USC Viterbi
School of Engineering
iPodia

ISE501/AME501 Innovative Conceptual Design For New Product Development

Units: 3 units
Time: Tuesdays, 18:30 – 21:00 (Pacific Standard Time)

USC Session/Section: 048/31501 (On-campus); 034/31798 (DEN)
Location: RTH 217 (On-campus) and Online (DEN) – hybrid mode

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

Note:

1. This is a USC degree required course for Master of Science in Product Development Engineering degree. https://viterbigradadmission.usc.edu/programs/masters/msprograms/aerospace-mechanical-engineering/ms-product-development/
2. This course is jointly delivered as an iPodia class (https://ipodia.usc.edu) with University of Patras in Greece (https://www.upatras.gr/en/). Some logistic details described in this syllabus are for USC students. U. of Patras students should refer to their local information (e.g., dates, times, etc.) instead.
3. This iPodia class is supported by the P2P (peer-to-peer) system developed in collaboration with Microsoft Teams. (https://www.microsoft.com/en-us/microsoft-teams)

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I. Course Description

A new product development (NPD) process typically consists of three types of design activity, namely (1) Functional Design that chooses Functional Requirements (FR) of the said product to satisfy the newly uncovered Customer Needs (CN), (2) Conceptual Design that ideates Design Parameters (DP) to embody the chosen FRs, and (3) Parametric Design that determines Parametric Values (PV) to optimize the ideated DPs. The conceptual design activity, where a set of dependency relationships between upstream market demands (i.e., CNs and FRs) and downstream physical constraints (i.e., DPs and PVs) is established, presents the best opportunity for engineers to develop innovative products to initiate a new blue-ocean market.

While conceptual design plays the most important role in innovative product development, 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 for systematic ideation. Some business school courses in market benchmarking, demand forecasting, and customer survey are only useful for improving existing products; whereas current engineering curriculum are mostly focused on geometric and computational methods for parametric (or technical) design. To develop competitive new products for blue-ocean markets, engineers must learn conceptual design to creatively ideate innovative design concepts after functional design and before parametric design activities.

In ISE/AME-501, students will learn the theoretical foundation and practical methods of a logic-based framework to systematically carry out the conceptual design activity during new product development. The course will start with an introduction of the new product development process 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 (which is covered in another USC graduate course, ISE545), the theoretic foundation of logic propositions and a systematic 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 is logically feasible, functionally simple, and physically feasible, through a unique zigzagging process is introduced. For concept improvement, functional schematics and two methods that can reduce the relative complexity of ideated or existing design concepts will be introduced. 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.

In spring semester 2022, ISE/AME-501 will be delivered as **an iPodia class** jointly with University of Patras in Greece, a member of the iPodia Alliance (www.ipodialliance.org). A special peer-to-peer (P2P) system joint developed with Microsoft (www.microsoft.com) will be used to support the weekly iLearning process. All students 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, 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 widen their exposure to the fields of conceptual design and product development. Real-world product examples and industrial case studies will be used to help students understand important concepts and practical applications.

II. Learning Objective

After successfully completing this iPodia class, students will have basic knowledge and necessary skills to perform the followings:

- 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 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.
- Know different conceptual design phases in new product development processes and their corresponding design theories and applicable decision methodologies.
- Practice the IDT concept generation process and basic design axioms to generate and compare initial design concepts through direct synthesis reasoning (vs. iterative analyses).
- Understand the basics of concept improvement methods and tools for concept improvement phase and how they can be used in a complementary manner 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

ISE/AME-501 is organized as 12 weekly learning modules in three phases as follows: (see Section VIII)

PHASE I: the background of new product development and innovative conceptual design

1. An introduction of **iPodia** and **iLearning**, and how to learn effectively, and succeed in, an iPodia class
2. An overview of key concept and technology: **design**, **design thinking**, and technology **innovation**
3. An Innovative Design Thinking (**IDT**) framework to support New Product Development (**NDP**) process
4. **Functional Design**: select functional requirement (FR) to satisfy newly uncovered customer need (CN)

PHASE II: systematically ideate new design concepts for chosen functional requirement

5. The Concept **Generation Phase**: make logic-based propositions systematically to create new concepts
6. Concept **Formation Step**: ideate an initial option space of design concepts that are logically feasible
7. Concept **Categorization Step**: use dependency to identify design concepts that are functionally simple
8. Concept **Selection Step**: select a preliminary design concept that is most physically certain; zigzagging

PHASE III: reduce relative complexity to improve ideated (or existing) design concepts

9. The **Concept Improvement** Phase: Complexity Theory & functional schematics to improve concepts
10. Find **functional schematics** to plan for improvement strategies, and introduction of the **TRIZ** method
11. Resolve TRIZ system and physical contradictions to **remove coupled terms** in the off-triangular area
12. Decision Coupling Sequences (DCS) method to find **optimal execution sequence** of design concepts

