Characterizing the Complexity of Curricular Patterns in Engineering Programs

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University of New Mexico

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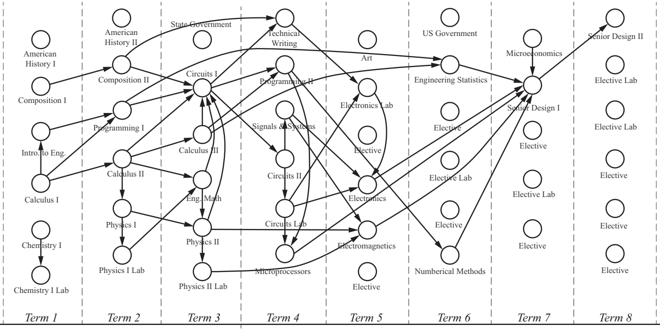
Two EE Programs



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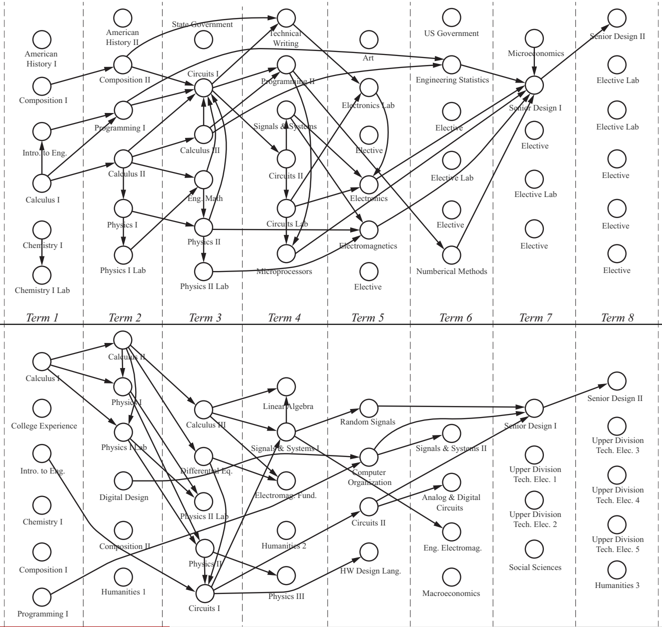

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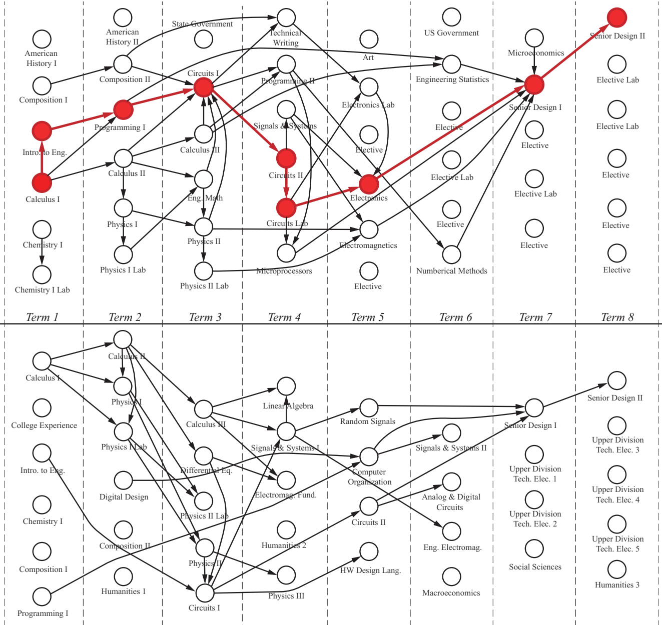

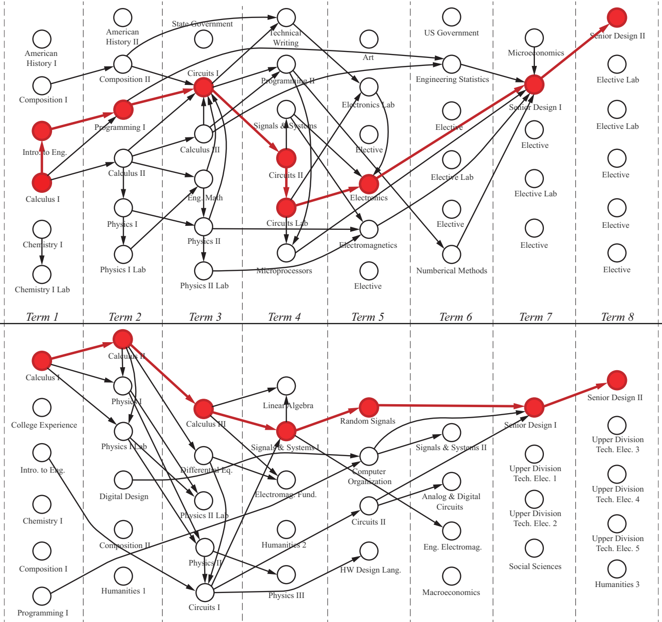
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Circuits Lab
Microprocessors
Art
Electronics Lab
Elective
Electronics
Electromagnetics
Elective
US Government
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Elective
Elective Lab
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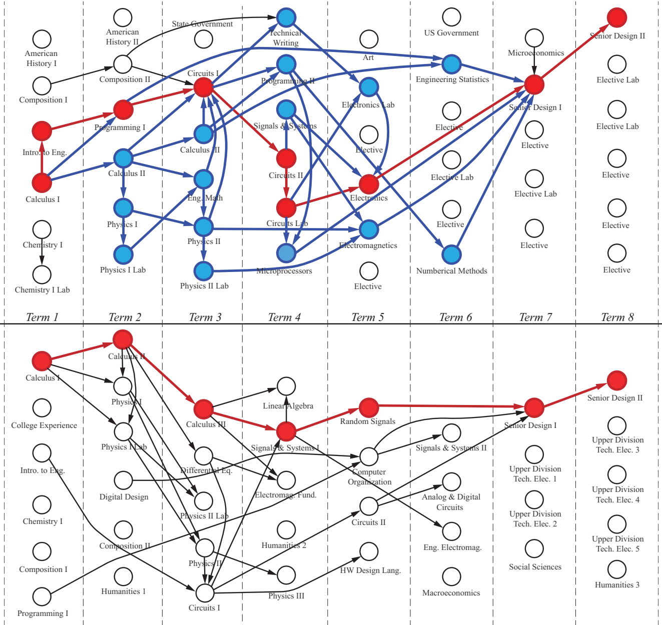

