To: The Faculty of the College of Engineering

From: The Curriculum Committee of the Innovation and Leadership Studies Program

RE: New Undergraduate Course, ENGR 49000 Breakthrough Thinking for Complex Challenges

The Curriculum Committee of the Innovation and Leadership Studies Program has approved the following new course. This action is now submitted to the Engineering Faculty with a recommendation for approval.

ENGR 49000 Breakthrough Thinking for Complex Challenges
Sem. 1, Lecture 3, Cr. 3
Prerequisites: None.

Description: This course helps students learn and effectively employ high-impact design principles and structured problem solving methods to address complex multi-stakeholder socio-technical challenges. Case discussions of historical and contemporary high impact solutions to complex challenges are used to introduce techniques to frame problems, structure ambiguity, intentionally design non-incremental solutions, and communicate, trial, and iterate solutions to drive adoption and multifaceted sustainability. Techniques are drawn from multiple schools of thought such as business, design, engineering, and the social sciences. Over the course of the term, multi-disciplinary student teams directly apply cumulative learning to address selected parts of a real-world complex societal challenge in close collaboration with a partner organization, in an experiential learning format.

This course can be counted toward the College of Engineering Minor in Innovation and Transformational Change and the Burton D. Morgan Center for Entrepreneurship (BDMCE) Certificate in Entrepreneurship and Innovation.

Reason: Engineers are increasingly engaged in developing solutions to major challenges which are referred to under varying names such as complex problems, grand challenges, or wicked problems. These categories of problems require solutions that span technical, economic, social, and cultural domains and thus impede approaches derived from only one perspective. Major challenges share the characteristics of being ambiguously bounded, involving multiple stakeholders and interdependencies, and displaying non-linear emergent behavior, network effects, and hysteresis. This course introduces and allows students to apply methods from varying fields that enable them to integrate differing ways of thinking to frame major challenges and design aspects of holistic solutions, helping to build critical awareness and skills consistent with the College's vision to prepare Purdue engineers for leadership roles in the 21st century.

This course has been offered 3 times as a CE597 course, with the following enrollments: S15 (21), S16 (14), S17 (8).

Director of the Innovation and Leadership Studies _

ENGR490
Breakthrough Thinking for Complex Challenges

Course: ENGR-49000 "Breakthrough Thinking for Complex Challenges"

Description: In this course, students engage in problem exploration and participatory design in close partnership with an external organization to frame, design, and advance holistic solutions to major challenges varyingly categorized as complex problems, grand challenges, or wicked problems. These categories of problems share the characteristics of being ambiguously bounded, involving multiple stakeholders and inter-dependencies, and displaying non-linear emergent behavior, network effects, and hysteresis, and require solutions that span technical, economic, social, and cultural domains. Conceived solutions focus on two or more aspects of the major challenge, and may include means to address technical challenges, aspects of stakeholder education and awareness, cultural adoption, resource availability and access, economic and operational sustainability, or governance. Collectively, co-designing solutions with a holistic perspective of the aforementioned components, in collaboration with involved stakeholders, helps build critical awareness and skills consistent with the College's vision to prepare Purdue engineers for leadership roles in the 21st century.

Pre-requisites: None

Instructor: Professor Joe Sinfield **Office:** HAMP G231 **Phone:** x6-2742

Class hours: Two meetings per week: (1) 50 min + (1) 110 min

Classroom: TBD

Learning outcomes: Upon successful completion of this course, students will be able to:

1. Employ rigorous issue analysis methods to develop mutually-exclusive collectively-exhaustive structured inventories of the issues involved in a major challenge
2. Understand stakeholder motivation and interpret the funds, services, and influence exchanged in stakeholder ecosystems
3. Understand the benefits and limitations of qualitative and quantitative methods to identify and interpret stakeholder needs
4. Gain familiarity with habit conversion methodologies and the role they can play in design activities
5. Recognize the importance of empathy in solution design and apply structured ideation methods to engender empathy in designers
6. Understand patterns of innovation success and the contextual

circumstances in which they apply
7. Understand combinatorial business design methods to explore and prioritize alternative paths to achieve financial sustainability for an idea
8. Discern the broader societal impacts of design activities
9. Develop robust assessments of the assumptions underlying new ideas and means to test those assumptions rapidly and at low cost
10. Recognize and define influence paths and communication methods to drive awareness, consideration, conversion, and retention of new solutions

Alignment with standards:

