challenging situations in which professionals are truly tested in the workplace or in their personal life.	It replicates the key challenges of real life engineering problems by the specific design constraints set by the professor for students while doing the project (i.e., limited amount of materials, specific design criteria's: truss span, height, etc).
5	Assess the student's ability to use a repertoire of knowledge and skill.	It is a comprehensive task that covers many of the static's concepts and principles (i.e., equilibrium, internal/external forces, structure analysis, etc).
6	Allow appropriate opportunities to rehearse, practice and get feedback.	It is a 3-stage project as the students get a detailed and ungraded feedback for the first two drafts and a graded feedback for the final draft of the project.

G. Rubric for the authentic assessment evaluation

According to Hansen (2011) a good grading rubric for an assignment has to clearly communicate what the students are expected by doing the assignment and how it help them in reaching out to the course outcomes. He further adds that a good grading rubric is consisted of the quality and level of mastery dimensions along with the commentary part that define each of these two dimensions. Considering the above and with reference to the design projects in statics developed by Atadero, Balgopal, Fontane, and Hernandez (n.d.) , the author has accepted the following 3-point scale quality rubric for assessing the authentic performance task:

Table 6. Rubric for assessing the authentic task, a 3-stage class project (LO.1, LO.2 and LO.6)

Quality / Criteria	Excellent Proficiency (100 %)	Satisfactory Proficiency (80%)	Unsatisfactory Proficiency (60% and lower)	Rating
Preliminary Design Stage				
Simple truss type selection	Project report highlighting one sample of each of the truss type with specific loads application. Selection of the truss type backed up with required calculations and logical reasoning	Project report highlighting one sample of each of the truss type with specific loads application. Selection of the truss type backed up with limited calculations and logical reasoning	Project report highlighting one sample of each of the truss type with inconsistent loads application. Selection of the truss type backed up with no calculations and logical reasoning	
Drawings	Drawings drawn by hand or Auto CAD with all the required dimensions and at least two of the truss bridge views.	Drawings drawn by hand or Auto CAD lack some of the dimensions details or one of the truss bridge views.	Drawings drawn by hand or Auto CAD that lack on all/substantial part of the dimensions and specific views of the truss bridge.	
Detailed Design Stage				
Analysis of the truss bridge	Magnitude and nature of the internal forces in each of the truss member is identified and supported with the required calculations and analysis method.	Magnitude and nature of the internal forces in a few of the truss members are missing but the rest of them are identified and supported with the required calculations and	Magnitude and the nature of the internal forces are not identified in the truss members.	

		analysis method.		
Assumptions for analysis	Assumptions are clearly listed and explained.	Assumptions are listed but not explained.	Assumptions are not made.	
Predictions about the potential failure member	Failure location is identified and supported by specific reasoning and calculations.	Failure location is identified but not supported with specific reasoning and calculations.	Failure location is not identified.	
Maximum load the truss can withstand without failure	Maximum load carrying capacity per unit of mass is determined and supported with proper calculations.	Maximum load carrying capacity per unit of mass is determined but not supported with proper calculations.	Maximum load carrying capacity per unit of mass is not calculated.	
Report communication	The overall report is well organized, precise, and comprehensive.	The overall report lacks in some parts on organization, preciseness, and comprehensiveness.	The overall report is not well organized, precise, and comprehensive.	
Construction Stage				
Design constraints and compliance with the design drawings.	The constructed truss bridge has full compliance with the design drawings as well as with the design constraints previously set by the professor.	The constructed truss bridge doesn't comply in limited parts with the design drawings as well as the design constraints previously set by the professor.	The constructed truss bridge doesn't comply with the design drawings and also the design constraints.	
Oral defense	Fully explains why the utilized procedures were selected as well as why there was a difference between the predicted and actual failures (if there is any)	Lack of explanations on the procedures utilized as well as why there was a difference between the predicted and actual failure (if there is any)	Not able to explain and defend what were presented in the project.	

