Applying a Competency-Based Education Approach for Designing a Unique Interdisciplinary Graduate Program: A Case Study for a Systems Engineering Program

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Amy Thompson, **Matthew Stuber**, Song Han, Abhishek Dutta, Shengli Zhou, Hongyi Xu, Qian Yang, Fei Miao, George Bollas

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Systems Engineering Division

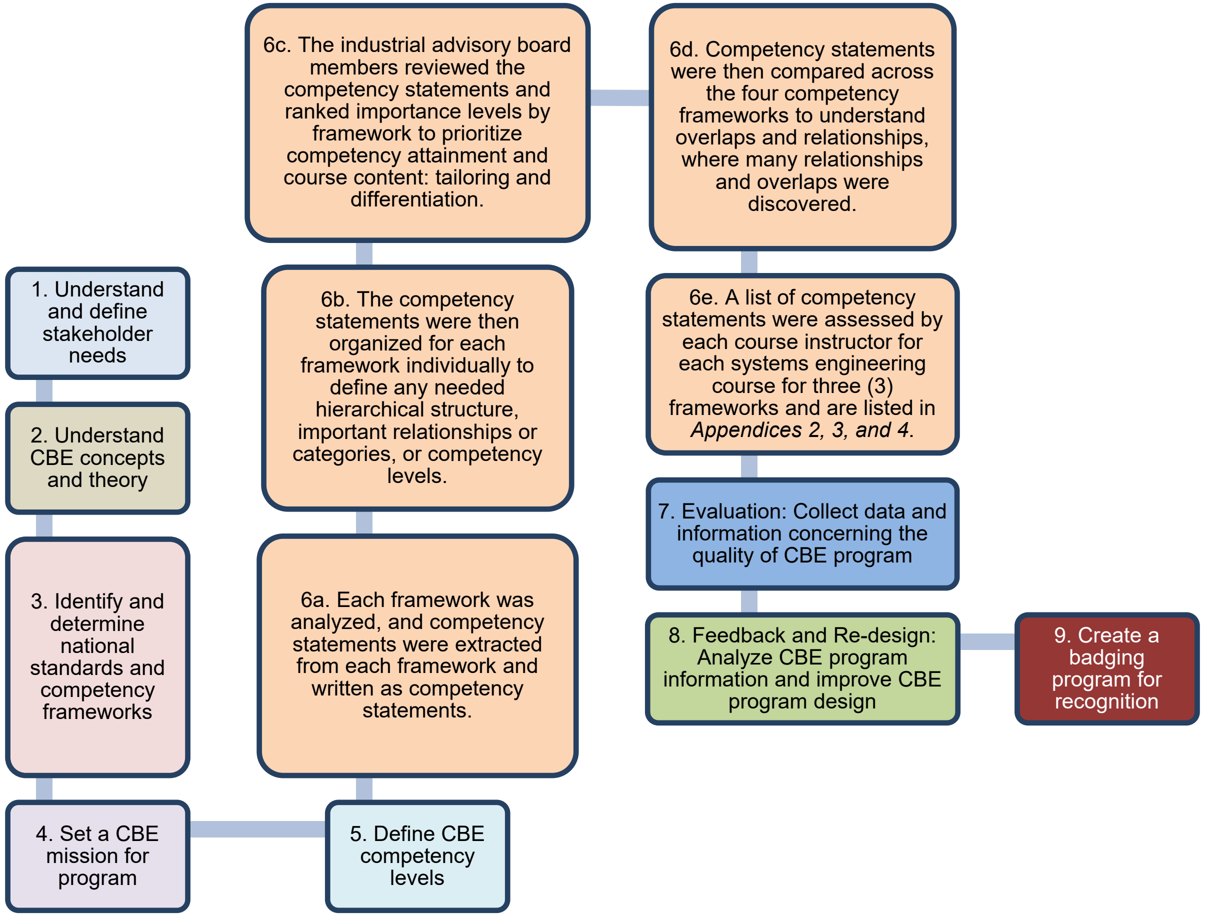
Phone: 860-486-8462, Email: amy.2.thompson@uconn.edu
Website: http://www.iase.engr.uconn.edu/

UCONN | SCHOOL OF ENGINEERING
PRATT & WHITNEY INSTITUTE FOR ADVANCED SYSTEMS ENGINEERING

Agenda: Path and Process to Implement CBE

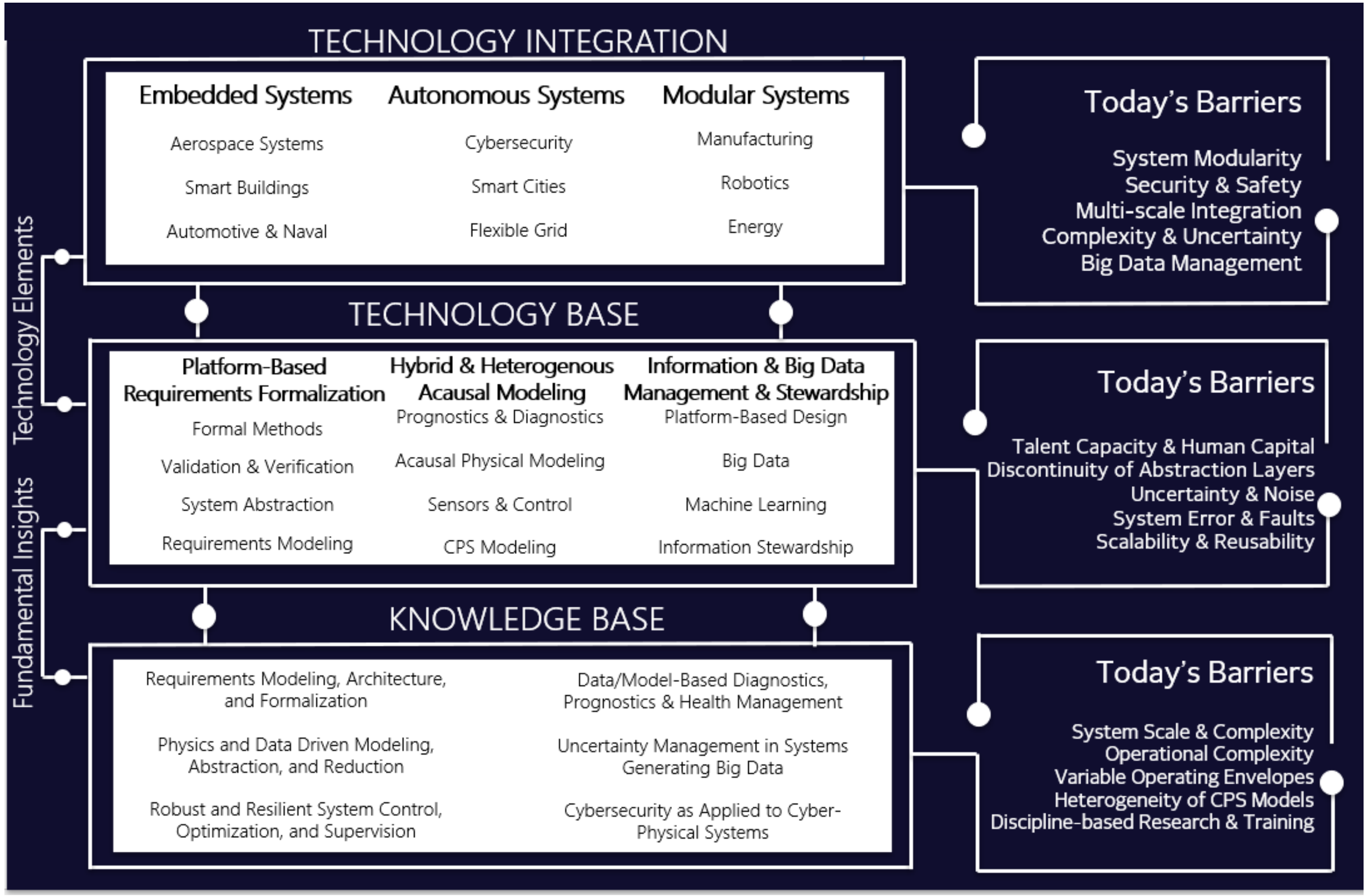
1. Understand and define stakeholder needs
2. Understand CBE concepts and theory
3. Identify and determine national standards and competency frameworks
4. Set a CBE mission for program
5. Define CBE competency levels
6. Analyze and apply the competency frameworks
7. Evaluation: Collect data and information concerning the quality of CBE program
8. Feedback and Re-design: Analyze CBE program information and improve CBE program design
9. Create a badging program for recognition