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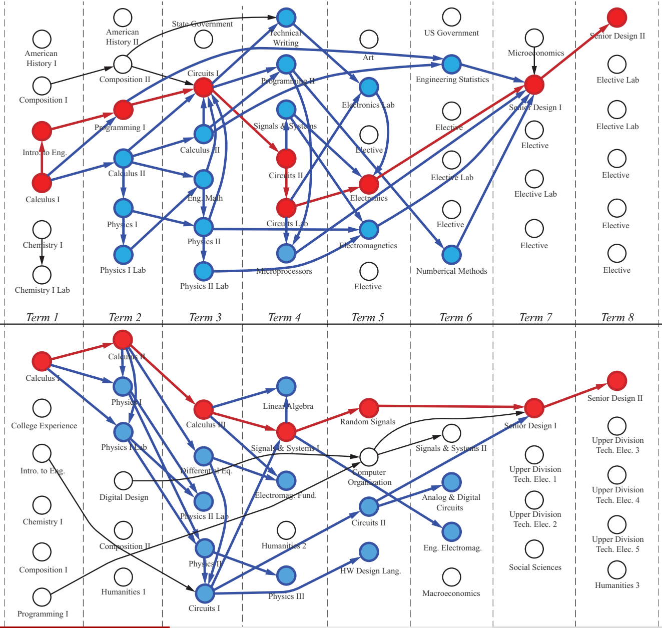

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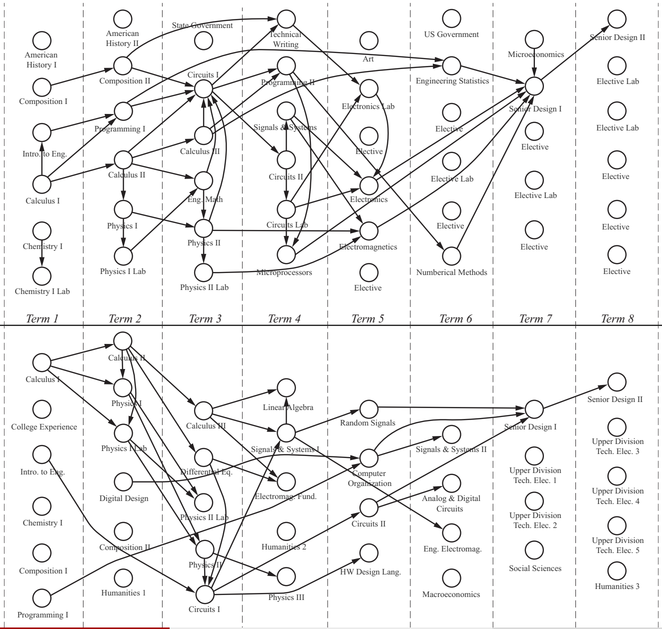

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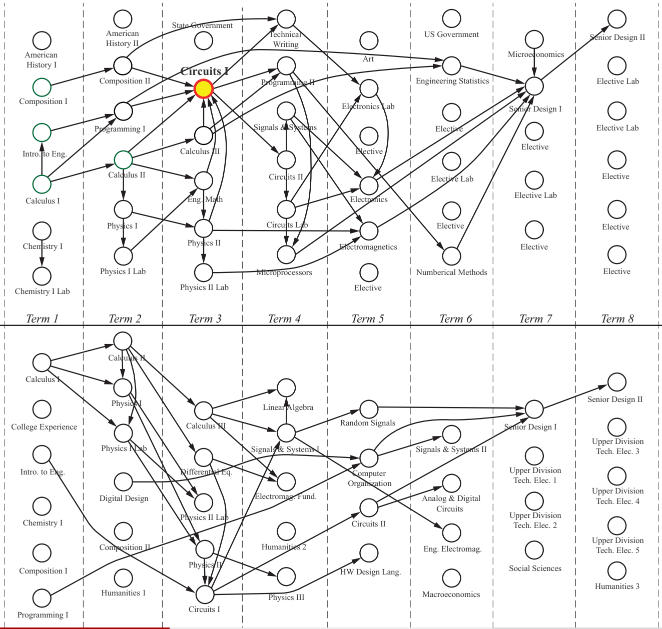

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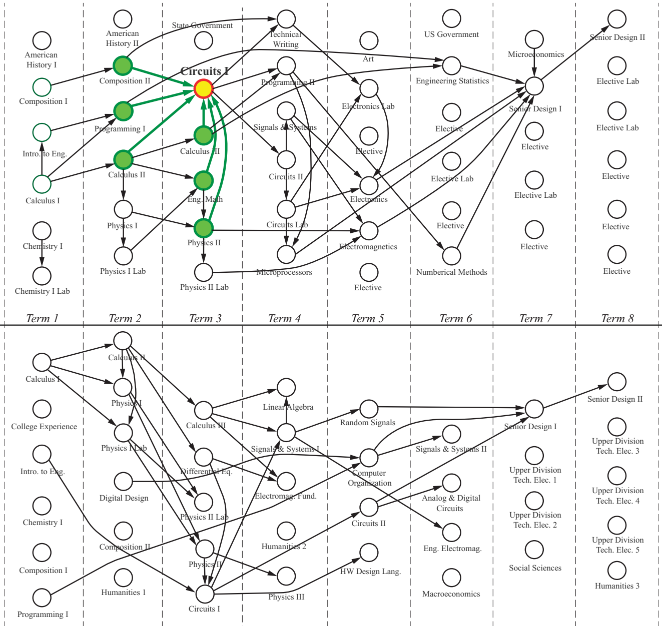

