ta le construe of Engineering 中華工程教育學會

The International Conference on Innovative Engineering Education 2025

12 September 2025 Bangkok, Thailand

Sharing International Experience on Capstone Design Projects

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Professor, Dept. of Civil Engineering, National Taiwan University

President, Taiwan Society for Construction Safety Chair, Chinese Taipei APEC Engineer/International Professional Engineer

Monitoring Committee



About OBE & OBA

Outcome-based education (OBE)

means clearly focusing and organizing
everything in an educational system around
what is essential for all students to be able to
do successfully at the end of their learning
experiences. This means starting with a clear
picture of what is important for all students to be
able to do, then organizing curriculum
(outcome), instruction (activity), and
assessment to make sure this learning
ultimately happens

Outcomes-based Accreditation (OBA)

primarily assesses whether the graduate (completed product!) meets the defined expectations, called «outcomes» or «attributes»

Outcomes-Based Education: Critical Issues by William Spady (1995)



Student Outcomes/Graduate Attributes Are the Key to Determine Program Quality

Graduate attributes form a set of individually assessable outcomes that are the components indicative of the graduate's potential to acquire competence to practise at the appropriate level.

The graduate attributes are exemplars of the attributes expected of graduate from an accredited program.

1. Engineering knowledge

2. Problem analysis

3. Design/ development of solutions

4. Investigation

5. Tool usage

6. The engineers and the world

7. Ethics

8. Individual and collaborative team work

9. Communication

10. Project management and finance

11. Lifelong learning



WA Graduate Attributes



	Washington Accord Accord **cognise**
Engineering Knowledge: Breadth, depth and type of knowledge, both theoretical and practical	Apply knowledge of mathematics, natural science, computing and engineering fundamentals, and an engineering specialization as specified in WK1 to WK4 respectively to develop solutions to complex engineering problems
2. Problem Analysis Complexity of analysis	Identify, formulate, research literature and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences and engineering sciences with holistic considerations for sustainable development* (WK1 to WK4)
3. Design/developm ent of solutions: Breadth and uniqueness of engineering problems i.e., the extent to which problems are original and to which solutions have not previously been identified or codified	Design creative solutions for complex engineering problems and design systems, components or processes to meet identified needs with appropriate consideration for public health and safety, whole-life cost, net zero carbon as well as resource, cultural, societal, and environmental considerations as required (WK5)
4. Investigation: Breadth and depth of investigation and experimentation	Conduct investigations of complex engineering problems using research methods including research-based knowledge, design of experiments, analysis and interpretation of data, and synthesis of information to provide valid conclusions (WK8)
5. Tool Usage: Level of understanding of the appropriateness of technologies and tools	Create, select and apply, and recognize limitations of appropriate techniques, resources, and modern engineering and IT tools, including prediction and modelling, to complex engineering problems (WK2 and WK6)
6. The Engineer and the World: Level of knowledge and responsibility for sustainable development	When solving complex engineering problems, analyze and evaluate sustainable development impacts* to: society, the economy, sustainability, health and safety, legal frameworks, and the environment (WK1, WK5, and WK7)
7. Ethics: Understanding and level of practice	Apply ethical principles and commit to professional ethics and norms of engineering practice and adhere to relevant national and international laws. Demonstrate an understanding of the need for diversity and inclusion (WK9)
8. Individual and Collaborative Team work: Role in and diversity of team	Function effectively as an individual, and as a member or leader in diverse and inclusive teams and in multi-disciplinary, face-to-face, remote and distributed settings (WK9)
9. Communication: Level of communication according to type of activities performed	Communicate effectively and inclusively on complex engineering activities with the engineering community and with society at large, such as being able to comprehend and write effective reports and design documentation, make effective presentations, taking into account cultural, language, and learning differences.
10. Project Management and Finance: Level of management required for differing types of activity	Apply knowledge and understanding of engineering management principles and economic decision-making and apply these to one's own work, as a member and leader in a team, and to manage projects and in multidisciplinary environments.
11. Lifelong learning: Duration and manner	Recognize the need for, and have the preparation and ability for i) independent and life-long learning ii) adaptability to new and emerging technologies and iii) critical thinking in the broadest context of technological change (WK8)



Engineer Graduate at the Washington Accord Level:



[should be able to] Apply knowledge of mathematics, natural science, computing and engineering fundamentals, and an engineering specialization... to

develop solutions to COMPLEX

ENGINEERING PROBLEMS

Note: IEA-Graduate-Attributes-and-Professional-Competencies-2021.1-Sept-2021



Complex Problem Solving is the Top Skill Required





2025

- 1.Analytical thinking and innovation
- 2.Active learning and learning strategies
- 3.Complex problemsolving
- 4.Critical thinking and analysis
- 5.Creativity, originality and initiative
- 6.Leadership and social influence
- 7.Technology use, monitoring and control
- 8.Technology design and programming
- 9. Resilience, stress tolerance and flexibility
- 10.Reasoning, problemsolving and ideation

2020

- 1.Complex Problem Solving
- 2. Critical Thinking
- 3. Creativity
- **4.People Management**
- 5. Coordinating with Others
- **6.Emotional Intelligence**
- 7. Judgement and Decision Making
- **8. Service Orientation**
- 9. Negotiation
- 10.Cognitive Flexibility

2015

- 1.Complex Problem Solving
- 2.Coordinating with Others
- 3.People Management
- **4.Critical Thinking**
- 5. Negotiation
- **6.Quality control**
- 7. Service Orientation
- 8. Judgement and Decision Making
- 9.Active Listening
- 10.Creativity



Defining Complex Problems...



