Framework for Transferability between Engineering and Technology Programs

Instructions: Make new friends! Please make groups of 3 or 4 with at least one person who teaches in engineering programs and one in technology programs.

Summary handouts, the framework and sample questions are provided. Please connect your phones, tablets or laptops to the wifi.

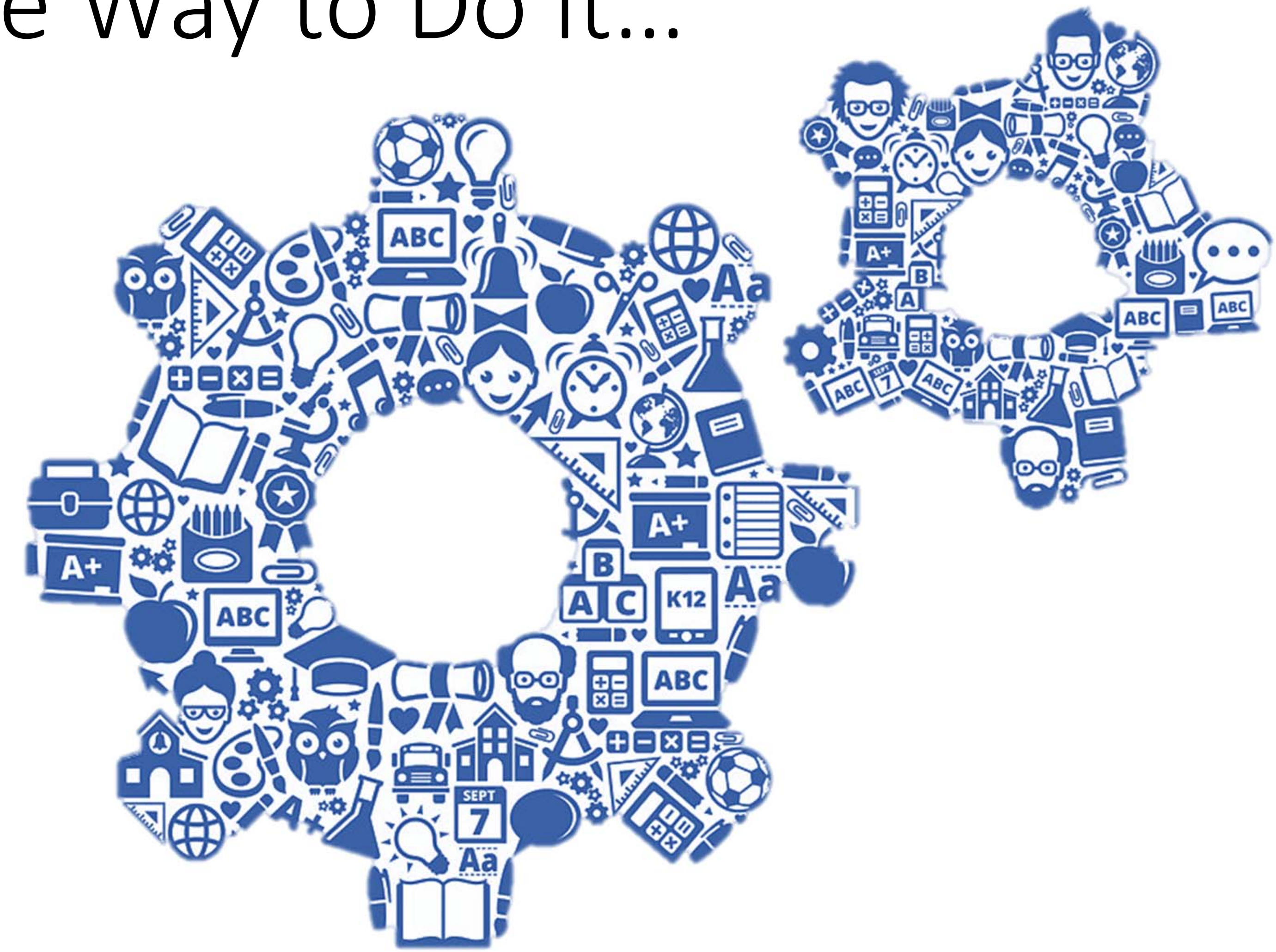
Presenters: Sima Zakani, Brian Frank, Roderick Turner

Support by: Jake Kaupp

Motivation

- Reluctance of institutions to accept transfer credits
- Trust is a significant factor – it must be addressed. Engineering transfer also requires support from accreditor (CEAB).
- Need for a documented, evidence-based transfer analysis, from a reliable source
- Requirement of buy-in and engagement from significant Ontario institutions
- Hope of developing widely-applicable learning modules, as needed, that will facilitate transfer University←→College

The Way to Do it…



Learning Outcomes

Measurable statements of student **knowledge**

(what students should know)

and **skills**

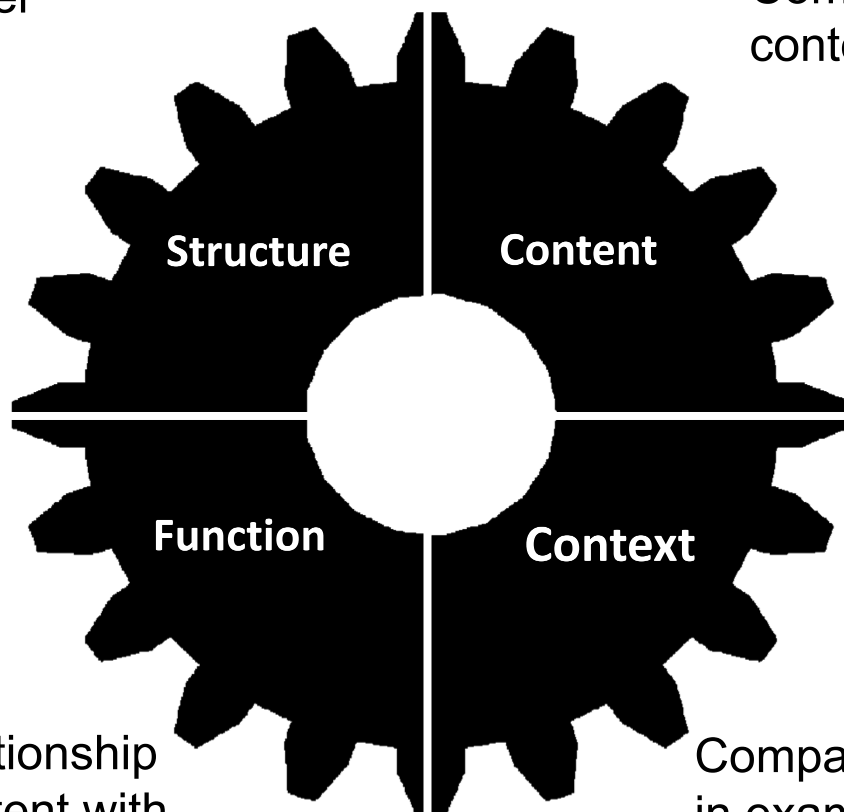
(what students should be able to do)

We are examining **explicit** and **implicit** outcomes.