IV. PEDAGOGY

As the third item in Backward design principles outlined by Wiggins & McTighe(2005), instructional activities (pedagogy) can be planed once we have the course results (enduring outputs) clearly defined, as well as we have the appropriate evidence for measuring it (assessment) available. Wiggins & McTighe (2005) further adds that, the following questions to be asked while planning the instructional activities:

- What prior knowledge the student might need which can help them in reaching out the desired results?
- What are the activities that can get students the required knowledge and skills?
- What and how the students to be taught in order to reach out the desired results?
- What learning materials and recourse are appropriate in reaching out the desired results?
- How well the pedagogy part is aligned with the content and assessment parts?

In order to answer the aforementioned questions and to properly align the pedagogy with content and assessment parts, the *seven principles of making learning whole* introduced by Perkins (2009) have been applied:

> As described by Moseley and McCord (2014) one of the most important element of the *cognitive apprenticeship* for transforming the novices into experts in the engineering problem solving process of statics [*enduring outcomes*], is highlighting and making clear for novices, the ways experts use their content knowledge in solving engineering problems in statics.

A. Applying the *Seven Principles of Making Learning Whole*

1. Principle 1. Play the whole game

As described by Perkins (2009) in the principle of *playing the whole game*, students are given the sense of a big picture from the course content. In order to help students maintain the big picture of statics, the summary of major concepts (Concept map) are placed in the course introduction section and then briefly reviewed at the beginning of each chapter (Dollár & Steif, 2008). This task will also help with the implementation of the *deliberate, distribute and practice* strategy for effective learning of the main concepts of the course. The author puts special emphasize on inclusion of a short description on the boundary of statics with mechanics physics and subsequent engineering mechanics courses in the course introduction session as, well as the explaining the crucial role of statics that can play in learning the subsequent engineering mechanics courses.

2. Principle 2. Make the game worth playing

As explained by Perkins (2009) in the principle of *Make the game worth playing,* students' motivation has to be fostered and also to make sure they realize the importance of what they learn throughout the course. In this course design model, special emphasize is put to link every main concept of statics to the real world engineering problems by working with physical artifacts at the beginning of each class for those concepts taught in the previous class session, multimedia visualization of complicated concepts of the lectures, as well as application of those concepts through written class assignments and a 3-stage final project which is an exact representation of a real world engineering problem. First 60 minutes of each class session is assigned to aforementioned lab activities and also peer discussions.

3. Principle 3. Work on the hard parts

As outlined by Perkins (2009) in the principle of *Work on hard parts,* students need to do more practice on the difficult concept and misconceptions in a given course as well as have to receive regular feedback from the instructor in order to fully understand these hard parts. The four main concepts explained in part (I.C.1) that students normally struggle with, to properly understand and apply, and also the main reason behind making errors in solving statics problems is that students have misconceptions about the basic statics concepts such as force, FBD and equilibrium (Douglas et al., 2010). In order to overcome this problem, enhancement of the linkage between procedures and concepts is considered crucial, which is based on the three major parts of the Cognitive Learning Theory described by Venters et al. (2013) as expertise, conceptual and procedural knowledge development, and conceptual change. Considering the above, part of the written class assignments and lab activities is to not only solve the engineering problems utilizing appropriate methods and mathematical applications, but also to link it to the relevant concepts in statics. Students will receive feedback on these ungraded but required written class assignments from both their peers and professor. Moreover the professor will be explaining the Metacognition process while solving difficult problems in the lecture session.

4. Principle 4. Play out of town

As explained by Perkins (2009) in the principle of *Play out of town*, the instructor works with students on the transfer of knowledge to the real world problem situations that are not exactly identical to what the students are taught in the course. Doing the class 3-stage project by students with two times comprehensive and ungraded feedback from the instructor, can be considered a better ground for most of the basic statics theoretical concepts application as well as a proper representation of the complexities in the real world problems situations that will help in realization of this principle.