According to ABET...

Complex engineering problems include one or more of the following characteristics: involving wide-ranging or conflicting technical issues, having no obvious solution, addressing problems not encompassed by current standards and codes, including many component parts or sub-problems, involving multiple disciplines, or having significant consequences in a range of contexts.

Note: https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2025-2026/



Range of Problem that Defines Complex Problems



	Range of Problem
Depth of knowledge required	Cannot be resolved without in-depth engineering knowledge at the level of one or more of WK3, WK4, WK5, WK6 or WK8 which allows a fundamentals-based, first principles analytical approach
Range of conflicting requirements	Involve wide-ranging and/or conflicting technical, non-technical issues (such as ethical, sustainability, legal, political, economic, societal) and consideration of future requirements
Depth of analysis required	Have no obvious solution and require abstract thinking, creativity and originality in analysis to formulate suitable models
Familiarity of issues	Involve infrequently encountered ssues or novel problems
Extent of applicable codes	Address problems not encompassed by standards and codes of practice for professional engineering
Extent of stakeholder involvement and conflicting requirements	Involve collaboration across engineering disciplines, other fields, and/or diverse groups of stakeholders with widely varying needs
Interdependence	Address high level problems with many components or sub-problems that may require a systems approach



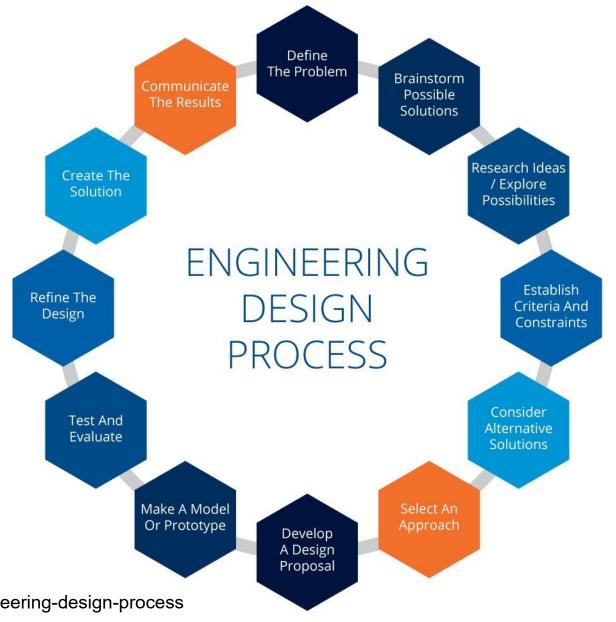
Knowledge Required to Solve Complex Problems



gine	ius Ha	#工程教育学習 Knowledge and Attitude Profile **COGNISED************************************
	WK 1	A systematic, theory-based understanding of the natural sciences applicable to the discipline and awareness of relevant social sciences
	WK 2	Conceptually-based mathematics, numerical analysis, data analysis, statistics and formal aspects of computer and information science to support detailed analysis and modelling applicable to the discipline
	WK 3	A systematic, theory-based formulation of engineering fundamentals required in the engineering discipline
	WK 4	Engineering specialist knowledge that provides theoretical frameworks and bodies of knowledge for the accepted practice areas in the engineering discipline; much is at the forefront of the discipline.
	WK 5	Knowledge, including efficient resource use, environmental impacts, whole-life cost, re-use of resources, net zero carbon, and similar concepts, that supports engineering design and operations in a practice area
	WK 6	Knowledge of engineering practice (technology) in the practice areas in the engineering discipline
	WK 7	Knowledge of the role of engineering in society and identified issues in engineering practice in the discipline, such as the professional responsibility of an engineer to public safety and sustainable development*
	WK 8	Engagement with selected knowledge in the current research literature of the discipline, awareness of the power of critical thinking and creative approaches to evaluate emerging issues
	WK 9	Ethics, inclusive behavior and conduct. Knowledge of professional ethics, responsibilities, and norms of engineering practice. Awareness of the need for diversity by reason of ethnicity, gender, age, physical ability etc. with mutual understanding and respect, and of inclusive attitudes



Problem-Solving Process is the ENGINEERING DESIGN Process



Note: https://www.twi-global.com/technical-knowledge/faqs/engineering-design-process



Engineering Design Process



1. Define The Problem

What is the problem that needs to be solved? Who is the design product for, and why is it important to find a solution? What are the limitations and requirements? Engineers need to ask these types of critical questions regardless of what is being created.

2. Brainstorm Possible Solutions

Good designers brainstorm possible solutions before opting to start a design, building a list of as many solutions as possible. It is best to avoid judging the designs and instead just let the ideas flow.

3. Research Ideas / Explore Possibilities for your Engineering Design Project

Use the experience of others to explore possibilities. By researching past projects you can avoid the problems faced by others. You should speak to people from various backgrounds, including users or customers. You may find some solutions that you had not considered.

4. Establish Criteria and Constraints

Having listed potential solutions and determined the needs of the project alongside your research, the next step is to establish any factors that may constrain your work. This can be done by revisiting the requirements and bringing together your findings and ideas from previous steps.

5. Consider Alternative Solutions

You may wish to consider further solutions to compare the potential outcomes and find the best approach. This will involve repeating some of the earlier steps for each viable idea.

6. Select An Approach

Once you have assessed your various options you can determine which approach best meets your requirements. Reject those that don't meet your requirements.