Comparing Courses

Compare the order and sequence of topics within the program

Compare and match content and outcomes



Compare the relationship of the course content with other courses

Compare depth and complexity in exams, projects and learning outcomes

We think most transfers happen:

From **end of Advanced Diploma** to **Engineering program**
From **middle** of Engineering program to **Advanced Diploma**

"My first-choice college should have lots of closet space."

Focusing on three content areas:

Mathematics	Natural and Engineering Science	Design & Investigation
Integral and differential calculus	Mechanics and Electro-magnetism	Engineering design Team dynamics Project management Communication Lab skills

Sources of Information

		Tasks, e.g. exams	Learning outcomes	Syllabi	Instructor input
Structure				✓	
Content		✓	✓	✓	
Context	Cognitive process	✓	✓		
	Type of Knowledge	✓	✓		
	Transfer	✓	✓		
	Depth of Knowledge	✓	✓		
	Interdependence	✓	✓		
	Novelty				✓
	Scaffolding				✓
	Autonomy				✓
	Proximity				✓
	Communication		✓		✓
Function					✓

Sources of Information

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	Depth of Knowledge	✓	✓		
	Interdependence	✓	✓		
	Novelty				✓
	Scaffolding				✓
	Autonomy				✓
	Proximity				✓
	Communication		✓		✓
Function					✓

What We Mean by…

Cognitive process	The process of thinking as the student actively engages in meaningful thinking. Anderson, et al. (2001)
Type of Knowledge	A classification of different types of knowledge that learners may be expected to acquire or construct. Anderson, et al. (2001)
Transfer	Moving from the context in which the learning happened to other contexts and real-world applications. Daggett (2014)
Depth of Knowledge	Extent of specialized engineering knowledge that provides theoretical frameworks and bodies of knowledge for the accepted practice areas in the engineering/technology discipline. IEA (2013)
Interdependence	A classification of different levels of complexity in an engineering problem. IEA (2013)

What We Mean by…

Cognitive process	**Remember** Retrieve relevant knowledge from long term memory.	**Understand** Construct meaning from instructional messages.	**Apply** Carryout or use a procedure in a given situation	**Analyze** Break material into constituent parts and determine how parts relate to one another and to an overall structure or purpose.	**Evaluate** Make judgment based on criteria and standards.	**Create** Put elements together to form a coherent whole
Type of Knowledge	**Factual** Knowledge of discrete, isolated bits of information that the students must know to be acquainted with a discipline or solve problems in it.		**Conceptual** Complex,organized knowledge form of the interrelationships among the basic elements within a larger structure that enables them to function together.	**Computational**	**Math translation**	**Investigative**
Transfer	**Mathematical Knowledge**		**Apply in a context using disciplinary knowledge**	**Apply in a context using engineering knowledge**	**Apply to real-world predictable situations**	**Apply to real-world unpredictable situations**
Depth of Knowledge	**Solved by standardized ways**		**Solved by well-proven analysis techniques**		**Originality in analysis, no obvious solutions**	
Inter-dependence	**Discrete components**		**Parts of or systems within Complex engineering problems**		**High level problems including many component parts or sub-problems**	

Sources of Information (analysis underway)

		Tasks, e.g. exams	Learning outcomes	Syllabi	Instructor input
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	Depth of Knowledge	✓	✓		
	Interdependence	✓	✓		
	Novelty				✓
	Scaffolding				✓
	Autonomy				✓
	Proximity				✓
	Communication		✓		✓
Function					✓

What We Mean by…

Novelty	A descriptor of question unfamiliarity in an assessment compared to previous examples or problems solved in class, assignments, projects or previous exams.
Scaffolding	A variety of instructional techniques used to move students progressively toward stronger understanding and independence that are gradually removed to give more responsibility to the student.
Autonomy	An autonomous learner independently chooses aims and purposes and sets goals, chooses materials, methods and tasks, exercises choice and purpose in organizing and carrying out the chosen tasks and chooses criteria for evaluation. [Holec 1981]
Proximity	Chronological closeness of instruction to the assessment.
Communication	Development and expression of ideas in writing which may include content development in lieu of context and purpose of writing. [AAC&U Written Communication Value rubrics]

What We Mean by…

<table>
<tr>
<td>Novelty</td>
<td colspan="2">Familiar problem: the problem was very similar to a question previously used in homework, a prior test, homework question, or in-class example. It required students to use the same process, equations and variables, though perhaps different numbers, and tested the same outcomes/content.</td>
<td colspan="2">Reorganized problem: the problem was similar in context to a question previously used in homework, a prior test, homework question, or in-class example. It required students to use similar equations, though perhaps combined differently, solving for different variables, or slightly different approach.</td>
<td colspan="2">New problems: the problem examined content that may have been tested previously, but the problem itself was novel to the students.</td>
</tr>
<tr>
<td>Scaffolding</td>
<td colspan="2">Prescribed problem: the problem instructs the student to follow a prescribed sequence of calculations or an explicitly stated approach.</td>
<td colspan="2">Constrained problem: the problem description does not specify the solution; however, the general approach is implied through question sequencing, section headings, etc.</td>
<td>Scaffolded problem: the problem requires the student to choose from a range of approaches.</td>
<td>Adopted problem: the problem requires the student to synthesize different methods and formulate novel methods or apply existing methods to novel applications.</td>
</tr>
<tr>
<td>Communication</td>
<td>Interpretation: explaining information presented in mathematical forms (e.g., equations, graphs, diagrams, tables, words)</td>
<td>Representation: converting relevant information into various mathematical forms (e.g., equations, graphs, diagrams, tables, words)</td>
<td>Calculation: carrying out comprehensive calculations</td>
<td>Application: making judgments and drawing appropriate conclusions based on quantitative data</td>
<td>Assumptions: making and evaluating important assumptions in estimation, modeling, and data analysis</td>
<td>Communication: expressing quantitative evidence in support of the argument or purpose</td>
</tr>
</table>

Framework for Transferability between Engineering and Technology Programs

Summary: This ONCAT-funded project is developing a framework to support transfer between engineering and engineering technology programs in Ontario using explicit and implicit course outcomes to help develop and define new pathways.

