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Piloting A Personalized Learning Model for Chemical Engineering Graduate Education – Lessons Learned from Creating a Chemical Engineering Body of Knowledge

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Susan Fullerton is an Associate Professor, Bicentennial Board of Visitors Faculty Fellow, and Vice Chair for Graduate Education in the Department of Chemical and Petroleum Engineering at the University of Pittsburgh. She earned her Ph.D. in Chemical Engineering at Penn State in 2009, and joined the Department of Electrical Engineering at the University of Notre Dame as a Research Assistant Professor. In 2015 she established the Nanoionics and Electronics Lab at Pitt as an Assistant Professor, and was promoted to Associate Professor with tenure in 2020. Fullerton's work has been recognized by an NSF CAREER award, an Alfred P. Sloan Fellowship, a Marion Milligan Mason award for women in the chemical sciences from AAAS, and a Ralph E. Powe Jr. Faculty Award from ORAU. For her teaching, Fullerton was awarded the 2018 James Pommersheim Award for Excellence in Teaching in Chemical Engineering at Pitt. For more information: http://fullertonlab.pitt.edu/

Piloting A Personalized Learning Model for Chemical Engineering Graduate Education –

Lessons Learned from Creating a Chemical Engineering Body of Knowledge

April Dukes | Mary Besterfield-Sacre | Susan Fullerton | Goetz Veser

University of Pittsburgh

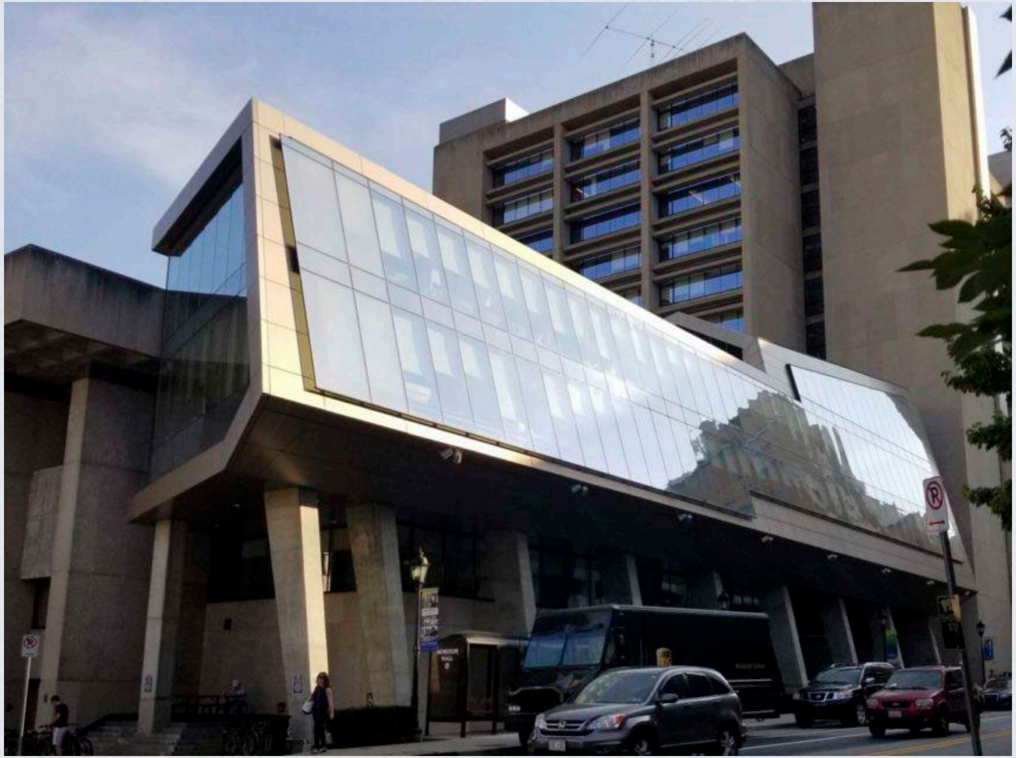
Swanson School of Engineering

University of Pittsburgh

Swanson School of Engineering

Overview

- Need for innovation in graduate STEM education
- Personalized Learning Model
  - Developing the Body of Knowledge
  - Concept Mapping of Learning Objectives
  - Modularization of Core Courses
- The New Curriculum
- Implications and Takeaways
- Next steps



https://pittnews.com/article/159247/top-stories/swanson-engineers-a-path-for-fall-semester/#modal-photo

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Need for Innovation in Graduate Education and STEM Training

- Current graduate STEM education does not fully address the diverse needs of graduate students, especially at a time when cultivating diverse talent is crucial.
  - Primarily designed to produce research results and publications
  - Essential skills like communication, teamwork in diverse settings, mentoring, networking, and leadership are needed in the workforce
- To remain relevant in the evolving landscape of science, engineering, and society, graduate STEM education requires significant cultural transformation.

National Academies of Sciences, Engineering, and Medicine. 2018. Graduate STEM Education for the 21st Century. Washington, DC: The National Academies Press. https://doi.org/10.17226/25038.