5. Principle 5. Uncover the hidden game

As described by Perkins (2009) in the principle of *Uncover the hidden game*, the instructor has to implement proper instructional strategies in order to make clear for students the tacit knowledge, and unspoken rules of the course, as well as to take them through step by step process in making the tacit knowledge explicit and comprehensive for them. According to Moseley and McCord (2014) as an integral part of the *cognitive apprenticeship* theory where the novices transform into experts in the engineering problem solving process of statics, is to make explicit for novices, the ways experts use their content knowledge (Metacognition process) in solving engineering problems in statics. In this course design model, the professor will not only solve the engineering problems by using the procedural knowledge but also speak out the Metacognition process he utilized while solving the problems. Moreover the students are also required to do so while discussing their written class assignments with peers and also the professor. However written class assignments are not graded but every student is required to submit them as a perquisite for the exams.

6. Principle 6. Learn from/with the team

According to Perkins (2009) in the principle of *Learn from/with the team,* the instructor has to foster team work among the students and also provide them with collaborative learning opportunities, where they can share their ideas together and improve the learning process as a whole. For the realization of this principle students work on a 3-stage class project in the groups of (2-5) depending on the overall number of students in the class. Each group design a wooden truss-bridge model with a maximum load carrying capacity per unit of mass (authentic performance task). Each member of the group has to equally contribute to the project and present their part in front of the class during the final presentation. This design project not only foster teamwork among the students but also help the instructor to foster the spirit of healthy competition and motivation among the students that open ups way for innovations. At the end of the semester the truss bridge design project with the highest load carrying capacity per unit of mass will be announced as a winning project. Moreover group lab activities and written class assignment discussions among the peers are, other activities that could be helpful in realization of the principle.

7. Principle 7. Learning the game of learning

Perkins (2009) states that through the principle of *learning the game of learning*, Metacognition process is fostered and students are provided with the opportunities to self reflect on the ways they use while learning contents. As described in the Principle 5, based on the *cognitive apprenticeship* theory of Moseley and McCord (2014) in this course design model, the professor will be describing the Metacognition process to students while solving the statics problems in the classroom. This task helps students to learn the learning techniques experts use as they solve real world engineering problems. Moreover the students will be provided with the opportunity to reflect on their own Metacognition processes while dealing with engineering problems with their peers and also the professor. As a result of this the most convenient learning techniques will become clear for the students.

B. Lesson Plan for one section of instruction

Following is a lesson plan for the fifth session of instruction, indicating specific timeline for each activity as well as the instructional activities alignment with *the seven principles of making learning whole* by Perkins (2009).

Table 7. Sample lesson plan for week 7 specified in the course schedule (Table 9.)

Timeline		List of Activities	Application of *the Seven Principles of Making Learning Whole* by Perkins
60 min	5 min	Overall review of this class session activities and their linkage to the previous sections.	1
	30 min	Working with physical artifacts from the previous sections (Equilibrium of rigid bodies - 2D) in groups of (2-5) persons. The professor will be mentoring and coaching the process.	2, 4
	25 min	Discussing the previous session written class assignments with peers in groups of (2-5) persons. Discussing the specific approaches each student has used and comparing it with right answers sheet provided by the professor. Each group also receive feedback from the professor on hard parts (wrong answers).	3, 6, 7
90 min	30 min	The professor presents the concepts of the equilibrium of rigid bodies in space through PowerPoint slides with multimedia representation (animations and clips) and links it with the equilibrium of rigid bodies in plane as well as with the equilibrium of particles both in plane and space.	1, 2
	50 min	The professor works on solving the rigid bodies equilibrium (3D) related problems on the white board while explaining the Metacognition process behind them and also keep the students involved by asking questions.	5, 7
	10 min	Overall synthesis of the contents presented as well as assigning readings and assignments for the next session.	1, 3