The Project

The Ontario Council on Articulation and Transfer(ONCAT) is supporting a project to support transfer between engineering and engineering technology programs by:

1. Examining transfer in other jurisdictions
2. Examining outcomes, both explicit and implicit in Ontario course requirements
3. Developing a framework that identifies similarities and differences in program expectations
4. Recommending processes to improve transferability.

Transfer Pathways

Ontario students face obstacles in transfer; inconsistent transfer policies between schools, lack of articulated syllabi, and subsequent perceived differences on the delivery of comparable courses are only a few examples.

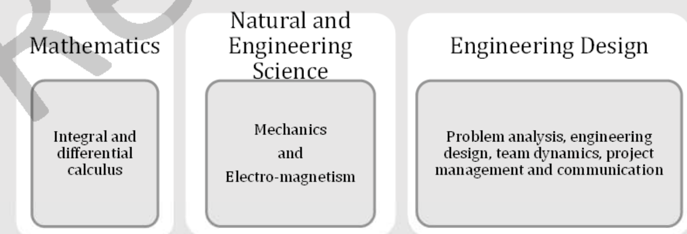
We hope to alleviate some of these discrepancies by further exploring the course contents and learning outcomes in a systematic manner.

Focus

We think most transfers happen at one of these stages:

- End of three-year Advanced Diploma→ Engineering programs
- Within the first two years of Engineering programs → Advanced Diploma

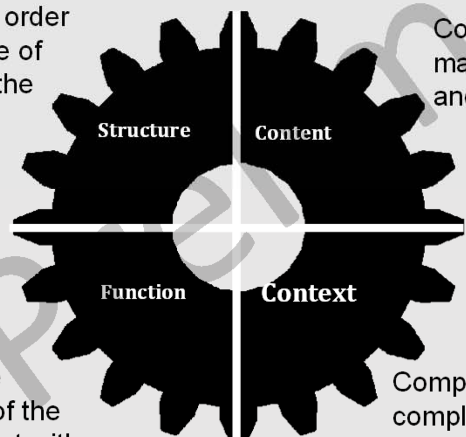
Currently the project is primarily focusing on:



Comparing courses

Compare the order and sequence of topics within the program

Compare and match content and outcomes



Compare the relationship of the course content with other courses

Compare depth and complexity in exams, projects and learning outcomes

Sources of Information

		Tasks, e.g. exams	Learning outcomes	Syllabi	Instructor input
Structure				✓	
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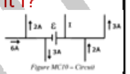
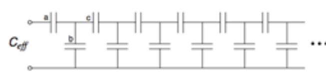
	Type of Knowledge	✓	✓		
	Transfer	✓	✓		
	Depth of Knowledge	✓	✓		
	Interdependence	✓	✓		
	Novelty				✓
	Scaffolding				✓
	Autonomy				✓
	Proximity				✓
	Communication		✓		✓
Function					✓

Framework for Contextual Comparison of Calculus

The table below summarizes criteria used to analyze explicit and implicit learning outcomes in course artefacts. Other dimensions, such as novelty, proximity, scaffolding, etc. need direct input from instructors and are assessed in an online survey. The red text in each box is an example of a question that has that characteristic.

Cognitive process	**Remember** Definition of Function	**Understand** True or False: If f is an invertible function, then $f o f^{-1} o f = f$	**Apply** Using first principles, calculate the derivative.	**Analyze** Investigative questions	**Evaluate** Investigative questions	**Create** Investigative questions
Type of Knowledge	**Factual** If $f(x) = e^{x}$ then $f^{-1}(x) = e^{-x}$.		**Conceptual** Is the histogram below a normal distribution?	**Computational** Using first principles, calculate the derivative. $y = \left[\frac{{}^{3}/{}_{5}}{x}\right]$	**Math translation** A soda can is to be made in the shape of a cylinder with a volume of 400 cm^{3}. Find values for the radius and height of the cylinder that minimize the surface area of the can.	**Investigative** Setup a process to investigate questions
Transfer	**Mathematical Knowledge** Using first principles, calculate the derivative. $y = \left[\frac{{}^{3}/{}_{5}}{x}\right]$		**Apply in a Disciplinary context** For Electrical Engineering/ Technology T he charge across a capacitor is $q = 2e^{-t}sin(225t)$ Find the current in the capacitor at t= 35 ms.	**Apply in Other Engineering Contexts** For Electrical Engineering/ Technology students: A particle moves in the xy plane along the curve with the equation $(3x + 2)y = y^{3} + 1$ What is the speed of the particle at point (0,1).	**Apply to real-world predictable situations** Use the mathematical understanding to solve for the current in a circuit for a design project with specific requirements	**Apply to real-world unpredictable situations** Use their mathematical knowledge in the discipline to design energy supply for an area that is off grid
Depth of Knowledge	**Solved by standardized ways** Find the slope of the tangent line to this curve at the point with coordinates (0, 1)		**Solved by well-proven analysis techniques** Give the general solution to $xyy' + 4\,x^{2} + y^{2} = 0$		**Originality in analysis, no obvious solutions** Investigative questions	
Interdependence	**Discrete components** The mass M(t) of a bacteria culture at time t (in hours) is given by *M(t)=k(3+2t)3* where k is a constant. If M''(1) = 360, then what is k?		**Parts of or systems within Complex engineering problems** As a robotic arm rotates up and down, the potentiometer wire produces a voltage directly proportional to the arm's position. If we connect the potentiometer's output to a differentiator circuit, we will obtain another signal representing something else. What physical variable does the differentiator output signal represent?		**High level problems including many component parts or sub-problems** Investigative questions	

