Curricular Analytics

Curricular Analytics Workshop
Fall 2020 Virtual UVP Network Meeting

November 12, 2020

About Us

Greg Heileman
Professor, Dept. of Electrical & Computer Engineering
Associate Vice Provost for Academic Administration
heileman@arizona.edu

Hayden Free
Undergraduate Researcher, Dept. of Computer Science
hayden.free@uky.edu

Learning Outcomes

THE UNIVERSITY OF ARIZONA

After participating in this workshop, you should be able to ...

- Understand various metrics/statistics related to the complexity of curricula and degree plans;
- Apply curricular and degree plan metrics while studying various student success scenarios;
- Use curricular analytics tools that have been provided as open-source software;
- Understand how to incorporate curricular analytics into curriculum redesign efforts;
- Understand how degree plan analytics can be incorporated into advising practices.

Agenda

I. **Background**
   - Terminology and Definitions
   - Curricular Analytics

II. **Curricular Analytics Tools**
   - Overview of the Tools
   - Structural Complexity
   - Using the Tools

III. **Curricular Studies**
   - Curriculum Redesign
   - Curricular Complexity vs. Program Quality
   - STEM Curricula and Math Preparation
   - Transfer Articulation and Degree Plan Optimization
   - Simulating Student Progress

I. Background

Cur·ric·u·lum
/Kə'rikyələm/

- First used in an educational context by University of Paris professor Petrus Ramus, in *Professio Regia*,1576.
- Latin origin, from a word that means "the course of a race."
- The origins of the word are linked to the Calvinist desire to bring greater order to education.

The Fate of Petrus Ramus

"It's like trying to build a puzzle, without knowing what it's supposed to look like."

–Undergraduate Student

College Catalog – Degree Plan

THE UNIVERSITY OF ARIZONA

BS Accounting

School of Arts & Soc Sciences

124 Credit Hours

/ BS Accounting / Degree Plan

Starting in an Even Year | Starting in an Odd Year

Plan | Grid | Graph

Semester 1

16 Credit Hours

ACCT 211 - Principles of Accounting I

ECON 265 - Principles of Economics I - Macro

CPTR 105 - Introduction to Computers

COMM 105 - Introduction to Human Communication

ENGL 101 - Composition

INTD 105 - First-Year Experience

Semester 2

15 Credit Hours

ECON 266 - Principles of Economics II - Micro

ACCT 212 - Principles of Accounting II

Religious Studies

ENGL 102 - Research and Literature

MATH 110 - Probability and Statistics

Semester 3

16 Credit Hours

MKTG 310 - Principles of Marketing

ACCT 301 - Intermediate Accounting I

FNCE 290 - Business Finance

College Catalog – Degree Plan (Grid)

THE UNIVERSITY OF ARIZONA

BS Accounting

School of Arts & Soc Sciences

124 Credit Hours

Majors / BS Accounting / Degree Plan

Starting in an Even Year | Starting in an Odd Year

Plan | Grid | Graph

Semester 1	Semester 2	Semester 3	Semester 4	Semester 5	Semester 6	Semester 7	Semester 8
ACCT 211 Principles of Accounting I	**ECON 266** Principles of Economics II - Micro	**MKTG 310** Principles of Marketing	PSYC 105 OR SOCI 105	**CSYS 265** Advanced Computer Applications	COOP 351 OR COOP 380	**INTD 100** Community Service	History/Social Electives
ECON 265 Principles of Economics I - Macro	**ACCT 212** Principles of Accounting II	**ACCT 301** Intermediate Accounting I	**MGMT 338** Advanced Human Resources I	**ACCT 421** Advanced Accounting	**ACCT 325** Accounting Information Systems	**ACCT 405** Auditing	**ACCT 309** Managerial Accounting
CPTR 105 Introduction to Computers	Religious Studies	**FNCE 290** Business Finance	MATH 120 OR MATH 126 OR MATH 151	**ACCT 321** Income Tax I	**ACCT 322** Income Tax II	**COMM 315** Small Group Communication	**BUAD 415** International Business Environment
COMM 105 Introduction to Human Communication	**ENGL 102** Research and Literature	**MGMT 201** Introduction to Management I	**ACCT 302** Intermediate Accounting II	Religious Studies	**BUAD 315** Quantitative Methods	HMNT 100 OR HMNT 270 OR HIST 126 OR HIST 257 OR HIST 276 OR HIST 283 OR PHIL 150 OR PHIL 250	**MGMT 485** Business Strategy and Policy
ENGL 101 Composition	**MATH 110** Probability and Statistics	Religious Studies	**HLSC 110** Healthier Living	**BUAD 375** Business Law I	**BUAD 360** Ethics and Professionalism in Business	LITR 227 OR LITR 232 OR LITR 236 OR LITR 335	**ACCT 327** Government and Fund Accounting
INTD 105 First-Year Experience	16 Credits	Physical Education Activity Elective	15 Credits	15 Credits	**BIOL 130** Humans and Their Environment	Religious Studies	15 Credits
16 Credits		16 Credits			16 Credits	15 Credits	

College Catalog – Degree Plan (Grid)