Repetitive and iterative process



Step 1: Understand and define stakeholder needs

- Stakeholder and industry input drives original program design in 2017
- Needs developed through a workshop approach



Step 1: Understand and define stakeholder needs: Cyber-Physical Systems Engineering-focused

- National standards and best practices
- U.S. National Academies of Sciences, Engineering, and Medicine (NASEM) and the KSAs for engineers working in the development of complex CPS were defined in their report [1].
- Other researchers found similar competencies: *supervisory control, maintenance of system availability using distributed control, assurance of integrity of control functions under cyber-attack, dealing with uncertainty in human interactions, need to achieve high levels of safety and security, ensure privacy of data and control access, the ability to evaluate CPS resilience in different environments, and the ability to make hard design decisions and tradeoffs in system performance, safety, and security in uncertain environments* [2].

Computer and Network Security
Computer Architecture
CPS Architecture
Embedded and Real-Time Systems Architecture
Feedback Control
Formal Methods
Hybrid Systems
Inference under Uncertainty
Machine Learning
Medical Embedded Systems
Modeling from Data
Networked Control Systems Architecture
Robotics and Mechatronics
Sensor Networks
Signal Processing
Systems Engineering
Systems Thinking and Meta Modeling

[1] National Academies of Sciences, Engineering, and Medicine, “A 21st century cyber-physical systems education,” National Academies Press, Jan. 27, 2017, doi: 10.17226/23686.
[2] T.A. McDermott, “Emerging education challenges for resilient cyber physical systems,” in INCOSE International Symposium, Jul. 2019, vol. 29, no. 1, pp. 636-51, doi: 10.1002/j.2334-5837.2019.00625.x.

Result of Step 1: Course Offerings 2017 - 2022

System Life Cycle

Requirements Formalization & Architecture	System Modeling	System Design	System Manufacturability	System Control & Security	System Verification	Commissioning & Operation
Systems Engineering Fundamentals (2017)	**Acausal Physical Systems Modeling (2014)**	**Uncertainty Analysis, Robust Design, and Optimization (2018)**	**Data Science for Materials & Manufacturing (2020)**	**Modern Control Systems (2017)**	**Formal Methods (2014)**	**Machine Learning for Physical Sciences & Systems (2018)**
Model-Based Systems Engineering (2017)	**Embedded/ Networked Systems Modeling Abstractions (2014)**	**Model-Based Design for Real-Time Cyberphysical Systems (2022)**				**Architecture of IOT (2020)**

Platform Based Design

Step 2. Understand CBE concepts and theory: Literature Review

- The use of multiple competency frameworks for academic programs [6-8].
- CBE history, motivation, and approaches. [1,7,9-13].
- The value of using CBE [14].
  - (1) student responsibility for the selection of and adherence to a learning path,
  - (2) students choose courses and competency attainment that they feel will differentiate themselves in a competitive labor market,
  - (3) students choose courses and competencies that build upon prior experience providing them validation of the skills they have attained previously, and
  - (4) students have clear expectations and relevance of work to the ultimate academic goal: competency maps create cohesive and transparent program sequencing that allow students to have a clear view of the direction and requirements for their learning.
- Other researchers have identified that competency frameworks are valuable for preparing students for workplace readiness [15].

[9] S. Hodge, "The origins of competency-based training," Aust. J. Adult Learn, vol. 47, no. 2, pp. 179–209, Jul. 2007, doi: 10.18260/p.25977.

[10] P. Howard, "Preparation and reflection: making professional practice explicit," in 2009 Annual Conference & Exposition, Jun. 14, 2009, pp. 14-970.

[11] National Academy of Engineering, "The Engineer of 2020: Visions of Engineering in the New Century," National Academies Press, May 28, 2004.

[12] J. Bughin, E. Hazan, S. Lund, P. Dahlström, A. Wiesinger, and A. Subramaniam, "Skill shift: Automation and the future of the workforce," McKinsey Global Institute, vol. 1, pp. 3-84, May 23, 2018.