Framework for Contextual Comparison of Physics

<table>
<tr><td>Cognitive process</td><td>Remember
What is the property of an objects to maintain its motion?</td><td>Understand
Compared with a 1 kg block of solid iron, a 2kg block of solid iron has twice as much?!</td><td>Apply
The force of friction on a sliding object is 18 N. What is the applied force needed to maintain a constant velocity?</td><td>Analyze
Investigative questions</td><td>Evaluate
Investigative questions</td><td>Create
Investigative questions</td></tr>
<tr><td>Type of Knowledge</td><td colspan="2">Factual
If a freely falling object's acceleration due to gravity is 10 m/s2, then its speed reading would increase each second by ?</td><td>Conceptual
A force is a vector quantity because it has both:
- Action and reaction counterparts
- Magnitude and direction
- Mass and acceleration</td><td>Computational
Calculate the area of the capacitor plates where the charge stored is 7nC and the electric field between the plates is measured to be 6.90 kV/m.</td><td>Math translation
A solid rod (L, M) has a pivot through its center and is horizontal. Another mass 2M is attached to one end of the rod, and released. What is the maximum speed of the mass 2M attained thereafter?</td><td>Investigative
Setup a process to investigate questions</td></tr>
<tr><td>Transfer</td><td colspan="2">Knowledge of physical concepts
Explain whether the following particles do or do not have acceleration:
a particle moving in a straight line with constant speed</td><td>Apply in a disciplinary context
For Electrical Engineering/ Technology: The charge across a capacitor is
$q = 2e^{-t}sin(225t)$
Find the current in the capacitor at t= 35 ms.</td><td>Apply in other engineering contexts
For Electrical Engineering/ Technology students:A bridge is being built in an area that sees frequent thunder storms. During these storms, it is known that all parts of the bridge will acquire a linear charge density of λ = -1 μC/m. What is the electric potential at point P for each of the following two arc designs?</td><td>Apply to real-world predictable situations
Use the understanding of physical concepts to solve for the current in a circuit for a design project with specific requirements</td><td>Apply to real-world unpredictable situations
Use the understanding of a physical concept in the discipline to design energy supply for an area that is off grid</td></tr>
<tr><td>Depth of Knowledge</td><td colspan="2">Solved by standardized ways
Consider the circuit shown in Figure MC10. What is the magnitude of the current I?
</td><td colspan="2">Solved by well-proven analysis techniques
What is the effective capacitance C(eff) of this infinite chain of capacitors?
</td><td colspan="2">Originality in analysis, no obvious solutions
Investigative questions</td></tr>
<tr><td>Interdependence</td><td colspan="2">Discrete components
The acceleration of a particle moving along the x axis is given by $a_x = -4\pi^2 cx$. What is the period of the motion?</td><td colspan="2">Parts of or systems within Complex engineering problems
Consider a horizontal capacitor A, capacitance in vacuum C, which contains a dielectric material with dielectric constant K. The dielectric slides frictionless and is attached via a massless string and a massless pulley to a block of mass m. The block pulls the dielectric from the capacitor as it falls. Compute the speed of the block at the instant the dielectric leaves the capacitor assuming start at rest and the voltage across the capacitor after dielectric removed measured to be 100 V.</td><td colspan="2">High level problems including many component parts or sub-problems
Investigative questions</td></tr>
</table>

Preliminary Framework for Contextual Comparison of Design/ Investigation Courses

Cognitive Process	Remember	Understand	Apply	Analyze	Evaluate	Create
Type of Knowledge	**Factual** PEO code of ethics Environmental/ social/ public interest		**Conceptual** Idea-generation Decision-making	**Component Sizing and Experimental Techniques** Safety regulations	**Programming and Modelling**	**Methods of Inquiry** Research Info validation Stakeholder needs Presenting arguments
Transfer	**Use of disciplinary technical principles in non-contextualized situations**		**Use of engineering design principles in non-contextualized situations**	**Use of disciplinary technical principles in real-world predictable situations**	**Use of engineering design principles in real-world predictable situations**	**Use of engineering design principles in real-world unpredictable situations**
Depth of Knowledge	**Solved by standardized ways**		**Solved by well-proven analysis techniques**		**Originality in analysis, no obvious solutions**	
Interdependence	**Discrete components**		**Parts of or systems within Complex engineering problems**		**High level problems including many component parts or sub-problems**	
Disciplinarity	**Non-disciplinary**		**Disciplinary**		**Cross-disciplinary**	
Use of tools, instruments and equipment	**Conduct practical building, experimentation, testing and measurement using specialized and standard tools, instruments and equipment**			**Apply and adapt standard tools, instruments and equipment**		

How You Can Help

At the moment, we are assessing:

- **Course syllabi,** ideally including course learning outcomes
- **Summative assessments,** final exam, design report instructions, lab report instructions, etc.
- **Mapping between learning outcomes and assessment measures,** questions on final exam, rubrics on final reports, etc.

We are also interested in talking to instructors about the novelty of questions asked, scaffolding and expected levels of student autonomy and written communication skills.

About Us

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EGAD Project Program Manager, Faculty of Engineering and Applied Science, Queen's University

Sima Zakani
ONCAT Project Coordinator, Faculty of Engineering and Applied Science, Queen's University

Glossary

Analyze Break material into constituent parts and determine how parts relate to one another and to an overall structure or purpose. [Anderson 2001]
Apply Carryout or use a procedure in a given situation. [Anderson 2001]
Autonomy A matter of the learner's psychological relation to the process and content of learning which includes a capacity for detachment, critical reflection, decision-making, and independent action. An autonomous learner independently chooses aims and purposes and sets goals, chooses materials, methods and tasks, exercises choice and purpose in organizing and carrying out the chosen tasks and chooses criteria for evaluation. [Holec 1981]
Cognitive Process The process of thinking as the student actively engages in meaningful thinking. [Anderson 2001]
Communication Development and expression of ideas in writing which may include content development in lieu of context and purpose of writing. It may also be aware of disciplinary conventions and support sources and evidence. [AAC&U Written Communication Value rubrics]
Conceptual Complex, organized knowledge form of the interrelationships among the basic elements within a larger structure that enables them to function together. [Anderson 2001]
Create Put elements together to form a coherent whole. [Anderson 2001]
Evaluate Make judgment based on criteria and standards. [Anderson 2001]
Factual Knowledge of discrete, isolated bits of information that the students must know to be acquainted with a discipline or solve problems in it. [Anderson 2001]
Novelty A descriptor of question unfamiliarity in an assessment compared to previous examples or problems solved in class, assignments, projects or previous exams.
Proximity Chronological closeness of exam to instruction.
Remember Retrieve relevant knowledge from long term memory. [Anderson 2001]
Scaffolding A variety of instructional techniques used to move students progressively toward stronger understanding and, ultimately, greater independence in the learning process. Like physical scaffolding, the supportive strategies are incrementally removed when they are no longer needed, and the teacher gradually shifts more responsibility over the learning process to the student.
Transfer Moving from the context in which the learning happened to other contexts and real-world applications
Understand Construct meaning from instructional messages. [Anderson 2001]

Your turn!

- We will present three sample questions, which we ask you to score using the framework
- You will need to use two pages of the handout:
  - p.2 (Calculus framework) and the Glossary
- The questions and responses are in our web app at:

http://bit.ly/1VqpmFI

Question 1 (Calculus)

Assume a melting snowball remains spherical in shape. If the surface area of the snow decreasing at a rate of $0.48\pi\ cm^2/min$, what is the rate of change of the radius of the snowball when the surface is $46\pi\ cm^2$?

