



ISE 599 Innovative Conceptual Design for New Product Development

Units: 3

Fall 2019—Tuesday—6:40-9:20pm

Course section: 31519D (On-Campus); 31719D (DEN)

Location: OHE 100D

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Office Hours: Tuesday, 5:00-6:00 pm

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The email is usually replied within 48 hours

1. Course Description

As the competitions for more function, higher quality, lower costs, swift delivery and life-cycle accountability of products and systems intensify rapidly, product development has been no longer focused on optimization. To succeed on today's highly-competitive global technology market, the company must totally revamp the traditional product development processes and systems thinking so that designers can creatively "do-the-right-thing" first, and then effectively "do-the-thing-right". Having a strategic way to develop products from upstream has become more and more important. Conceptual design is an early stage in design process. It determines more than 70% of the total costs and performance of the product. However, conceptual design can not be directly implemented by the engineering principles and mathematic formulas from technical design because concepts are abstract and lack of values. Therefore, this course aims to teach a systematic conceptual design approach that helps engineering students understand decision principles and design theories in conceptual design, and be able to develop design concepts that not only creative but also logically feasible.

This graduate-level course will start from covering the fundamental decision principles, logic foundations, relevant design theories for conceptual design, and then introduces an "innovative design thinking" (IDT) framework and "Design Coupling Sequence" (DCS) methods which can systematically guide rational and optimal engineering decisions through conceptual design including concept generation phase and concept improvement phase for product development. Real-world examples of using IDT and DCS in various product industries will be included to help the students' understandings of the basic concepts.

2. Course Goal and Learning Objectives

The goal of this course is to prepare students with the necessary foundations and skills to become an innovative design thinker who can ideate design concept creatively and rationally, and refine the design practically as ideal as possible. In a typical undergraduate engineering design curriculum, main focuses are placed on using physics-based engineering knowledge to perform technical analyses to support evaluations of mechanical components design. Some advanced-level undergraduate design courses briefly discuss design theories and methodologies, with emphases on specific design procedures. These analysis-based design approaches, which are mostly "bottom-up" in nature, and procedural-oriented design processes, which are without deep theoretical understandings, are not sufficient for students to deal with the real-world design tasks when they join the industrial workforce, nor to comprehend the state-of-the-art of engineering design research when they enter the graduate school.

As the first graduate-level engineering design course at the ISE and AME department and a program required course of the Master of Science in Product Development Engineering (MSPDE) degree, this course - Advanced Conceptual Design for Product Development bridges the gaps between students' undergraduate education in engineering components design (i.e., bottom-up and analysis-based) with graduate-level advanced issues in engineering systems design (i.e., top-down, synthesis-based). Following the innovative design thinking framework, the students will learn how to rationally identify break-through design opportunities from market intelligences and then carry out innovative conceptual designs during a new product development process. Equipped with knowledge from this course, the students should have sufficient backgrounds to utilize proven design theories, methods and techniques developed from recent design researches to enhance their abilities to perform advanced engineering design of technical products, processes, and systems. In short, this course is an important transition from the undergraduate-level bottom-up analysis-based components design to the graduate-level top-down synthesis-based systems design.

The specific learning goals of this course include:

1. Understand the Innovative Design Thinking (IDT) framework, which consists of "do-the-right-thing" rationally and "do-the-thing-right" optimally.
2. 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.
3. Understand conceptual design phases and their applicable design theories and methodologies.

4. Learn the basics of innovation theories and techniques for concept generation phase including the Axiomatic Design theory, Innovative Design Thinking, decision-making techniques.
5. Learn the basics of concept improvement methods and tools for concept improvement phase such as TRIZ (Inventive problem-solving method), Extended Algorithm methods, modular design, and Design Coupling Sequence (DCS) approach, and how they can be used in a complementary manner to support innovative design thinking.
6. Practice applying those methods and principles in real design cases within in-class exercises, homework assignments, and team projects.
7. Practice the IDT concept generation process and basic design axioms to generate and compare initial design concepts through direct synthesis reasoning (vs. iterative analyses).
8. Practice the usage of DCS methods to improve initial design concepts by formulating execution sequences and refining the design concept by function modules.
9. Put all the innovative design thinking principles and practices together in a big picture of complex engineered systems to highlight the key takeaways of the course.

3. Recommended Preparation:

A graduate student standing in engineering is required (or with a special approval by the instructor).

4. Office Hours:

Standard office hours are from 5:00pm to 6:00pm, on every Tuesday. Students can come to instructor's office for face-to-face meetings. On-line meetings (such as Bluejeans or Hangouts) with instructor are also available by appointment via email. Group meetings or on-line meetings with the Instructor during office hours are also possible in the same manner.