7. Develop A Design Proposal

Having chosen your approach, the next step is to refine and improve the solution to create a design proposal. This stage can be ongoing through the length of your project and even after a product has been delivered to customers.

8. Make A Model Or Prototype

Use your design proposal to make a prototype that will allow you to test how the final product will perform. Prototypes are often made from different materials than the final version and are generally finished to a lesser standard.

9. Test And Evaluate

Each prototype will need testing, re-evaluation and improvement. Testing and evaluation allows you to see where any improvements are needed.

10. Refine The Design

Once testing has been completed, the design can be revised and improved. This step can be repeated several times as more prototypes are created and evaluated.

11. Create The Solution

After your refinements have been completed and fully tested, you can decide upon and create your finished solution. This may take the form of a polished prototype to demonstrate to customers.

12. Communicate The Results

The final stage is to communicate your results. This can be in the form of a report, presentation, display board, or a combination of methods. Thorough documentation allows your finished product to be manufactured to the required quality standards.



Engineering Design Involves Human-based Design Thinking, Hands-on Training

WA Attributes 3: Design creative solutions for complex engineering problems and design systems, components or processes to meet identified needs with appropriate consideration for public health and safety, whole-life cost, net zero carbon as well as resource, cultural, societal, and environmental considerations as required.

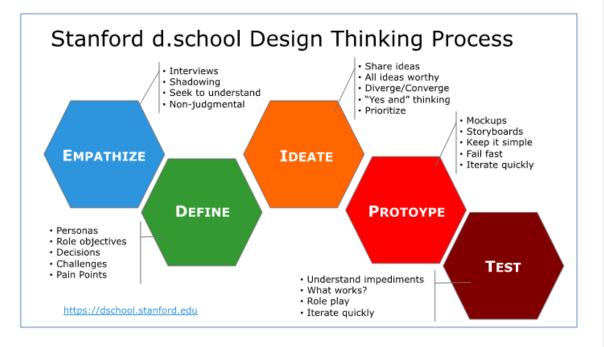
Conceive: includes defining customer needs; considering technology, enterprise strategy, and regulations; and, developing conceptual, technical, and business plans.

Operate: uses the implemented product to deliver the intended value, including maintaining, evolving and retiring the system.

MIT CDIO

Design: focuses on creating the design, that is, the plans, drawings, and algorithms that describe what will be implemented.

Implement: refers to the transformation of the design into the product, including manufacturing, coding, testing and validation.





Accreditation Process Looks for...

evidence of student outcomes,

evidence of engineering design

evidence of student ability in solving complex problems...

IEET Accreditation Criteria Modified in 2014...

ability to identify, formulate, research literature, analyze and solve complex engineering problems reaching substantial conclusions (IEET Criterion 3.6)

technical and professional engineering components must account for at least three-eighths of the credits required for graduation, including an integrative CAPSTONE DESIGN PROJECT; (IEET Criterion 4.1.2)

Starting from the intake students of 2014, all students must take a major culminating design project, i.e. capstone course before graduation as required by IEET.



Criteria of Some Other Signatories on Capstone (1/2)

ABET (USA)

Criterion 5. Curriculum d: a culminating major engineering design experience that 1) incorporates appropriate engineering standards and multiple constraints, and 2) is based on the knowledge and skills acquired in earlier course work.

ABET Definition of Capstone: A culminating course that allows students who are nearing graduation to "put together" the knowledge and skills they have acquired in their program and apply it to a major project or assignment.

EA (Australia)

 AP5 Program curriculum (learning outcomes, content, pedagogy, assessment): Engineering Application Experience: Engineering application activities must pervade the curriculum and include problem solving, design and project work at the appropriate level. It is expected that programs will embody at least one major engineering project experience, which draws on technical knowledge and skills, problem solving capabilities and design skills from several parts of the program and incorporates broad contextual considerations as part of a full project life cycle.



Criteria of Some Other Signatories on Capstone (2/2)

IES (Singapore)

• Criterion 3-- Curriculum and Teaching-Learning Processes (iii): A culminating demonstration of learning outcomes in solving complex engineering problems is commonly incorporated in the final year or capstone project which invariably constitutes an integral part of the engineering curriculum.

ABEEK (Korea)

