USC Viterbi
School of Engineering
iPodia

ISE/AME 501
Innovative Conceptual Design for New Product Development

Units: 3 Units. USC Session/Section: 048/31501D (On-campus); 034/31798D (DEN)
Time: Tuesdays, 18:30 – 21:00 (Pacific Standard Time)
Location: RTH 217 (On-campus) and Online (DEN) – hybrid mode

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

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 course is offered as an iPodia class (https://ipodia.usc.edu) with the University of Patras in Greece and Ndejje University in Uganda. The logistic information (e.g., time, location, etc.) included in this syllabus is for USC students only. non-USC students should refer to their local information. Due to different academic calendars, non-USC students will join the live class and team project of this iPodia class on different weeks.
3. This iPodia class will be delivered via the P2P (peer-to-peer) hybrid learning system jointly developed with Microsoft Teams. (https://www.microsoft.com/en-us/microsoft-teams)

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I. Course Description

A typical new product development (NPD) process consists of three different design activities, namely (1) the Functional Design to select Functional Requirements (FR) of the said product to satisfy the newly uncovered Customer Needs (CN), (2) the Conceptual Design to ideate Design Parameters (DP) to embody the above-chosen FRs, and (3) the Parametric Design to determine Parametric Values (PV) to optimize the above-embodied DPs. The conceptual design activity, where 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 engineers 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 industries due to the lack of rigorous foundations and practical methods for systematic ideation. Some business school courses in market benchmarking, demand forecasting, and customer survey are only helpful in the functional design of existing products, whereas most current engineering curricula primarily focus on geometric and computational methods for the parametric (or technical) design. To develop competitive new products for blue-ocean markets, engineers must learn how to ideate innovative design concepts during conceptual design beyond traditional functional and parametric design activities.

In this iPodia class, students will learn the theoretical principles and practical methods based on a logical foundation to systematically carry out the conceptual design activity during new 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 (mainly covered in another USC course, ISE545), 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, conceptual design activities are 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 is logically feasible, functionally simple, and physically feasible, through a unique zigzagging process is introduced. Functional schematics and two methods that can reduce the relative complexity of ideated (or existing) design concepts will be introduced for the concept improvement phase. The first method uses conflict resolution strategies from TRIZ (i.e., Theory of Inventive Problem Solving) to redesign and eliminate coupled 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.

As an iPodia class, all students will follow a weekly iLearning process on a special peer-to-peer (P2P) hybrid learning system jointly developed with Microsoft (www.microsoft.com). They will have opportunities to work with classmates directly across physical, institutional, and cultural boundaries to broaden their perspectives in ideating innovative design concepts. To practice the knowledge learned in the class, small design teams will be assembled for students to work with global teammates of diverse backgrounds. Industry experts may be invited to share their practical 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 help students understand essential concepts and practical applications.

II. Learning Objective

After completing this course, students will have the basic knowledge and necessary skills to perform the followings tasks relate to innovative conceptual design:

- 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 “learning modules” in three consecutive Parts. Each week is devoted to studying and exercising a learning module per the weekly schedule in Section VIII. A learning module includes several key concepts, each explained by a few PowerPoint slides with sequence animations.

PART I: Introduction – what is new product development, and what is innovative conceptual design?

1. Overview of learning **requirements** and introduction to design and 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 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 the TRIZ method to remove some **undesirable off-triangular coupled terms** of existing concepts
13. Decision Coupling Sequences (DCS) method for **optimal execution sequences** of existing concepts

IV. Learning Activity

Students are required to work “individually” by themselves as well as “collaboratively” with classmates in different learning activities, including (A) live class, (B) quiz & survey, (C) cohort exercise, (D) design project, and (E) paper study, designated by different colors here for easy identification:

(A). **Live Class:** Individual efforts on Tuesdays, from 6:30 pm to 9:00 pm (PST).
Note, whether attending the live class in person or online in a synchronized mode, all students must log in to the P2P system (see Section VII) from their laptop (with webcam on and mic off) to appear in the iPodia virtual classroom. Weekly live classes include the following learning activities (see Fig.1 below):

(1) Randomly selected cohorts to report their last week’s design exercise results to the class.

(2) The teacher lectures this week’s learning module to the class. The live class attendance requirements for USC on-campus, DEN students, and other iPodia 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 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.
- For students at participating iPodia universities, synchronized participation in the live class is highly encouraged for productive engagement with classmates. Otherwise, they must also view the live class recording within 48 hours to complete the online quiz and survey.

(3) The teacher announces this week's design assignment for the cohort exercise (see C below).

(B). **Quiz & Survey:** Individual efforts on Wednesdays and Thursdays (see Figure 1 below).
All students must complete online quizzes and answer survey questions related to this week's learning module within 48 hours after the end of the live class.

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

(2) Survey questions have no right/wrong answer and are designed to solicit students' different preferences/viewpoints toward something related to the course subject. Survey completion is mandatory (for you to be included in the Cohort Exercise), but its answers will not be graded.

(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 next).

