USC Viterbi School of Engineering
iPodia

ISE 501 (co-listed as AME 501) –
Innovative Conceptual Design for New Product Development

Units: 4 Units. USC Session/Section: 048/31501D (On-campus); 034/31798D (DEN)
Time: Tuesdays, 17:00 – 20:20 (Pacific Standard Time)
Location: RTH 217 (On-campus) and Online (DEN) – hybrid mode in iPodia virtual classroom

Prerequisite: An advanced undergraduate or entry-level graduate student good standing in engineering is required (or with special approvals by the instructor)

Special Note:

1. This degree-required course is for a Master of Science in Product Development Engineering at USC. https://viterbigradadmission.usc.edu/programs/masters/msprograms/aerospace-mechanical-engineering/ms-product-development/
2. This class will be delivered in RTH 217 (the Viterbi iPodia classroom) for on-campus students and simultaneously via the P2P (peer-to-peer) hybrid learning system jointly developed with Microsoft Teams. (https://www.microsoft.com/en-us/microsoft-teams) for DEN students.

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I. Course Description

A complete new product development (NPD) process consists of three different design stages, namely the **Functional Design** stage to select Functional Requirements (FR) of the said product to satisfy the newly uncovered Customer Needs (CN), the **Conceptual Design** stage to ideate Design Parameters (DP) to embody the above-chosen FRs, and the **Parametric Design** stage to determine Parametric Values (PV) to optimize the above-embodied DPs. The conceptual design stage, where the functional dependency relationships between upstream market demands (i.e., CNs and FRs) and downstream physical constraints (i.e., DPs and

PVs) are established, is the most important stage and presents the best opportunity for designers to develop innovative products to initiate a new blue-ocean market.

While conceptual design plays the most critical role in innovative product development, it has been chiefly practiced as a “black art” with ad-hoc experiences in the industries due to the lack of rigorous foundations and practical methods for systematic ideation. Some business courses, such as benchmarking, forecasting, and surveys, are only helpful in the Functional Design stage, whereas most engineering curricula primarily focus on geometric and computational methods for the Parametric (or technical) Design stage of existing products. To develop competitive new products for blue-ocean markets (i.e., “breakthrough product development”), designers must learn to generate new concepts during the Conceptual Design stage beyond traditional functional and parametric design activities.

Students in this class will learn the theoretical principles and practical methods based on a logical foundation to systematically carry out the conceptual design activity during breakthrough product development. The course will start with an introduction to the new product development practices with clear definitions of functional, conceptual, and parametric design activities according to the Innovative Design Thinking (IDT) framework. After a summary of the Functional Design stage (mainly covered in another USC course, ISE445), the theoretical bases of logical propositions and a systematic process of making analytic and synthetic propositions to ideate new design concepts will be explained. According to the IDT framework, the Conceptual Design stage is organized as the Concept Generation phase and the Concept Improvement phase. For concept generation, a three-step process to generate an ideal preliminary design concept, which is logically feasible, functionally simple, and physically feasible, through a unique zigzagging process is introduced. Functional schematics and two methods to reduce the relative complexity of ideated (or existing) design concepts will be introduced for concept improvement. The first method uses conflict resolution strategies from TRIZ (i.e., Theory of Inventive Problem Solving) to redesign and eliminate coupled functional relationships between FRs and DPs, and the second method uses a Design Coupling Sequence (DCS) algorithm to determine the best execution sequence that minimizes the relative design complexity for concept improvement.

Students will follow a weekly iLearning (as opposed to traditional eLearning) process on a special peer-to-peer (P2P) hybrid learning system jointly developed with Microsoft. They will have opportunities to work with classmates to broaden their perspectives in ideating innovative design concepts. To practice the knowledge learned in the class, small design project teams will be assembled for students to work with teammates of diverse backgrounds. Industry experts (time permits) may be invited to share their practical conceptual design experiences, guide student projects, and participate in final design reviews. Besides general reference materials, reading assignments of relevant research papers will be given to students to widen their exposure to conceptual design and product development. Real-world product examples and industrial case studies will be provided to help students understand essential concepts and practical applications.