Need for Innovation in Graduate Education and STEM Training

- Our research project explores the impact of Personalized Learning Models (PLM) on the development and training of CHE graduate students.
  - Customized Learning Paths
  - Individual Development Paths
  - Modular Coursework
  - Student-Centered Approach
  - Continuous Assessment and Feedback

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Overall Research Goals

- **Goal 1:**
  - Create a personalized learning model (PLM) for graduate STEM education that is inclusive and incorporates professional training
- **Goal 2:**
  - Generate the knowledge and examine the potential to extend the PLM from one STEM context to another

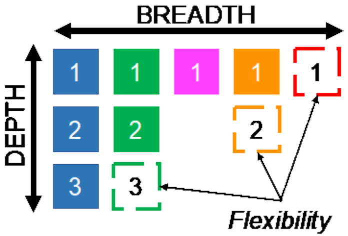
A Personalized Learning Model (PLM) for STEM Graduate Education

INSTRUCTIONAL GOALS

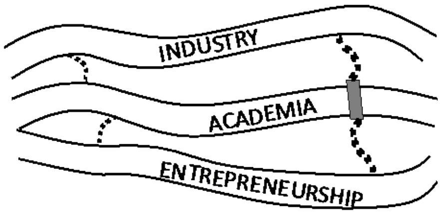
- Learner profile
- Individual development plans (IDP)

TASK ENVIRONMENT

Single-credit Modules



Professional Development Streams



SCAFFOLDING OF INSTRUCTION

Zone of Proximal Development

Learner Assistance Instructor Active Learning Weeks 1-4	Learner Assistance Peer Learning Weeks 1-4	→	Towards Independence PLP Project or Exam Week 5

ASSESSMENT OF PERFORMANCE AND LEARNING

Student:

- Non-technical core competency
- Improved understanding of industry/entrepreneurship
- Highly competitive for target employment

Faculty

- Formative & summative feedback on model
- Feedback on student interactions with learning & research
- Lower barrier to teaching modern/emerging topics
- Strengthen academic-industry relationships

REFLECTION AND EVALUATION

- Student growth along IDP
- Ph.D. satisfaction
- Feedback on PD activities
- Advisory Board & Alumni Feedback

- Entering Research Learning Assessments
- Faculty Learning Community (FLC) Feedback

Diversity, Inclusivity, and our PLM

- IDPs are a student-centered tool for academic and career development planning. (*Instructional Goals*)
- Increased choice in courses and professional development stream activities respects diverse interests and career paths. (*Task Environment*)
- *Scaffolding of instruction* supports students who have different starting points in their academic preparation, background, and experience.
- Graduate student feedback is collected and utilized to support the program in the *assessment, reflection, and evaluation*.

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Body of Knowledge

Demographic Data – Subject Matter Experts

Role on the NSF IGE grant

OPTION	FREQUENCY	%
Junior Advisory Board	8	33.33 %
Technical Advisory Board	7	29.17 %
Faculty Member	6	25.00 %
Educational Advisory Board	2	8.33 %
Other	1	4.17 %
Total	24	

Type of organization

OPTION	FREQUENCY	%
Academia	11	45.83 %
For Profit	10	41.67 %
Non-Governmental Organization	1	4.17 %
Governmental Organization	1	4.17 %
Other	1	4.17 %
Total	24	

Disciplinary background

OPTION	FREQUENCY	%
Chemical engineering	21	84.00 %
Chemistry	1	4.00 %
Other engineering	2	8.00 %
Other	1	4.00 %
Total	25	

Job focus

OPTION	FREQUENCY	%
Client Service	1	3.13 %
Administration	2	6.25 %
Operations	7	21.88 %
Research and Development	16	50.00 %
Other	6	18.75 %
Total	32	

Terminal degree

OPTION	FREQUENCY	%
BS/BA	6	25.00 %
MS	5	20.83 %
PhD	13	54.17 %
Other Professional Degree	0	0.00 %
Total	24	

Body of Knowledge Process

- Collected and refined learning objectives (LOs) for five graduate chemical engineering courses covering six topics:
  - Thermodynamics, Kinetics and Reactor Design, Transport Phenomena, Mathematical Methods, Ethics, and Safety
- These updated LOs were inputted into GroupWisdom™.
- Our subject matter experts (SMEs) read through the LOs and individually added LOs in the brainstorming phase.

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Brainstorming

ENG

96 statements collected

More info

FINISH

FOCUS PROMPT :

Please review the list of learning outcomes across the six topics of graduate chemical engineering education: Thermodynamics, Kinetics and Reactor Design, Transport Phenomena, Mathematical Methods, Ethics, and Safety. Add any additional learning outcomes that you feel are not represented.

Add Ideas

Type to add an idea

(0/250 characters left)

ADD STATEMENT

Collected statements:

Refresh list

Search

Transport: Write out the constitutive equations for momentum, thermal energy and mass transport. Be able t o explain each term.

Transport: Split PDEs into two or more ODEs and solve via separation of variables

Transport: Specify and apply boundary conditions

Transport: Solve PDEs and visualize numerical results in Matlab

Transport: Solve and physically interpret simple steady-state conduction, diffusion, and fluid flow problems in rectangular, cylindrical, and spherical geometries, with and without zero-order and first-order generation/los s using shell (i.e., integral) balances.

Body of Knowledge Process

- Collected and refined learning objectives (LOs) for five graduate chemical engineering courses covering six topics:
  - Thermodynamics, Kinetics and Reactor Design, Transport Phenomena, Mathematical Methods, Ethics, and Safety
- These updated LOs were inputted into GroupWisdom™.
- Our subject matter experts (SMEs) read through the LOs and individually added LOs in the brainstorming phase.

➢ Most added LOs were non-curricular skills or specialized topics.

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Body of Knowledge Process

- The SMEs individually grouped the curricular LOs for these six topics into different categories: ***undergraduate, graduate, specialized, and unknown***.

Sorting

ENG

Cards

82 Kinetics/ReactorDesign: Differentiate between molecular, Knudsen, and single-file diffusion regimes when given a set of unlabeled cartoon schematics less

43 Math Methods: Solve nonlinear first order ODEs by exact differentials.

95 Ethics: Compare and contrast basic ethical theories (e.g. moral absolutism vs. relativism, utilitarianism, virtue ethics) less

70 Math Methods: Apply Bessel function to solve various chemical engineering problems

12 Transport: Develop a model for a defined chemical engineering transport problem involving at least two modes of transport that can be solved using the base package of COMSOL. Transport models can include steady-state, unsteady transport processes, irregular

0 of 96 statements sorted

More info >

FINISH

FOCUS PROMPT:

Please review the list of learning outcomes across the six topics of graduate chemical engineering education: Thermodynamics, Kinetics and Reactor Design, Transport Phenomena, Mathematical Methods, Ethics, and Safety. Add any additional learning outcomes that you feel are not represented.