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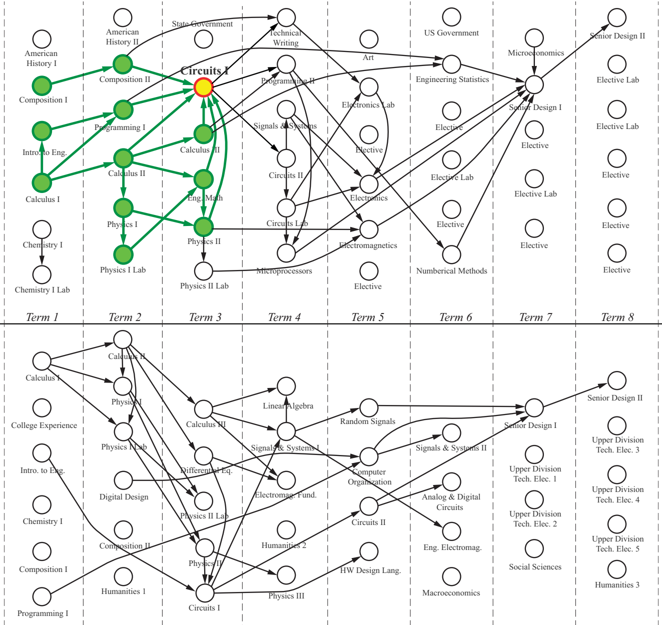

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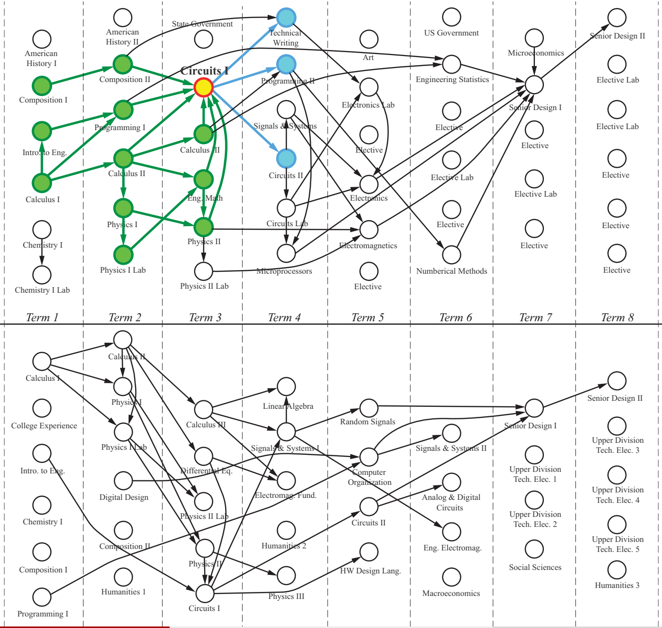

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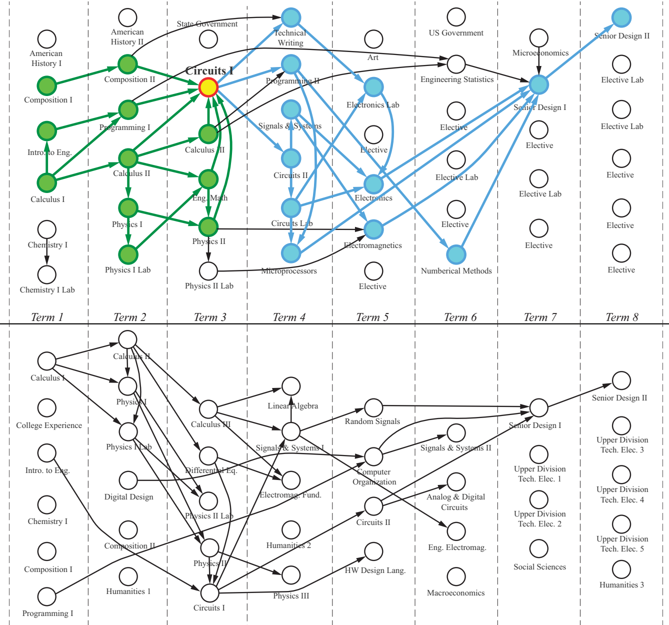

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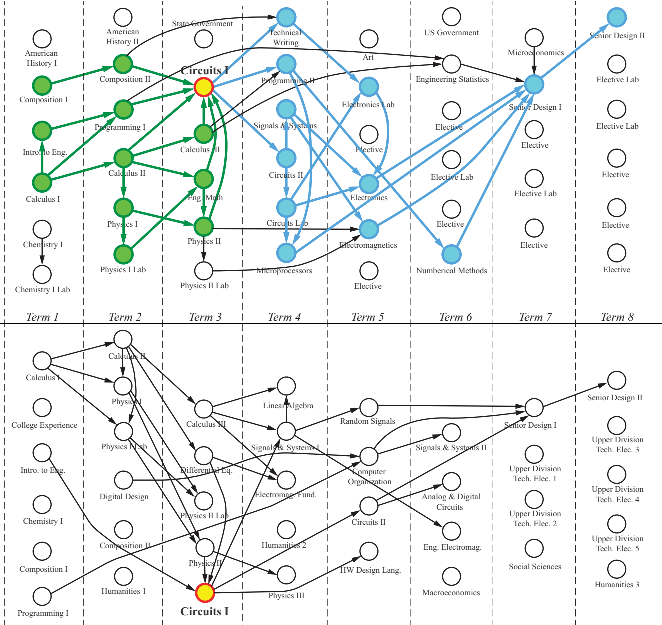