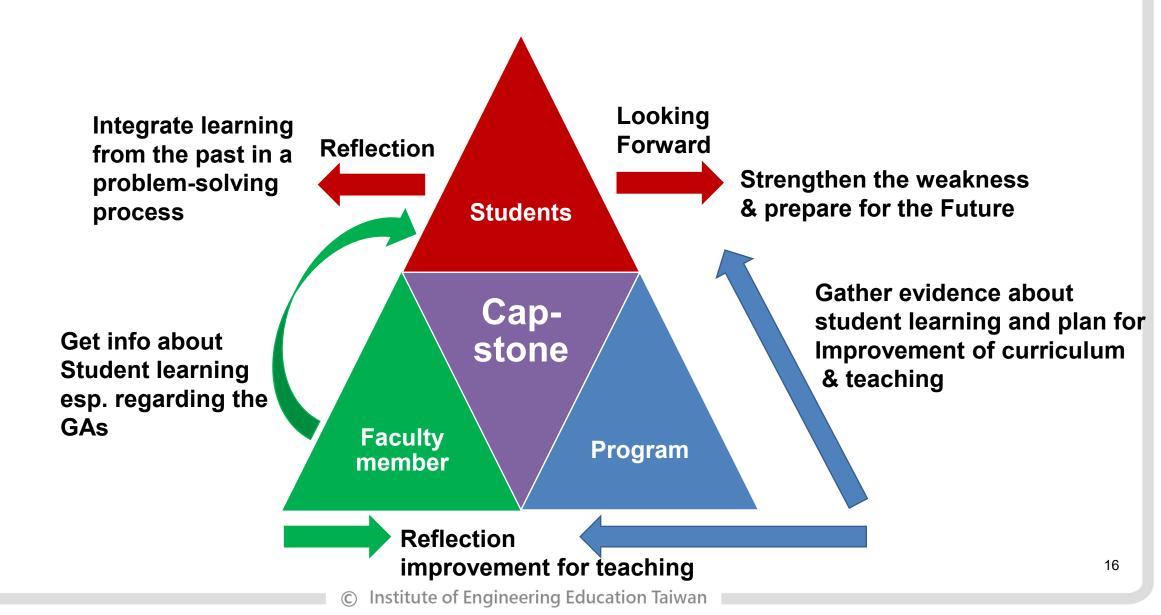
• Criterion 3. Curriculum 3.3 The curriculum shall include a minimum of 45 credits of engineering and related topics including design, experiment and practice components. The design component shall include an entry-level design course and a capstone design course.

EngNZ (New Zealand)

 Criterion 1.5. The programme includes substantive, integrative project work (incorporating design or development of solutions) which is assessed against a range of overall programme graduate outcomes.



Capstone is the Realization of OBE

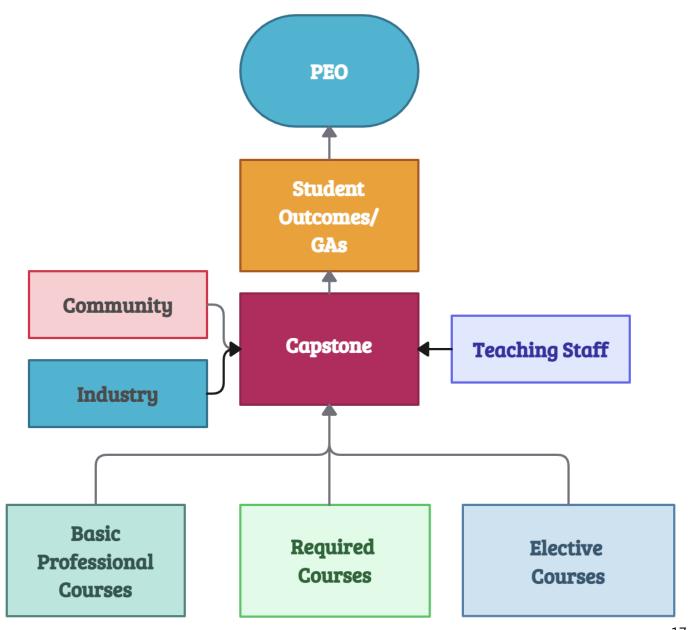




Students are assessed in the Capstone course to determine whether they have obtained the kind of knowledge and skills for graduation.

The Capstone should be designed in consideration of the inputs from teaching staff, the industry, and the community

Capstone is the last mile for student learning when students apply learned knowledge and skills from all courses in a problem-solving scenario.





General Courses vs Capstone

	General Professional Courses	Capstone
Knowledge/Skills	Single or limited area	Incorporating 4-6 coures
Student outcomes	Mapping to fewer student outcomes and mostly hard knowledge/skills	Mapping to all student outcomes
Assessment	Most of the time, exams or tests	Normally, report, oral presentation, competition, etc.



Capstone Could Assess GAs in Technical as well as Contextual Skills

Technical (Hard)

Complex Problem Solving

Ability to Design

Contextual (Soft)

Teamwork, Interdisciplinary

Communication

Project Management (Finance)

Life-long Learning

作 Manufacture of Engineering 中華工程教育學會

中華工程教育學會 Capstone is An Integration of 4-6 Core Courses Over the Duration of the Program

Fresh	Freshman		ior	Sopho	omore	Sen	ior	
Required	Elective	Required	Elective	Required	Elective	Required	Elective	
Required	Required	Required	Required	Required	Elective	Requ GA 1	2 3 4 5	6 7 8
Required	Required	Required	Required	Reduired	Elective	Required	Elective	Each of these
Required	Required	Required	Keyanou	2 3 4 5	6 7 8 L.J.J.Ve	Required	Elective	core courses correspond to
Required	Required	Required	Required	Required	Elective	Required	Elective	different Gas,
Required	Required	Required	Required	Required	Elective	Required	Elective	and taken together, they
Required	Required	Required	Required	Required	Elective	Required	Elective	should cover
Requi GA	1 2 3 4 5	6 7 8 d	Rec GA 1	2 3 4 5	⁶ ⁷ ⁸ ve	Required	Elective	all of the GAs
Required	Required	Re nuired	Required	Required	Elective	Requ GA 1	2 3 4 5	6 7 8
Required	Required	Required	Required	Required	Elective	Required	Elective	
Required	Required	Required	Rec GA 1	2 3 4 5	⁶ ⁷ ⁸ ve	Required	Elective	
Required	Required	Required	Required	Required	Elective	Required	Elective	



