USC Viterbi
School of Engineering

ISE501/AME501 Innovative Conceptual Design for New Product Development

Units: 3
Time: Spring 2021 — Tuesdays — 6:40pm-9:20pm

Course Section: 31501D (on campus) / 31798D (DEN)
Location: Online sessions only

Prerequisite: A graduate student standing in engineering is required (or approved by the Instructor).
Note**:** This is a degree required course for the MSPDE degree (Master of Science in Product Development Engineering)

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I. Course Description

The objective of this course is for students to learn the theoretical foundation and practical applications of a logic framework to systematically carry out conceptual design in new product development. There are three types of design activity in a new product development process: (1) functional design that chooses the functional requirements (FR) to satisfy the uncovered customer needs (CN), (2) conceptual design that ideates the design parameters (DP) to embody the chosen FR, and (3) technical design that determines the parametric values (PV) to specify the ideated DP. Conceptual design, where a set of dependency relationships between upstream market demands (i.e., CN, FR) and downstream physical constraints (i.e., DP, PV) is established, presents the best innovation opportunity for developing new products in a competitive market.

While conceptual design plays the most important role in product innovation, it has mostly been practiced as a “black-art” with ad-hoc experiences in industries due to the lack of rigorous foundations and practical methods. Product development related courses offered by business schools typically cover market forecasting and customer survey techniques that are suitable for functional design; whereas those from engineering curriculum are mostly focused on geometric and computational methods that are useful for technical design (also called parametric design). Unfortunately, these design courses are only applicable when design parameters are already known (i.e., after conceptual design during the technical design stage). The lack of courses that focus on conceptual design has been a major shortcoming in modern engineering design curriculum that must prepare students for today’s industries that strive to innovate to remain competitive in new product development.

This conceptual design course is aimed at strengthening the existing engineering design and product development curricula at the Viterbi School of Engineering at USC. The course will start with an introduction of the new product development process with clear definitions of functional, conceptual, and technical design activities based on the Innovative Design Thinking (IDT) framework. After a brief review of functional design activities (which is the focus of another graduate course, ISE545), the theoretical foundation of logic propositions and a systematic decision process of making analytic and synthetic propositions to ideate new design concepts will be explained. Then, conceptual design activities will be organized as the Concept Generation phase and the Concept Improvement phase. For concept generation, a three-step process to ideate an ideal preliminary design concept, which must be logically feasible, functionally simple, and physically feasible is introduced through a zigzagging process. For concept improvement, two methods that can reduce the complexity of design concepts from the concept generation phase or existing products will be introduced. The first method uses conflict resolution strategies from the TRIZ method to redesign and eliminate coupled relationships between FR and DP; and the second method uses a Design Coupling Sequence (DCS) algorithm to determine the best execution sequence that minimizes the design complexity.

To provide opportunities for students to practice the knowledge and tools learned in the class, design teams will be assembled to carry out conceptual design projects throughout the semester. The instructor will guide student teams through the conceptual generation and improvement phases during in-class exercises and after-class meetings. Student teams will be required to present progresses in a scheduled review meeting. Industry experts may be invited to share their experiences, to guide student projects, and to participate in design reviews. Besides general reference materials, reading assignments of relevant research papers will be given to students to broaden their exposure to the field conceptual design and product development. Real examples and industrial case studies may be used to help students understand the important concepts and the applications.

II. Learning Objective

The learning objectives of this course include:

- Understand the Innovative Design Thinking (IDT) framework, which consists of "do-the-right-thing” rationally and "do-the-thing-right” optimally.

- Clarify the notions of social and brute realities, the concepts of rationality and optimality, and their different roles in the conceptual design of product/system developments.
- Understand conceptual design phases in new product development and their applicable design theories and methodologies.
- Learn the basics of innovation theories and techniques for concept generation phase including the Axiomatic Design Theory, Innovative Design Thinking, and decision-making techniques.
- Learn the basics of concept improvement methods and tools for concept improvement phase and how they can be used in a complementary manner to support innovative design thinking.
- Practice applying those methods and principles in real design cases within in-class exercises, homework assignments, and team projects.
- Practice the IDT concept generation process and basic design axioms to generate and compare initial design concepts through direct synthesis reasoning (vs. iterative analyses).
- Practice the usage of DCS methods to improve initial design concepts by formulating execution sequences and refining the design concept by function modules.