ABET Standard	***Corresponding Course Content***
A. Ability to apply mathematics, science and engineering principles	Team project involving designing and iteratively testing aspects of holistic solutions for complex challenges
C. Ability to design a system, component, or process to meet desired needs	Team work sessions and lecture content on issue and ecosystem analysis and stakeholder definition; lectures on systems thinking and solution right-sizing; team work session on systems-level solution prioritization
D. Ability to function on multidisciplinary teams	Team project involving multidisciplinary student teams; team work session and lecture on ideation best practices
E. Ability to identify, formulate, and solve engineering problems	Lectures on problem framing, hypothesis-driven problem solving, and leveraging structure and analogies to generate solutions; term project and collaborative co-design requiring development of aspects of holistic solutions to a major challenge
G. Ability to communicate effectively	Lecture on persuasive communications, ghosting, storylines, and storytelling; team oral presentations in class and to engaged partner organization
H. The broad education necessary to understand the impact of engineering solutions in a global and societal context	Team project and course content centered around designing for major challenges
J. Knowledge of contemporary issues	Lecture and case discussions focused on addressing major

	societal challenges
K. Ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	Lectures and multiple problem solving sessions on design, linking quality to context, and identifying barriers to uncover paths to breakthrough opportunity

Relation to Engineer of 2020 Target Attributes

Target Attribute	***Corresponding Course Content***
Decision-making ability	Team working sessions on systems-level solution prioritization; lecture on the many forms of risk
Ability to synthesize engineering, business, and societal perspectives	Team working sessions and lecture on multifaceted sustainability (operational, economic, environmental and cultural)
Open-ended design and problem solving skills	Term project aimed at framing and addressing major challenge that has no discreet solution path or solution; See also ABET standards A, C, E, and K; lecture on developing an outside-in perspective on solutions
Analytical skills	Lectures and iterative team working sessions to gather, analyze, and interpret multiple forms of technical, economic and social data; See also ABET standard C
Innovative mindset	Lecture on forms of innovation and impact; case studies illustrating achievement of high-impact innovation and innovator attributes
Adaptability in a changing environment	Team work sessions and lectures on ecosystem analysis, habit conversion, stakeholder influence and communication strategies

Grading:

Weight	Activity
65%	Term project team assignments: The term project for the class centers on a multifaceted problem representative of a major societal challenge that is provided by an external organization. Students in the class divide into teams of 3 to 5 and engage with the external organization and key stakeholders in problem framing and co-design activities leading to the development of

	key aspects of holistic solutions to help address the organization's challenge. Team assignments consist of 6 to 8 interim deliverables (e.g., issue analysis, stakeholder maps, context characterization, holistic solution requirements, solution design space definition, prioritization criteria development, system-level solution selection, and assumption analysis) that are developed by the teams over the course of the semester and shared with the external organization as they work their way through framing and developing aspects of solutions to address the provided challenge.
35%	Homework and cases: Brief individual written assignments (< 3 pages) are employed to guide students through exploration of course concepts and cases illustrating discussed design principles and behaviors (typically 3-5 assignments)

Text: **Innovator's Guide to Growth: Putting Disruptive Innovation to Work** by Scott D. Anthony, Mark W. Johnson, Joseph V. Sinfield, and Elizabeth J. Altman

Attendance: Due to the nature of this class, class participation is a must. In order to receive course credit and a full grade, a student must:

1. Have no more than two unexcused absences.
2. Satisfactorily complete ALL assignments.

Three unexcused absences will result in a grade reduction of one letter grade. Four unexcused absences will result in a grade of 'I' or 'F', depending on whether or not the student is considered to be passing in all other aspects at the time of the fourth absence. Failure to complete ALL assignments will result in a grade of 'I' or 'F', depending on whether or not the student is considered to be passing in all other aspects.

Homework/ cases/project deliverables: No assignments can be missed without penalty, unless the missed assignment is authorized by the instructor.

Ethics: Students are expected to uphold all university policies and regulations on academic integrity and conduct. Academic dishonesty will not be tolerated, and any acts of academic dishonesty will be dealt with on a case by case basis. Penalties for violations will be levied at the discretion of the instructor and may include but are not limited to reduction in the grade received for an assignment or exam, loss of credit for an assignment or exam, reduction in the FINAL grade for the course, and/or failure of the course.