5. Textbooks:

No required textbook is assigned. Lecture notes in the form of PowerPoint slides will be provided for each lecture weekly. However, students are encouraged to gain easy accesses to the following two books as recommended reference books (items 1 and 2 in bold-face are the key references):

- 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) *"Platforms, Markets and Innovation"*, edited by Annabelle Gawer, Edward Elgar Publishing.
- 4) *"Smart questions: Learn to ask the right questions for powerful results"*, by Gerald Nadler and William Chandon, John Wiley & Sons.
- 5) *"Creating Breakthrough Products – Innovation from Product Planning to Program Approval"*, by Jonathan Cagan and Craig M. Vogel, Financial Times, Prentice Hall.
- 6) *"Complexity: Theory and Applications"*, Nam P. Suh, Oxford University Press, USA
- 7) *"The Design of Things to Come: How Ordinary People Create Extraordinary Products"*, by Craig M. Vogel, Jonathan Cagan, and Peter Boatwright, Wharton School Publishing.
- 8) *"The Sciences of the Artificial"*, by Herbert A Simon, MIT Press.
- 9) *"Product Design – Techniques in Reverse Engineering and New Product Development"*, by Kevin Otto and Kristin Wood, Prentice Hall.
- 10) *"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.

6. Course Website:

Students' learning of this graduate course is supplemented by a website (D2L System) on USC's DEN instruction system, DEN@Viterbi (<https://courses.uscden.net/>). All students will have full access to this website. The copies of lecture slides and other class information will be posted on the course website on DEN@Viterbi (D2L system). Students should browse around the entire site to familiarize themselves with various areas and functions of this course website.

7. Grading Scheme:

Students will be graded according to the following grading scheme:

- **25% -- active learning activities**
 - (20%) **five (5) in-class exercises (E)**
 - (5%) **innovative product presentation (M)**
- **40% -- individual learning by doing**
 - (15%) **three (3) individual homework assignments (HW)**
 - (10%) **individual project presentation (IPP)**
 - (15%) **individual project report (IPR)**
- **35% -- collaborative learning by doing**
 - (10%) **two (2) team project progress log reports (TPL)**
 - (10%) **team project presentation (TPP)**
 - (15%) **team project report (TPR)**
- **Up to 10% -- extra credits**
 - (5%) **individual case study report (CS)**
 - (5%) **individual Provisional Patent Application (PPA) report**

Total: **100%**

Note that, 35% of a student's final grade (i.e., for team project) is determined based on his/her teamwork performance. All work done by the team is first given a "team grade". This team grade is then weighted for each member based on a confidential peer-evaluation by all teammates at the end of the semester. Each student will be asked to fill out a questionnaire, which evaluates every team member (including him/herself) for the percentage contribution to the teamwork in different categories. The calculation of the weighted team grade will be explained in detail in class.

8. Grading Scale

Course final grades will be determined using the following scale

A	91%-100%
A-	86%-90%
B+	81%-85%
B	76%-80%
B-	71%-75%
C+	66%-70%
F	65% and below

9. Learning Components

• **In-Class Design Exercise (20%)**

Five In-Class design exercises (E) are designed to assist students understand and assimilate the important concepts in some learning modules. To learn by following and then creating, the instructor will assign a few detailed and specific design exercises for students to reflect the key lecture content. The purpose of such exercises is to deepen student's theoretical understanding of the key concepts and to enhance student's practical capability of employing certain design principles to address real-world problems.

Students will form 3 - 6 member groups themselves for these exercises, with several groups consisting of students physically present, and other groups consisting of the DEN students completing the exercises electronically. For on-campus students, the hardcopy results must be submitted right after the class on behalf of the group. For the DEN students who are not able to attend class physically, considering

communication difficulties, the results must be submitted to the dropbox folder on our course website in 4 days (before Sunday midnight (i.e. 12AM on Monday)) on behalf of the group. A total of 5 exercises will be assigned, making each exercise count 4% of your semester grade.

- **Innovative Product Presentation (5%)**

Innovation Product Presentation is an individual 3-minute presentation (i.e., mini-presentation, M). At the beginning of the assigned three classes up to 3 students give a three-minute presentation on **an innovative feature** or **an innovative product**. The student is welcome to cover any field of innovations and/ any kind of innovation features, as long as it has not already be covered in class, has not be presented by other classmates, or is not pulled from the primary textbook. This presentation should focus on explaining the innovative feature(s) of the product(s) to students who may not familiar with, and provide enough information so students can learn how to apply the same feature(s) while product development.

Students who complete the above requirements will earn full credits (5% of semester grade). Over-time presentation, not focusing on innovative features, not shown in signed-up time, late submission of the presentation materials will result score deductions.