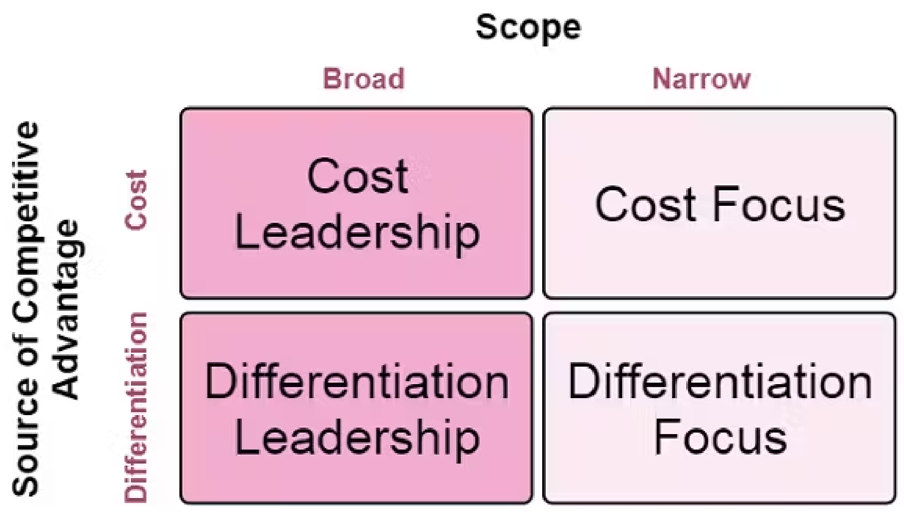
[13] P. Zimmerman, T. Gilbert, and F. Salvatore, "Digital engineering transformation across the Department of Defense," The Journal of Defense Modeling and Simulation, vol. 16, no. 4, pp. 325-38, Oct. 2019, doi: 10.1177/1548512917747050.

[14] A.S. Van Epps, I. Ashby, C.M. Gray, and M. Exter, "Supporting student attainment and management of competencies in a transdisciplinary degree program," in 2016 ASEE Annual Conference & Exposition, New Orleans, Louisiana, Jun. 2016.

[15] S.F. Child and S.D. Sha, "A purpose-led approach towards the development of competency frameworks," Journal of Further and Higher Education, vol. 44, no. 8, pp. 1143-56, Sep. 13, 2020, doi: 10.1080/0309877X.2019.1669773.

Step 2. Understand CBE concepts and theory: Differentiation, Tailoring, and Scoping

- Mind the gap: tailoring competency frameworks is necessary to, "handle variation both in the nature of the Systems Engineering that the organization does, and the nature of the existing organization in which Systems Engineering is performed [16]."
- Higher education institutions implement CBE differently than private corporations. Academic institutions need to apply and tailor competency frameworks to courses differently than private corporations, understanding that higher education institutions (HEIs) are different, and that they have a broader mission [17].



Michael Porter Competitive Advantage Strategy, 1985

[16] R. Beasley, "The need to tailor competency models–with a use case from Rolls-Royce," in INCOSE International Symposium, Jun. 2013, vol. 23, no. 1, pp. 428-42, doi: 10.1002/j.2334-5837.2013.tb03029.x.
[17] C. Dondi, E. Mancinelli, and M. Moretti, "Adapting existing competence frameworks to higher education environments," in The Challenge of eCompetence in Academic Staff Development, I. Mac Labhrainn, C. McDonald Legg, D. Schneckenberg, and J. Wildt. Galway: CELT, 2006, pp. 19-28.

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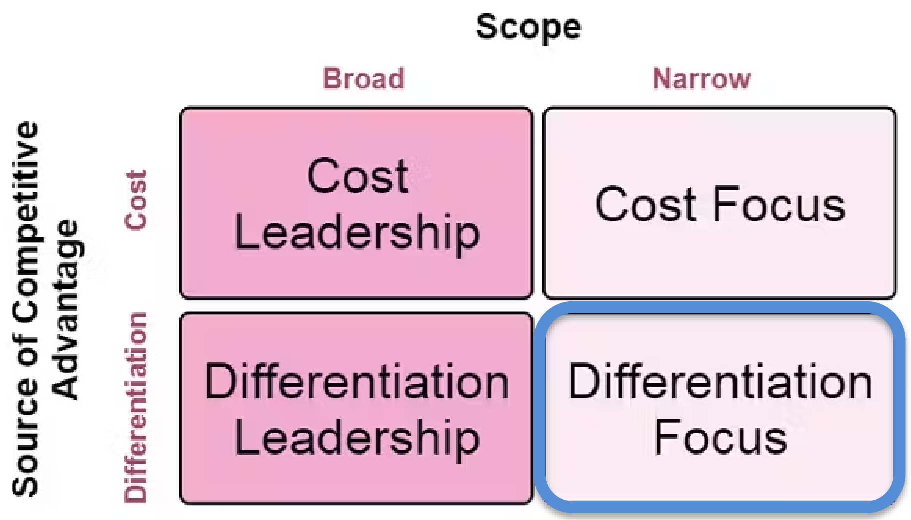

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Step 2. Understand CBE concepts and theory: Technical Assistance Guide for CBE

Competency models, “support curriculum development by [18]:

(1) identifying essential skill requirements within industries and occupations,

(2) providing a business-oriented framework for developing teaching and learning objectives,

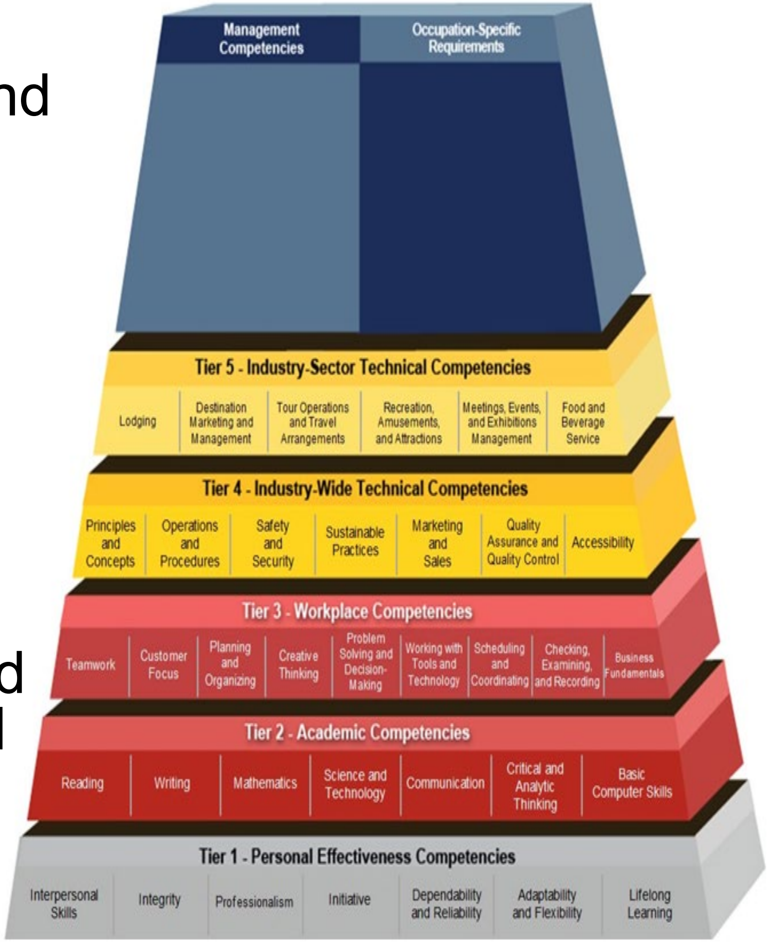
(3) supplying content for enriching instructional materials,

(4) providing a resource for instructional designers to tailor courses to specific student populations or industry needs,

(5) reducing the development time of instructional materials, courses, and program curricula,

(6) establishing common terminology for use by business and education communities to facilitate collaboration on technical education projects, and

(7) highlighting gaps in current training offerings.”