Expand All | Collapse All

Drag and drop cards to create piles

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Body of Knowledge Process

- The SMEs individually grouped the curricular LOs for these six topics into three levels: ***undergraduate, graduate, specialized, and unknown***.
- The SMEs then individually rated the importance of each LO based on their own experiences within their career/jobs.

RATING

Rating the Importance of Learning Outcomes

ENG

0 of 96 statements rated

More info

FINISH

FOCUS PROMPT:

Please review the list of learning outcomes across the six topics of graduate chemical engineering education: Thermodynamics, Kinetics and Reactor Design, Transport Phenomena, Mathematical Methods, Ethics, and Safety. Add any additional learning outcomes that you feel are not represented.

Page 1 of 1

Statements 1 to 96

On this page: All (96) Unrated (96) Rated (0)

1 Math Methods: Dissect the long-term dynamical responses of arbitrarily complex, first order, ordinary differential equations using flow analysis.

1	2	3	4	5
Not at all important	Slightly important	Moderately important	Very important	Extremely important

2 Transport: Reason how developing (unsteady) or developed (steady state) temperature or concentration profiles interact with developing or developed velocity profiles

1	2	3	4	5
Not at all important	Slightly important	Moderately important	Very important	Extremely important

Body of Knowledge Process

- The SMEs individually grouped the curricular LOs for these six topics into three levels: ***undergraduate, graduate, specialized, and unknown***.
- The SMEs then individually rated the importance of each LO based on their own experiences within their career/jobs.
- The researchers then analyzed grouping similarities between all SMEs.

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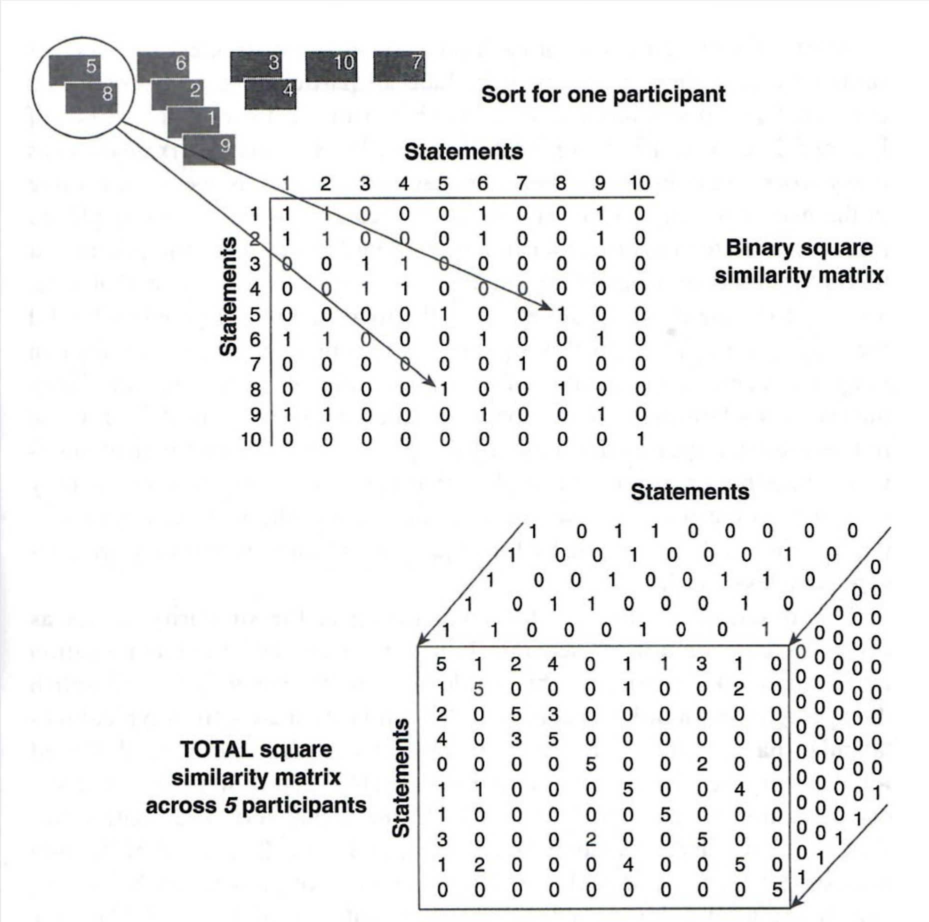
Analysis