III. Learning Module

This course is organized as the following eleven (11) learning modules:

1) The Innovative Design Thinking (IDT) framework for new product development
2) Using insights of emerging lifestyles to uncover customer needs in a blue-oncan market
3) The logic-based theoretical foundation of design decision and conceptual design
4) The Concept Generation Phase (FR → DP): ideate innovative design concepts systematically
5) IDT Concept Generation (Step 1): make logic propositions to form a space of initial concepts
6) IDT Concept Generation (Step 2): organize concept options by functional dependency
7) IDT Concept Generation (Step 3): select a preliminary concept by physical uncertainty
8) The Concept Improvement Phase (FR ← DP): reduce the complexity of existing design concepts
9) IDT Concept Improvement (Step 1): sequence functional coupling orders of design parameters
10) IDT Concept Improvement (Step 2): eliminate off-triangular coupled non-zero terms
11) IDT Concept Improvement (Step 3): use TRIZ to resolve system physical contradictions

IV. Learning Activity

Students enrolled in this class will work "independently" and "collectively" in five (5) types of learning activity, including (A) live class, (B) online quiz, (C) cohort exercise, (D) design project, and (E) paper study. The following terminologies are used in explaining each of these learning activities:

- "Individual" refers to a single student.
- "Class" refers to the collection of all students registered in this course.
- "Cohort" refers to a group of students assembled each week for online discussions and exercises.
- "Team" refers to a group of students assembled at the start of the semester for design projects.

(A). Live Class: (Weekly) Tuesdays, from 6:40pm to 9:20pm.

Each week is devoted to study and exercise of one learning module (see Section III). The weekly live class includes the following activities (see Figure 1):

- 6:40pm – 7:10pm: "cohorts" report last week's design exercise results to the "class"
- 7:10pm – 8:50pm: the teacher gives live lectures of the weekly learning module to the "class." All "individuals" attend the live lecture remotely via Microsoft Teams/Together mode (see Section VII).
- 8:50pm – 9:00pm: the teacher announces this week's design exercise assignment for cohorts
- 9:00pm – 9:20pm: open questions/answers (led by the TA)

(B). Online Quiz: (Weekly) Wednesdays, from 00:01am – 11:59pm

"Individuals" are required to take an online quiz during a 24-hour period on Wednesdays.

- Quiz questions will be limited to key concepts relate to the subject of the learning module discussed in the live class in that week.

- Quiz includes some multiple-choice questions (must choose all correct answers, no partial credit) and some open-end questions (no right/wrong answer).
- Individuals' quiz performance, together with other appropriate diversity criteria, will be used to assemble "cohorts" for online discussions of assigned design exercises (see Sections III.A and C).

(C). Cohort Exercise: (Weekly) Thursdays, 12:00pm – Mondays, 12:00pm

"Cohorts" assembled above are to meet in designated online chatrooms during the next five (5) days.

- "Cohort" members compare their "individual" answers to quiz questions and explain the reasons for their different answers if any.
- "Cohort" members work together to complete the weekly design exercise assignment, focusing on sharing diverse rationales behind their different ideas.
- Each "cohort" combines the best ideas from "individual" members to form a group design exercise result to be reported at the beginning of next week's live class (see VI.A above).

The above lerarning activities, designated by different colors, constitute a 24/7 iLearning cycle (Figure 1), where "i" stands for interactive, in which students must work individually and with cohort members weekly.