II. Learning Objective

After completing this course, students will have the essential knowledge and skills to perform the following tasks related to innovative conceptual design in new product development:

- Explain the characters of social and brute realities, rationality and optimality, and their different roles in the conceptual design of product/system developments.
- Apply the Innovative Design Thinking (IDT) framework that prescribes methods to "do the right thing” rationally and "do the thing right” optimally in a new product development (NDP) process.
- Carry out different conceptual design phases in new product development processes using relevant design theories and applicable decision methodologies.
- Practice the IDT concept generation process and fundamental design axioms to generate and compare initial design concepts through direct synthesis reasoning (vs. iterative analyses).

- Master the basics of concept improvement methods and tools for the concept improvement phase and how they can be complementary to improve ideate or existing design concepts.
- Use the DCS methods to improve initial design concepts by formulating execution sequences and refining the design concept by function modules.
- Apply those methods and principles in real design cases within in-class exercises, homework assignments, and team projects.

III. Learning Module

This course is organized as 13 weekly "Learning Modules" in three consecutive Parts per the class schedule in Section VIII. Each learning module includes four (4) key concepts, and its contents are explained by five (5) PowerPoint slides with sequence animations.

PART I: Introduction – What is breakthrough new product development and innovative conceptual design?

1. Learning **requirements** overview and introduction to breakthrough new product development (NDP)
2. The basic principles of **design thinking** and the **innovative design thinking** (IDT) framework for NPD
3. **Functional Design** to select/organize functional requirements as the conceptual design objectives

PART II: Concept **Generation –** How to create new design concepts for the chosen functional requirements?

4. The **Foundation**: use the Axiomatic Design Theory and logic propositions to ideate new concepts
5. Concept **Formation**: ideate an initial space of options of logically feasible design concepts
6. Concept **Categorization**: use dependencies to identify functionally simple design concepts
7. Concept **Selection**: select a preliminary design concept that is most physically certain
8. **Zigzagging** Process: systematically generate more details of the preliminary design concept

PART III: Concept **Improvement –** How to reduce relative complexity to improve existing design concepts?

9. The **Foundation**: use the Complexity Theory and functional schematics to improve existing concepts
10. Improvement **opportunities** and **strategies** to reduce existing design concepts' relative complexity
11. The Inventive Problem Solving (**TRIZ**) method to convert design couplings to TRI contradictions
12. Use TRIZ to redesign/eliminate **undesirable off-triangular coupled terms** of existing concepts
13. Use the Decision Coupling Sequences (DCS) to optimize **execution sequences** of existing concepts

IV. Learning Activity

Students are required to work "individually" by themselves as well as "collaboratively" with classmates and teammates in different learning activities, including (A) live class, (B) quiz and survey, (C) cohort exercise, (D) design project, and (E) research paper study, designated by different colors below and in the class schedule (Section VIII) for easy identification:

(A). **Live Class:** Individual efforts on Tuesdays, from 17:00 to 20:00 (PST) – continuous without a break.

- The live class attendance requirements for USC on-campus and DEN students are as follows:
  - ✓ All USC on-campus students are required to attend the live class in person (in RTH217).
  - ✓ Whenever possible, USC DEN students are encouraged to attend the live class in person in RTH217 or online via the P2P system (i.e., in a synchronized mode).
  - ✓ For those DEN students who are unable to attend the live class in a synchronized mode, they must view the class recording within 48 hours to complete the online quiz and survey.
- When attending the live class in person or online synchronized, all students must log in to the P2P system from their laptop with webcam on and mic off to appear in the iPodia virtual classroom.

Weekly live classes include the following learning activities:

(1) Randomly called cohorts to report the results of their last week's design exercise to the class.
(2) The teacher lectures on the subject contents of this week's learning module.
(3) The teacher announces this week's design exercise assignment for the cohort (see C below).

(B). **<u>Quiz and Survey</u>:** Individual efforts on Wednesdays and Thursdays.

All students must complete an online <u>quiz</u> and then answer <u>survey</u> questions related to this week's learning subject <u>within 48 hours after the end of the live class</u>.

(1) Single-choice <u>quiz</u> questions are limited to the key concepts of this week's learning subject explained/discussed during the live class. <u>Quiz answers will be graded</u> weekly (see 2. Next).

(2) Open-ended <u>survey</u> questions have no right/wrong answer and are designed to solicit students' different preferences/viewpoints toward subjects related to the module. <u>Survey completion is mandatory</u> (for you to be included in the Cohort Exercise), but its answers are <u>not graded</u>.

