ISE501/AME501  Innovative Conceptual Design for New Product Development

Units: 4 units
Time: Tuesdays, 18:00 – 20:30

Course Section: TBD (on campus) / TBD (DEN)
Location: RTH-217

Prerequisite: A graduate student standing in engineering is required (or approved by the Instructor).

Note:
1. This is a required course for Master of Science in Product Development Engineering degree. See: https://viterbigradadmission.usc.edu/programs/masters/msprograms/aerospace-mechanical-engineering/ms-product-development/
2. This is also an iPodia course to be offered jointly with partner universities of the iPodia Alliance. See: https://ipodia.usc.edu

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Teaching Assistant: TBD
Office Hours: TBD
Contact Email: TBD
I. Course Description

There are three types of design activity in a new product development process: (1) functional design that chooses the Functional Requirements (FR) of the new product to satisfy newly 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 opportunity for engineers to develop innovative products in competitive markets.

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. Business school courses related to market benchmarking, demand forecasting, and customer survey are only useful for improving existing products; whereas engineering curriculum are mostly focused on geometric and computational methods for technical (or parametric) design. To develop new products for blue-ocean markets, engineers must learn conceptual design to creatively ideate innovative design concepts after functional design and before technical design.

In ISE/AME-501, students will learn the theoretical foundation and practical applications of a logic framework to carry out the conceptual design activity systematically during 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 Viterbi course, ISE445), 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 (that are 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 concept generations or existing products will be introduced. The first method uses conflict resolution strategies from the TRIZ (i.e., Theory of Inventive Problem Solving) 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, small design teams will be assembled to carry out conceptual design projects throughout the semester. As an iPodia course, students will work in multi-school design teams with members of diverse backgrounds to broaden their ideation perspectives. The instructor will guide these cross-campus teams through the conceptual generation and improvement phases during in-class exercises and after-class meetings. Cross-campus teams will be required to present progresses in a scheduled review meeting. Industry experts may be invited to share their practical experiences, to guide student projects, and to participate in final 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 will be used to help students understand the important concepts and the applications.

II. Learning Objective

After completing this course, students will have basic knowledge and necessary skills to:

- Understand the Innovative Design Thinking (IDT) framework that prescribes methods to "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 different conceptual design phases in new product development processes and their applicable design theories and methodologies.
• Know the basics of innovation theories and techniques for concept generation phase including the Axiomatic Design Theory, Innovative Design Thinking, and decision-making techniques.
• Understand 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.
• Apply 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).
• Use the 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) weekly 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-ocean 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 in this class will work “independently” by themselves and “collectively” with classmates from participating iPodia universities in five (5) different 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 cross-campus 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):
• “Cohorts” report last week’s design exercise results to the “class”
• 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).
• The teacher announces this week’s design exercise assignment for cohorts
• Open questions/answers (led by the TA)

(B). Online Quiz: (Weekly)
“Individuals” are required to take an online quiz during a 24-hour period after self-study pre-class assignments.
• 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)
“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 learning activities, designated by different colors, constitute a 24/7 iLearning cycle (Figure 1 – hours are for examples only), where “i” stands for interactive, in which students must work individually and with cohort members weekly.

![Figure 1: Students follow the 24/7 iLearning Cycle](image)

(D). **Design Project**: (throughout the entire semester)
Cross-campus “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 and Week 14.

(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 for this course. Lecture notes for each learning module 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.
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.

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 cross-campus 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 paper study reports)

VII. Course Website:

A peer-to-peer (P2P) system built from Microsoft’s Teams collaboration system (a part of the Microsoft 365 platform) will be used in this course. Each registered student will be given a P2P 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 P2P system. The unique Together mode of the Microsoft/Teams system will be used for lectures and group exercises during weekly live class.
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).

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