[18] Personnel Decisions Research Institutes, Inc. (PDRI), JBS International, Inc., Aguirre Division, Coffey Consulting, LLC, and JBS International, Inc., “Competency Models – Communicating Industry’s Education and Training Needs: Competency Model Development and Use – A Technical Assistance Guide,” Oct. 2019.

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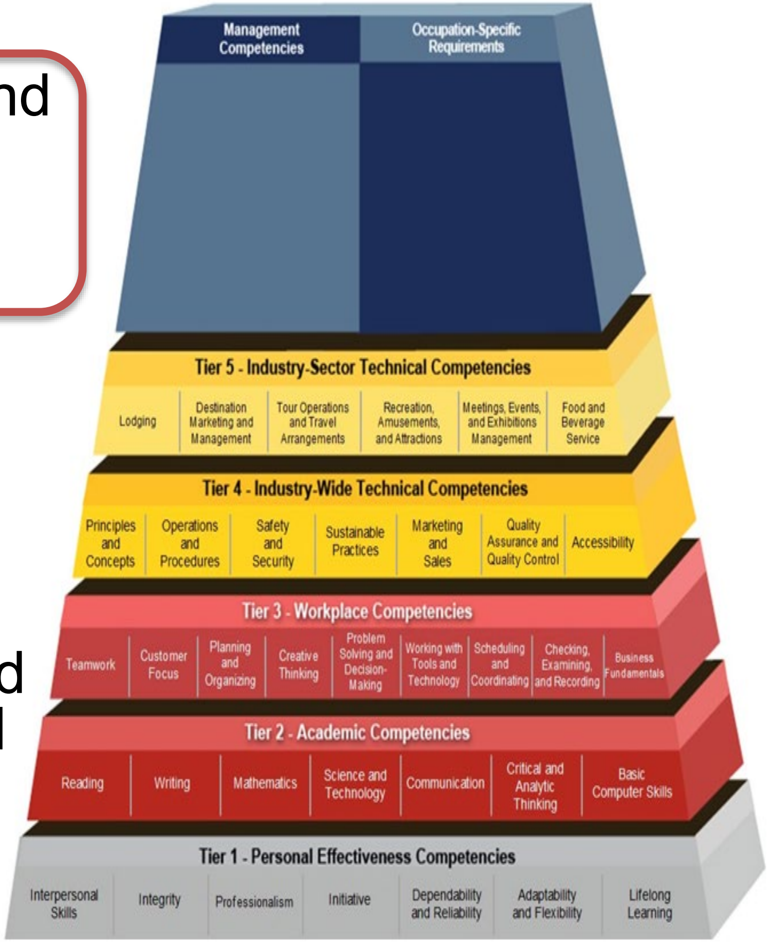

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Step 2. Competency vs. Outcome and Example [18]

- *Competency:* A general statement that describes the desired knowledge, skills, and behaviors of a student graduating from a program (or completing a course). Competencies commonly define the applied skills and knowledge that enable people to successfully perform in professional, educational, and other life contexts.
- *Outcome:* A very specific statement that describes exactly what a student will be able to do in some measurable way. There may be more than one measurable outcome defined for a given competency."
- *Our Example:*
  - **Competency:** Modeling skills. Can analyze systems by simulation.
  - **Learning Outcome:** The student can define the behavior of an engineered system using a state machine and activity diagram and can use an MBSE tool simulator to simulate the behavior to determine how well an identified technical performance measure is met.
  - **Assessment:** The student delivers a model that correctly defines states and state transitions based upon modeling language standards and engineering principles. The student creates and runs a simulation that produces a result that can be compared to the identified technical performance measure. The student accurately describes their assumptions, process, and methodology with correct use of terminology and determines the confidence that the model produces accurate results.

[18] Personnel Decisions Research Institutes, Inc. (PDRI), JBS International, Inc., Aguirre Division, Coffey Consulting, LLC, and JBS International, Inc., "Competency Models – Communicating Industry's Education and Training Needs: Competency Model Development and Use – A Technical Assistance Guide," Oct. 2019.

Step 3: Identify National Standards & Competency Frameworks

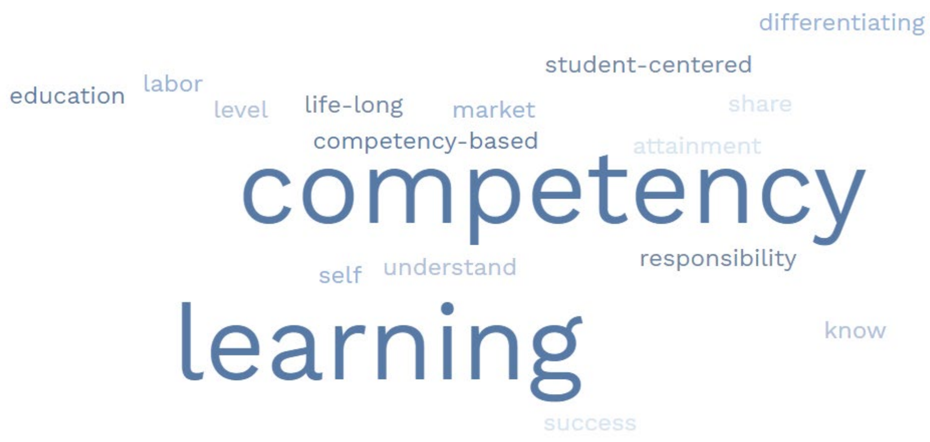
The following four competencies were found to be most relevant to the technical mission for the systems engineering institute based upon stakeholder input:

1. 21st Century Cyber-Physical Systems Education report published by the National Academies Press [1]
2. Applied Mathematics at the U.S. Department of Energy report published by Lawrence Livermore National Laboratory [21]
3. INCOSE Systems Engineering Competency Framework [22]
4. INCOSE Model-Based Enterprise Capabilities Matrix [23]

[1] National Academies of Sciences, Engineering, and Medicine, "A 21st century cyber-physical systems education," National Academies Press, Jan. 27, 2017, doi: 10.17226/23686.
[21] D.L. Brown, J. Bell, D. Estep, W. Gropp, B. Hendrickson, S. Keller-McNulty, D. Keyes, J.T. Oden, L. Petzold, M. Wright, "Applied mathematics at the US Department of Energy: Past, present and a view to the future," Lawrence Livermore National Lab (LLNL), (No. LLNL-TR-401536), Livermore, CA, Feb. 15, 2008.
[22] R. Beasley, D. Gelosh, M. Heisey, I. Presland, and L. Zipes. INCOSE Systems Engineering Competency Framework. INCOSE-TP-2019-002-01.0. 2018.
[23] J. Hale and A. Hoheb, "A Model-Based Enterprise Capabilities Matrix," in Annual International Council on Systems Engineering (INCOSE) International Workshop, (No. M18-7144-1), Jan. 1, 2019.

Step 4: Set a CBE Mission for Academic Program

"Create a CBE program that is *student-centered*, drives students to take *responsibility* for their learning path, encourages students to participate in *life-long learning*, supports students in *defining and differentiating themselves* and their skills in the labor market, supports their understanding of *what they are learning and why*, supports their understanding of their level of competency in certain skills, and provides a social media mechanism for them to *share their competency attainment and success*."



Step 5: Define CBE Competency Levels

- **Based upon INCOSE Systems Engineering Competency Framework Definitions [22]**
- **Awareness:** The person displays knowledge of key ideas associated with the competency area and understands key issues and their implications. They ask relevant and constructive questions on the subject. This level characterizes engineers new to the competency area. It could also characterize an individual outside Systems Engineering who requires an understanding of the competency area to perform their role.
- **Supervised Practitioner:** The person displays an understanding of the competency area and has some limited experience. They require regular guidance and supervision. This level defines those engineers who are “in-training” or are inexperienced in that competency area.

[22] R. Beasley, D. Gelosh, M. Heisey, I. Presland, and L. Zipes. INCOSE Systems Engineering Competency Framework. INCOSE-TP-2019-002-01.0. 2018.

Step 6: Analyze & Apply the Competency Frameworks

The following steps were taken to analyze and apply the four (4) competency frameworks:

a. Each framework was analyzed, and competency statements were extracted from each framework and written as competency statements.
b. The competency statements were then organized for each framework individually to define any needed hierarchical structure, important relationships or categories, or competency levels.
c. The industrial advisory board members reviewed the competency statements and ranked importance levels by framework to prioritize competency attainment and course content: tailoring and differentiation.
d. Competency statements were then compared across the four competency frameworks to understand overlaps and relationships, where many relationships and overlaps were discovered.
e. A list of competency statements were assessed by each course instructor for each systems engineering course for three (3) frameworks and are listed in *Appendices 2, 3, and 4*.

Step 6a. Relevant Competencies from INCOSE SECF [22]

Competency Category	Competency Area	Two Competency Levels
SE Management	Decision Management	AWARENESS, SUPERVISED PRACTITIONER
SE Management	Risk and Opportunity Management	AWARENESS, SUPERVISED PRACTITIONER
SE Technical Processes	Design For…	AWARENESS, SUPERVISED PRACTITIONER
SE Technical Processes	Requirements Definition	AWARENESS, SUPERVISED PRACTITIONER
SE Technical Processes	Operation and Support	AWARENESS, SUPERVISED PRACTITIONER
SE Technical Processes	System Architecting	AWARENESS, SUPERVISED PRACTITIONER
SE Technical Processes	Interfaces	AWARENESS, SUPERVISED PRACTITIONER
SE Technical Processes	Integration	AWARENESS, SUPERVISED PRACTITIONER
SE Technical Processes	Transition	AWARENESS, SUPERVISED PRACTITIONER
SE Technical Processes	Validation	AWARENESS, SUPERVISED PRACTITIONER
SE Technical Processes	Verification	AWARENESS, SUPERVISED PRACTITIONER

[22] R. Beasley, D. Gelosh, M. Heisey, I. Presland, and L. Zipes. INCOSE Systems Engineering Competency Framework. INCOSE-TP-2019-002-01.0. 2018.