Similarity Matrix

Frequency of how many times LOs were sorted together



Kane, M. & W. Trochim, *Concept Mapping for Planning and Evaluation*, page 91

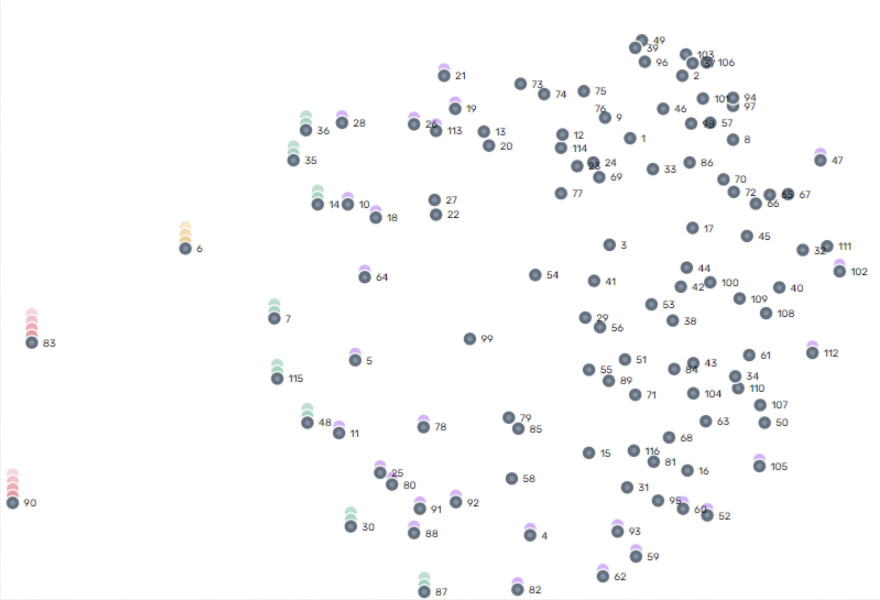
Analysis

Multidimensional scaling

Outcomes frequently sorted closer together are plotted together, and outcomes frequently sorted differently are plotted further from each other.

Result is an X, Y map of the points

Stress value (akin to reliability) is low indicating that the similarity matrix is well represented in two dimensions.



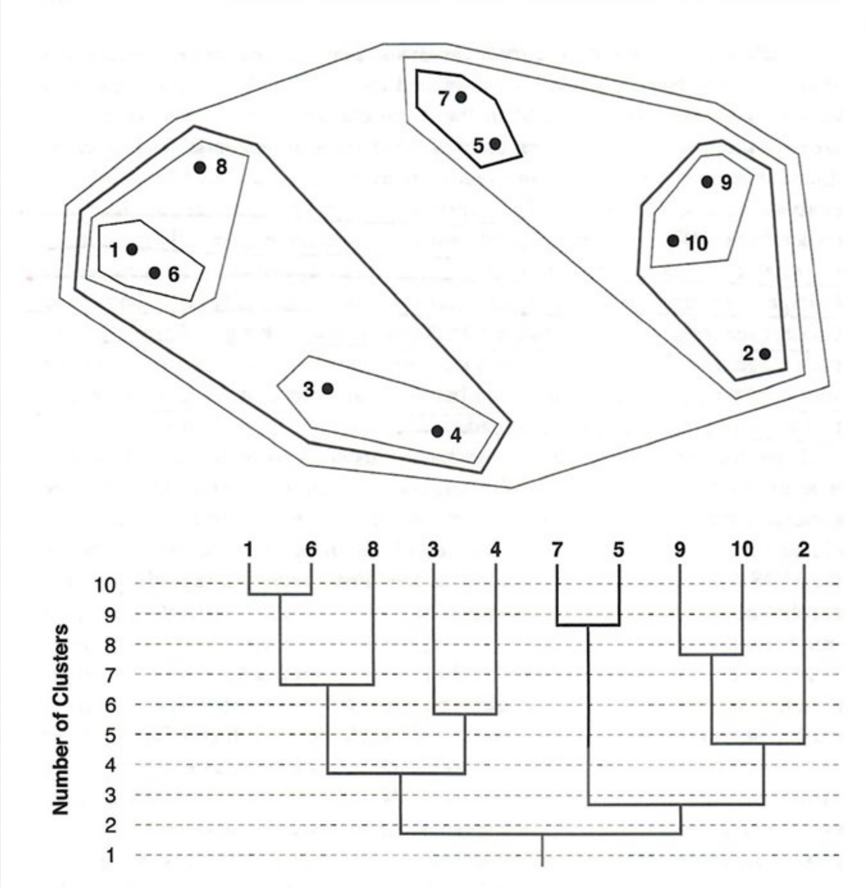
20 Participants | 0.2609 Stress Value | 12 Iterations

Analysis

Hierarchical Cluster Analysis

Groups outcomes on the point map into clusters that aggregate to reflect similar concepts

Takes the XY coordinate matrix and produces a tree structure of all cluster solutions from one giant cluster to multiple clusters that don't overlap.