- **Individual Homework (15%)**

Different from in-class exercise, homework assignments (HW) are more difficult or needs more time to complete. Three individual homework assignments and one group homework will be assigned right after the conclusion of some learning modules as shown in course schedule. The instructor will assign a few detailed and specific design problems for students to design by using the methods taught in the lectures. The purpose of such assignment is also to deepen student's theoretical understanding of the key concepts and to enhance student's practical capability of employing certain design principles to address real-world problems. The individual homework helps enhancing understanding by hands-on practice in person. Students are also encouraged to discuss with their classmates about the homework (i.e. learning-from-peers).

Homework assignments must be submitted to the corresponding dropbox folder on our course website. Please refer [Late assignment](#) for the late assignment policy.

- **Individual Project (25%)**

This class emphasizes the importance of learning by doing. The best way to understand the methods is to practice. Each individual student will work on an individual design project (IP), to begin the product development process. Students will follow the instructions to select their design target and will further work on it as a design project. Design tasks and techniques will be assigned and taught in class. Students require to follow the instructions to complete the design tasks step by step. At the midterm, each student will submit a report (IPR) and give a presentation (IPP) on their work.

- **Team Design Project (35%)**

The best way to learn advanced conceptual design for innovative product development is to work on a real product development project. Several design teams, each with 3-6 students (depending on the final class enrollment number), will be organized to design a new product/service following the innovative design thinking framework. Selecting a problem statement from one of their team members' individual project subjects, every design team is to improve the design concepts by applying the design improvement methods learning from the lectures. The final project deliverable will be the conceptual design of a technical system that can satisfy the design target. The design concepts must be represented as virtual or physical models that clearly illustrate/explain the working principles and how they function as function modules to satisfy the customer needs. No construction of live-scale real systems nor physical prototypes is required.

Team progresses are to be discussed in TP discussions (TPL). Each team should email the instructor to schedule an one-hour meeting in the weeks shown on the course schedule. Each design team is expected to show their results as a [progress log report](#) (TPL) up to that stage to receive comments/questions and approvals from the instructor before proceeding further. The log report will be graded based on the completeness of the assigned tasks.

Each team will present their project design results (TPP) in class to receive comments/questions from class which may help to increase the performance of their project report (TPR). Team project presentation

counts 10% of the semester grade, and report counts 15%. Based on the performances and efforts on presentation and report, a team grade will be given, and then weighted by the above team-grading scheme for individual grades.

• **Extra Credit- Individual Project PPA Report (5%)**

This extra credit assignment will be given up to 10% of the semester grade for the team or individual who further write up the individual project final results and innovative aspects of project designs as a Provisional Patent Application (PPA) report, according to the requirements defined by the U.S. Patent and Trademark Office (<http://www.uspto.gov>), as the bonus report. PPAs are due at 6:40pm on Tuesday right before the last class (See course schedule). All the required sections and necessary information of a typical PPA, as specified by the U.S. Patent and Trademark Office, must be included in the PPA report. A list of “patent claims” should include all technical details and justifications to be reviewed and evaluated for their innovativeness.

• **Extra Credit- Case Study Report (5%)**

Relevant research papers will be posted for detail readings and comments. Students, who write a study report with a/some product design case(s) according to the papers, will be given up to 5% credits.

It is considered as a formal study report, which should include

1. a cover page with the report title, the author’s name and affiliation, and submission date,
2. a page of Table of Content,
3. Content pages with section and figure numbers and titles. (12 pt, type, typewritten, double-spaced, with maximum 1" margins)
 - A section of paper summary
 - A section of the studied case(s)- description & analysis
 - A section of discussion
 - A section of conclusion
4. a page of References

There is no page limitation, but please be concise and clear. Please use/convert the file in the format of PDF (*.pdf) or WORD (*.doc, *.docx).

Please avoid doing copy-and-paste the content of the paper. Reports are due at 6:40pm on Tuesday right before the last class (See course schedule).

Please note that NO credits will be given for LATE extra credit assignments and team project report and slides due to the restriction of the semester schedule.

10. Course Schedule (A Weekly Breakdown)

A tentative course schedule, which includes weekly learning subject and activities, is as follow. The Instructor reserves the right to change this schedule during the semester to better fit students' learning needs and progresses.