THE UNIVERSITY OF ARIZONA

BS Accounting

School of Arts & Soc Sciences

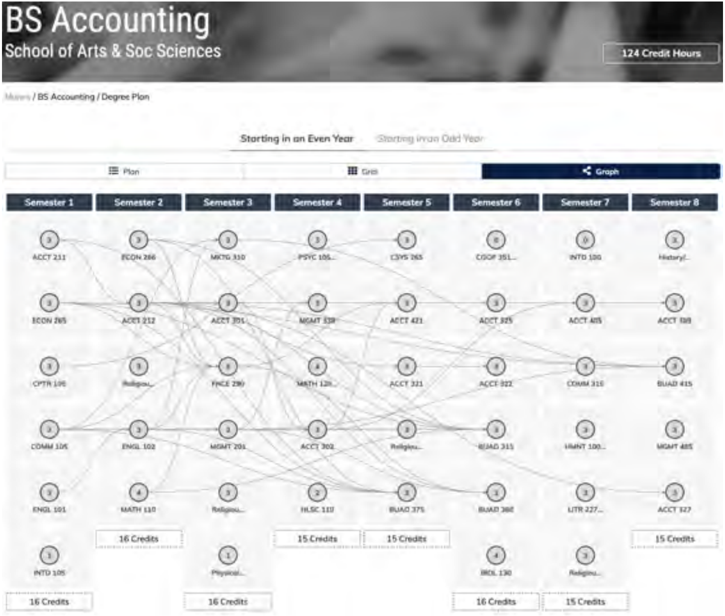
124 Credit Hours

Starting in an Even Year | Starting in an Odd Year

Plan | **Grid** | Graph

Semester 1	Semester 2	Semester 3	Semester 4	Semester 5	Semester 6	Semester 7	Semester 8
ACCT 211 Principles of Accounting I	**ECON 266** Principles of Economics II - Micro	MKTG 310 [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
ECON 265 Principles of Economics I - Macro	**ACCT 212** Principles of Accounting II	ACCT 301 [illegible]	[illegible]	**ACCT 421** Advanced Accounting	[illegible]	[illegible]	[illegible]
CPTR 105 [illegible]	[illegible]	**FNCE 290** Business Finance	[illegible]	ACCT 321 [illegible]	[illegible]	COMM 315 [illegible]	[illegible]
COMM 105 Introduction to Human Communication	**ENGL 102** Research and Literature	MGMT 301 [illegible]	ACCT 302 [illegible]	[illegible]	[illegible]	[illegible]	[illegible]
ENGL 101 Composition	**MATH 110** Probability and Statistics	[illegible]	HLSC 110 [illegible]	[illegible]	**BUAD 360** Ethics and Professionalism in Business	[illegible]	[illegible]
INTD 105 [illegible]	16 Credits	[illegible]	15 Credits	15 Credits	[illegible]	[illegible]	15 Credits
16 Credits		16 Credits			16 Credits	15 Credits	

College Catalog – Degree Plan (Graph)



College Catalog – Degree Plan (Graph)

THE UNIVERSITY OF ARIZONA

Terminology

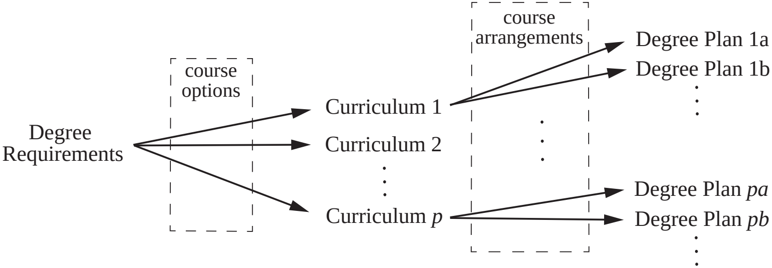
- **Academic Program** – Pedagogy organized around a specific discipline under the auspices of an academic unit, leading to a credential (degree).
  Ex: A.S. Chemistry, B.A. Music, B.S. Biology

- **Degree Requirements** – The set of requirements that must be satisfied in order for a student to earn a degree.

  Generally,
  requirements = courses (content)
  passed courses $\longrightarrow$ earned units of credit

- **Curriculum** – The structure and content of an academic program, specified as set of course that if completed will satisfy the degree requirements.

- **Degree Plan** – A term-by-term arrangement of courses in a curriculum.



- **Initial work involved analysis of curricula, in particular their graph structure and overall complexity.**
  - How does the complexity of curricular relate to student success and equity?
  - How much do curricula for the same program at different schools differ from one another? Are some better than others?
  - Can we use curricular analytics to guide curricular redesign efforts? Improve 2+2 plans?

- **More recently we've been working on analytics related to degree plans and degree requirements.**
  - Many degree plans can be created for a single curriculum, are some better than others?
  - Can we combine curricula (e.g., minor+major, double major, 2+2) in an optimal way?
  - Can more accurate plans be used to better estimate class fill rates and graduation rates?

Curricular Analytics: How It's Been Used

Curriculum Redesign

- Provide curriculum committees with analytical tools that can be used to predict the impact of curricular redesigns.
- Ability to more formally compare/contrast how different schools solve similar curricular challenges: curricular design patterns.

Curricular Comparisons

- Ability to analyze the entire curricular inventory of a college or university: common curricular patterns, meta-majors, important courses, complexity outliers?
- Ability to compare and contrast the curricula across a discipline, and to relate curricular measures to other factors, e.g., complexity vs. quality, curricular equity.