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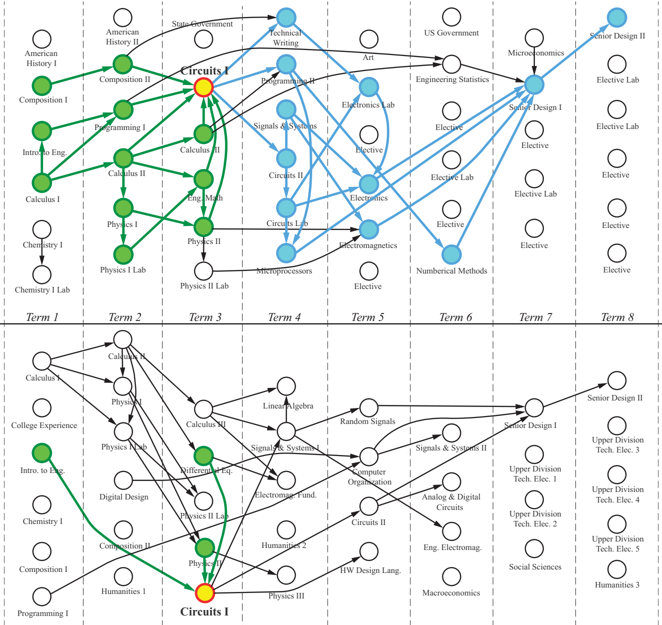

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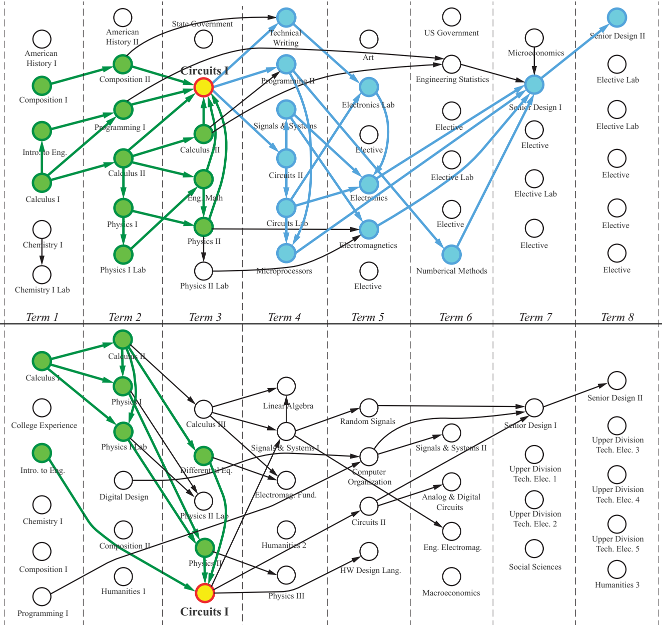

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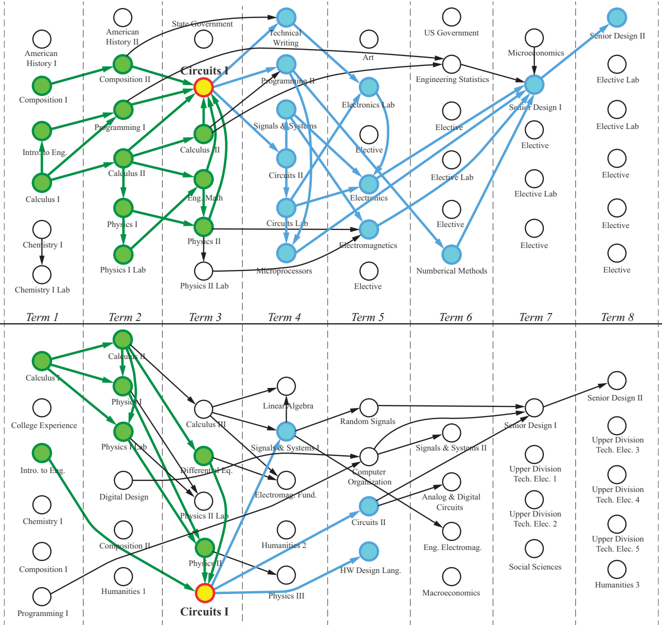

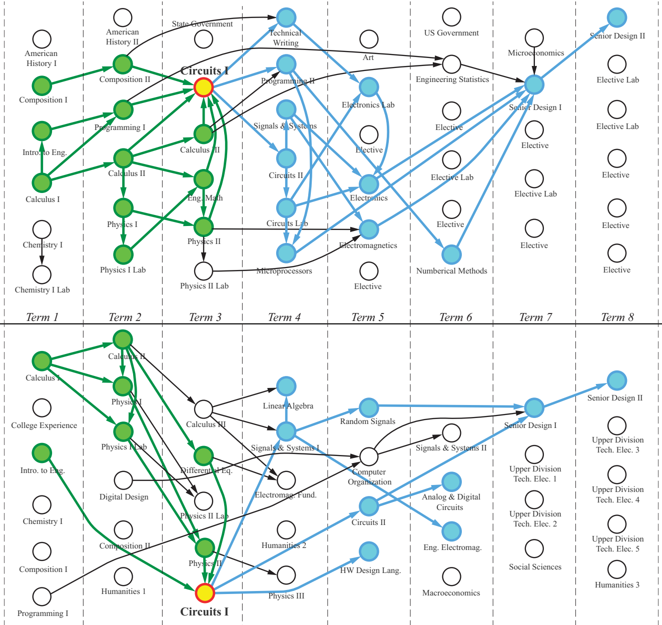
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  - **Degrees of Freedom:** the extent to which a curriculum can be rearranged if certain courses are not passed.