Capstone Should Correspond to All or Most GAs

GAs	1 ability to apply knowledge of mathematics, science, and engineering	ability to design and conduct experiments, as well as to analyze and interpret data	ability to apply techniques, skills, and modern tools necessary for engineering practice	ability to design an engineering system, component, or process	ability to manage project, communicate effectively, work in multi- disciplinary environment, and function on teams	ability to identify, formulate, research literature, analyze and solve complex engineering problems reaching substantial conclusions	knowledge of contemporary issues; an understanding of the impact of engineering solutions in the environmental sustainability, social good, and global contexts; and the ability and habit to engage in life-long learning	apply ethical principles and commit to professional and information ethics and responsibilities and norms of engineering practice, and a sense of respect for diversity
Core course 1	X		X					
Core course 2	X	X		X	X			
Core course 3		Χ	X			Χ		
Core course 4			X			Χ	X	
Core course 5				Χ			X	X
Core course 6					X	Χ		X
Capstone	X	X	X	X	X	X	X	Х



Demonstration of Evidence: Capstone

(Student Work for Each Team Must be Kept for Evidence)



Student works could be in diverse forms

- Finished Product
- Prototype
- •Simulations or other form (Design diagram)



Must require students to produce project report in paper/electronic form for assessment



Must require students to make oral presentation as part of the assessment plan



Could encourage students to participate in competitions



Capstone Assessment (Student Teams)

Course: Civil Engineering Capstone Project Year: Junior (2nd Semester)

Student: Team A/ Smart · Smith · Springfield Topic: Design of Tamkang Bridge

#	Graduate Attribute	Weight	Score	Total
1	ability to apply knowledge of mathematics, science, and engineering	10%	90	9
2	ability to design and conduct experiments, as well as to analyze and interpret data	15%	80	12
3	ability to apply techniques, skills, and modern tools necessary for engineering practice	20%	70	14
4	ability to design an engineering system, component, or process	20%	90	18
5	ability to manage project, communicate effectively, work in multi-disciplinary environment, and function on teams	10%	80	8
6	ability to identify, formulate, research literature, analyze and solve complex engineering problems reaching substantial conclusions	8%	80	6
7	knowledge of contemporary issues; an understanding of the impact of engineering solutions in the environmental sustainability, social good, and global contexts; and the ability and habit to engage in life-long learning; and	10%	87	9
8	apply ethical principles and commit to professional and information ethics and responsibilities and norms of engineering practice, and a sense of respect for diversity	7%	85	6
			Total	82



Capstone Assessment (Whole Class)

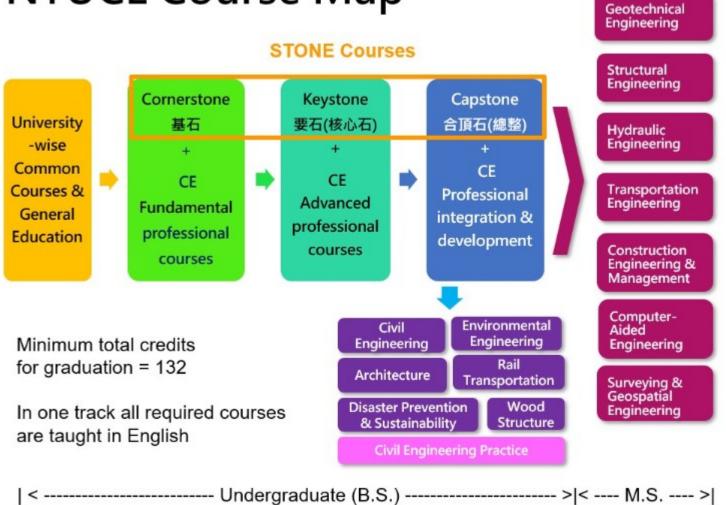
#	Graduate Attribute	Weight	Team A	Team B	Team C	Team D	Team	Aver- age
1	ability to apply knowledge of mathematics, science, and engineering	10%	90	90	91	89		90
2	ability to design and conduct experiments, as well as to analyze and interpret data	15%	80	67	87	74		80
3	ability to apply techniques, skills, and modern tools necessary for engineering practice	20%	70	85	90	85		88
4	ability to design an engineering system, component, or process	20%	90 lust im	70	80	65		68
5	ability to manage project, communicate effectively, work in multi-disciplinary environment, and function on teams		ning of			65		72
6	ability to identify, formulate, research literature, analyze and solve complex engineering problems reaching substantial conclusions	8%	80	75	80	75		85
7	knowledge of contemporary issues; an understanding of the impact of engineering solutions in the environmental sustainability, social good, and global contexts; and the ability and habit to engage in life-long learning; and	10%	87	80	93	80	-	-
8	apply ethical principles and commit to professional and information ethics and responsibilities and norms of engineering practice, and a sense of respect for diversity	7%	85	78	90	85		86
	Te	eam Score	82	76	86	76		80

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In 2011, NTU-CE asked... NTUCE Course Map

- Why students aren't motivated in learning?
- How do we enhance students' interest in civil engineering?
- What do we change in the curriculum to meet the industry needs?





That's why and how **NTU-CE** came up with... **Trilogy of** Design **Projects**



Design projects	Targeted students	disciplinary courses
Cornerstone (Compulsory) #1 1st semester: Conceptual Design #2 2nd semester: Design to Fabrication Lab.	First year	Before
Keystone (Elective) Fluid & Structure Lab.	Second year	During
Capstone (Compulsory) Civil Engineering Capstone Challenge	Third/Fourth year	After



NTU-CE: Cornerstone

In the Cornerstone stage, students implement civil engineering projects before any engineering training, to motivate their thirst for knowledge of the discipline.