Academic Program Review

- Compare a program's curricula to the programs at peer institutions.
- Relate a program's curriculum to other programmatic issues, e.g., change of major, success rates, etc.

New Program Creation

- By comparing to similar curricula at other schools, we can better estimate *a priori* resource requirements, e.g., # new courses, # new faculty, # of students in classes, etc.
- Being used to inform creation a new Software Engineering program at UArizona.

Transfer Articulation*

- Evaluate the efficiency of transfer articulation curricula: is complexity equally balanced across institutions, is it really a 2+2 program?
- Ongoing work to provide a statewide transfer articulation system (Kentucky Council on Postsecondary Education).

Personalized Degree Plans*

- Create degree plans that take into account: prior coursework, toxic course combinations, major/minor combinations, etc.
- Particularly beneficial for advisors, and might be useful in projecting course demand.

*Requires optimization capabilities in toolbox.

II. Curricular Analytics Tools

Curricular Analytics Tools

- **Web-based application:** `CurricularAnalytics.org`
  - Compute the structural complexity of a curriculum.
  - Create different degree plans for a curriculum.
  - Allows you to organize and compare your curricula to others.

- **Curricular Analytics Toolbox:**
  - Allows for more sophisticated analyses of curricula and degree plans.
  - The analytics engine behind the aforementioned web application.
  - Toolbox code is here:
    `github.com/CurricularAnalytics/CurricularAnalytics.jl`
  - Working to add more toolbox capabilities to the web application.

- **Curricular Analytics Notebooks**:
  `github.com/CurricularAnalytics/CA-Notebooks`
  - A place to share curriculum-based studies using Jupyter notebooks.
  - A good place to learn about the toolbox features.

- The web application allows you to upload or create a curriculum (as well as associated degree plans), and provides an analysis of structural complexity.

- The complexity of an academic curriculum is a function of:

  - **Structural complexity** – determined by the manner in which the courses in the curriculum are structured, e.g., prerequisites, number of courses, etc.

  - **Instructional complexity** – determined by the inherent difficulty of the courses in the curriculum, the quality of the faculty, academic support, etc.

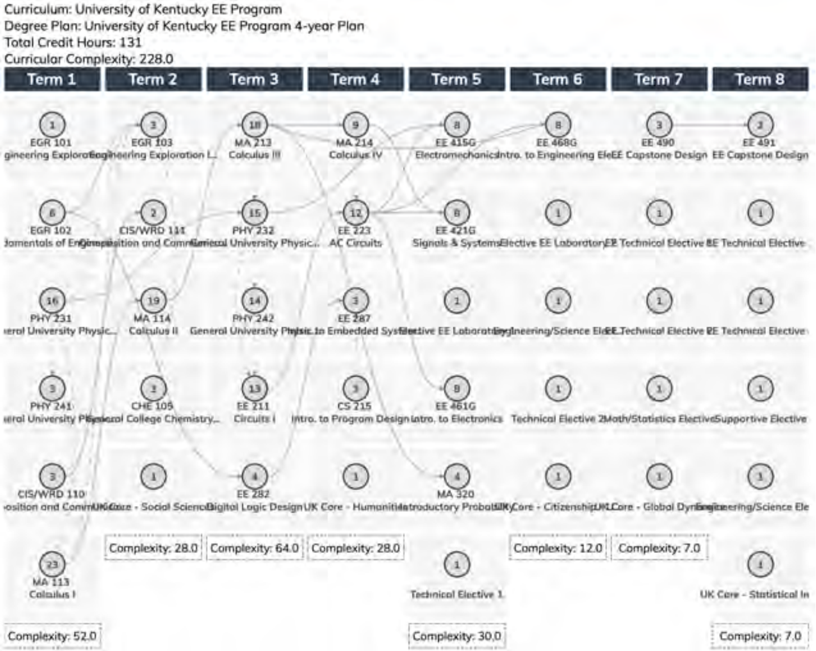
Structural Complexity

The following graph properties impact student progression:

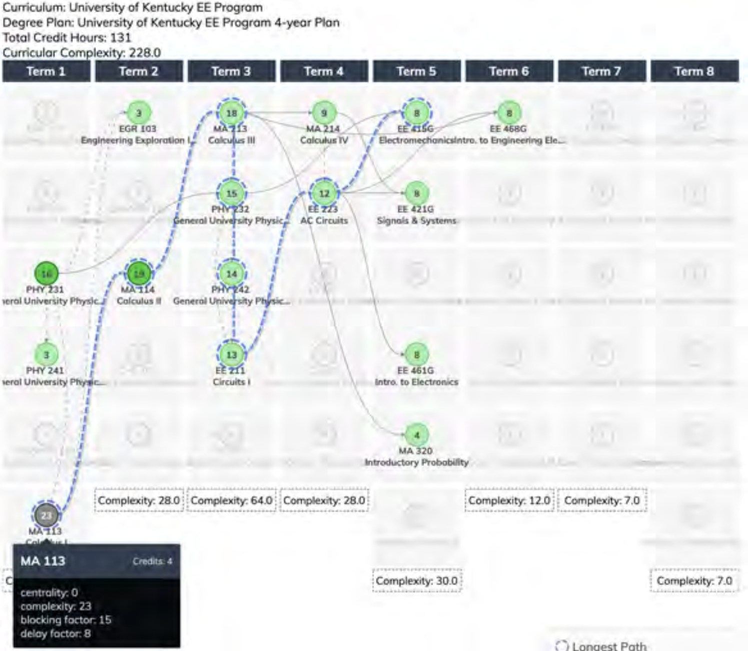
- **Delay Factor:** characterized by long paths in the curriculum.
- **Blocking Factor:** the number of courses a student is precluded from taking until they pass a given class.
- **Central Courses:** key courses in a curriculum — many prerequisites must be satisfied to reach them, and they “unblock” many courses in the curriculum that follow them.
- **Degrees of Freedom:** the extent to which a curriculum can be rearranged if certain courses are not passed.