Course outline:

Week	*Topic*		*Reading/References*
1	I.	Addressing grand challenges	Sinfield and Solis, 2016b
2	II.	Forms of innovation / defining impact	Solis and Sinfield, 2014
3	III.	Design thinking and achieving breakthrough	Breakthrough Case #1; Sinfield and Solis, 2016b; Crismond and Adams, 2012
4,5,6	IV.	Issue analysis; hypothesis-driven problem solving	Minto, 1996
7,8	V.	Framing a problem; ecosystem analysis; stakeholder engagement	Belone et al., 2016
9	VI.	Making a problem personal; jobs-to-be-done and ethnography	Anthony et al., 2007; Beebe, 2014
10	VII.	Developing an outside-in perspective on solutions	Solis and Sinfield, 2016a
11	VIII.	Systems thinking; patterns of innovation success	Breakthrough Case #2 DeLaurentis and Callaway, 2004; Mostafavi et al., 2011
11	IX.	Focusing on context to "right size" solutions	Sinfield, 2007
12	X.	Ideation best practices and stimuli development	Sinfield and Anthony, 2006; Sinfield et al., 2014; Girotra et al., 2010
13,14	XI.	Business model innovation to facilitate economic sustainability	Weill et al. 2004; Johnson et al. 2008; Sinfield et al. 2012
14	XII.	The many forms of risk	Damanpour, 1996; Sinfield and Solis, 2016a
15	XIII.	Persuasive communications; ghosting, storylines, and storytelling	Breakthrough Case #3
16	XIV.	Planning to learn	Mintzberg and Waters 1985; McGrath and MacMillan 1995

Reading list: Readings will be drawn from the following references

1. Anthony, S. D., and Sinfield, J.V. (2007) "Product for Hire: Master the Innovation Lifecycle with a Jobs-to-be-Done Perspective of Markets,"*Marketing Management*, March/April, 19-24.
2. Beebe, J. (2014). **Rapid Qualitative Inquiry: A Field Guide to Team-Based Assessment**, Second Edition. Lanham MD: Rowman & Littefield. 258 pp.
3. Belone, L., Lucero, J.E., Duran, B., Tafoya, G., Baker, E.A., Chan, D., Chang, C. Greene-Moton, E., Kelley, M. A., and Wallerstein, N., (2016). "Community-Based Participatory Research Conceptual Model: Community Partner Consultation and Face Validity," *Qualitative Health Research*, 26(1): 117-135.
4. Crismond, D. P., and Adams, R. S. (2012). "The Informed Design Teaching and Learning Matrix." *Journal of Engineering Education*, 101(4), 738-797.
5. Damanpour, F. (1996). "Organizational Complexity and Innovation: Developing and Testing Multiple Contingency Models." *Management Science*, 42(5), 693 - 716.
6. DeLaurentis, D., & Callaway, R. (2004). "A systems-of-systems perspective for public policy decisions." *Review of Policy Research*, 21(6), 9.
7. Girotra, K., Terwiesch, C., and Ulrich, K. T., (2010) "Idea Generation and the Quality of the Best Idea", *Management Science*, Vol. 56, No. 4 (April 2010), pp. 591-605.
8. Johnson, M., Christensen, C., and Kagermann, H. (2008). "Reinventing your business model." *Harvard Business Review*, December, 51-59.
9. McGrath, R., and MacMillan, I. (1995). "Discovery-driven planning." *Harvard Business Review*, 73(4), 44-54.
10. Minto, B. (1996) **The Minto Pyramid Principle: Logic in Writing, Thinking, and Problem Solving**, Minto International, Inc., London.
11. Mintzberg, H., and Waters, J. (1985). "Of strategies, deliberate and emergent." *Strategic Management Journal*, 6(3), 257-272.
12. Mostafavi, M., Abraham, D., DeLaurentis, D., and Sinfield, J. (2011). "Exploring the Dimensions of Systems of Innovation Analysis: A System of Systems Framework." *IEEE Systems Journal,* 5(2), 256 - 265.
13. Sinfield, J. and Anthony, S. (2006) "Constraining Innovation: How Developing and Continually Refining Your Organization's Goals and Bounds Can Help Guide Growth", *Strategy & Innovation*, November – December, v. 4, n. 6, 1, 6-9.
14. Sinfield, J.V., (2007) "Gives, Gets, and the Good Enough: A methodical, consumer driven approach to cutting features, benefits—and costs", *Strategy & Innovation*, November – December, v. 5, n. 6, 1, 6-10.
15. Sinfield, J.V., and Solis, F., (2016a) "Finding a Lower-risk Path to High-impact Innovations," **Sloan Management Review**, 79-89,