During the cornerstone stage, the first-year students take two courses: #1 Conceptual Design Studio #2 Physical Model Design Laboratory.











Case Study











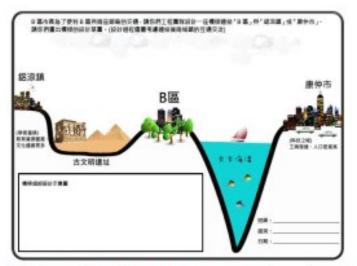
Course Materials for Conceptual Design

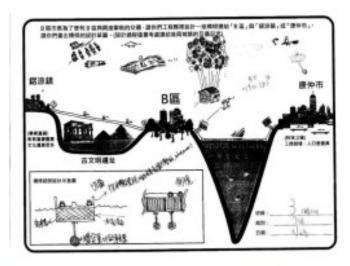




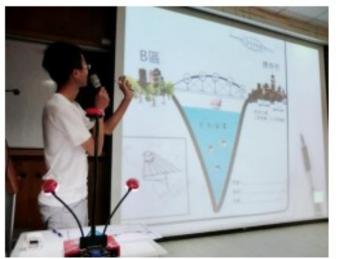


Emphasizing Student Participation







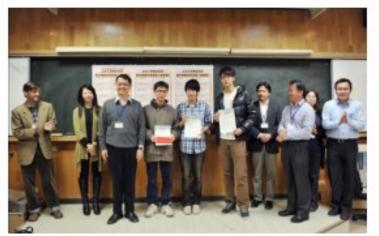




Final Design Poster Exhibition and Competition



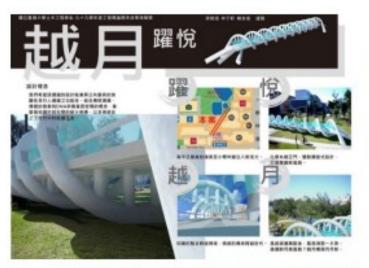








Selected Winners



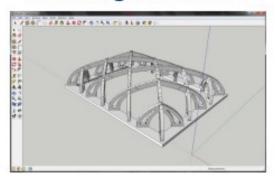








From digitial model



To physical model



V-Lab, 6F (Visualization Lab)





Then, test to fail or to see how it works





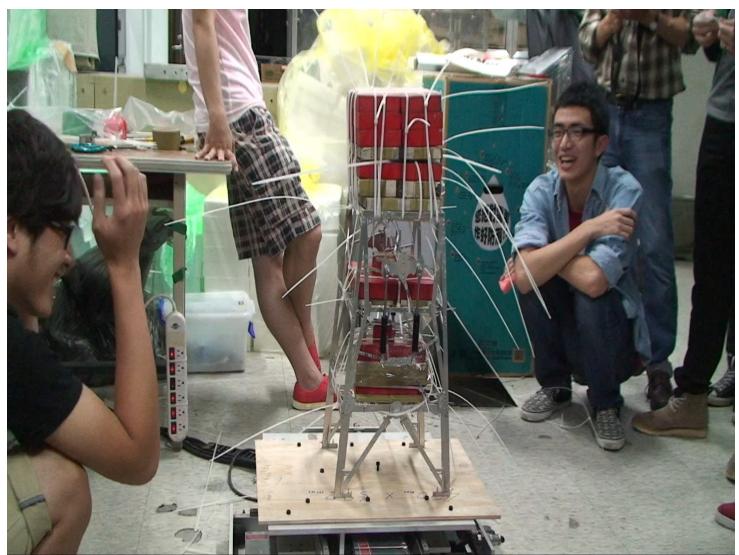
F-Lab, 3F (High pressure water jet)