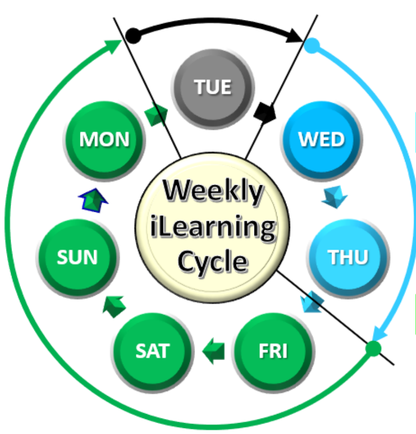
(C). **Cohort Exercise:** Collective efforts with cohort members from Fridays to Mondays (see Figure 1 below).
"Cohorts" assembled above will meet in designated online chatrooms during the next four (4) days to

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

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

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

The above three learning activities. i.e., live class, quiz & survey, and cohort exercise constitute **a weekly iLearning cycle** (where "i" stands for interaction). This weekly iLearning cycle, which is a unique feature of the iPodia class, is summarized and illustrated below (see Figure 1):



(A) Live Class: Tuesdays, from 6:30pm to 9:00pm (PST)
- Cohort reports (of last week's design exercise)
- Teacher lectures (of this week's learning module)
- Design exercise assignment (for cohorts to work)
- Questions/answers (of this week's learning module)

(B) Quiz & Survey: Wednesdays and Thursdays (PST)
- Quiz (to evaluate your understanding of lecture content)
- Survey (to solicit your viewpoints toward some topics)
- Only quiz answers are graded (2 points each week)
- Quiz and survey results are used to assemble cohorts

(C) Cohort Exercise: From Fridays to Mondays (PST)
- Assembled cohort members collaborate online to:
  – Compare/explain different quiz answers (if any)
  – Share diverse ideas to the design exercise assignment
  – Synthesize individual ideas to form a collective result
  – Elect a member to report the cohort result

Figure 1: The Weekly iLearning Cycle consisting of live lecture, quiz and survey, and cohort discussion

(D). **Design Project:** Team efforts throughout the entire semester.

10 project teams (max. 6 members) are assembled at the semester start 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 design 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 14, 2023, and then submit their project results online on April 25, 2023.

(E). **Paper Study:** Individual efforts to develop 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 content and its relevance to the course subjects.

- For each assigned paper, students must write a report up to 5 pages 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 Material

No textbook is required for this course. The teacher weekly will provide lecture notes and related reference materials for each learning module.

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 appropriate.

VI. Grading Scheme

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

(A). Live Class (total **50%** – including 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

(B). Final Examination (total **15%** – an open-book in-class exam)

(C). Design Project (total **25%** including a design review and final deliverables)

- Each cross-campus project team will receive a "team score" first based on their project review presentations. 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). 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 (i.e., cohort exercises, 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.

VIII. Weekly Schedule

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

Date	Module	The Subject of the Weekly Learning Module (and Live Class)		Quiz & Survey	Cohort Assign	Paper Study	Design Project
1/10	1	PART I Introduction	Introduction to design and **new product development** (NDP) and overview of course learning **requirements**				
1/17	2		Understand the principles of **design**, **design thinking**, and **innovative design thinking** (IDT) for product development	1	1	1st Paper Assignment	Design Project Assignment
1/24	3		**Functional Design**: to select functional requirements that satisfy customer needs as the conceptual design objective	2	2		Design Team Assembly
1/31	4	PART II Concept Generation	The **foundation**: use the Axiomatic Design theory and logic propositions to ideate new design concepts	3	3		
2/07	5		Concept **Formation**: ideate an initial space of options of logically feasible design concepts	4	4		
2/14	6		Concept **Categorization**: use functional dependencies to identify functionally simple design concepts	5	5		
2/21	7		Concept **Selection**: select a preliminary design concept that is estimated to be most physically certain	6	6	1st Paper Report Due	
2/28	8		**Zigzagging** Process: systematically generate more details of the preliminary design concept	7	7	2nd Paper Assignment	
3/07	n/a	USC Spring Break (no live class this week)					
3/14	n/a	Design Project Progress Review (Team Presentations)					Mid-term Reports
3/21	9	PART III Concept Improvement	The **foundation**: use the Complexity Theory and functional schematics to improve design concepts	8	8		
3/28	10		Improvement **opportunities** and **strategies** to reduce the relative complexity of existing design concepts	9	9		
4/04	11		The Inventive Problem Solving (**TRIZ**) method and convert design couplings to the system and physical contradictions	10	10		
4/11	12		Use the TRIZ method to remove some **undesirable off-triangular coupled terms** of existing concepts	11	11		
4/18	13		Use the Decision Coupling Sequences (DCS) method to find the **optimal execution sequences** of existing concepts	12		2nd Paper Report Due	
4/25	n/a	Design Project Final Deliverables Due (online submission before the final exam begins)					Final Reports
		Open-Book Final Examination (Semester grades are due on May 4, 2023)					

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