C. Course Syllabus

The course syllabus is prepared with reference to the statics syllabuses in above stated ABET accredited colleges as well as in full compliance with the criteria's discussed in the previous sections of this project:

[Course Code]
Engineering Mechanics I (Statics)
[Term] [Academic Year]
[Weekday], [Time] [Class Venue]
Instructor:
Email:
Office:
Office hours:

Course goals, objectives and expectations

Course Description:

Statics a sophomore level course which mainly deals with the study of objects that are either in the state of rest or uniform motion, under the interaction of forces acting in two and three dimensional space. It's considered an essential course in engineering mechanics that works as a pre-requisite for subsequent courses such as dynamics, strength of materials, fluid mechanics, structural analysis and other design related courses. The main topics covered in statics include: vectors, forces, moments and couples, free body diagrams and equilibrium, statically determinate structures analysis, external and internal forces in beams, trusses, frames and simple machines, shear and moment diagrams, friction, centroids and centers of gravity, moment of inertia and virtual works.

Prerequisites:

Grade C (70- 79%) or better in the following courses:

- Freshmen-level Math in the relevant discipline.
- Freshmen-level Physics in the relevant discipline.

Learning Objectives:

Upon successful completion of the course students will have developed the following abilities:

- LO1. Ability to work to apply basic engineering mechanics principles required for analyzing and solving statics structures.
- LO2. Ability to identify an appropriate structural system to studying a given problem and isolate it from its environment.
- LO3. Ability to identify and model various types of loading and support conditions that act on structural systems.
- LO4. Ability to find out centers of gravity/centroids and moments of inertia using integration methods.
- LO5. Ability to model the problem using good free-body diagrams and accurate equilibrium equations.
- LO6. Ability to communicate the solutions to all problems in an organized and coherent manner and elucidate the meaning of the solution in the context of the problem.

Required Texts:

- Vector Mechanics for Engineers - Statics and Dynamics, 9th edition, the McGraw-Hill.
- Other reading materials as assigned by the instructor on weekly basis.

Grading criteria

Table 8. Grading criteria

Task	Grade Percentage
Class participation (Including, attendance, class dissuasion, Lab activities, and written class assignments)	30%
Midterm Exam	20%
Final Exam	20%
3- Stage Class Project	30%
Total	100%

Grading Scale:

- 90% = A
- 80-89% = B
- 70-79% = C
- 60-69% = D
- < 60 % = F

Grading criteria for each of the assignments

Class Participation:

Class participation is required and considered a major part of the course grade. Each of the class session carries 2% weight of the course overall grade (Total weight of the class participation: 30%). The mentioned total score is uniformly distributed among the class attendance (7.5%), Lab activities (7.5%), and Class written assignment from the text book specified by the professor: The assignments are not graded by the professor but they are required to be done by each student (7.5%) and then class discussion among peers and also with the professor on these assignments (7.5%). At the last part of the first 60 minutes of each session students receive the right answers and procedures sheet for the given assignments from the instructor and then compare their answers with the ones on that sheet and look out for any discrepancies that might exist. By doing this the instructor gets an overall sense of the students understanding in the given topic.

Midterm and Final Exams:

Midterm and final exams will be given at the predetermined slots stated in the class schedule, during the regular class sessions in the classroom assigned to this course. Both midterm and final exams will be closed book and no makes are available. Both exams will be comprehensive and cover the contents delivered through lecture notes. Each of the midterm and final exam carries 20% of the total grade of the course.

- No credit will be given for correct answers not supported with proper reasoning and calculations.

- Partial credit will be given for work that includes a portion of the correct solution.

3 -Stage Class Project:

It carries 30% of the total grade of the course and is equally distributed among the 3 stages of the project as follows:

- Preliminary design stage : 10%
- Detailed Design Stage: 10%
- Construction Stage: 10%

Each of the above stage is graded based on rubric criteria and percentages listed in Table.6.