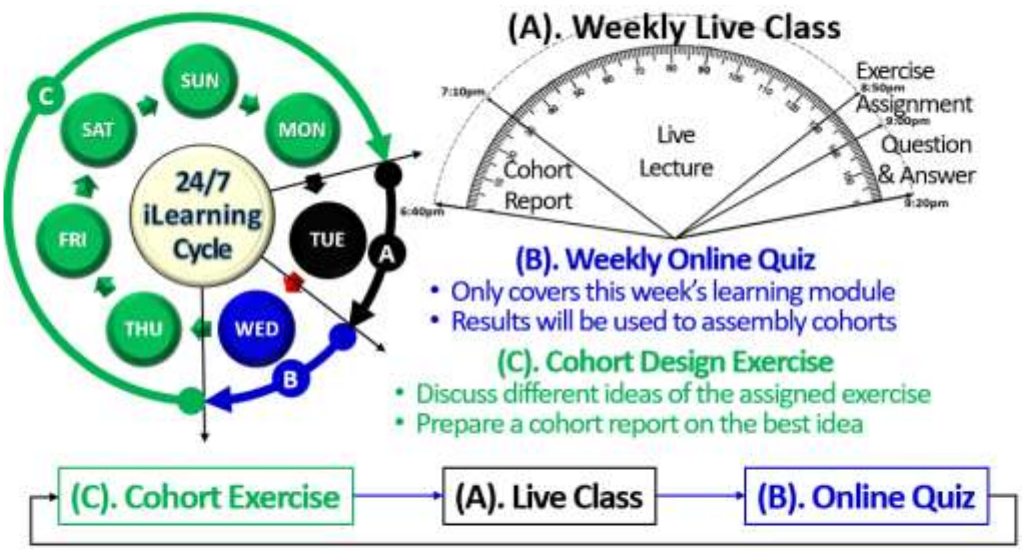

Figure 1: Students must follow the 24/7 iLearning Cycle

(D). Design Project: (throughout the entire semester)

"Teams" are assembled at the semester start to carry out design projects (i.e., conceptual design of a new product/system) that can satisfy the assigned customer need (CN)

- The customer need (i.e., design project theme) will be announced during the 2nd week of the class. Teams assembled in the 3rd week are to work together on their projects outside the live class time.
- Teams are required to make a presentation of their results at two design progress review meetings, scheduled on Week 9 (March 16) and Week 14 (April 27).

(E). Paper Study: (two assignments/reports during the semester)

Two (2) research papers will be assigned for individuals to study and develop written reports to show their understanding of the content and its relevance to the course subjects.

- For each assigned paper, students are asked to write a study report up to 5 pages in length (space taken by figures is not counted), 12 pt, typewritten, double-spaced, with maximum 1" margins.
- Reports are due at the beginning of the class (see the Course Schedule). Students can turn in paper study reports one week late for 50% of the credit. No credit will be given afterwards
- Additionally, individuals are encouraged to post their inputs, opinions and suggestions of the paper onto the Discussion Board before and after the due date of the written reports.

V. Reading Materials

No textbook is required. Lecture notes for the live class will be provided by the teacher weekly. Each week is devoted to the study and exercise of one learning module (see Section III). Each learning module is organized as 4 or 5 key concepts, explained by a set of PowerPoint slides with sequence animations.

A list of recommended reading materials is as below:

1) "Axiomatic Design – Advances and Applications", by Nam P. Suh, the Oxford University Press.
2) "Systematic Innovation – an introduction to TRIZ", by John Terninko, Alla Zusman, and Boris Zlotin, St. Lucie Press.
3) "*Creating Breakthrough Products – Innovation from Product Planning to Program Approval*", by Jonathan Cagan and Craig M. Vogel, Financial Times, Prentice Hall.
4) "*Complexity: Theory and Applications*", Nam P. Suh, Oxford University Press, USA
5) "*Product Design and Development*", (the third edition), Karl T. Ulrich and Steven D. Eppinger, the McGraw-Hill Companies, Inc.
6) "*The Design of Things to Come: How Ordinary People Create Extraordinary Products*", Craig M. Vogel, Jonathan Cagan, and Peter Boatwright, Wharton School Publishing.
7) "*Engineering Design – A Systematic Approach*", G. Pahl and W. Beitz, Springer-Verlag
8) "*Product Design – Techniques in Reverse Engineering and New Product Development*", by Kevin Otto and Kristin Wood, Prentice Hall.
9) "Engineering of Creativity – Introduction of TRIZ Methodology of Inventive Problem Solving", by Semyon D. Savransky, St. Lucie Press, CRC Press Company.