Kane, M. & W. Trochim, *Concept Mapping for Planning and Evaluation*, page 100

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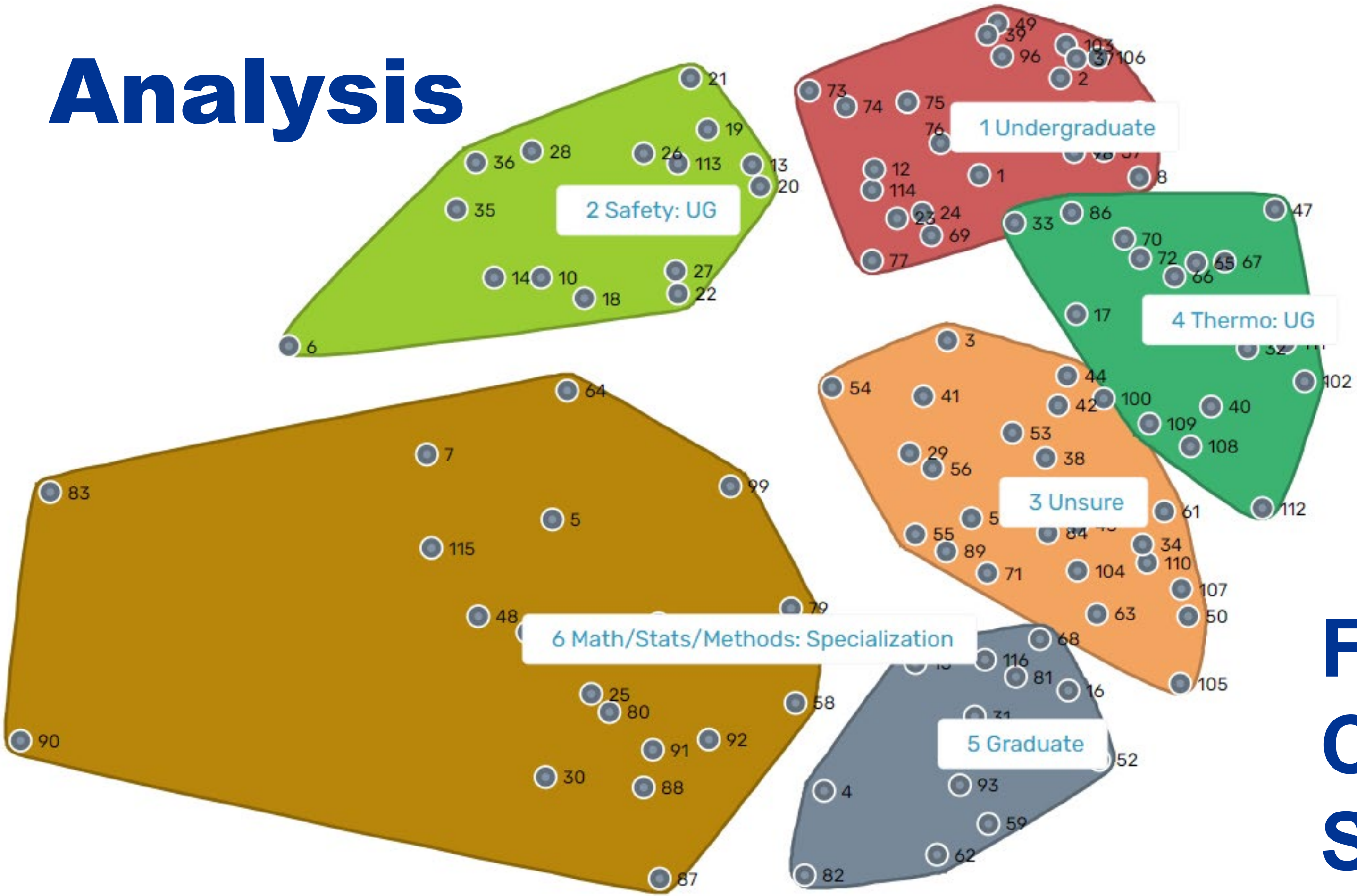
Analysis



Final Cluster Solution

How do we get from the cluster solution to learning objectives for undergraduate, graduate, and specialized modules?

Organized Clusters by Module Level (e.g., Undergrad)

Cluster 8									
Cluster 9									
Cluster 1									
Cluster 2									
	Math Methods		**Transport**		**Thermo**		**Kinetics**		**Safety/Ethics**
17	Math Methods: Principles and applications of probability, statistics, analytics, and machine learning/AI	45	Transport: Perform vector and tensor operations	33	Thermo: Read quantitatively and interpret two-and three-species phase diagrams in mixtures involves solids, liquids, gases, compounds/alloys, and critical phenomena	102	Kinetics/ReactorDesign: Differentiate between molecular, Knudsen, and single-file diffusion regimes when given a set of unlabeled cartoon schematics	9	Safety: Recognize personal, process, & community safety
86	Math Methods: Define linear regression using least squares and compare the results of linear regression when applied to continuous versus categorical data	47	Transport: Given a stress-strain relationship, categorize the behavior as Newtonian or non-Newtonian	65	Thermo: Compute property changes on mixing using partial molar properties	108	Kinetics/ReactorDesign: Compute estimates of elementary reaction rates using transition state theory and collision theory	12	Safety: introduction to the Elements of OSHA's Process Safety Management and EPA's Risk Management Program
1	Math Methods: Restate the accuracy, assumptions, and extrapolation for modeling techniques	40	Transport: Solve PDEs and visualize numerical results in Matlab	66	Thermo: Compute fluid properties from two and three parameter corresponding states	109	Kinetics/ReactorDesign: Compute estimates for viscosity, thermal conductivity, and diffusivity of gases from expressions given by the kinetic theory of gases	73	Safety: Recall key facts about the safety system of the University. For example, the phone number for campus police; the names of individuals to contact within the department, school, and university in case of safety-related questions; basic rules of storing chemicals.
23	Math Methods: Demonstrate familiarity with modeling techniques (including things to watch out for with respect to accuracy, assumptions, and extrapolation)	37	Transport: Write out the constitutive equations for momentum, thermal energy and mass transport. Be able to explain each term.	67	Thermo: Compare and contrast the origins and limitations of various equations of state	111	Kinetics/ReactorDesign: Compare the differences between internal and external mass transfer limitations in catalytic processes	74	Safety: Perform common lab activities safely, e.g. using needles and syringes, replacing a gas cylinder and regulator, removing gloves safely.
24	Math Methods: Demonstrate familiarity with data evaluation techniques (e.g., data quality, applicability, completeness, bias)	39	Transport: Specify and apply boundary conditions	70	Thermo: Calculate phase equilibria using activity coefficient models	112	Kinetics/ReactorDesign: Compare and contrast physisorption and chemisorption in terms of enthalpy of adsorption	75	Safety: Judge the hazards of a substance from its safety data sheet.
2	Math Methods: Solve ordinary differential equations with established analytical methods	46	Transport: Improve understanding of underlying transport processes by carrying out dimensional analyses	72	Thermo: Calculate changes in thermodynamic properties using the first and second laws of thermodynamics in conjunction with equations of state or departure functions	8	Kinetics/ReactorDesign: Predict the reactant/product composition exiting a reactor under conditions involving multiple reactions	76	Safety: Identify and select the personal protective equipment (gloves, eyewear) suitable for a specific substance or operation.
		49	Transport: Describe and give examples of the three modes of transport	32	Thermo: Calculate basics of electrochemical equilibrium, e.g. Nernst equation	94	Kinetics/ReactorDesign: Use the steady-state approximation to develop a valid rate equation for a multi-step reaction sequence	77	Safety: Assess the safety of a laboratory operation.
		57	Transport: Calculate heat flux due to radiation	69	Thermo: Calculate pure fluid and mixture phase equilibria	96	Kinetics/ReactorDesign: Solve material and energy balance equations for batch, semi-batch, stirred-flow, plug-flow, and packed bed reactors	114	Ethics: Formulate ethical decisions applied to engineering case studies using their "ethical toolbox"
						97	Kinetics/ReactorDesign: Solve for the compositions in an equilibrium reacting mixture, given the equilibrium constant and initial conditions		
						98	Kinetics/ReactorDesign: Schematically describe residence time distributions for ideal plug-flow, stirred-flow, and nonideal reactors		
						101	Kinetics/ReactorDesign: Explain the basic requirements of a reaction rate equation using language a first-year college student (near peer) would understand		
						103	Kinetics/ReactorDesign: Differentiate between elementary and nonelementary reaction equations		
						106	Kinetics/ReactorDesign: Define selectivity, yield, space time, space velocity		