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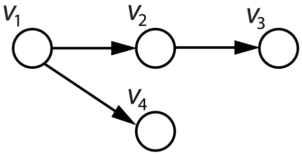

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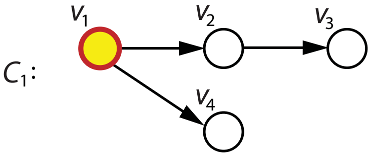

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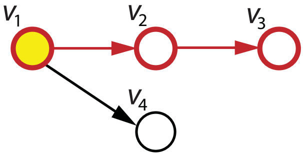

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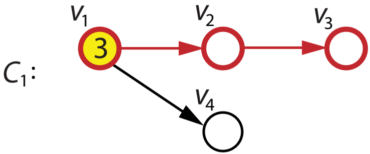

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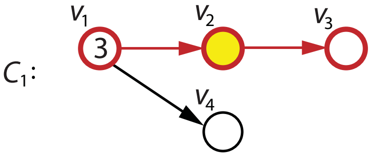

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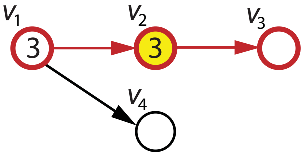

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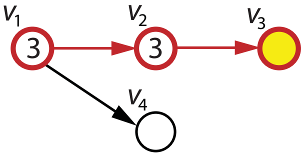

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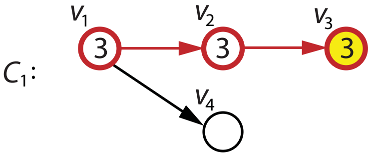

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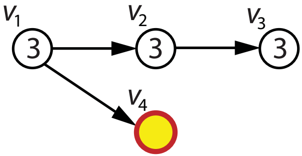

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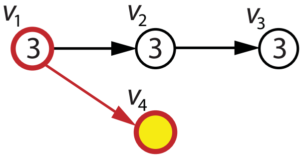

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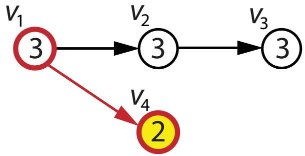

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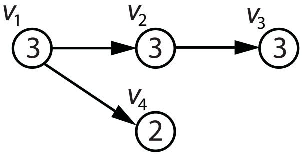

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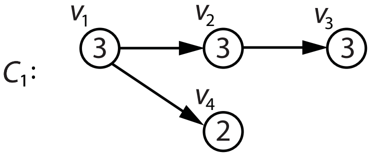

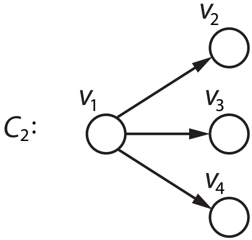

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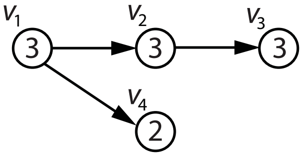

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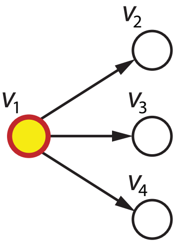

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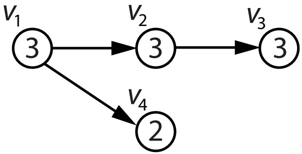

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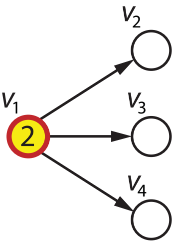

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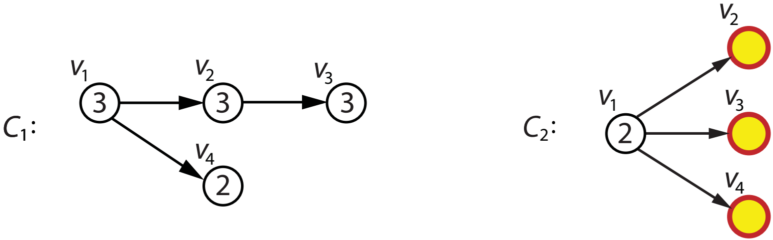
- $t = \max_{v_k \in V} d(v_k)$ determines the minimum number of terms required to complete a curriculum.
- Failure to complete a course on the longest path means that at least $t + 1$ terms will be required to complete the curriculum.

Ex:



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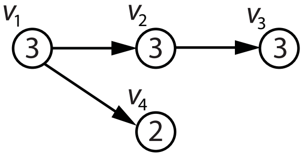

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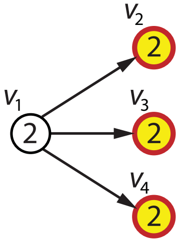

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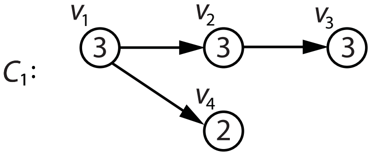

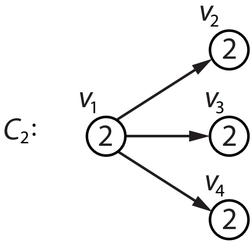

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$$b(v_i) = \sum_{v_j \in V} I(v_i, v_j),$$

where I is the indicator function:

$$I(v_i, v_j) = \begin{cases} 1, & \text{if } v_i \rightsquigarrow v_j; \\ 0, & \text{if } v_i \not\rightsquigarrow v_j. \end{cases}$$

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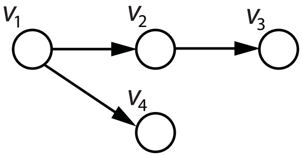

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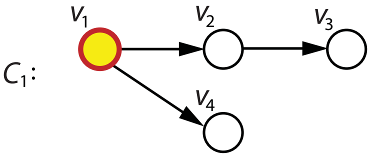

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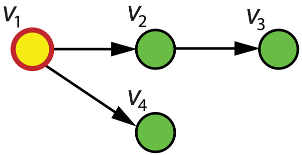

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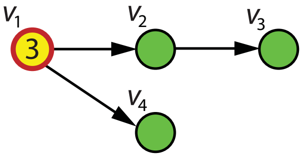

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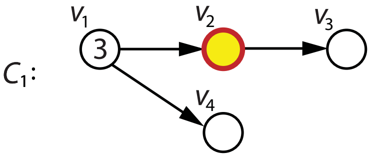

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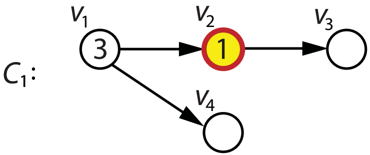

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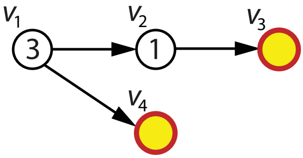

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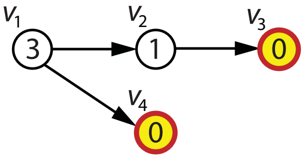