Structural Complexity – A Real Curriculum

The University of Arizona



Structural Complexity – A Real Curriculum

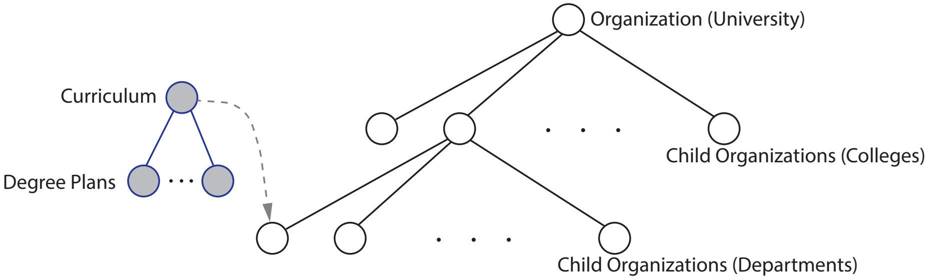


Structural Complexity – A Real Curriculum

www.CurricularAnalytics.org Tour

Web App – Organizations

A user belongs to an **organization** that may contain **child organizations**, that may also contain child organizations.



A curriculum can have many degree plans, and can belong to any organization.

III. Curricular Studies

Curricular Analytics: Practice

University of New Mexico

- Used as a part of university-wide curricular reform that involved significant reductions in curricular complexity.
- Over six years, 4-year graduation rate improved $\sim$300%, with little change in 6-year graduation rate.

APLU Western Land-Grant Cluster

- Curricular analytics used as a part of the Powered by Publics student success initiative.
- Eleven schools took a deep dive into the course requirements for critical degree programs common across the universities, to identify blocking and delay factors. See: `tinyurl.com/y6bjaq2e`

Virginia Tech

- Used curricular complexity to assess how transfer students would be affected by a large-scale curricular change in the ECE department.
- Quantitatively articulating concerns prompted the department to consider ways of integrating transfer students into the new curriculum.

University of South Florida

- Campus-wide review of curricula, initiated as a part of three campus consolidation (into one accredited institution).
- Particular focus on STEM curricula and math pathways.

New Mexico State University

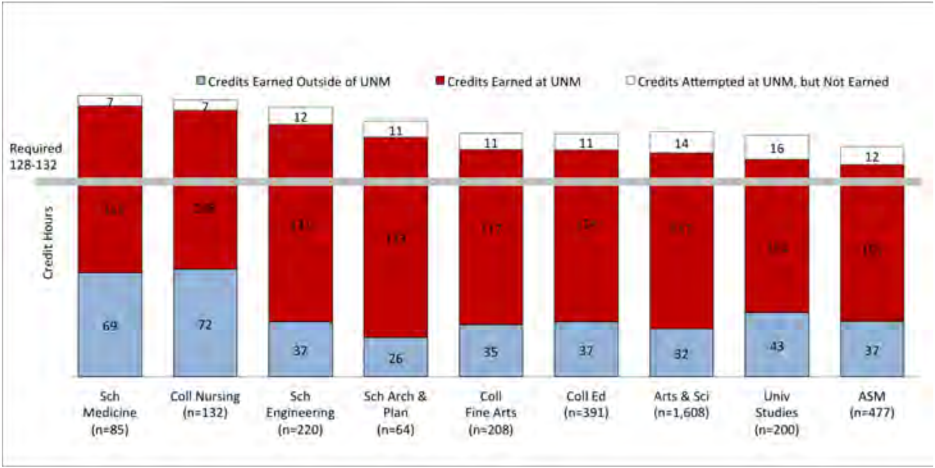
- Curricular Analytics Project: Provide departments and faculty with data and tools to analyze and improve curricular structures & degree road maps, and to inform other improvement efforts
- Departments were asked to upload NMSU degree plans to the curricular analytics website, and use the resulting analyses to analyze their programs, with an eye towards reducing complexity.

Kentucky Council on Postsecondary Education

- Collected the degree plans associated with all programs at all institutions of higher education in the State of Kentucky (see: `KYDegreePlans.com`.
- Statewide ability to compare and contrast curricula.
- Ongoing work to create an automated transfer articulation system using degree plan optimization capabilities.