(3) The P2P system will use various learning/learner diversity criteria to automatically assemble cohorts that will work on the design exercise assignment together (see C. next).

(C). **<u>Cohort Exercise</u>:** Collective efforts with cohort members from Fridays to Mondays.

"Cohorts" assembled above will meet in designated P2P chatrooms during the next four (4) days to

(1) Work together to complete the weekly design exercise assignment, focusing on sharing diverse experiences, viewpoints, and perspectives behind members' different ideas.

(2) Synthesize different ideas from individual members to form a collective result and submit up to three (3) PowerPoint slides to summarize your cohort results.

(3) Identify a representative member to report it (max. 1 minute) if/when the cohort is called upon during next week's live class.

<u>Note</u>: The above three learning activities. i.e., live class, quiz and survey, and cohort exercise constitute a weekly **<u>iLearning cycle</u>** (where "i" stands for interaction) that encourages peer-to-peer interactive learning. This weekly iLearning cycle is a unique feature of the iPodia class.

(D). **<u>Design Project</u>:** Team efforts throughout the entire semester.

Eight (8) project teams (max. 6 members) are assembled at the start of the semester to carry out design projects (i.e., conceptual design of a new product/system) that can satisfy the given customer need (CN).

- The given customer need (i.e., a CN or "project theme") will be announced in the 2nd week.
- Design teams (assembled in the 3rd week) will work together outside the weekly live class time.
- Design teams must present their progress on March 19, 2024, and then submit their project results (deliverables) online on April 30, 2024.

(E). **<u>Research Paper Study:</u>** Individual efforts to develop written reports for two assigned research papers.

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

- For each assigned paper, students must write a report <u>up to 5 pages</u> in length (space taken by figures is not counted), 12 pt., typewritten, double-spaced, with a maximum of 1" margins.
- Reports are due at the beginning of the class as indicated on the Course Schedule (see Section VIII). Students can turn in reports one week late for 50% of the credit. No credit will be given afterward.
- Additionally, individuals are encouraged to post their comments, opinions, and suggestions of the assigned papers onto the P2P Discussion Board before and after the due date of the written reports.

V. Reading Materials

Students are not required to purchase any textbooks for this course. The teacher will provide "draft" chapters of his upcoming book on "**Innovative Conceptual Design for Breakthrough Product Development**" relevant to the subjects of learning modules. PowerPoint lecture notes (in PDF files) and related reference materials for each learning module will also be provided weekly.

A list of "recommended" reading materials is as follows:

(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 appropriate.

VI. Grading Scheme

Students learning performances will be evaluated according to the following grading scheme:

(A). Live Class (total **50%** – including weekly online quizzes, design exercises, and class attendance)
- 12 online quizzes – 2% for each quiz with survey completion (total 24%)
- 11 cohort design exercises – 2% for each exercise result (total 22%)
- Live class attendance – Y/N (total 4%): missing no more than two live classes per semester
  - ✓ Attendance of on-campus students is based on live class signup sheets
  - ✓ Attendance of DEN students is based on P2P online study records of lecture recordings

(B). Final Examination (total **15%** – an open-book in-class exam on May 7, 2024)

(C). Design Project (total **25%** including a midterm design review and final project deliverables)
- Each design project team will receive a "team score" based on their project review presentations and final deliverables. This team score will then be converted to individual scores for each member based on a confidential peer-review survey to be conducted at the end of the semester.

(D). Research Paper Study (total **10%** for two paper study reports)

VII. The P2P System (based on Microsoft Teams)

A peer-to-peer (P2P) hybrid learning system built from Microsoft Teams will be used in this iPodia class. Each registered student will be given a special account on the www.ipodiaplatform.org platform to access the P2P system (note that this P2P account differs from your school's email account). All course-related information and activity, such as assignments, reading materials, communications (e.g., posts, notifications, etc.), and interactions (e.g., cohort exercises, design team projects, etc.), should be conducted on this P2P system. The unique Together mode of Microsoft Teams (i.e., a virtual iPodia world-classroom) will be used for student interactions and group exercises in a hybrid mode during the weekly live class.