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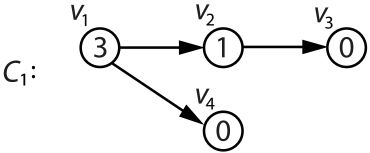

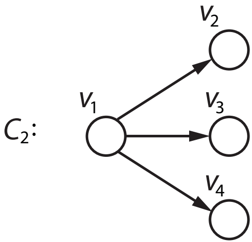

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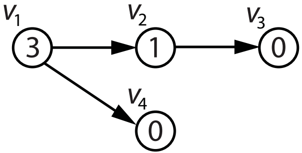

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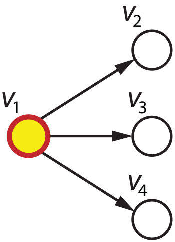

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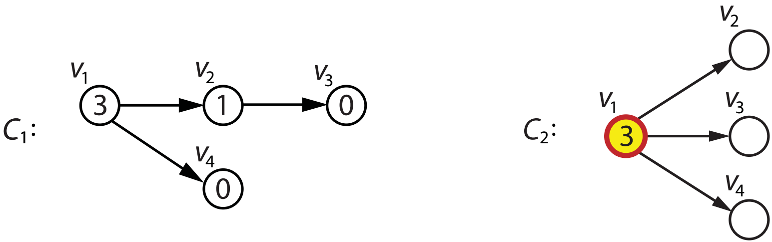

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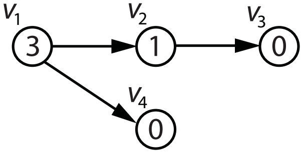

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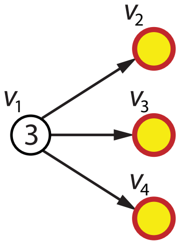

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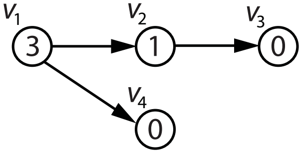

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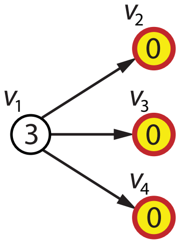

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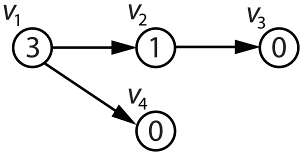

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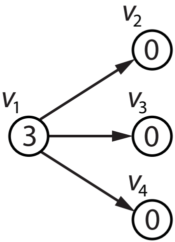

Network Information Theory —

- **Betweenness Centrality**: measures the extent to which a vertex lies on paths between other vertices.

- We're working on the proper way to quantify this.

Structural Complexity – Degrees of Freedom

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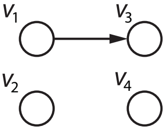

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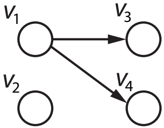

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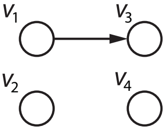

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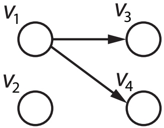
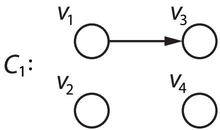
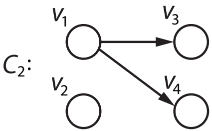


C_1 **Plan —**

term 1: v_1, v_2, v_4

term 2: v_3





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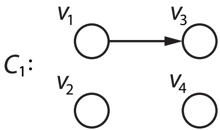

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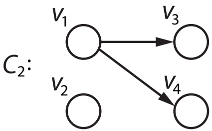

C_2 Plan —

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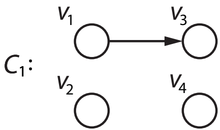
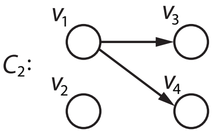
Assume v_1 and v_4 are not passed on first attempt.





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C_1 **Revised Plan —**
term 1: v_1, v_2, v_4
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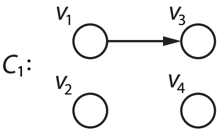

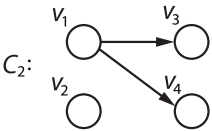

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term 4: v_4

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Instructional Complexity

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- There is another factor at play here.
- The **instructional complexity** of curriculum C, denoted γ_C, is a function of the difficulties of the courses in C:

$$\gamma_C = h(\text{course difficulties})$$

Instructional Complexity

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  - etc.

- γ_C is extremely difficult to characterize.

- The historic pass rates of the courses in a curriculum C provides a good approximation to γ_C.

- The overall complexity of a curriculum C, denoted Ψ_C, is a combination of the inherent difficulty associated with traversing a curriculum graph (structural complexity), and the manner in which the courses are taught (instructional complexity):

$$\Psi_C = f(\alpha_C, \gamma_C).$$

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- Does higher curricular complexity lead to higher quality (improved student learning outcomes)?

- How do we make Ψ_C useful?

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- We can learn $g(\cdot)$ —

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—Simulation—

$$\text{Completion rates} = f\left(g(G_C), \text{fixed pass rate}\right)$$

Vary $g(\cdot)$, and measure correlation between completion rates and the various $g(\cdot)$'s.