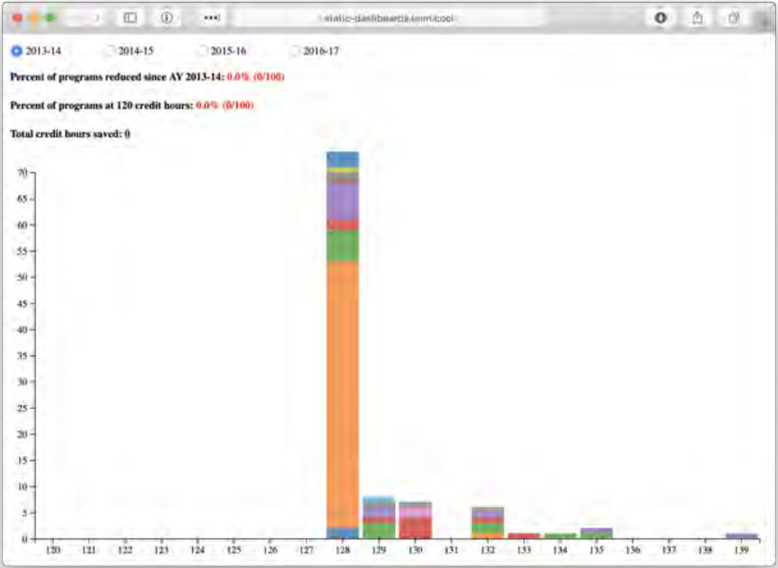
Curricular Study: University of New Mexico

Avg. credit hours, UNM bachelor's recipients, 2011-12 AY:



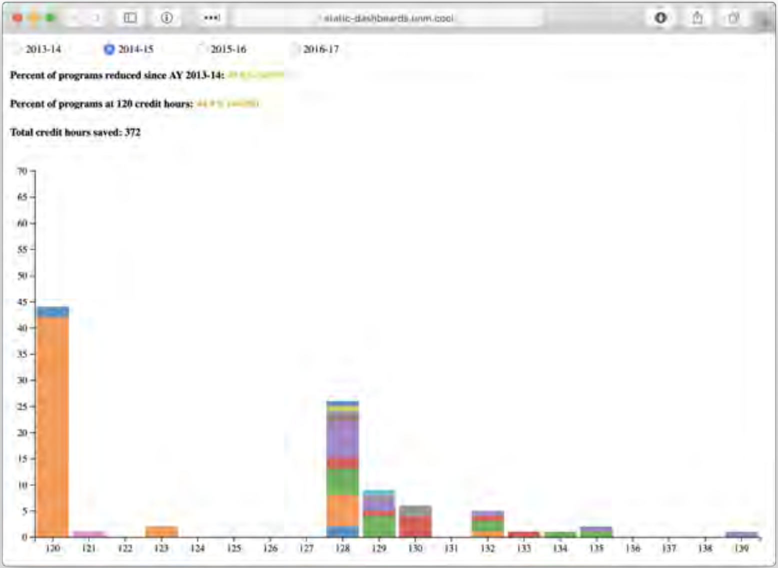
Reduction in Program Credit Hours

University of New Mexico —



Reduction in Program Credit Hours

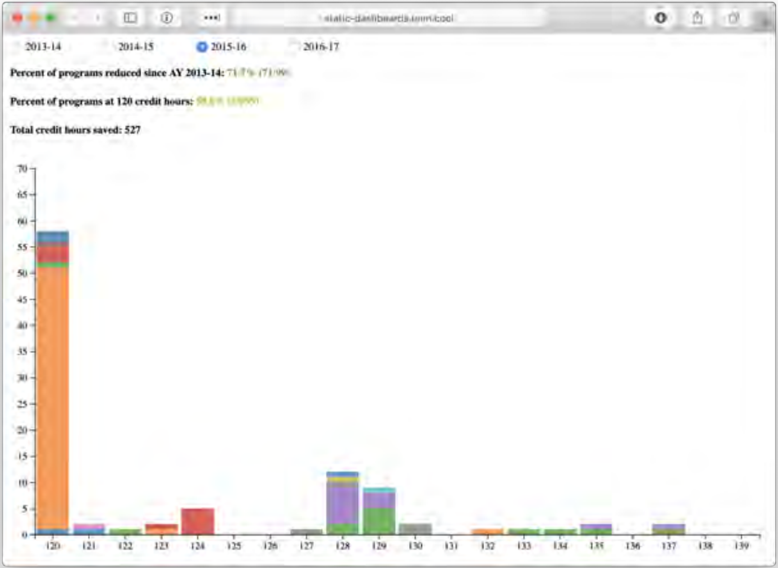
University of New Mexico —



Reduction in Program Credit Hours

The University of Arizona

University of New Mexico —



Reduction in Program Credit Hours

University of New Mexico —

Reduction in Program Credit Hours

- Over a 8-year time period (2010–18) 4-year graduation rate increase:
  $12.6\% \rightarrow 35\%$