Step 6c. Example Advisory Board Member Ranking Average

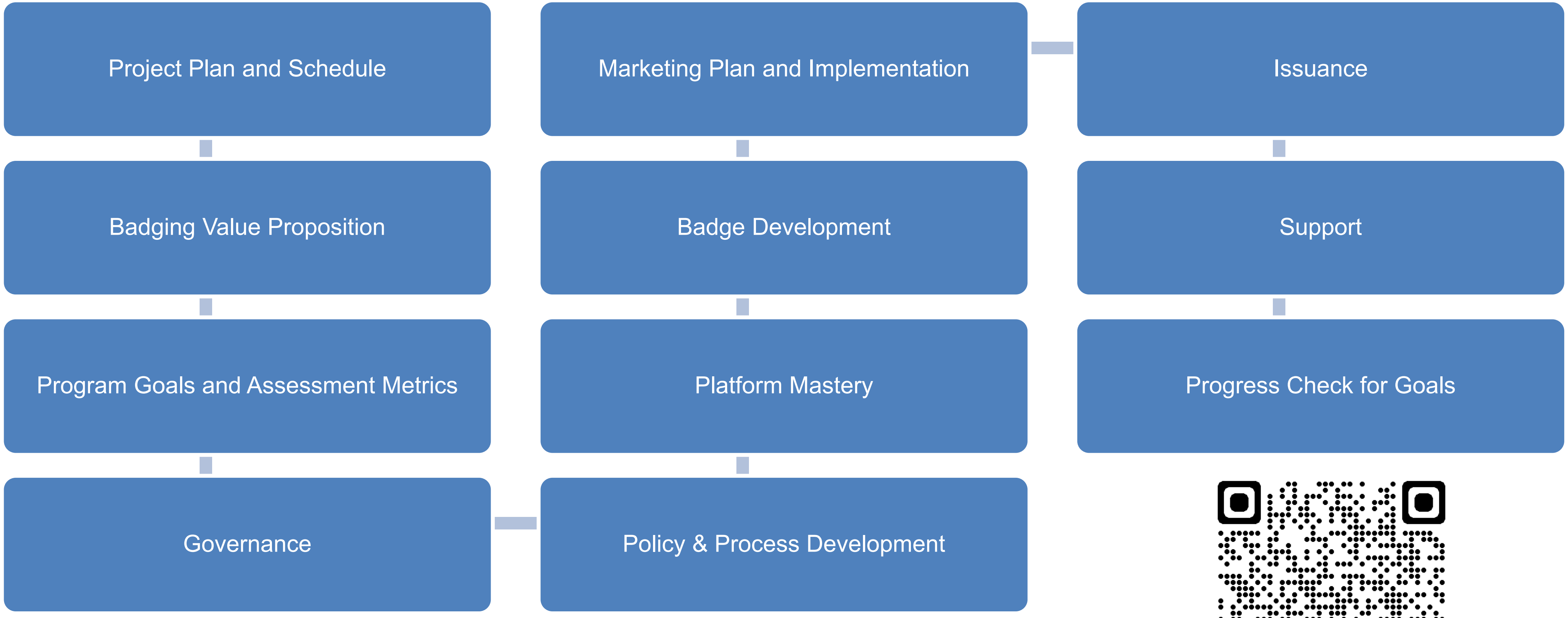
ID	COMP CATEGORY	COMP AREA	EFFECTIVE INDICATORS OF KNOWLEDGE AND EXPERIENCE	Two COMPETENCY LEVELS	Rank 1 = very important 2 = important 3 = not that important
1	CORE SE Principles	Lifecycles	Identifies different lifecycle types (e.g., waterfall, Vee, incremental, iterative, spiral) and summarizes the key characteristics of each.	AWARENESS	2.7
2	CORE SE Principles	Lifecycles	Explains why selection of lifecycle is important when developing a system solution.	AWARENESS	2.7
3	CORE SE Principles	Lifecycles	Explains why it is necessary to define an appropriate lifecycle process model and the key steps involved.	AWARENESS	2.7
4	CORE SE Principles	Lifecycles	Explains why differing engineering approaches are required in different lifecycle phases and provides examples.	AWARENESS	2.3
5	CORE SE Principles	Lifecycles	Describes the key characteristics of differing lifecycles and how these relate to the system lifecycle.	AWARENESS	2.3
6	CORE SE Principles	Lifecycles	Describes systems engineering lifecycle processes.	SUPERVISED PRACTITIONER	2.3
7	CORE SE Principles	Lifecycles	Assists in lifecycle definition activities at system or system element level.	SUPERVISED PRACTITIONER	2.7
8	CORE SE Principles	Lifecycles	Describes the system lifecycle in which they are working on their project.	SUPERVISED PRACTITIONER	2.7
9	CORE SE Principles	Lifecycles	Identifies the systems engineering lifecycle processes in place on their project.	SUPERVISED PRACTITIONER	2.0
10	CORE SE Principles	Lifecycles	Identifies the advantages and disadvantages of different types of systems lifecycle and where each might be used advantageously.	SUPERVISED PRACTITIONER	2.3
74	CORE SE Principles	Lifecycles	Explains why it is important to consider future lifecycle stages in the current stage, with examples.	SUPERVISED PRACTITIONER	2.7
29	CORE SE Principles	Capability Engineering	Describes and illustrates the difficulties of translating capability needs of the wider system into system requirements.	AWARENESS	2.3

Step 7 and 8: Evaluation, Feedback, Re-Design

- Evaluation: Collect data and information concerning the quality of CBE program (on-going)
  - Collect information from students on value or effects of CBE program
  - Collect information from stakeholders on value or effects of CBE program
- Feedback and Re-design: Analyze CBE program information and improve CBE program design (future)

Step 9: Badging to Support CBE Process

The process for implementing the badging program followed Credly's guidelines and is shown in Figure 3.



Example Implementation

Example Course: Model-based systems engineering

Example Module: Requirements modeling

Example Implementation for MBSE Course

#	Module Competencies	Hierarchy or Level
1	Can develop and update formal specifications for cyber-physical designs and systems.	Course
2	Can apply systems engineering methods and principles to the design and operation of a CPS.	Course
3	Can design large-scale meta systems and predict behavior and performance with systems models during early phase design.	Course
4	Can perform modeling and analysis to design and predict operating characteristics for a complex system.	Course
5	Can perform modeling and analysis of a stochastic system and simulate it to understand performance based upon performance measures.	Course
6	Can use modeling and simulation tools and techniques to represent a system or system element.	Course
7	Can contribute to the model development and interpretation activities.	Course
8	Can describe and apply the systems engineering Technical Processes to a real-world problem.	Course
9	Can model stakeholder needs and system requirements.	Module

Example Implementation for MBSE Course

#	Module Competencies	Hierarchy or Level
10	Can apply knowledge of how CPS methods integrate at the large, meta system level.	Module Activity
11	Can perform modeling and analysis to quantify cost, schedule, and technical risk.	Module Activity
12	Can conduct model-based verification and validation.	Module Activity
13	Can develop and update verification and validation methods for cyber-physical designs and systems.	Module Activity
14	Can manage design change through system modeling.	Module Activity
15	Can perform modeling and analysis to design and predict the effects of introducing a new technology into a current complex system.	Module Activity
16	Can modify a model of a complex system to introduce new data types and formats.	Module Activity
17	Can define and quantify uncertainty in systems flows and processes for a systems model.	Module Activity
18	Can interpret and use outcomes of modeling and analysis, with guidance.	Module Activity
19	Can develop a high-quality systems model using SysML or other standard language.	Module Activity

Example Implementation for MBSE Course

Module Student Learning Outcome	Competency
Use an MBSE tool to create, organize, and categorize requirements.	N/A
Create requirement relationships using an MBSE approach.	Can apply knowledge of how CPS methods integrate at the large, meta system level.
Model and visualize requirement relationships using the SysML requirements diagram.	
Model and handle requirement risks and concerns in an MBSE tool.	Can perform modeling and analysis to quantify cost, schedule, and technical risk.
Define how requirements are satisfied and verified using SysML and an MBSE tool.	Can conduct model-based verification and validation
	Can develop and update verification and validation methods for cyber-physical designs and systems.