Learning Structural Complexity

$$g(G_C) = \sum_{v_k \in V} (d(v_k) + b(v_k))$$

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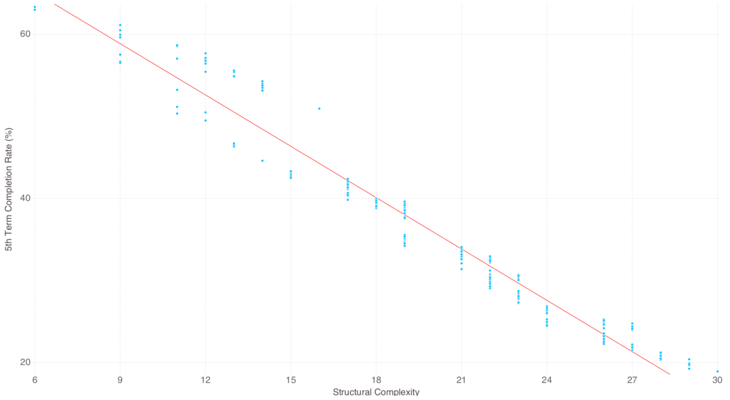
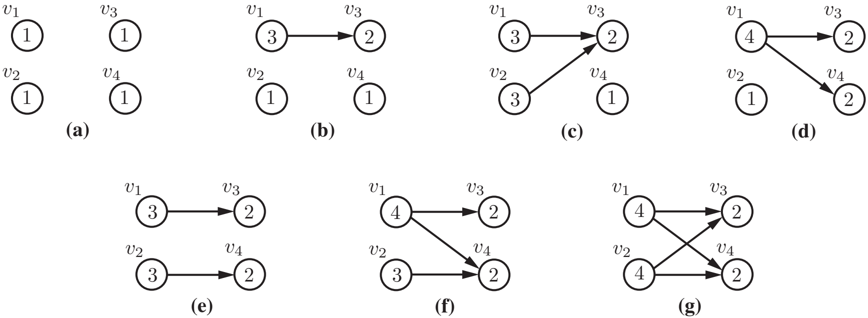


$g(G_C)$ vs. 5-term completion rates for six-course curricula balanced over 3 terms

All four-course curricula balanced over two terms:



Structural Complexity Validation

	t_1	t_2	t_3	t_4
v_1	50	75	87.5	93.75
v_2	50	75	87.5	93.75
v_3	50	75	87.5	93.75
v_4	0	50	75	87.75
grad. rate	0	28.13	50.24	**72.30**

(a)

	t_1	t_2	t_3	t_4
v_1	50	75	87.75	93.75
v_2	50	75	87.75	93.75
v_3	0	25	50	68.75
v_4	50	75	87.75	93.75
grad. rate	0	10.55	33.78	**56.65**

(b)

	t_1	t_2	t_3	t_4
v_1	50	75	87.75	93.75
v_2	50	75	87.75	93.75
v_3	0	12.5	34.38	55.47
v_4	50	75	87.75	93.75
grad. rate	0	5.27	23.23	**45.71**

(c)

	t_1	t_2	t_3	t_4
v_1	50	75	87.75	93.75
v_2	50	75	87.75	93.75
v_3	0	25	50	68.75
v_4	0	25	50	68.75
grad. rate	0	3.52	19.25	**41.54**

(d)

	t_1	t_2	t_3	t_4
v_1	50	75	87.75	93.75
v_2	50	75	87.75	93.75
v_3	0	25	50	68.75
v_4	0	25	50	68.75
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(e)

	t_1	t_2	t_3	t_4
v_1	50	75	87.75	93.75
v_2	50	75	87.75	93.75
v_3	0	25	50	68.75
v_4	0	12.5	34.38	55.47
grad. rate	0	1.76	13.24	**33.52**

(f)

	t_1	t_2	t_3	t_4
v_1	50	75	87.75	93.75
v_2	50	75	87.75	93.75
v_3	0	12.5	34.38	55.47
v_4	0	12.5	34.38	55.47
grad. rate	0	1.58	9.10	**27.04**

(g)

Application: Curricular Design Patterns

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- Allows architects to capture, in general terms, design decisions and ideas that have proven successful in solving particular design challenges.
- Provides a useful collection of knowledge that other architects may consult in the future when confronting similar design challenges.
- These design patterns constitute a language that architects may use to more efficiently communicate with one another.

Summary:

“[e]ach pattern describes a problem which occurs over and over again in our environment, and then describes the core of the solution to that problem, in such a way that you can use this solution a million times over, without ever doing it the same way twice.”

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- This led to the formalization of a large number of software design patterns that have been shown to greatly aid in the development of complex software systems.
- Provides developers with a reusable set of proven solutions to generalized problems.
- Software design patterns are similar to their architectural counterparts in that they provide software engineers with a language that can be used to discuss software design issues.

Curriculum Design Pattern

THE UNIVERSITY of NEW MEXICO

Definition: (Curricular Design Pattern). A collection of curricular and co-curricular learning activities intentionally structured so as to allow students to attain a set of learning outcomes within a given educational context.

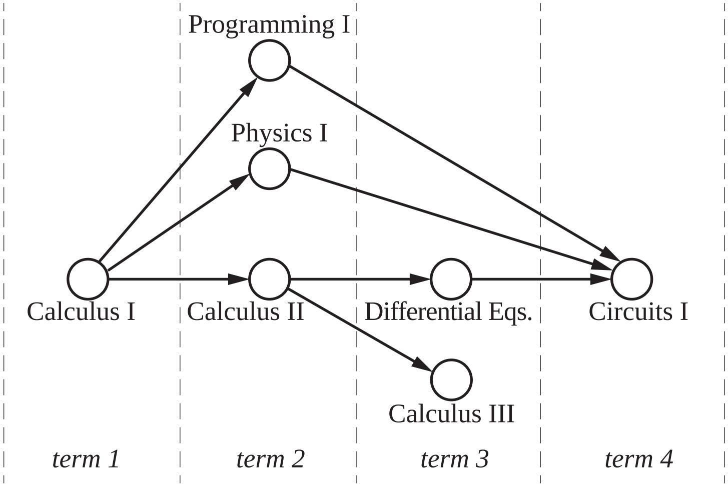
Example: Traditional Circuits I–Calculus Ready

This curricular design pattern is constructed so as to attain a set of learning outcomes that involve the ability to design, build and analyze simple electronic circuits, under the assumption that a student is prepared for Calculus I. Some of the specific learning outcomes are as follows. Students will:

1. Understand the functions of basic electrical circuit elements and sources;
2. Have the ability to apply Ohm's and Kirchhoff's circuit laws in the lumped element model of electrical circuits;
3. Appreciate the consequences of linearity, in particular the principle of superposition and Thevenin and Norton equivalent circuits;
4. Understand the concept of state in a dynamical physical system and have the ability to analyze simple first and second order linear circuits containing memory elements.