  $\boxed{\sim 300\% \text{ increase!}}$

- **Saves students at least $35M/year.**

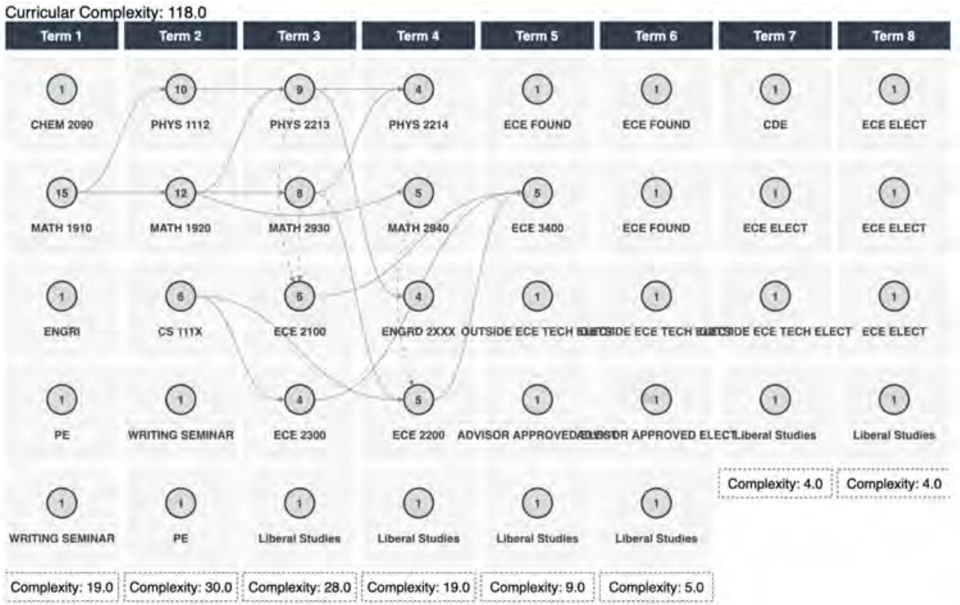
- Very little change in the six-year graduation rate … the pathways were made more efficient.

Curricular Study:
Math Preparation/Success in STEM Disciplines

Notebook: CA-Notebooks site $\rightarrow$ Quality-Complexity Studies

- Do higher quality programs have higher curricular complexity?
- Consider undergraduate electrical engineering programs at doctoral institutions.
- Let U.S. News & World Report rankings serve as a proxy for quality.