Summer.
16. Sinfield, J.V., and Solis, F., (2016b) "Thinking Big to Address Major Challenges: Design and Problem-Solving Patterns for High-Impact Innovation, National Academy of Engineering, *The Bridge*, 11-18, Summer.
17. Sinfield, J.V., Calder, E.S., Colson, S., McConnell, B., (2012) "How to Identify New Business Models," *Sloan Management Review*, v. 53, n. 2, Winter.
18. Sinfield, J.V., Gustafson, T., and Hindo, B. (2014) "The Discipline of Creativity," *Sloan Management Review*, 55(2), 24-26, Winter.
19. Solis, F. and Sinfield, J.V. (2014) "Rethinking Innovation: Characterizing Dimensions of Impact," ASEE Annual Conference, 360 Degrees of Engineering Education, June 15 - 18, 2014 Indianapolis, Indiana, Paper ID #9284.
20. Solis, F., and Sinfield, J.V., (2016) "From Entrepreneur to Designer: The Transferable Design Principles of the Entrepreneur," (2016) ASEE Annual Conference & Exposition, Jazzed about Engineering Education, June 26-29, 2016, New Orleans, LA, Paper ID#15965.
21. Weill, P., Malone, T. W., D'Urso V.T., Herman, G. and Woerner S. (2004) "Do Some Business Models Perform Better Than Others?" MIT Sloan School of Management Working Paper/ MIT Center for Coordination Science Working Paper No. 226, 6 May.

ENGR - 49000 - Breakthrough Thinking for Complex Challenges

2017-2018 Course Create New Undergraduate

General Course Information

Originating Campus*

- [x] West Lafayette
- [ ] Northwest
- [ ] Fort Wayne
- [ ] IUPUI

Non-Originating Campus(es): (Select the correct combination of additional campuses offering this course)*

- (•) No other campus involved
- ( ) West Lafayette
- ( ) Northwest
- ( ) Fort Wayne
- ( ) IUPUI
- ( ) Northwest & Fort Wayne
- ( ) Northwest & IUPUI
- ( ) West Lafayette & Northwest
- ( ) West Lafayette & Fort Wayne
- ( ) West Lafayette & IUPUI
- ( ) Fort Wayne & IUPUI
- ( ) Northwest, Fort Wayne, & IUPUI
- ( ) West Lafayette, Fort Wayne, & IUPUI
- ( ) West Lafayette, Northwest, & IUPUI
- ( ) West Lafayette, Fort Wayne, & Northwest

Multiple Campuses: There is only one version of a course in the Banner catalog. All campus locations offering this course must agree. Choosing the locations above allows all involved campuses to approve the proposal.

College/School*

College of Engineering - WL

Department*

-College of Engineering Administration (Graduate) - WL

Course Numbers: All course numbers may only be used once for a course in order to allow our repeat course audit to work properly. Before submitting a form for a new course or renumber, please make sure the course number is available. Please remember Purdue

now uses 5-digit course numbers to allow more options for the departments. This may be verified through the following:

Legacy Course Catalog: https://www.purdue.edu/registrar/legacy/catalog.cfm

Banner Course Catalog: https://selfservice.mypurdue.edu/prod/bwckctlg.p_disp_dyn_ctlg

Proposed Effective Term	Spring 2018
Proposed Subject Code*	ENGR
Proposed 5 digit course #*	49000
Long Title*	Breakthrough Thinking for Complex Challenges
Short Title (max 30 characters)	
Terms offered (Select all that apply)	☑ Fall ☑ Spring ☐ Summer

Credit Hour Guidelines: Purdue's credit hour guidelines are provided below.

http://www.purdue.edu/registrar/documents/forms/Credit_Hr_Guidelines.pdf

Please use the following two options to specify if the course credit is fixed or variable:

Option #1: Fixed Credit Hours

Proposed Credit Hours	3

Option #2: Variable Credit Range

Minimum	
Variable Credit	○ To ○ OR
Maximum	
Course Repeat Status	☐ Course may be repeated ☐ Course may not be repeated
If repeatable:	☐ Unlimited Amount of times

	☐ Maximum Repeatable Credit Amount
Maximum Credit Amount	
Grade modes (Select all that apply)	☐ Regular Grade ☐ Pass/No Pass Option ☐ Audit ☐ Satisfactory/Unsatisfactory

If this course is crosslisted, navigate to the crosslisting icon in the Proposal Toolbox.