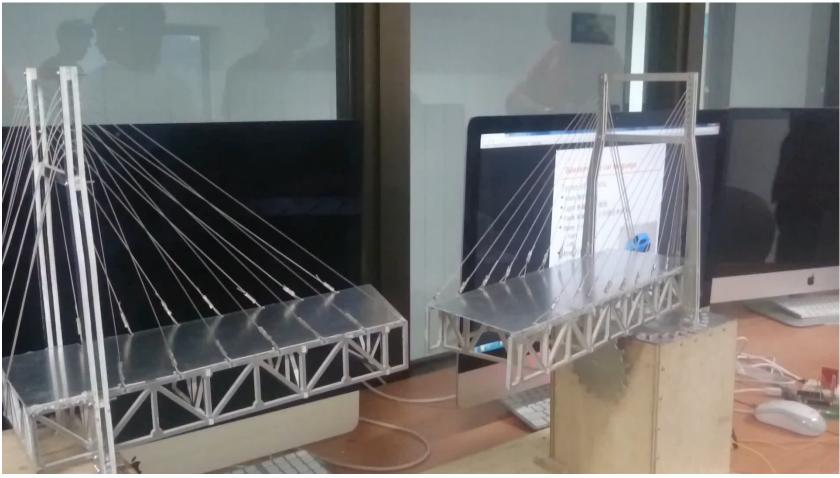












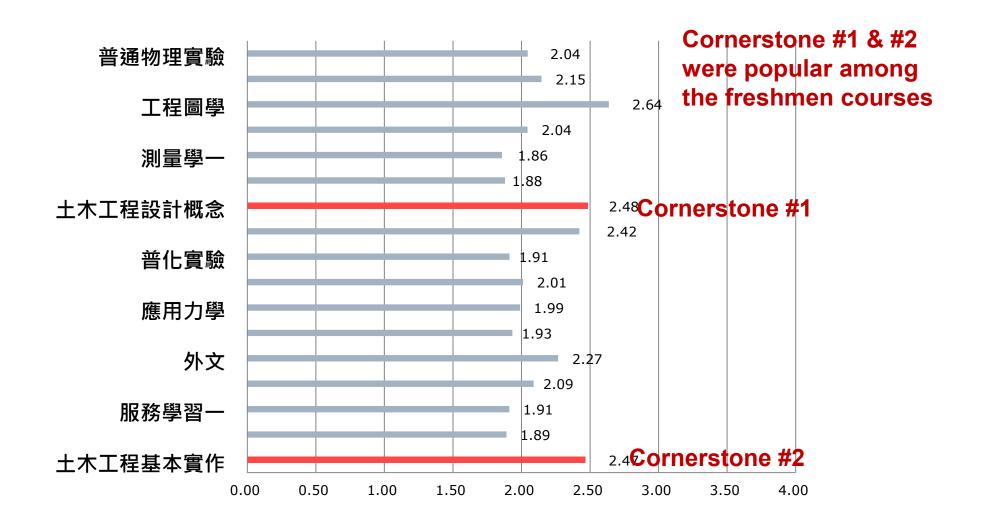








Student Feedback on Cornerstone





Keystone (4th Semester): Fluid & Structure Lab.



Second year students interested in hands-on projects are invited to enroll in the following 3 optional courses, called Keystone B, C and D. Each course is of 2 credits and includes a collaborative workshop with another university program.

- B: Treasure Hill Topology Workshop/ Earthquake-Resistant Tower Project
- C: Lab, Monitoring, and Design Analysis of Dike
- D: Micro Air Vehicle Project/ Tainan Floating Structure Workshop



Keystone (4th Semester): Fluid & Structure Lab.

A Project Ignites Student Motivation



















Keystone (4th Semester): Fluid & Structure Lab.

Copper Pneumatic Floating Toy Project



















Keystone (4th Semester): Fluid & Structure Lab.

Bridge Structure Fabrication











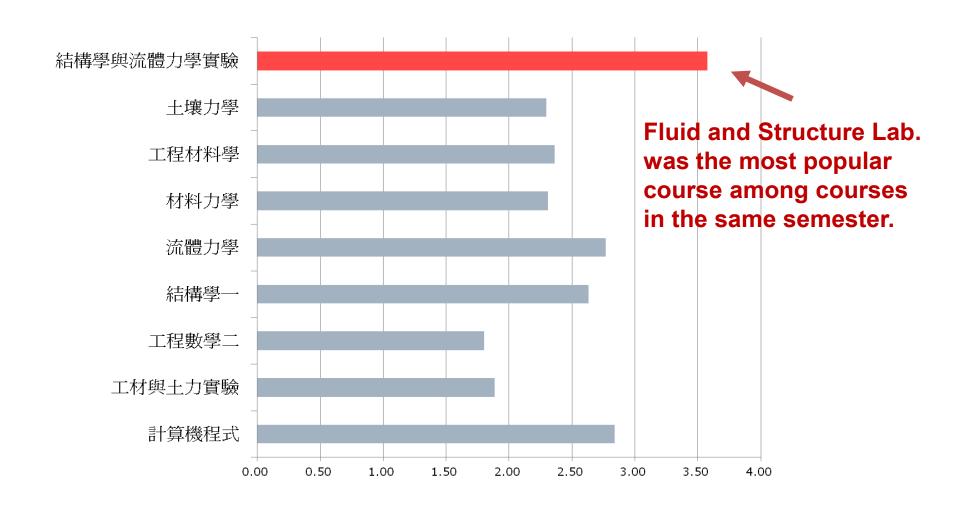








Student Feedback on Keystone





NTU-CE Capstone Project: 3rd or 4th Year







Team Work...Less Lecturing... Engineers Participation





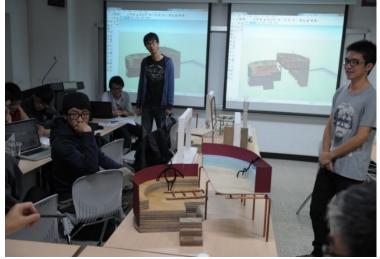




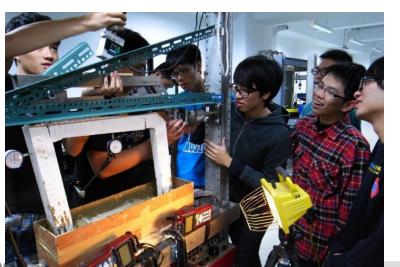


Students are to design, build, test, and do oral and written reporting











Let Them Make



Wood Design to Fabrication

Winter Workshop 2013.01.26 ~ 2013.02.02

木工實作研習











Topics for NTU-CE Capstone Design (About 5 Topics Every Year)

Feasibility Assessment and Planning of a Cableway System in Xitou Forest

Preliminary Planning and Feasibility Assessment of a Desilting and Anti-silting System in the Wushe Reservoir

The Assessment of Design of the Humanities Building of NTU

The Renovation of Student Space of the Civil Engineering Department of NTU

Flood Monitoring of the Lao-Nong River and the Design of a Temporary Bridge for Emergency Evacuation

The Retrofitting of the Student Space of the Civil Engineering Department of NTU

The Roof Renovation and Retrofitting of the Management Building of NTU

Design of a Pedestrian Bridge in Xitou Forest

Safety Assessment of the Shihmen Reservoir and Disaster Prevention

Design and Operation of a Resident Sports Center

Building Structure Renovation and Retrofitting of the Forestry Department of NTU

Case Study of the Road Pavement of the City Street, Greening and Revitalizing of the Apartments of South Airport

Safety Assessment of the Hushan Reservoir

Detailed design and prototyping of a roof-supporting wood structure for the Civil Engineering Building basement

The Sustainable She-Zi Island – The Development Blueprint of She-Zi Island Considering the Ecosystem, the Flood Control, and the Transportation Infrastructure Plans

Understanding of Seismic Design of Building Structures – From Structural Dynamic Experiments to Real-World Applications

.....