The instructors may recommend additional reading materials and website reference resources during the semester whenever appropriately.

VI. Grading Scheme:

Students' semester learning performances will be graded according to the following scheme:

(A). Live Class (total **40%** for 10 weeks)

- Each week's performances count 4%, including 2% for quiz answers and 2% for participation in cohort discussions of design exercises.

(B). Final Examination (1 open-book exam for **20%**)

(C). Design Project (total **30%** for two design reviews)

- Each team will receive a group score based on their project review presentations. This group score will then be converted to individual grades for each member based on a confidential peer-review at the end of the semester.

(D). Paper Study (total **10%** for 2 ppaer study reports)

VII. Course Website:

Microsoft's Teams collaboration system (a part of the Microsoft 365 platform) will be used in this course. Each registered student will be given an account at the beginning of the semester to access the system. All course and reading materials will be posted, as well as all communications (e.g., notifications, etc.) and interactions (i.e., cohort discussions, etc.) should be conducted, on this system. The unique Together mode of the Microsoft/Teams system will be used for lectures and group exercises during weekly live class. For more information and technical support relates to the online learning platform, please contact Ankit Dalal at akdalal@usc.edu.

VIII. Course Schedule

The course schedule with weekly learning subjects and activities is shown in the following Table (note: different colors represent different learning activities explained in Section IV). The Instructor reserves the right to change this schedule during the semester to better fit students' learning needs and progress.

Week	Date	Module	Live Class (Subject of the Learning Module)	Quiz	Design Exercise	Paper Study	Design Project
1	1/19	n/a	Course introduction and subject overview				
2	1/26	I	The Innovative Design Thinking (IDT) framework for new product development	1	1	1st paper assign	Project assignment
3	2/02	II	Using insights of lifestyle changes to uncover customer needs for a new product	2	2		Team assembly
4	2/09	III	The logic-based theoretical foundation of design decision and conceptual design	3	3		
5	2/16	IV	Concept Generation Phase: ideate innovative design concepts systematically	4	4		
6	2/23	V	IDT Concept Generation (1): make logic propositions to form a space of concepts	5	5		
7	3/02	VI	IDT Concept Generation (2): organize concept options by functional dependency	6	6	1st report due	
8	3/09	VII	IDT Concept Generation (3): select a preliminary concept by physical uncertainty	7	7	2nd paper assign	
9	3/16	n/a	Design Review (mid-term project report)				Mid-term report
10	3/23		USC Wellness Day (no class this week)				
11	3/30	VIII	Concept Improvement Phase: reduce the complexity of existing design concepts	8	8		
12	4/06	IX	IDT Concept Improvement (1): sequence coupling orders of design parameters	9	9		
13	4/13	X	IDT Concept Improvement (2): eliminate off-triangular coupled non-zero terms	10	10		
14	4/20	XI	IDT Concept Improvement (3): use TRIZ to resolve system physical contradictions	11		2nd report due	
15	4/27	n/a	Design Review (final project presentation)				Final presentation
	5/11	n/a	Open-Book Online Final Examination				

Academic Integrity:

"The Viterbi School of Engineering adheres to the University's policies and procedures governing academic integrity as described in SCampus. Students are expected to be aware of and to observe the academic integrity standards described in SCampus, and to expect those standards to be enforced in this course."

Students with Disabilities:

Any Student requesting academic accommodations based on a disability is required to register with Disability Services and Programs (DSP) each semester. A letter of verification for approved accommodations can be obtained from DSP. Please be sure the letter is delivered to the instructor as early in the semester as possible. DSP is located in STU 301 and is open 8:30 a.m. - 5:00 p.m., Monday through Friday. The phone number for DSP is (213)740-0776.

Academic Conduct:

Plagiarism – presenting someone else's ideas as your own, either verbatim or recast in your own words – is a serious academic offense with serious consequences. Please familiarize yourself with the discussion of plagiarism in *SCampus* in Part B, Section 11, "Behavior Violating University Standards" policy.usc.edu/scampus-part-b. Other forms of academic dishonesty are equally unacceptable. See additional information in *SCampus* and university policies on scientific misconduct, http://policy.usc.edu/scientific-misconduct.