Conducted a Second Organization According to Course (e.g., Transport)

Transport

	Undergraduate		Graduate		Specialize		Not Sure
45	Transport: Perform vector and tensor operations	41	Transport: Solve and physically interpret simple steady-state conduction, diffusion, and fluid flow problems in rectangular, cylindrical, and spherical geometries, with and without zero-order and first-order generation/loss using shell (i.e., integral) balances.	48	Transport: Develop a model for a defined chemical engineering transport problem involving at least two modes of transport that can be solved using the base package of COMSOL. Transport models can include steady-state, unsteady transport processes, irregular geometry, and nonlinear	15	Transport: Rigorous and sophisticated understanding of the fundamental physics, transitioning to integrated applications in bio, materials, reactors, and separations.
47	Transport: Given a stress-strain relationship, categorize the behavior as Newtonian or non-Newtonian	51	Transport: Convert PDEs to ODEs using combination of variables and solve	30**	Transport: Apply knowledge of fundamental electrokinetic phenomena, such as the flow past charged surfaces and electrophoresis, to analyze and predict the behavior of charged particles and fluids in various electrochemical and biotechnological applications.	52**	Transport: Contrast Eulerian and Lagrangian viewpoints
40	Transport: Solve PDEs and visualize numerical results in Matlab	54**	**Transport: Construct and deliver effective oral (presentation) and written (paper) communication regarding the background, theory, methods, results,**			14	Transport: Classify and apply process intensification principles
37	**Transport: Write out the constitutive equations for momentum, thermal energy and mass transport. Be able to explain**	55	Transport: Compute temperature profiles using the finite difference method				
39	**Transport: Specify and apply boundary conditions**	56	Transport: Compare macroscopic, microscopic and molecular approaches to solving transport				
46	**Transport: Improve understanding of underlying transport processes by carrying out dimensional analyses**	38	Transport: Split PDEs into two or more ODEs and solve via separation of variables				
49**	**Transport: Describe and give examples of the three modes of transport**	42	Transport: Solve and physically interpret (i.e., evaluate) one-dimensional unsteady state transport problems and multi-dimensional steady-state transport problems.				
57	Transport: Calculate heat flux due to radiation	44	Transport: Reason how developing (unsteady) or developed (steady state) temperature or concentration profiles interact with developing or developed velocity profiles				
		53	Transport: Construct and simplify differential balances for momentum, thermal energy, and species mass in rectangular, cylindrical and spherical geometries, accounting for convective and diffusive (molecular-scale) transport and				
		34	Transport: Analyze the behavior of materials using constitutive equations in tensor form and				
		43	Transport: Recall and explain each term in the combined momentum flux tensor, the combined energy flux vector, and the combined mass flux				
		50**	Transport: Derive the Hagen-Poiseuille equation				

Sorted Learning Objectives Within Each Level According to Their Averaged Rated Importance

	Undergraduate		Graduate		Specialize		Not Sure
49	Transport: Describe and give examples of the three modes of transport	54	Transport: Construct and deliver effective oral (presentation) and written (paper) communication regarding the background, theory, methods, results, and analysis of your problem and calculation.	48	Transport: Develop a model for a defined chemical engineering transport problem involving at least two modes of transport that can be solved using the base package of COMSOL. Transport models can include steady-state, unsteady transport processes, irregular geometry, and nonlinear	14	Transport: Classify and apply process intensification principles
39	Transport: Specify and apply boundary conditions	44	Transport: Reason how developing (unsteady) or developed (steady state) temperature or concentration profiles interact with developing or developed velocity profiles	30	Transport: Apply knowledge of fundamental electrokinetic phenomena, such as the flow past charged surfaces and electrophoresis, to analyze and predict the behavior of charged particles and fluids in various electrochemical and biotechnological applications.	15	Transport: Rigorous and sophisticated understanding of the fundamental physics, transitioning to integrated applications in bio, materials, reactors, and separations.
37	Transport: Write out the constitutive equations for momentum, thermal energy and mass transport. Be able to explain each term.	42	Transport: Solve and physically interpret (i.e., evaluate) one-dimensional unsteady state transport problems and multi-dimensional steady-state transport problems.			52	Transport: Contrast Eulerian and Lagrangian viewpoints
46	Transport: Improve understanding of underlying transport processes by carrying out dimensional analyses	41	Transport: Solve and physically interpret simple steady-state conduction, diffusion, and fluid flow problems in rectangular, cylindrical, and spherical geometries, with and without zero-order and first-order generation/loss using shell (i.e., integral)				
57	Transport: Calculate heat flux due to radiation	56	Transport: Compare macroscopic, microscopic and molecular approaches to solving transport				
47	Transport: Given a stress-strain relationship, categorize the behavior as Newtonian or non-Newtonian	53	Transport: Construct and simplify differential balances for momentum, thermal energy, and species mass in rectangular, cylindrical and spherical geometries, accounting for convective and diffusive (molecular-scale) transport and				
40	Transport: Solve PDEs and visualize numerical results in Matlab	55	Transport: Compute temperature profiles using the finite difference method				
45	Transport: Perform vector and tensor operations	43	Transport: Recall and explain each term in the combined momentum flux tensor, the combined energy flux vector, and the combined mass flux				
		38	Transport: Split PDEs into two or more ODEs and solve via separation of variables				
		51	Transport: Convert PDEs to ODEs using combination of variables and solve				
		34	Transport: Analyze the behavior of materials using constitutive equations in tensor form and				
		50	Transport: Derive the Hagen-Poiseuille equation				