Structural Complexity – Institution 1

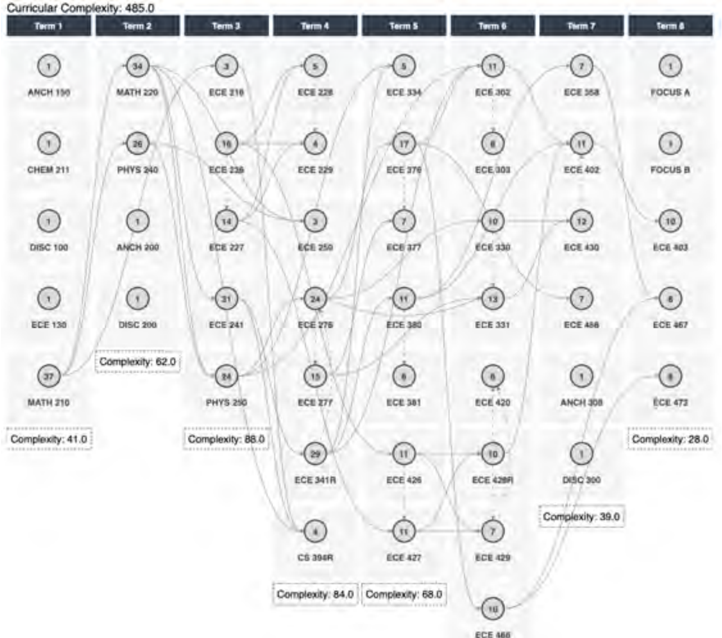


Structural Complexity – Institution 1

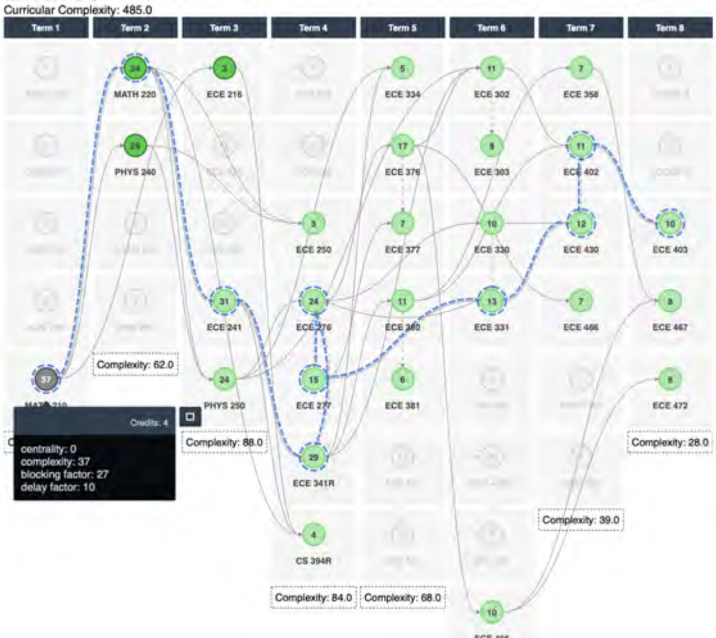
Structural Complexity – Institution 1

THE UNIVERSITY OF ARIZONA

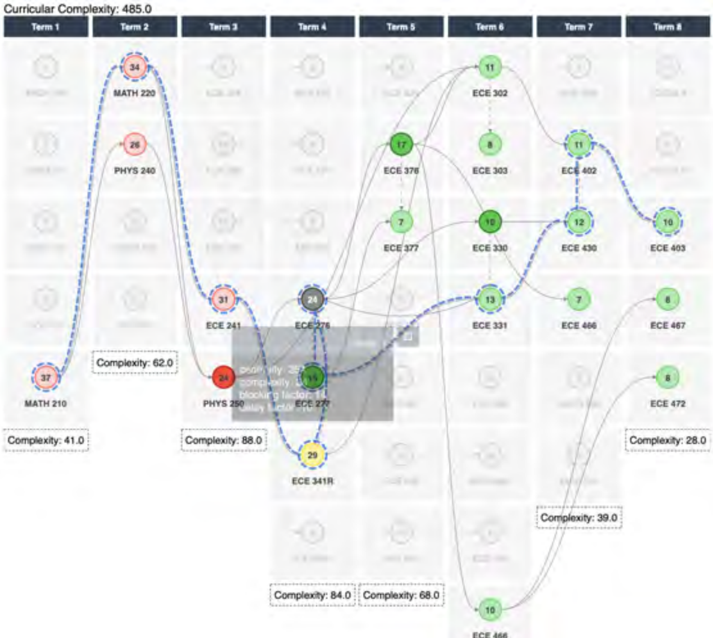
Structural Complexity – Institution 2



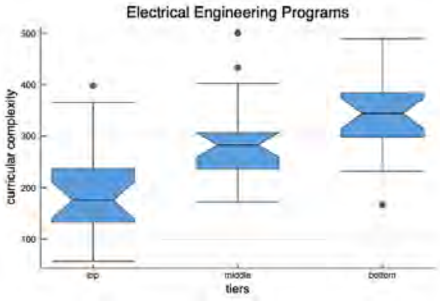
Structural Complexity – Institution 2

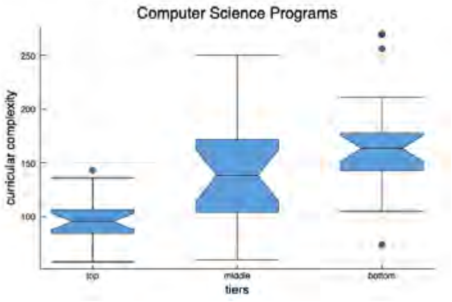


Structural Complexity – Institution 2



Complexity vs. Quality





- ANOVA analysis verifies a statistical difference between the means of these EE populations.
- ANOVA analysis verifies a statistical difference between the means of these CS populations.

Curricular Study:
APLU Western Land-grant Cluster

Notebook: CA-Notebooks site $\rightarrow$ Western Cluster-APLU

APLU Western Cluster Study Details

Cluster Schools:

- Colorado State University
- Langston University
- Montana State University
- New Mexico State University
- North Dakota State University
- Oklahoma State University
- South Dakota State University
- University of Idaho
- University of Nevada-Reno
- University of Wyoming
- Utah State University

- **Degree plans** associated with the following programs were collected from each school in the cluster:
  - animal science
  - mechanical engineering
  - music education
  - psychology
- **Curricular analytics** were applied to individual programs, similar programs across all schools (intra-group variance), and the groups of programs across the cluster (inter-group variance).

Individual Program Metrics

Colorado State University, Curriculum: Music Education

credit hours = 120, number of courses = 62

Blocking Factor –

entire curriculum = 96

max. value = 14, for course(s): MU 117

Centrality –

entire curriculum = 647

max. value = 138, for course(s): EDUC 450

Delay Factor –

entire curriculum = 199.0

max. value = 8.0, for course(s): MU 117, MU 118, EDUC 275, MU 217, EDUC 340, EDUC 350, EDUC 386, EDUC 475, EDUC 450, EDUC 477, EDUC 485A, EDUC 485B, EDUC 493A

Complexity –

entire curriculum = 295.0

max. value = 22.0, for course(s): MU 117

Longest Path(s) –

length = 8, number of paths = 2

path(s):

path 1 = EDUC 340 -> EDUC 475 -> EDUC 386 -> EDUC 350 -> EDUC 450 -> EDUC 493A -> EDUC 485B -> EDUC 485A

path 2 = MU 117 -> MU 118 -> MU 217 -> EDUC 477 -> EDUC 450 -> EDUC 493A -> EDUC 485B -> EDUC 485A

Individual Program Metrics

Colorado State University, Curriculum: Mechanical Engineering

credit hours = 129, number of courses = 39

Blocking Factor –

entire curriculum = 143

max. value = 26, for course(s): MATH 160

Centrality –

entire curriculum = 680

max. value = 81, for course(s): PH 141

Delay Factor –

entire curriculum = 176.0

max. value = 7.0, for course(s): MATH 160, MATH 161, MATH 261, MATH 340, MECH 342, MECH 338, MECH 486B, MECH 498B