IV. Learning Activity

Students in this iPodia class will work “individually” by themselves and “collaboratively” with classmates from participating iPodia universities in five (5) different learning activities, including (A) live class, (B) quiz & survey, (C) cohort exercise, (D) design project, and (E) paper study, throughout the semester. The following terminologies are used in explaining each of these learning activities (which is also designated by different colors for easy identification):

- “**Individual**” refers to a single student in this iPodia class.
- “**Class**” refers to the collection of all students (from multiple schools) in this iPodia class.
- “**Cohort**” refers to a group of cross-campus students assembled for weekly design exercise.
- “**Team**” refers to a group of cross-campus students assembled for semester-long design project.

(A). Live Class: Weekly on Tuesdays, from 6:30pm to 9:00pm (PST).

The weekly live class includes the following learning activities (see Figure 1 below):

(1) “Cohorts” report their last week’s design exercise results to the whole “class”

(2) The teacher lectures this week's learning module to the "class." "Individuals" can attend live lectures either in person (in RTH217) or remotely via the P2P system (see Section VII).
(3) The teacher announces this week's design exercise assignment for cohorts to work on.
(4) Opportunities for open questions/discussions relate to this week's learning module (led by the TA)

(B). Quiz & Survey: Weekly on Wednesdays and Thursdays (individual efforts in a 48-hour period)
All "individuals" are required to compete online quiz and answer survey questions related to this week's learning module during a 48-hour period after the end of live class.
(1) Quizzes, which may include some multiple-choice questions, will be limited to key concepts relate to the subject of the learning module discussed in the live class in that week.
(2) Surveys, which have no right/wrong answer, are designed to solicit individuals' different preferences/understandings toward the learning module discussed in the live class in that week.
(3) Individuals' quiz and survey results, together with other criteria (e.g., learner diversity), will be used to automatically assemble "cohorts" to work on design exercises assignment (see next).

(C). Cohort Exercise: Weekly from Fridays to Mondays (collaborative efforts in a 96-hour period)
"Cohorts" assembled above are to meet in designated online chatrooms during the next four () days.
(1) "Cohort" members first compare their "individual" answers to the quiz questions and explain the reasons for their different answers if any.
(2) "Cohort" members then work together to complete the weekly design exercise assignment, focusing on sharing diverse rationales and perspectives behind their different ideas.
(3) Each "cohort" synthesizes different ideas from "individual" members to form a group result and identifies a representative to report it at the beginning of next week's live class (see VI.A.(1)).

The above three learning activities. i.e., live class, quiz & survey, and cohort exercise, constitute **a weekly iLearning cycle** (where "i" stands for interaction) in which students must work individually by themselves first and then collaboratively with assigned cohort members. This weekly iLearning cycle, which is a unique feature of the iPodia class, is summarized and illustrated below (see Figure 1):