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Proposed Modularization - Thermo

Undergraduate	Graduate	Specialized	Not Sure
72 Thermo: Calculate changes in thermodynamic properties using the first and second laws of thermodynamics in conjunction with equations of state or departure functions	71 Thermo: Calculate chemical compositions in reaction equilibria involving multiple independent reactions in nonideal systems	64 Thermo: Create computer codes in Python or a similar language to solve problems such as computing changes in thermodynamic properties, phase equilibria, etc.	68 Thermo: Calculate thermodynamic properties of ideal gas polyatomic molecules using statistical mechanics
33 Thermo: Read quantitatively and interpret two-and three-species phase diagrams in mixtures involves solids, liquids, gases, compounds/alloys, and critical phenomena	29 Thermo: Calculate electrolyte equilibrium, e.g. acid base equilibrium, partioning of ions between phases, charge distribution near surfaces	58 Thermo: Solve the Schrodinger equation and calculate the eigenfunctions for the following model systems: particle-in-a-box, harmonic oscillator, and rigid rotor	31 Thermo: Analyze basics of interfacial thermodynamics (e.g. adsorption equilibrium, Gibbs dividing surface, interfacial excess, Gibbs Thompson equation) and self assembly (e.g. micellar equilibrium)
69 Thermo: Calculate pure fluid and mixture phase equilibria	61 Thermo: Describe how intermolecular potentials give rise to non-ideal fluid and solid behavior		16 Thermo: Establish precise logical structure of classical, nonmolecular Gibbsian thermo and its key appln to pure & mixture property relations and equilibrium & stability; link to molecular origins of thermochemical & substance properties (stat mech).
67 Thermo: Compare and contrast the origins and limitations of various equations of state	63 Thermo: Define the purpose of a partition function and give examples of how it is used		60 Thermo: Describe how statistical mechanics can be used to compute thermophysical properties of macroscopic systems
70 Thermo: Calculate phase equilibria using activity coefficient models			59 Thermo: Identify partition functions for different ensembles
32 Thermo: Calculate basics of electrochemical equilibrium, e.g. Nernst equation			62 Thermo: Derive the Gibbsian functions and the Gibbs-Duhem equation using Legendre transforms
65 Thermo: Compute property changes on mixing using partial molar properties			
66 Thermo: Compute fluid properties from two and three parameter corresponding states			

Each column sorted from <u>highest</u> outcome rating to <u>lowest</u> outcome rating
5 Average Rating Value 4.11 to 4.60
4 Average Rating Value 3.63 to 4.11
3 Average Rating Value 3.14 to 3.63
2 Average Rating Value 2.65 to 3.14
1 Average Rating Value 2.17 to 2.65

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Proposed Modularization - Safety

	Undergraduate
75	Safety: Judge the hazards of a substance from its safety data sheet.
9	Safety: Recognize personal, process, & community safety
76	Safety: Identify and select the personal protective equipment (gloves, eyewear) suitable for a specific substance or operation.
77	Safety: Assess the safety of a laboratory operation.
74	Safety: Perform common lab activities safely, e.g. using needles and syringes, replacing a gas cylinder and regulator, removing gloves safely.
73	Safety: Recall key facts about the safety system of the University. For example, the phone number for campus police; the names of individuals to contact within the department, school, and university in case of safety-related questions; basic rules of storing chemicals.
12	Safety: introduction to the Elements of OSHA's Process Safety Management and EPA's Risk Management Program

	Not Sure
20	Safety: Establish a basic knowledge of plant process control concepts, risk assessments, safety audits, and quality management systems.
19	Safety: Review major codes / regulations that chemical engineers students might encounter across a variety of industries.
28	Safety: Prepare safety documents: PHA (Process Hazard analysis), LOPA (Layers of protection analysis), MRA (machine risk assessment), MOC (management of change).
35	Safety: Explain the basic processes in fault tree analysis.
36	Safety: Identify components of a fault tree.

Each column sorted from highest outcome rating to lowest outcome rating
5 Average Rating Value 4.11 to 4.60
4 Average Rating Value 3.63 to 4.11
3 Average Rating Value 3.14 to 3.63
2 Average Rating Value 2.65 to 3.14
1 Average Rating Value 2.17 to 2.65

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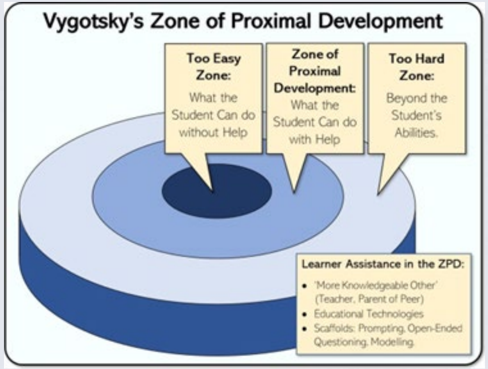
Implications and Takeaways

- Most LO's, especially the "important" ones, were sorted as Undergraduate Level



Eun B. (2017). The zone of proximal development as an overarching concept: A framework for synthesizing Vygotsky's theories. Educational Philosophy and Theory, 51(1), 18-30. https://doi.org/10.1080/00131857.2017.1421941

- In our BOK, the graduate core curriculum indicated that the mastery of undergraduate learning is essential for CHE graduate students.