W	Date	Learning Activity and Subject	Assignment, Activity	Due
1	08/27	Course Introduction and Product Development Overview: design process and innovation opportunities		
2	09/03	Functional Design and its Innovation Methods	IP	
3	09/10	Conceptual Design Introduction and its Innovation Methods	E1	
4	09/17	Concept Generation Phase: Concept Generation Methods, IDT Introduction	HW1, M1	
5	09/24	Generation Phase I: Form a Dual-Hierarchy Design Concept by Logic Propositions	E2	
6	10/01	Generation Phase II: Manage Functional Schematics by Functional Dependency	M2	HW1

7	10/08	Generation Phase III: Select a Preliminary Concept by Physical Uncertainty	HW2, E3	
8	10/15	Individual Project Presentation		IPP
9	10/22	Concept Improvement Phase: Design Ideality and Practicality, Reengineering Design and Modular Design	TP	IPR
10	10/29	Concept Improvement I: Eliminate Functional Coupling by TRIZ Inventive Principles	E4	HW2
11	11/05	Concept Improvement II: Manage Functional Coupling by Design Matrix Rearrangement Methods	HW3, M3, TPL1	TPL1
12	11/12	Concept Improvement III: Approach Ideality and Practicality by Design Coupling Sequence Method and Strategies	M4	
13	11/19	Case Studies- Application and demonstration	E5	HW3
14	11/26	Guest Talks: Work as a Product Design Engineer; New Product Startup	TPL2	TPL2
15	12/03	Summary of the lectures		CS, PPA
16	12/10	Study Day (no class)		
17	12/17	The Final Term Project Presentation		TPP, TPR

* Please note that the due date means the assignment is expected to be completed BEFORE the date. Students are encouraged to submit the assignments as early as possible.

11. Assignment Submission Policy and Late Assignments:

Except the in-class exercise results, all the assignments should be submitted to the corresponding folder in Dropbox on our course website (D2L system). The acceptable file format: PDF (*.pdf) or WORD (*.doc, *.docx) for reports; PowerPoint (*.ppt, *.pptx) or PDF (*.pdf) for slides.

Late Assignments are accepted except the extra credit assignments and term project report and slides, but they are with the following deductions. Do not wait until the last minute to upload. Unless there an emergency (in which case exceptions will be made) late assignments will have the following grades.

- 1 second to 5 minutes after deadline: -5% of assignment grade
- 5 minutes to 24 hour after deadline: -10% of assignment grade
- 24 to 72 hours after deadline: -25% of assignment grade
- 3 to 7 days after deadline: -50% of assignment grade
- More than 1 week after deadline: -75% of assignment grade

Please note that all emergency situations will require documentation (doctors note, police report, etc.). Losing internet access or power outages do not classify as an emergency. (be sure to submit before the deadline to account for things like internet outages)

12. Grading Timeline:

The feedback of the in-class exercises is usually given in next class. The grading and feedback of projects and homework is usually given in one to two weeks. The grades of innovative product presentation will be released in the next week of the last presentation. The extra credit reports will be graded in one week.

13. 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.

Statement on Academic Conduct and Support Systems

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>.

Support Systems:

Student Counseling Services (SCS) – (213) 740-7711 – 24/7 on call

Free and confidential mental health treatment for students, including short-term psychotherapy, group counseling, stress fitness workshops, and crisis intervention. engemannshc.usc.edu/counseling

National Suicide Prevention Lifeline – 1 (800) 273-8255

Provides free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week. www.suicidepreventionlifeline.org

Relationship and Sexual Violence Prevention Services (RSVP) – (213) 740-4900 – 24/7 on call

Free and confidential therapy services, workshops, and training for situations related to gender-based harm. engemannshc.usc.edu/rsvp

Sexual Assault Resource Center

For more information about how to get help or help a survivor, rights, reporting options, and additional resources, visit the website: sarc.usc.edu

Office of Equity and Diversity (OED)/Title IX Compliance – (213) 740-5086

Works with faculty, staff, visitors, applicants, and students around issues of protected class. equity.usc.edu

Bias Assessment Response and Support

Incidents of bias, hate crimes and microaggressions need to be reported allowing for appropriate investigation and response. studentaffairs.usc.edu/bias-assessment-response-support

The Office of Disability Services and Programs

Provides certification for students with disabilities and helps arrange relevant accommodations. dsp.usc.edu

Student Support and Advocacy – (213) 821-4710

Assists students and families in resolving complex issues adversely affecting their success as a student EX: personal, financial, and academic. studentaffairs.usc.edu/ssa

Diversity at USC

Information on events, programs and training, the Diversity Task Force (including representatives for each school), chronology, participation, and various resources for students. diversity.usc.edu

USC Emergency Information

Provides safety and other updates, including ways in which instruction will be continued if an officially declared emergency makes travel to campus infeasible. emergency.usc.edu

USC Department of Public Safety – UPC: (213) 740-4321 – HSC: (323) 442-1000 – 24-hour emergency or to report a crime.

Provides overall safety to USC community. dps.usc.edu