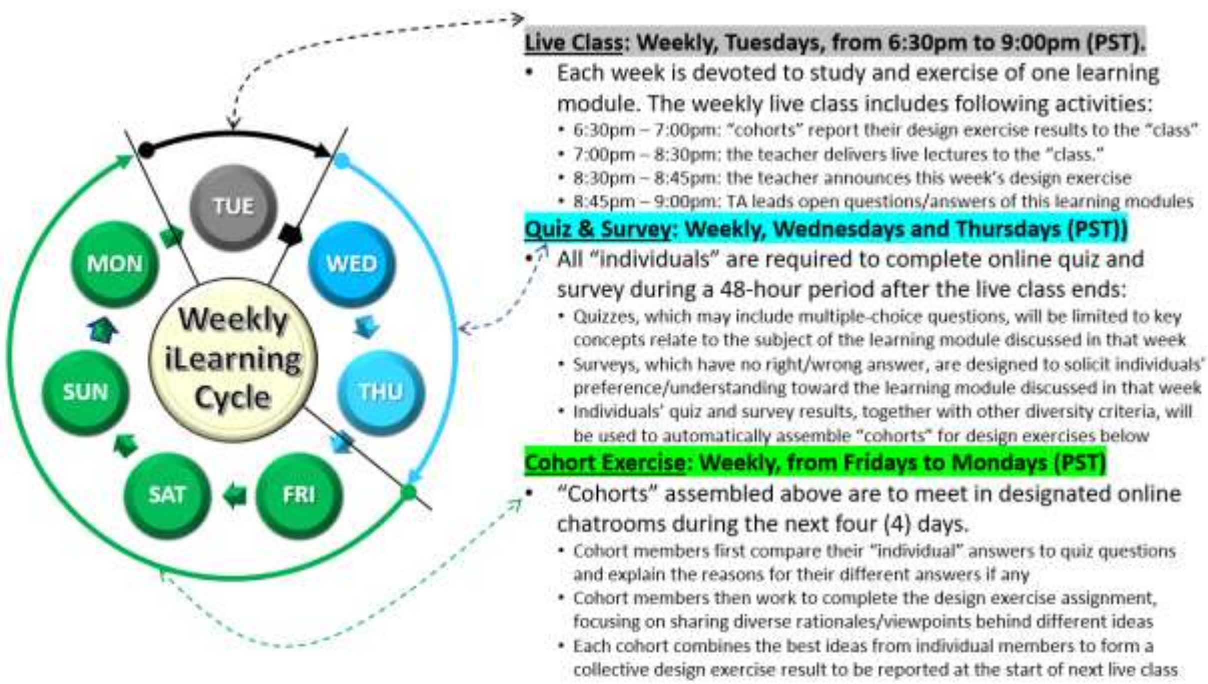

Figure 1: Students Follow the Weekly iLearning Cycle in this iPodia Class

(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 assigned customer need (i.e., a CN or design project theme) will be announced in the 2nd week.
- Design teams, which will be assembled in the 3rd week, are to work together on their projects outside the weekly live class time.
- Design teams are required to make a presentation of their progresses/results at two scheduled times on Week 10 (progress review) and Week 15 (final deliverable).

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

Two (2) research papers will be assigned for all "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 required to write a 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 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 afterwards.
- 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. Lecture notes and related reference materials 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). A learning module is organized as 4 key concepts, each is explained by 5 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 evaluated according to the following grading scheme:

(A). Live Class (total **40%** for 10 weeks – note: the lowest two scores of 12-weekly learning modules will be dropped automatically)

- Each week's quiz/survey and cohort exercise performances count 4%, including 2% for individual quiz answers, and 2% for cohorts' result/performance of design exercises assignments.

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

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

- 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 2 paper study reports)

VII. The P2P System (based on Microsoft Teams)

A special peer-to-peer (P2P) system built from Microsoft's Teams (a part of the Microsoft 365) will be used in this iPodia class. Each registered student will be given a P2P account on the "ipodiaplatform.org" platform to access the P2P system (note, this P2P account is different 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 the Microsoft Teams will be used for live class and group exercises (i.e., a virtual iPodia world-classroom) to deliver this class in the hybrid mode.

VIII. Weekly Schedule

Week	Date	Learning Module		Live Class (Subject of Weekly Learning Module)	Online Quiz	Design Exercise	Paper Study	Design Project
1	**1/18**	**Phase I**: the background of innovative conceptual design	**1**	An introduction of **iPodia** and **iLearning**, and how to learn effectively, and succeed in, an iPodia class				
2	**1/25**		**2**	An overview of key concept and technology: **design**, **design thinking**, and technology **innovation**	**2**	**2**	1st Paper Assignment	Design Project Assignment
3	**2/01**		**3**	An Innovative Design Thinking (**IDT**) framework to support New Product Development (**NDP**) process	**3**	**3**		Design Team Assembly
4	**2/08**		**4**	**Functional Design** (summary): select a right functional requirement (FR) to satisfy found customer needs (CN)	**4**	**4**		
5	**2/15**	**Phase II**: ideate new design concepts for chosen FRs	**5**	The Concept **Generation Phase**: make logic-based propositions systematically to create new concepts	**5**	**5**		
6	**2/22**		**6**	Concept **Formation** Step: ideate an initial space of options of design concepts that are logically feasible	**6**	**6**		
7	**3/01**		**7**	Concept **Categorization Step**: use dependency to identify design concepts that are functionally simple	**7**	**7**	1st Paper Report Due	
8	**3/08**		**8**	Concept **Selection Step**: select a preliminary design concept that is most physically certain - zigzagging	**8**	**8**	2nd Paper Assignment	
9	**3/15**			USC Wellness Day (no class this week)				
10	**3/22**			Team Design Review I (Mid-term design progress report)				Progress Review
11	**3/29**	**Phase III**: improve ideated (or existing) design concepts	**9**	The Concept **Improvement Phase**: Complexity Theory & functional schematics to improve existing concepts	**9**	**9**		
12	**4/05**		**10**	Find **functional schematics** to plan for improvement strategies, and an introduction of the **TRIZ** method	**10**	**10**		
13	**4/12**		**11**	Resolve TRIZ **system** and **physical contradictions** to remove coupled (non-0) terms in off-triangular area	**11**	**11**		
14	**4/19**		**12**	Use Decision Coupling Sequences (**DCS**) method to find optimal execution sequence of design concepts			2nd Paper Report Due	
15	**4/26**			Team Design Review II (Final design project presentation)				Final Presentation
16	**5/03**			USC Study Day (no class this week)				
17	**5/10**			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