Question 2 (Calculus)

(For electrical engineering/technology programs)

A capacitor is discharged through a load resistor. Find the expression for current given the following values: $C = 125\mu F$, $R = 400\Omega$ and the initial voltage across the capacitor, $V_{C_0} = 40\ v$. Use Laplace transform to solve this problem.

$$R_i + \frac{1}{C}\int_0^t i(t)dt = V_{C_0}$$

Question 3 (Calculus)

Lord Robert Crawley, was found in his study by his wife. He had been murdered, killed by a blow to the head. His body's temperature, after death, followed by Newton's law of heating and cooling: if H represents the temperature of the body, H changes at a rate proportional to the difference between H and the ambient temperature, T_a.

(a) write a differential equation that defines the rate of change of the body temperature.

(b) Use separation of variables to find the general solution to the differential equation.

http://bit.ly/1VqpmFI

Your Examples

Follow up

At your table, please discuss the framework:

- Does it capture the key elements?
- Does it identify key differences between courses?
- Are there unnecessary elements?

Data sources

Calculus		
	Colleges	Universities
Participating Institutions	5	5
Courses	8	8
Course syllabi	8	7
Learning Outcomes	8	1
Final Exams	7 +1*	8
Questions	179	140

Physics		
	Colleges	Universities
Participating Institutions	2	4
Courses	4	7
Course syllabi	3	4
Learning Outcomes	3	1
Final Exams	4	7
Questions	122	83

* Sample questions

Design material being collected and analyzed

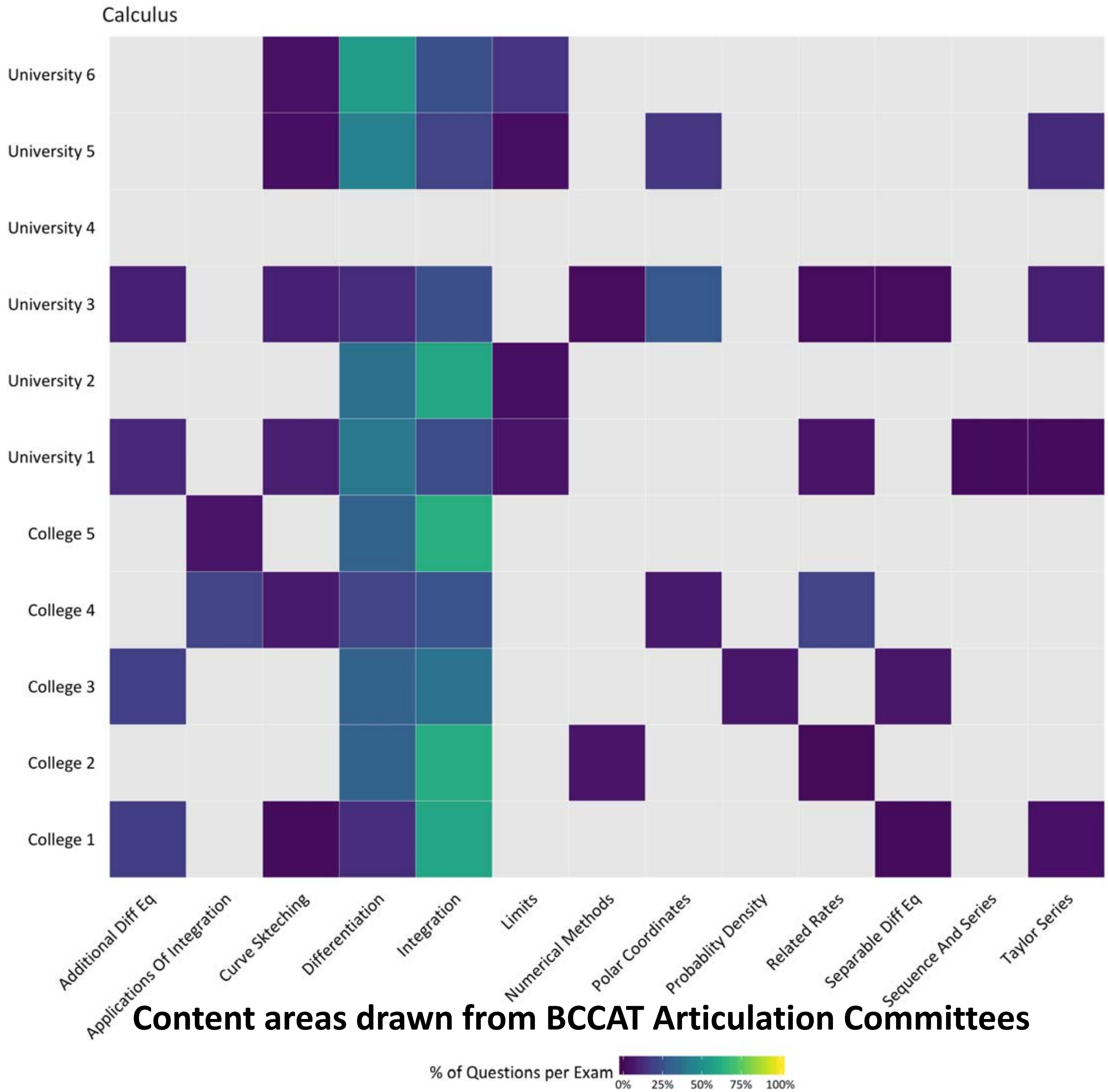
Assuming the material is representative of overall course at the institution