Xitou Forest Park, Nantou County





Ginkgo Bridge

Footbridge located in Xitou Forest Park, Taiwan/3 meters long and 1.6 meters wide

Designed by Xitou Bridge Design Team (Students in the Department of Civil Engineering of NTU)

Completion for use in March 2017₈





Site Hydraulics Analysis

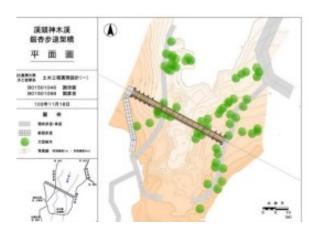
Three Design Proposals



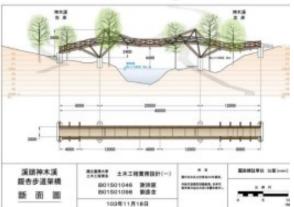










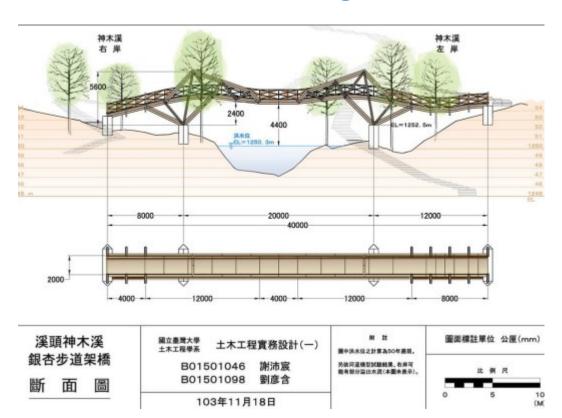


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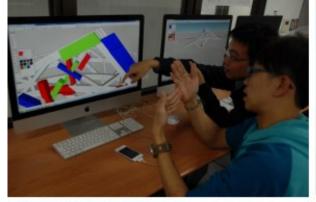




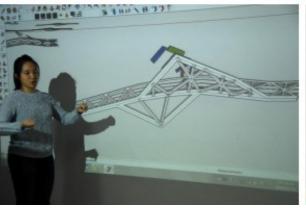
Final Design

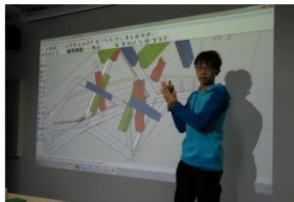


Worked Out Detailed Design













1:25 Model Fabrication

Load Test of the Scaled Model





















Completed in 2017









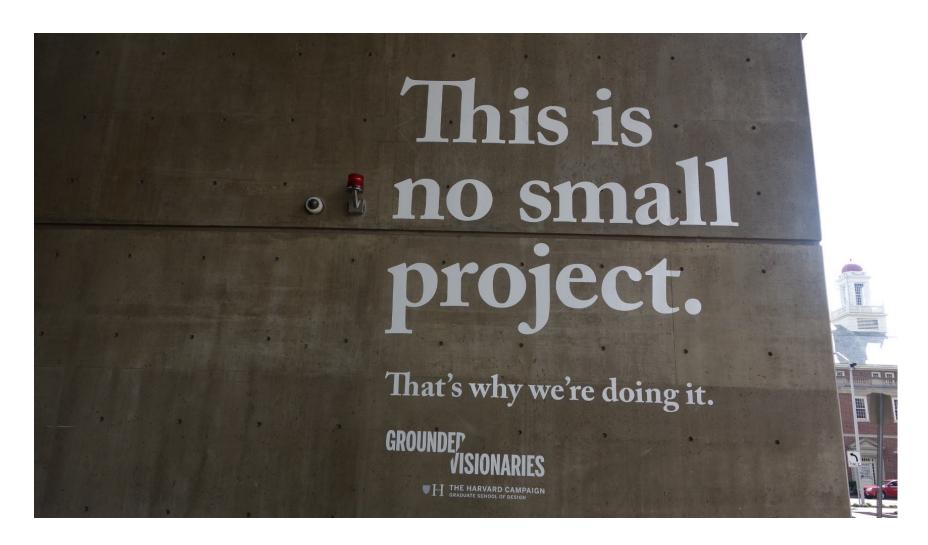








Harvard Graduate School of Design





Harvard Graduate School of Design





Reflections

1. Students love the design courses more than we expected, even though the time and energy consumed were much more than the other courses.

2. NTU-CE students used to be good in theories, less prepared for engineering practice, and now the design courses changed that.

3. Students with basic design courses, such as cornerstone and keystone, perform much better in capstone than those that without.

4. TRUST THE PROCESS!

5. After all, we are training engineers for now and the FUTURE.

Thank You

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