Implications and Takeaways

- BOK brainstorming generated many non-CHE learning objectives.
  - Approximately half were specialized knowledge sets (Life Cycle Analysis, programming, Process Control, Renewable Energy)
  - The other half make up “soft” skillsets: communication, project management, interpersonal skills, and business/finance
- Many can be addressed in the Professional Development streams, and others will need to be reinforced in core and elective courses.

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Implications and Takeaways

- Consider both pedagogy (active learning and project-based learning) and curriculum at same time when modularizing.

Implications and Takeaways

- Intentional design of all core courses and professional streams are needed to support the learning graduate students need to develop mastery in the BOK.

Next Steps

- Analyze Student data for Modularized Thermo Class (Spring 2025)
- Refine Modularization Process
- Modularize Transport, Kinetics, and Math courses
- Continue implementation of Goal 2

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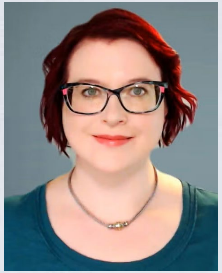
The Project Team

Susan Fullerton - PI

Götz Veser – co-PI

Mary Besterfield-Sacre co-PI

Bob Parker



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Questions

Forge Ahead.

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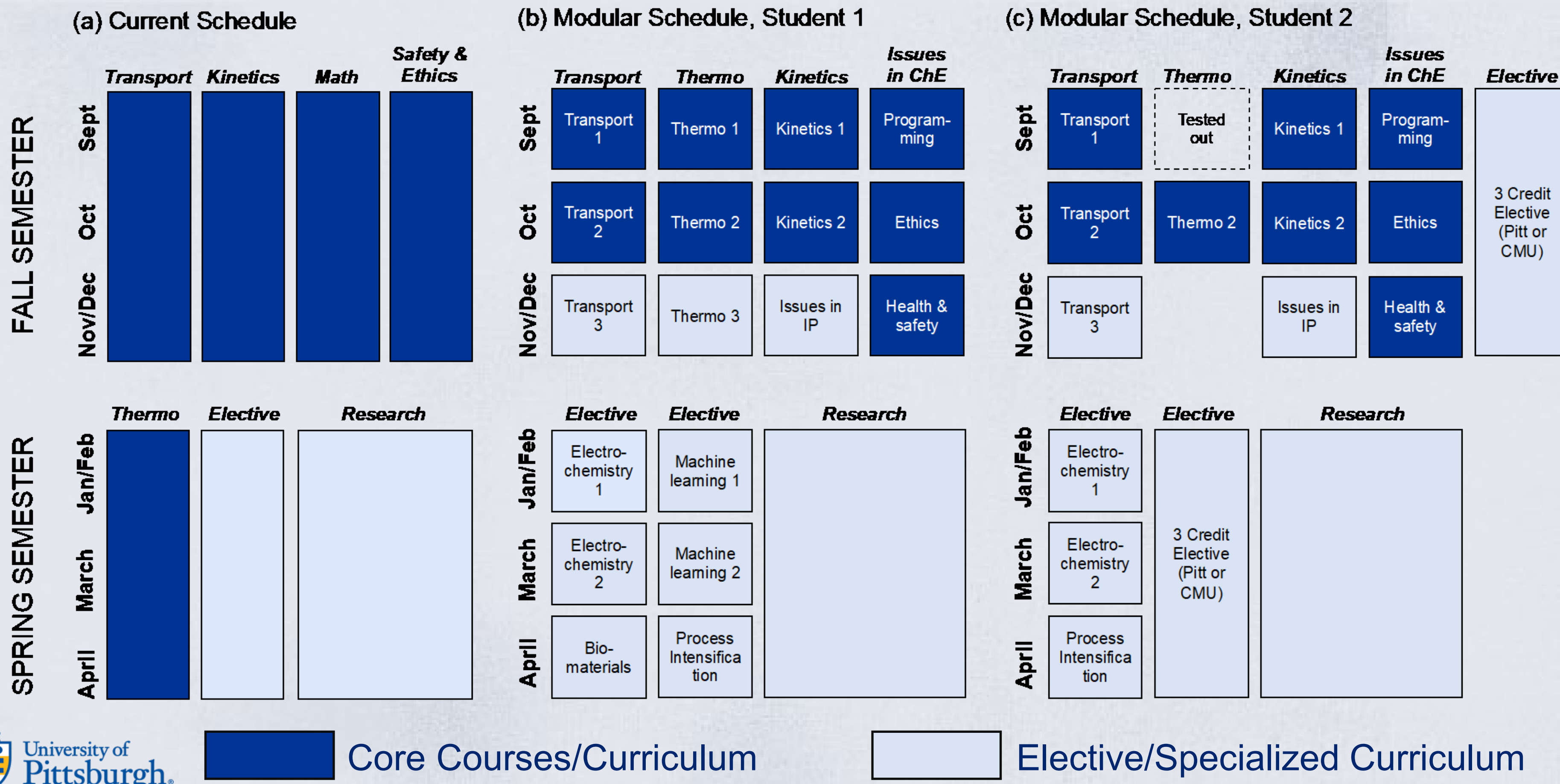
Single credit modules provide personalization, while maintaining strong ChE fundamentals



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