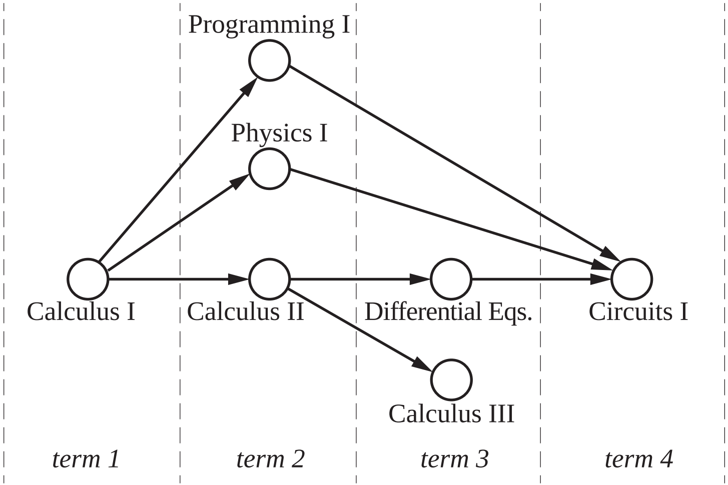
Traditional Circuits I – Calculus Ready

A curricular pattern of courses designed to allow students to attain the learning outcomes:



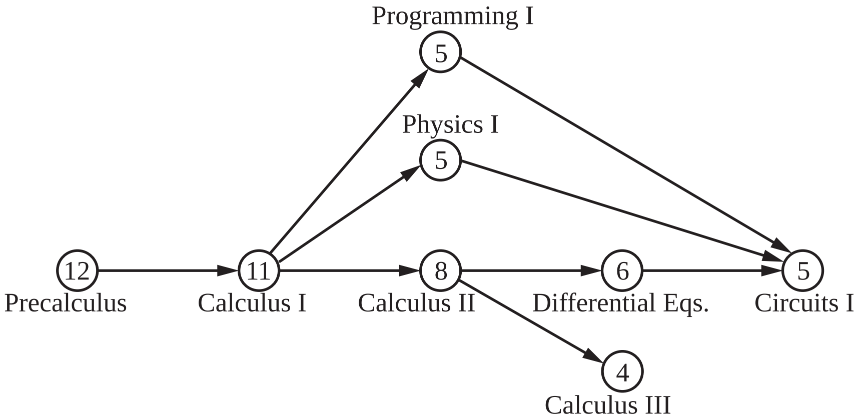
Traditional Circuits I – Calculus Ready

A curricular pattern of courses designed to allow students to attain the learning outcomes:



Traditional Circuits I – Not Calculus Ready

If we include Pre-Calculus:



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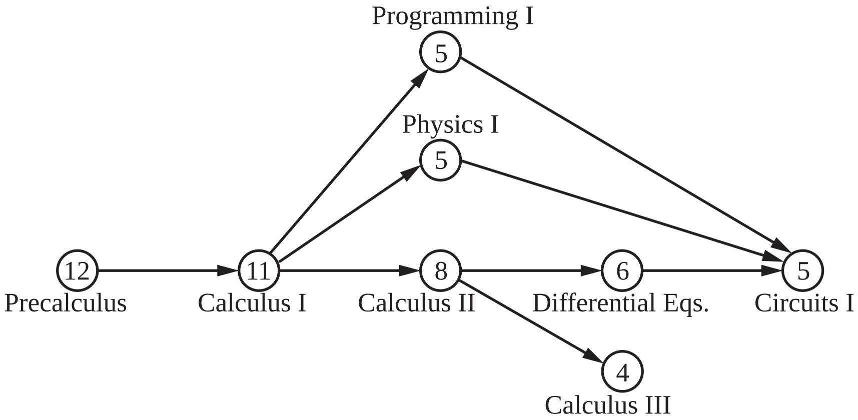
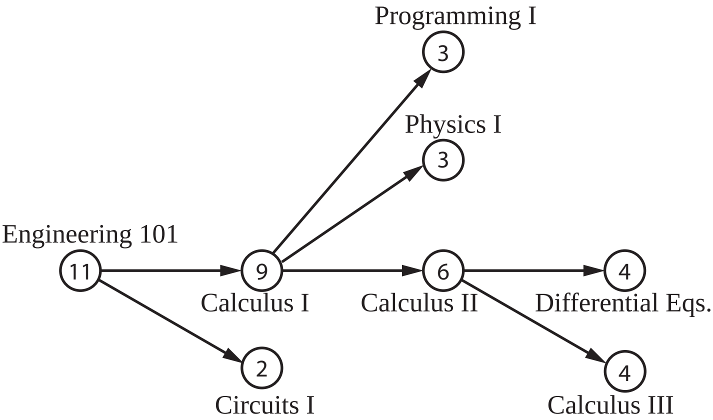


Structural Complexity = 56

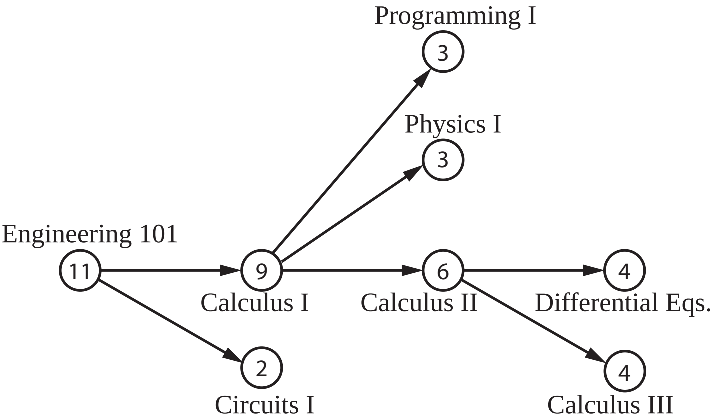
Traditional Circuits I – Alternative

Redesigning the pattern:



Structural Complexity = 41

Redesigning the pattern:



Structural Complexity = 41