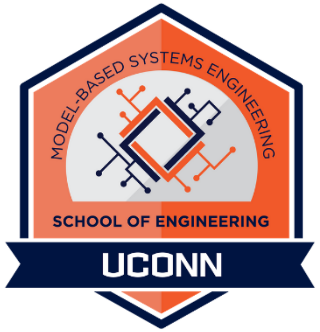
Example Implementation for MBSE Course

LO #	Change Status	Learning Outcome	Competency	COMP #
1	Existing	Create requirement relationships using an MBSE approach.	Can apply knowledge of how CPS methods integrate at the large, meta system level.	1
2	Existing	Model and visualize requirement relationships using the SysML requirements diagram.	Can apply knowledge of how CPS methods integrate at the large, meta system level.	1
3	Existing	Model and handle requirement risks and concerns in an MBSE tool.	Can perform modeling and analysis to quantify cost, schedule, and technical risk.	2
4	Existing	Define how requirements are satisfied and verified using SysML and an MBSE tool.	Can conduct model-based verification and validation	3
			Can develop and update verification and validation methods for cyber-physical designs and systems.	4
5	**New**	**Define and conduct a process to import a set of changed requirements into the model and update the requirements model.**	**Can manage design change through system modeling.**	**5**
6	**New**	**Define a process to change a requirement for the introduction of a new technology.**	**Can perform modeling and analysis to design and predict the effects of introducing a new technology into a current complex system.**	**6**
7	**New**	**Define a process to change a requirement for the introduction of a new data type.**	**Can modify a model of a complex system to introduce new data types and formats.**	**7**
8	**New**	**Write requirements with additional language to handle the uncertain nature of the operating environment.**	**Can define and quantify uncertainty in systems flows and processes for a systems model.**	**8**
9	**New**	**Describe and interpret the results of the requirements model.**	**Can interpret and use outcomes of modeling and analysis, with guidance.**	**9**
10	**New**	**Assess the requirements model for quality using model quality metrics.**	**Can develop a high-quality systems model using SysML or other standard language**	**10**

Example Implementation for MBSE Course

LO #	Learning Outcome	Competency	CP #	Standard
1	Create requirement relationships using an MBSE approach.	Can apply knowledge of how CPS methods integrate at the large, meta system level.	1	Standard (1) NAE-CPS
2	Model and visualize requirement relationships using the SysML requirements diagram.	Can apply knowledge of how CPS methods integrate at the large, meta system level.	1	Standard (1) NAE-CPS
3	Model and handle requirement risks and concerns in an MBSE tool.	Can perform modeling and analysis to quantify cost, schedule, and technical risk.	2	Standard (2) DOE-SIAM
4	Define how requirements are satisfied and verified using SysML and an MBSE tool.	Can conduct model-based verification and validation	3	Standard (4) INCOSE Model-Based Enterprise Capabilities Matrix
4	Define how requirements are satisfied and verified using SysML and an MBSE tool.	Can develop and update verification and validation methods for cyber-physical designs and systems.	4	Standard (1) NAE-CPS
5	Define and conduct a process to import a set of changed requirements into the model and update the requirements model.	Can manage design change through system modeling.	5	Standard (2) DOE-SIAM
6	Define a process to change a requirement for the introduction of a new technology.	Can perform modeling and analysis to design and predict the effects of introducing a new technology into a current complex system.	6	Standard (2) DOE-SIAM
7	Define a process to change a requirement for the introduction of a new data type.	Can modify a model of a complex system to introduce new data types and formats.	7	Standard (2) DOE-SIAM
8	Write requirements with additional language to handle the uncertain nature of the operating environment.	Can define and quantify uncertainty in systems flows and processes for a systems model.	8	Standard (4) INCOSE Model-Based Enterprise Capabilities Matrix
9	Describe and interpret the results of the requirements model.	Can interpret and use outcomes of modeling and analysis, with guidance.	9	Standard (3) INCOSE ISECF
10	Assess the requirements model for quality using model quality metrics.	Can develop a high-quality systems model using SysML or other standard language	10	Standard (3) INCOSE Model-Based Enterprise Capabilities Matrix

Example Credly Badge for MBSE Course



Earn this Badge

Model-Based Systems Engineering

Issued by University of Connecticut

Earners of the Model Based Systems Engineering Badge have developed skills in the discrete modeling and simulation of cyberphysical systems using a systems engineering approach and can construct high quality systems models using the SysML modeling language and an MBSE tool. They can analyze sensitivity of cyberphysical designs for variability and uncertainty in the context environment and perform verification and validation of requirements, design, systems, and systems models.

Learn more

Validation | Intermediate | Weeks | Paid

Skills

Complex System Modeling | Cyber-Physical Systems | Manage Design Change | Meta System Modeling | Model-based Systems Engineering | Model-Based Systems Engineering Management | Model-Based Systems Engineering Modeling | SysML | System Design | Systems Analysis | Systems Architecting | Systems Engineering | Systems Modeling | Systems Thinking | Uncertainty Quantification | Validation | Verification

Earning Criteria

•Badge earners complete SE 5001 Model Based Systems Engineering course at the University of Connecticut, which is a hybrid-online graduate course that can be taken from anywhere in the world. Earners can take this graduate course as a matriculated UConn graduate student or as a non-degree graduate student, which does not require admission to the UConn graduate school. Badge holders complete a course-long project and must earn a B- or better on this project to earn the badge.

•Badge earners can perform MBSE management practices for a real-world problem, can describe modeling roles and responsibilities, can describe knowledge, skills, and abilities for MBSE practitioners, can develop a MBSE use strategy for their organization and can conduct model-based verification and validation. See Standard [4] INCOSE Model-Based Enterprise Capabilities Matrix below.

•Badge earners can perform MBSE by system modeling using a systems modeling language, can describe different types of systems modeling languages and methods, can develop a systems engineering-driven model plan, can define model metrics, can develop a high-quality systems model based upon a defined purpose, can model stakeholder needs, and can develop a high-quality systems model using SysML or other standard language. See Standard [4] INCOSE Model-Based Enterprise Capabilities Matrix below.

•Badge earners can analyze systems by simulation, can verify and validate models, can define and develop model libraries, can conduct model-based reviews, can integrate models, can quantify model process quality can use existing models for analysis based upon different types of needs. See Standard [4] INCOSE Model-Based Enterprise Capabilities Matrix below.

•Badge earners can explain why models and simulations have a limit of valid use and explain the risks of fusing models and simulations outside those limits, can explain why models are developed for a specific purpose, can use modeling and simulation tools and techniques to represent a system or system element, can interpret and use outcomes of modeling and analysis, with guidance, and can contribute to the model development and interpretation activities. See Standard [3] INCOSE ISECF below.

•Badge earners can design large-scale meta systems and predict behavior and performance with systems models during early phase design, can perform modeling and analysis to design and predict operating characteristics for a complex system, can perform modeling and analysis to design and predict when changing meta system conditions cause system failures, See Standard [2] DOE-SIAM below.