Limitations of Using Explicit Learning Outcomes

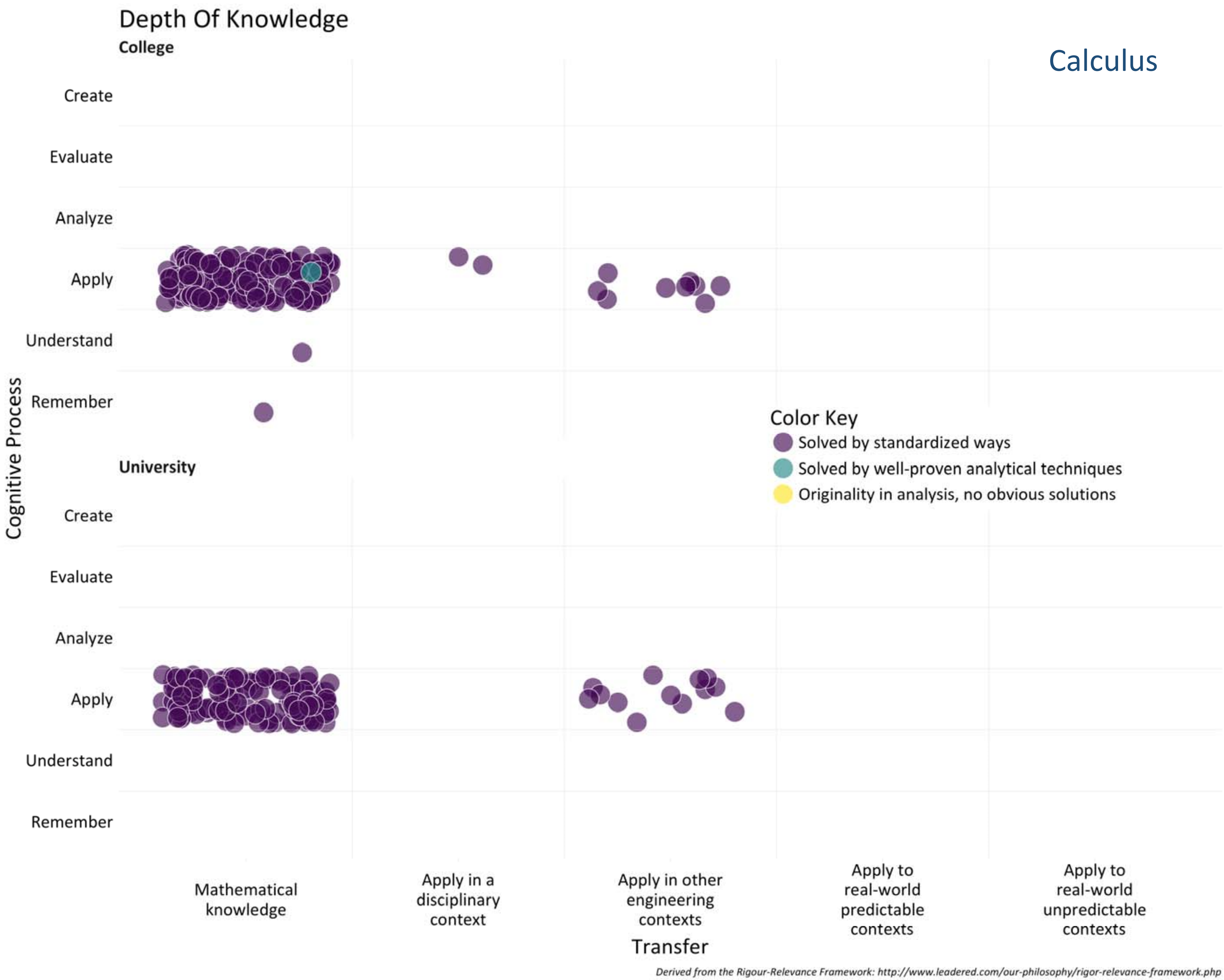
- Not always available
- Not necessarily aligned
- Not specific enough

Course Placement

College	College 1		College 2	College 3		College 4		College 5
Discipline	**Civil**	**Mech**	**Mech**	**Civil**	**ECE**	**Mech**	**ECE**	**Civil**
S1								
S2								
S3								
S4								
S5								
S6								