Whenever appropriate, the P2P system will provide students with direct access to ChatGPT during their weekly cohort design exercises. In these cases, cohorts are to interact with ChatGPT as a "conversation partner" rather than an "answering machine" to create/inspire innovative, out-of-the-box design ideas. If so, the cohorts are to explicitly indicate the contributions of ChatGPT (as opposed to their own) in their cohort discussion reports.

The live class will provide more details on using ChatGPT (and any other generative AI tools) properly to aid design brainstorming when weekly cohort exercise assignments are given.

VIII. Weekly Schedule

A tentative weekly schedule for the spring semester of 2024 is shown below. Note that the teacher may modify this schedule per learning progress and requirements.

Week	Date	Learning Module	Subjects and Activities of Weekly Learning Modules		Quiz & Survey	Cohort Assign	Paper Study	Design Project
1	1/16	1	PART I Introduction	Introduction to **breakthrough** new product development (NPD) and an overview of course **learning requirements**				
2	1/23	2		Understand the principles of **design**, **design thinking**, and **innovative design thinking** (IDT) for breakthrough NPD	1	1	1st Paper Study Assignment	Design Project Assignment
3	1/30	3		**Functional Design** Stage: select functional requirements to satisfy customer needs as the conceptual design objective	2	2		Design Team Assembly
4	2/06	4	PART II Concept Generation Phase	The **foundation** of IDT Concept Generation: The Axiomatic Design Theory and logic propositions to ideate concepts	3	3		
5	2/13	5		The Concept **Formation** Step: ideate an initial space of options of logically feasible design concepts	4	4		
6	2/20	6		The Concept **Categorization** Step: use functional couplings or dependencies to identify functionally simple concepts	5	5		
7	2/27	7		The Concept **Selection** Step: select a preliminary design concept that is estimated to be most physically certain	6	6	1st Paper Study Report Due	
8	3/05	8		The **Zigzagging** Process: systematically generate more details of the preliminary design concept	7	7	2nd Paper Study Assignment	
9	3/12	n/a	USC Spring Break (university holiday - no live class this week)					
10	3/19	n/a	**Design Project Midterm Progress Review (Design Team Presentations)**					Presentation
11	3/26	9	PART III Concept Improvement Phase	Midterm Reviews (Lessons Learned); and the **Foundation** of Concept Improvement: The Relative Complexity Theory	8	8		Midterm Review Reports Due
12	4/02	10		Use **Functional Schematic** of the Design Concept to Identify Concept Improvement Opportunities and Strategies	9	9		
13	4/09	11		The Inventive Problem Solving (**TRIZ**) Method to Convert Design Couplings to TRIZ System & Physical Contradictions	10	10		
14	4/16	12		Resolving TRIZ Contradictions to redesign (**eliminate**) **off-triangular** coupled elements to improve existing concepts	11	11		
15	4/23	13		Finding **Optimal Execution Sequences** by Decision Coupling Sequences (DCS) Method to **Minimize** Relative Complexity	12		2nd Paper Study Report Due	
16	4/30	n/a	**Design Project Final Deliverables Due (online submission only)**					Final Reports
17	5/07	n/a	**Open-Book Final Examination**					

USC 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.

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.

Support Systems:
- Counseling and Mental Health - (213) 740-9355 – 24/7 on call; studenthealth.usc.edu/counseling
- National Suicide Prevention Lifeline - 1 (800) 273-8255 – 24/7 on call; suicidepreventionlifeline.org
- Relationship and Sexual Violence Prevention Services (RSVP) - (213) 740-9355(WELL), press "0" after hours – 24/7 on call; studenthealth.usc.edu/sexual-assault
- Office of Equity and Diversity (OED) - (213) 740-5086 | Title IX – (213) 821-8298; equity.usc.edu, titleix.usc.edu
- Reporting Incidents of Bias or Harassment - (213) 740-5086 or (213) 821-8298; usc-advocate.symplicity.com/care_report
- The Office of Disability Services and Programs - (213) 740-0776; dsp.usc.edu
- USC Campus Support and Intervention - (213) 821-4710; campussupport.usc.edu
- Diversity at USC - (213) 740-2101; diversity.usc.edu
- USC Emergency - UPC: (213) 740-4321, HSC: (323) 442-1000 – 24/7 on call; dps.usc.edu, emergency.usc.edu
- USC Department of Public Safety - UPC: (213) 740-6000, HSC: (323) 442-120 – 24/7 on call; dps.usc.edu