•Badge earners can perform modeling and analysis of a stochastic system and simulate it to understand performance based upon performance measures, can decompose complex systems into canonical subsystems to design and predict system behavior and elucidating the coupling between components, can optimize a system to meet stakeholder needs and best engineering practice standards, and can perform modeling and analysis to quantify cost, schedule, and technical risk. See Standard [2] DOE-SIAM below.

•Badge earners can manage design change through system modeling, can perform modeling and analysis to design and predict the effects of introducing a new technology into a current complex system, can modify a model of a complex system to introduce to new data types and formats, can conduct sensitivity analysis for a complex system using a model during early phase design, and can define and quantify uncertainty in systems flows and processes for a systems model. See Standard [2] DOE-SIAM below.

•Badge earners can apply knowledge of how cyberphysical system methods integrate at the large, meta system level, can design and develop cyberphysical system architecture, can develop and update formal specifications for cyberphysical designs and systems, can develop and update verification and validation methods for cyberphysical designs and systems, can apply Systems Engineering methods and principles to the design and operation of a cyberphysical system. See Standard [1] NAE-CPS below.

•Badge holders complete a course-long project consisting of a proposal, midterm and final reports, and systems model artifact. The project consists of creating and developing a systems model that represents the design of a real system using an MBSE tool and a systems modeling language. The model must be defined and simulated to solve a particular problem. The model is simulated to determine if requirements and key performance parameters are met.

Standards

[1] NAE-CPSA 21st Century Cyber-Physical Systems Education. Committee on 21st Century Cyber-Physical Systems Education; Computer Science and Telecommunications Board; Division on Engineering and Physical Sciences; National Academies of Sciences, Engineering, and Medicine. ISBN 978-0-309-45163-5 | DOI: 10.17226/23686.
[2] DOE-SIAMSIAM APPLIED MATHEMATICS AT THE U.S. DEPARTMENT OF ENERGY: Past, Present and a View to the Future. A Report by an Independent Panel from the Applied Mathematics Research Community May 2008.
[3] INCOSE-ISECFINCOSE Model-Based Enterprise Capabilities Matrix 2.0b Draft June 2019 r4. Joe Hale, NASA
[4] INCOSE Model-Based Enterprise Capabilities Matrix INCOSE Systems Engineering Competency Framework. July 2018. INCOSE Technical Product Reference: INCOSE-TP-2018-002-01.0

Conclusions

- CBE an on-going and iterative process
- Value of CBE approach for UConn IASE
- Tailoring by CBE process results in a good explanation of why we named our program “Advanced” Systems Engineering – high level of analytical skills are developed by the program, focus on analysis, modeling, and simulation methods
- Future: How will Digital Engineering and Transformation effect courses and competencies?

Engage

Participate

Lead

Help

Find Collaborators

Reach Out

Get funded

Teach

Learn

Paper ID: 38917

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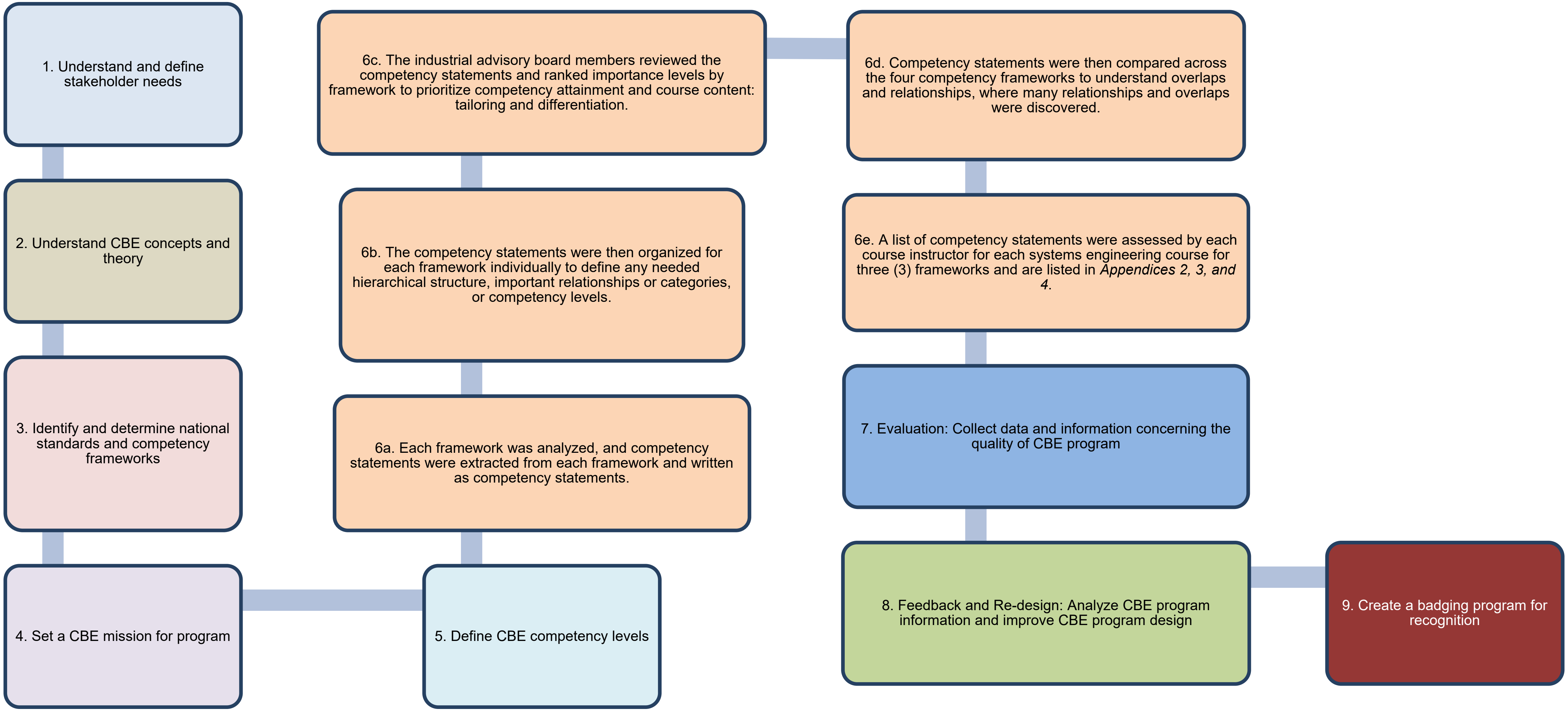
YouTube: https://www.youtube.com/channel/UCyIDa1nLXJE4JzvA039fmAA

Final CBE Process



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