Content areas drawn from BCCAT Articulation Committees



Depth Of Knowledge
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Calculus
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Evaluate
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Understand
Remember
Cognitive Process
University
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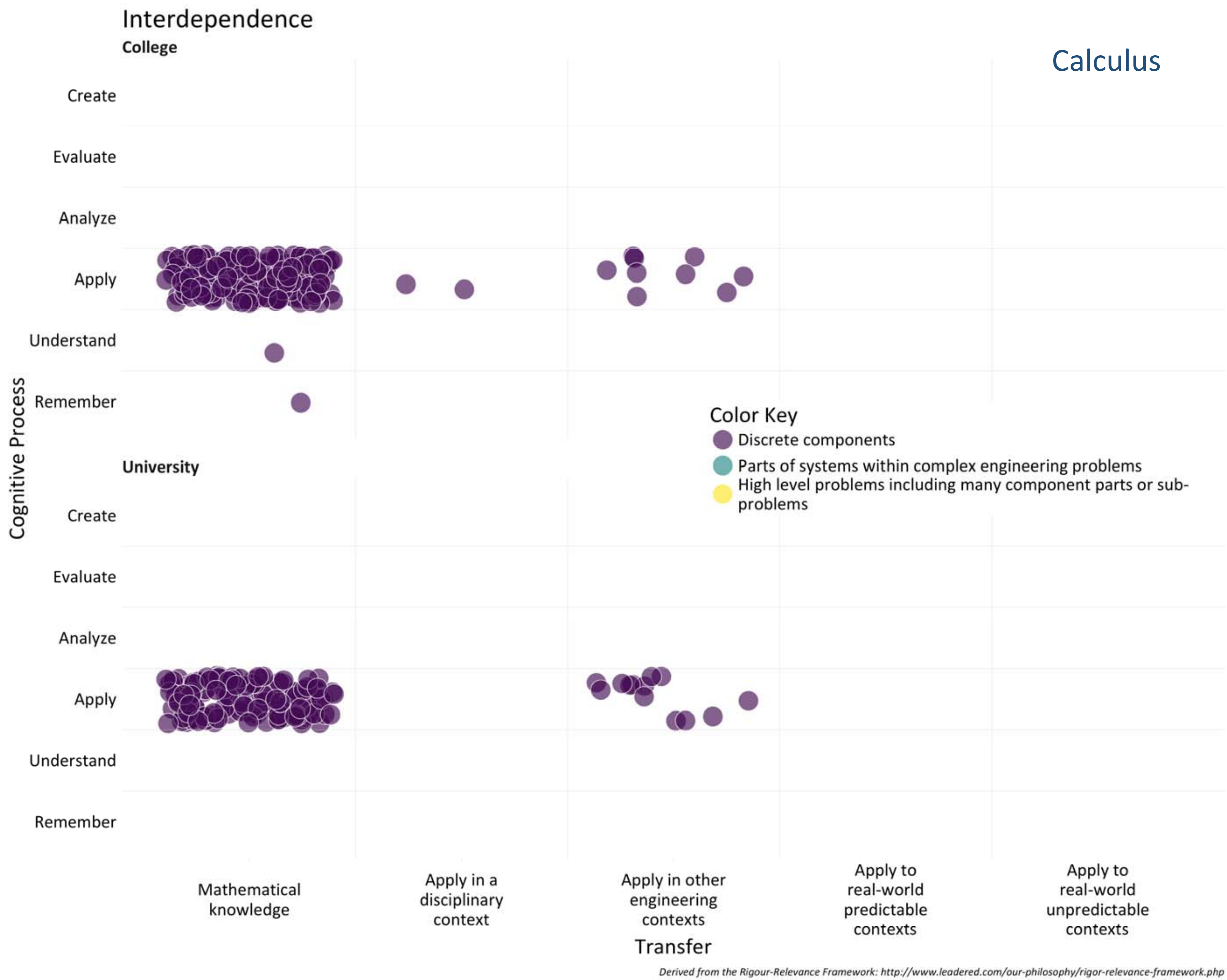
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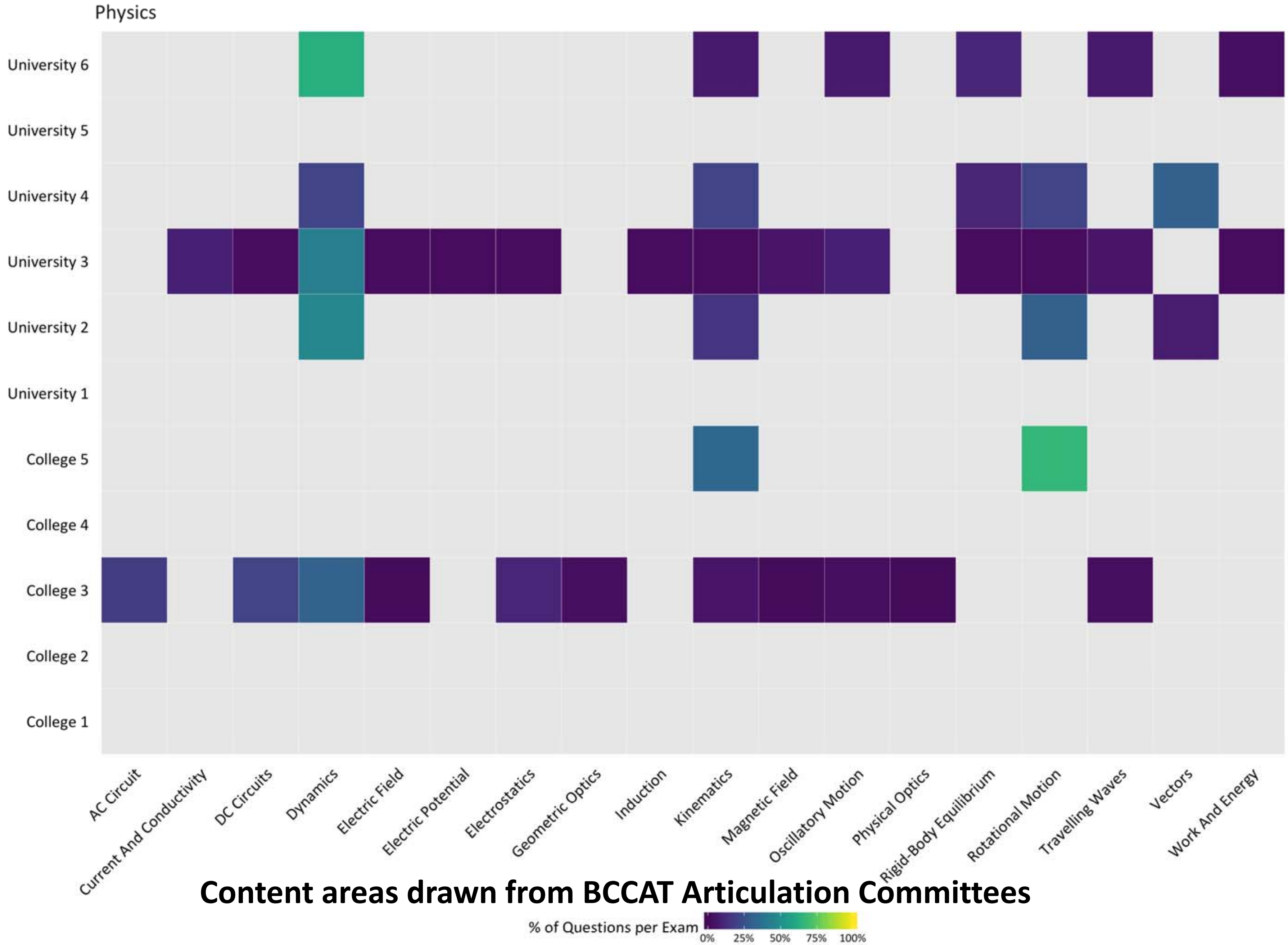

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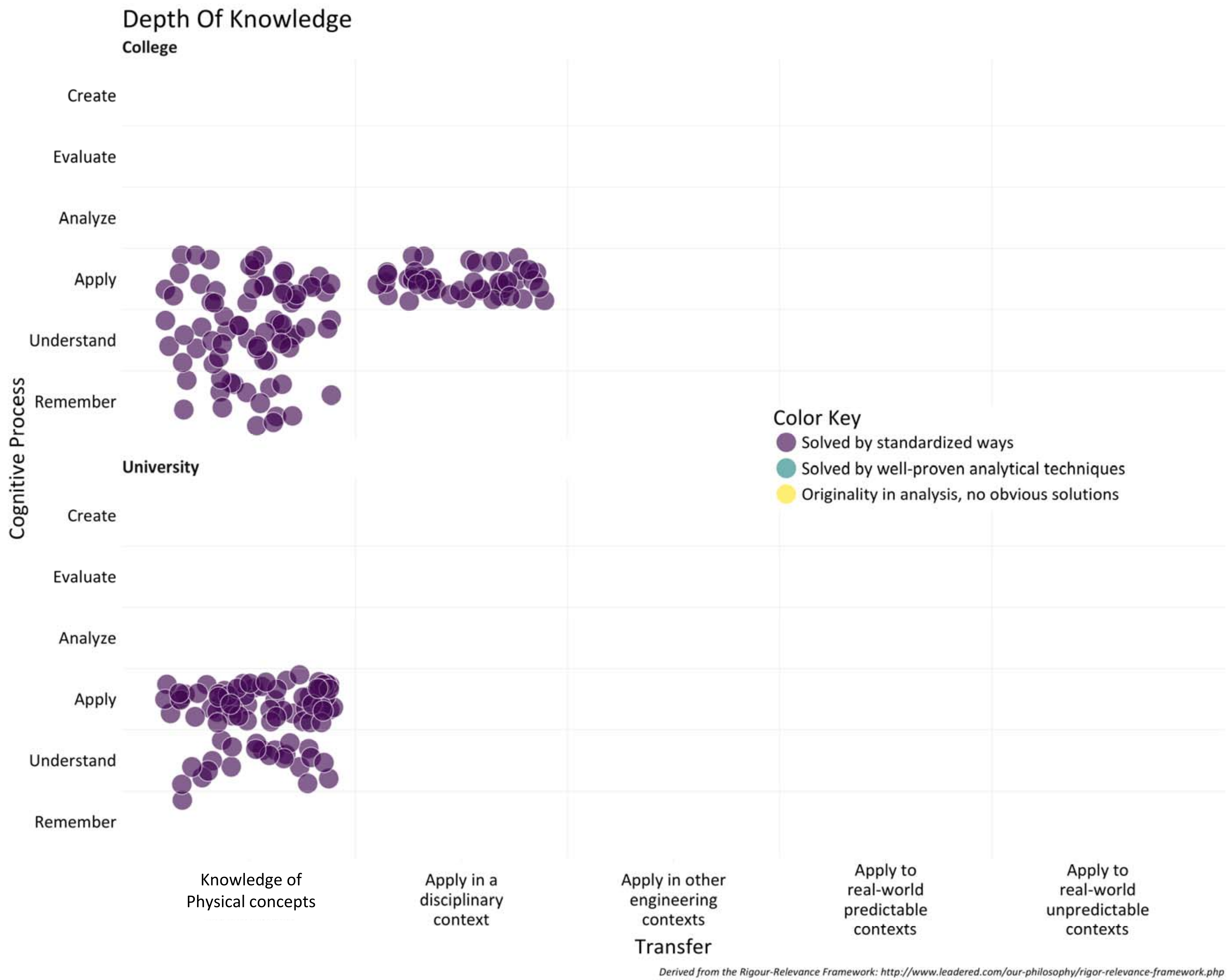