Teaching methods

The course contents are delivered through power points slides that are more interactive and contains the multimedia representations of the main concepts of statics. Specific problems from each section are worked out by the professor on the white board, outlining all the required steps and the Metacognition process behind the application of the appropriate principles. Student are assigned written class assignments, and readings from the textbook for the coming week. The first 60 minutes of each class session are assigned for the Lab activities, as well as, discussion about the written class assignments, and also working on the 3 -stage class project.

Student preparations for a class session

Students are required to read all the assigned readings, as well as solve the given problems before coming to the classroom.

Student expectations from the course instructor

The instructor is committed to providing a supportive learning environment where students can receive regular and on time feedback on their works as well the class sessions will be more collaborative that foster innovations and also the contents will be meaningful and interesting for the students. The class environment will be friendly and based on the mutual respect principles.

Advice on how to study the course materials

Students are encouraged to read the required and optional readings for grasping the main ideas and concepts of statics which can help them in solving the engineering problems that are similar to the real world situation problems.

Advice on how to study for quizzes/exams

As stated above, student are encouraged to have a deep understanding from the main concepts in statics and also to know how to apply them in solving the real world engineering problems which means the students should develop both conceptual and procedural knowledge of engineering mechanics together.

Schedule for course materials

Table 9. Course schedule (Beer, 2010)

Week	Class Topic	Assigned Reading (Textbook)	Assignment
1	Syllabus, Overview of the course contents and other required notes.		
2	Introduction to mechanics.	1.1 - 1.6	
3	Statics of particles - Forces in plane.	2.1-2.11	
4	Statics of Particles- Forces in space.	2.12-2.15	
5	Rigid bodies - Statically equivalent systems.	3.1-3.20	
6	Equilibrium of Rigid bodies -2D.	4.1-4.7	
7	Equilibrium of Rigid bodies -3D.	4.8-4.9	
8	Midterm Exam.		
9	Distributed Forces, Centroids, and center of gravity.	5.1-5.12	
10	Analysis of structures: Trusses, Frames and Machines.	6.1-6.12	
11	Forces in beams and cables.	7.1-7.10	First stage of the class project
12	Friction.	8.1-8.10	
13	Distributed Forces and Moment of Inertia	9.1-9.18	Second stage of the class project
14	Methods of Virtual Work.	10.1-10.9	Final stage of the class project and its testing
15	Oral Defense and Presentations.		
16	Continuation of Oral Defense and Presentations and also Exam Review.		
17	Final Exam		

V. CONCLUSION

Through this course design project the author has strived to align the three integral parts of a course design process: contents, assessment and pedagogy in single model based on the backward course design process introduced by Wiggins & McTighe (1998). Where in contrast to the traditional course design methods the learning outputs are determined at the beginning of the course design process. The course enduring outcomes are determined at the very first stage of course design process in accordance with the research findings by Condoor et al. (2008); Steif and Dollar (2005) and also in full compliance and proper alignment with the course objectives proposed by ABET criteria's. On the enduring outcomes part of this course model is to provide students with the essential knowledge and skills that enable them to visualize the engineering mechanics concepts and apply them in solving the real world engineering problems. In order to make sure the students get the required knowledge and skills and also to document that, the Cognitive Learning Theory proposed by Venters et al. (2013) is used which emphasizes on the enhancement of the linkage between procedures and concepts which is considered a major difference between novices and experts while dealing with solving the engineering problems. Moreover, the cognitive apprenticeship theory by Moseley and McCord (2014) is utilized in which novices (students) learning the cognitive strategies for solving engineering problems used by experts (instructors). At the end the instructional activities (pedagogy) part is designed by utilizing *the seven principles of making learning whole* introduced by Perkins (2009) which helps in achieving the enduring outcomes for the course by working with physical artifacts, doing written class assignments and peer discussions, giving more visualized and interactive lecture PowerPoint slides by the instructor, as well as doing a wooden truss bridge design project that's an identical representation of the real world engineering problems situations.