Click on 'Add Crosslisting'
Select the proposal that has (crosslisting) after the course title
Update any fields that pertain to the crosslisted course
Save your changes
Navigate back to the Primary proposal by clicking on the 'View Primary' icon in the top left corner of the proposal

Crosslisted Course/ Equivalent Course	

Course Fees: **The following fees are provided on the form: Coop, Lab, and Rate Request. In order to ensure the accurate fee is assessed on a course, the Bursar's Office would like to have an explanation included with the form along with the business manager's contact information if additional information is needed.**

Additional Fees:	○ Yes ◉ No
Explanation of fees	
Registration Approvals	☐ Department ☑ Instructor

Attributes: (Select all that Apply)	☐ Variable Title ☐ Honors ☐ Full-Time Privileges ☐ Half-Time Privileges ☐ Internship ☐ Coop ☐ Parallel Coop ☐ Credit by Exam

Schedule Types/Credit Hours: **The following links will provide explanations of the schedule types and credit hours to assist in assigning accurate types to a course.**

Schedule Type Classifications

Credit Hour Guidelines

Use the following instructions to add each schedule type for the course in the text box. Examples are listed below.

> **Schedule Types: Lecture (LEC), Recitation (REC), Presentation (PRS), Laboratory (LAB), Lab Prep (LBP), Studio (SD), Distance Learning (DIS), Clinic (CLN), Experiential (EX), Research (RES), Individual Study (IND), Practice Study Observation (PSO)**
> **Minutes per Meeting**
> **Number of Meetings per week**
> **Weeks per term**

Examples: (3 credit course) LEC/50min per mtg/3mtgs per wk/16 wks per term OR (3 credit course with Lecture and Lab) LEC/50/2/16 and LAB/100/1/16

Proposed Schedule Type:	LEC/50min per mtg/3mtgs per wk/16 wks per term

Restrictions:

If restrictions are being requested, please provide the proper Banner codes (major, program etc.) to ensure all are accurately reflected on the course. All codes may be found on our

website under Advisors/Active PWL Major Programs, and Active PWL Minors links:

Restriction Types: major, program or school codes; never use more than one
Use the words "and" or "or" when filling out form instead of commas

Restrictions List: Department, Field of Study, Class, Level, Degree, Program, Campus, College

Proposed Restrictions:	

Requisites:

Requisite information can only be selected from active offerings.

Co-requisite courses are always required to be taken at the same time
Concurrent prerequisite courses may be taken during the same semester or in a previous term
600-level prerequisites are not enforced, they are added to description as informational text

If there is an equivalent course the department would like listed with the prerequisties, that specific course will need to be specified on the form in order to have it enforced through the system.

Pre-Requisites: D- equals the lowest passing grade, unless otherwise noted	

Co-Requisites	

Course Information:

Course Description*	This course helps students learn and effectively employ high-impact design principles and structured problem solving methods to address complex multi-stakeholder socio-technical challenges. Case discussions of historical and contemporary high impact solutions to complex challenges are used to introduce techniques to frame problems, structure ambiguity, intentionally design non-incremental solutions, and communicate, trial, and iterate solutions to drive adoption and multifaceted sustainability. Techniques are drawn from multiple schools of thought such as business, design, engineering, and the social sciences. Over the course of the term, multi-disciplinary student teams directly apply cumulative learning to address selected parts of a real-world complex societal challenge in close collaboration with a partner organization, in an experiential learning format.
Learning Outcomes	Upon successful completion of this course, students will be able to: Employ rigorous issue analysis methods to develop mutually-exclusive collectively-exhaustive structured inventories of the issues involved in a major challenge Understand stakeholder motivation and interpret the funds, services, and influence exchanged in stakeholder ecosystems Understand the benefits and limitations of qualitative and quantitative methods to identify and interpret stakeholder needs Gain familiarity with habit conversion methodologies and the role they can play in design activities Recognize the importance of empathy in solution design and apply structured ideation methods to engender empathy in designers Understand patterns of innovation success and the contextual circumstances in which they apply Understand combinatorial business design methods to explore and prioritize alternative paths to achieve financial sustainability for an idea Discern the broader societal impacts of design activities Develop robust assessments of the assumptions underlying new ideas and means to test those assumptions rapidly and at low cost Recognize and define influence paths and communication methods to drive awareness, consideration, conversion, and retention of new solutions
Additional Course Information (if needed)	

Syllabus - Attach using the directions below:

Navigate to the Proposal Toolbox at the top of the right side.

Select the "Add Files" button 

Upload file to be attached.

Validate and Launch Proposal

Once you have completed all fields:

Click “Save All Changes” 

Click on the arrow  at the top of the page to launch the proposal. (Only launch the proposal after completing all necessary fields.) The proposal will now be sent on for approvals.

WL Catalog Use Only

Catalog Ownership	
Course Type	