Depth Of Knowledge
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Remember
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Knowledge of Physical concepts
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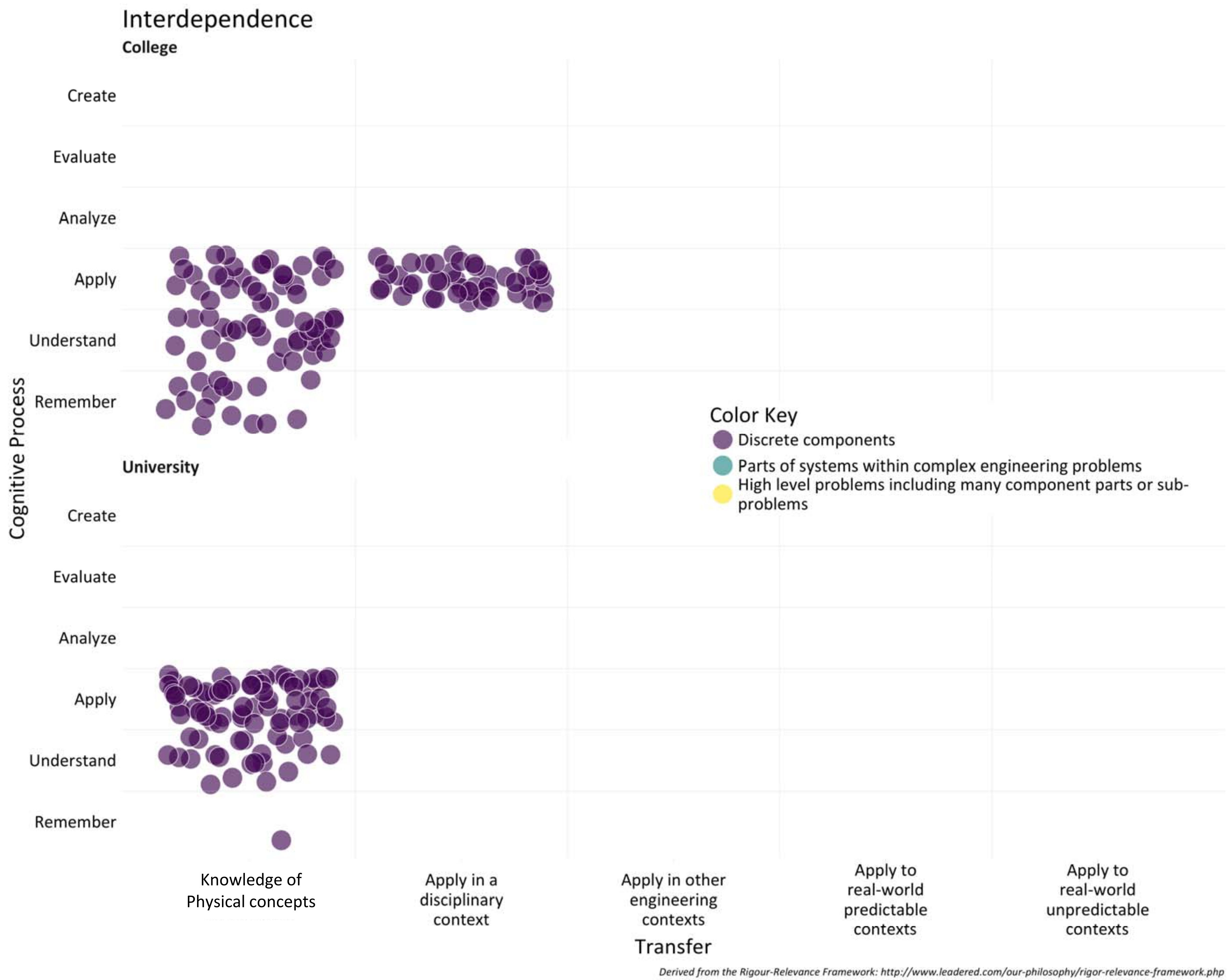
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Sources of Information (analysis underway)

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Structure				✓	
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Context	Cognitive process	✓	✓		
	Type of Knowledge	✓	✓		
	Transfer	✓	✓		
	Depth of Knowledge	✓	✓		
	Interdependence	✓	✓		
	Novelty				✓
	Scaffolding				✓
	Autonomy				✓
	Proximity				✓
	Communication		✓		✓
Function					✓

Examine the results: What would you infer?

Our first thoughts

- For the subject areas analyzed
  - Much closer correlation than many would have anticipated
  - Good alignment of outcomes and contextual classification between college and university courses
  - Key missing information: how novel the questions are to students
  - If our final analysis shows little difference, then we will argue that college students should receive direct university subject credit for the compared subjects
- Gap analysis for laboratory skills suggests practical learning modules for university → college transfers
- Project and Design comparison should be revealing (in progress)

Where we are going

Using analyze two pairs of disciplines:

- Electrical engineering/electrical technology (EE/ET)
- Mechanical engineering/mechanical technology (ME/MT)

We want to answer:

- Q1: How common are learning outcomes and task expectations among engineering programs in the disciplines under study, and among technology programs?
- Q2: How do program expectations between programs at the same qualification level (engineering degree) compare to variations between qualification levels (e.g. between engineering degrees and advanced diplomas)?

Framework for Transferability between Engineering and Technology Programs

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