Bibliography

1. Anand, S. (2005). A More Effective Sequence for Teaching Statics to Civil Engineering Students. In *2005 ASEE Annual Conference & Exposition: The Changing Landscape of Engineering and Technology Education in a Global World* (p. 3). Portland, OR; USA.
2. Anderson, L. W., Krathwohl, D. R., & Benjamin S Bloom. (2001). *A taxonomy for learning, teaching, and assessing : a revision of Bloom's Taxonomy of educational objectives*. New York: Longman.
3. Atadero, R., Balgopal, M., Fontane, D., & Hernandez, K. (n.d.). Project Assignments for Statics. Colorado State University. Retrieved from http://digitool.library.colostate.edu///exlibris/dtl/d3_1/apache_media/L2V4bGlicmlzL2R0bC9kM18xL2FwYWNoZV9tZWRpYS8zNDA1ODg=.pdf
4. Condoor, S., Jayaram, S., & Boyer, L. (2008). Learning statics - A foundational approach. In *2008 ASEE Annual Conference & Exposition*. American Society for Engineering Education.
5. Dollár, A., & Steif, P. S. (2008). An interactive, cognitively informed, web-based statics course. *International Journal of Engineering Education*, *24*(6), 1229–1241.
6. Douglas, T. C., Roman, A. S., & Streveler, R. (2010). Does conceptual understanding matter: Patterns of error in senior engineering student's problem solving in Statics? American Society for Engineering Education.
7. Engineering Mechanics (Statics) Syllabus. (2007). Walla Walla Community College. Retrieved from http://www.wwcc.edu/oca/syllfiles/200ENGR&214A90204258140582251ENGR_214_SYLLIBUS_2009.doc
8. Ferdinand P Beer. (2010). *Vector mechanics for engineers. Statics and dynamics* (9th edition). Boston: McGraw-Hill Companies.

9. Hansen, E. (2011). *Idea-based learning : a course design process to promote conceptual understanding* (1st edition). Sterling, VA: Stylus.
10. Moseley, S., & McCord, R. (2014). Honest expert solutions towards cognitive apprenticeship. American Society for Engineering Education.
11. Norman, & Thompson. (2008). Statics Design Project. Cedarville University. Retrieved from http://people.cedarville.edu/employee/thompson/links/courses/e274/Statics%20Design%20Project%202008.pdf
12. Pellegrino, J. W., Chudowsky, N., Robert Glaser, & National Research Council (U. S.). Division of Behavioral and Social Sciences and Education. Committee on the Foundations of Assessment. (2001). *knowing what students know : the science and design of educational assessment*. Washington, DC: National Academy Press.
13. Perkins, D. N. (2009). *Making learning whole : how seven principles of teaching can transform education* (1st edition). San Francisco, Calif: Jossey-Bass.
14. Rais-Rohani, M., Walters, A., & Vizzini, A. (2010). Emporium Based Redesign of Statics: An Innovative Approach to Enhance Learning and Reduce Costs. American Society for Engineering Education.
15. Steif, P. S., & Dollar, R. (2005). Reinventing the teaching of statics. *International Journal Of Engineering Education*, *21*(4), 723–729.
16. Streveler, R. A., Pilotte, M., Smith, K. A., & Smith, K. A. (2012). Aligning course content, assessment, and delivery: Creating a context for outcome-based education. Information Science Reference.
17. Venters, C., McNair, L. D., & Paretti, M. C. (2013). Using writing to link procedures and concepts in statics. American Society for Engineering Education.
18. Wiggins, G. P., & McTighe, J. (1998). *Understanding by design*. Alexandria, VA: Association for Supervision and Curriculum Development.
19. Wiggins, G. P., & McTighe, J. (2005). *Understanding by design* (Expanded 2nd edition). Alexandria, VA: Association for Supervision and Curriculum Development.