Complexity –

entire curriculum = 319.0

max. value = 33.0, for course(s): MATH 160

Longest Path(s) –

length = 7, number of paths = 4, path(s):

path 1 = MATH 160 -> MATH 161 -> MATH 261 -> MATH 340 -> MECH 342 -> MECH 338 -> MECH 486B

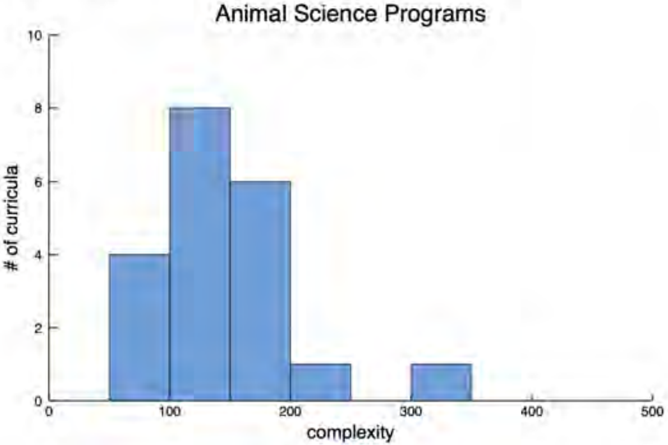
path 2 = MATH 160 -> MATH 161 -> MATH 261 -> MECH 337 -> MECH 342 -> MECH 338 -> MECH 486B

path 3 = MATH 160 -> MATH 161 -> MATH 261 -> MATH 340 -> MECH 342 -> MECH 338 -> MECH 498B

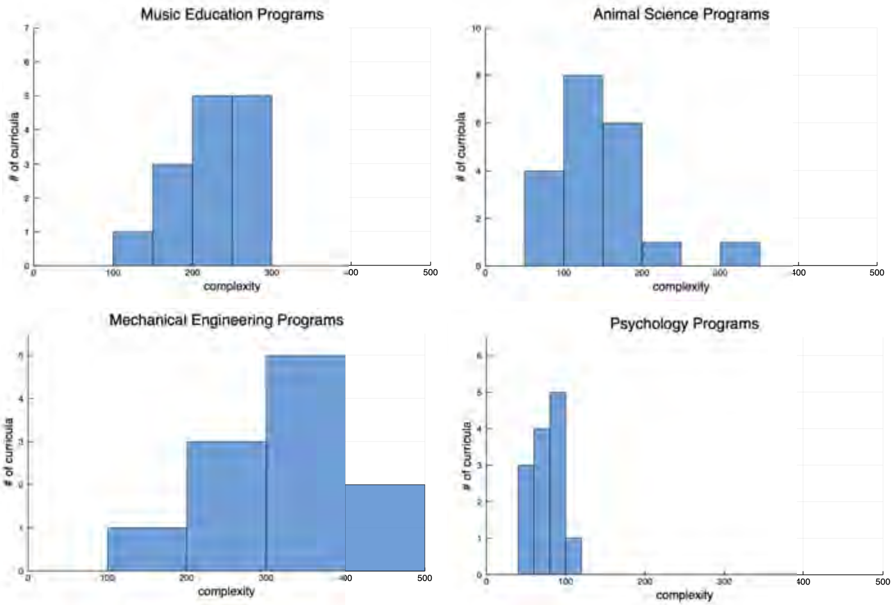
path 4 = MATH 160 -> MATH 161 -> MATH 261 -> MECH 337 -> MECH 342 -> MECH 338 -> MECH 498B

Intra-Group Curricular Complexities

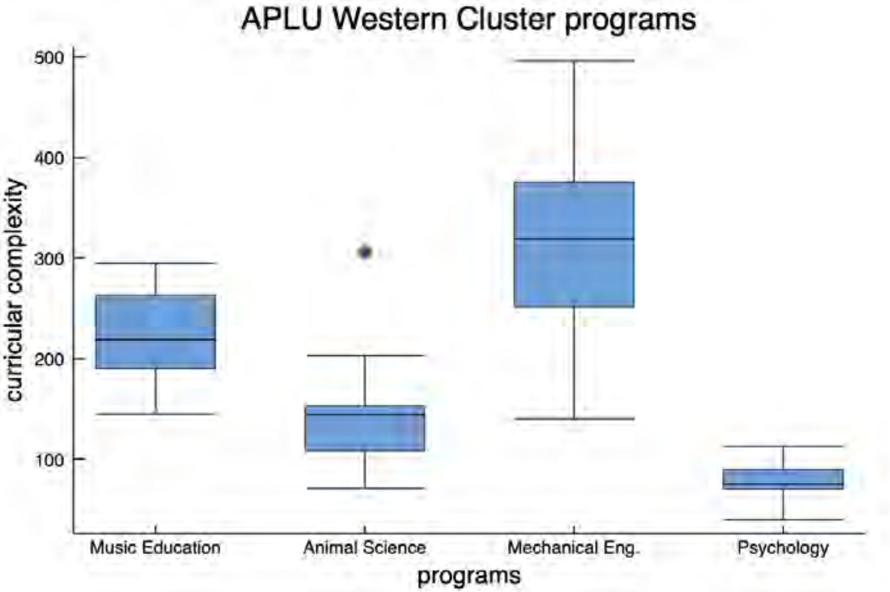
```
****** Animal Science Programs ******

 Metric -- complexity
  Number of curricula = 20
  Mean = 139.25
  STD = 13.248702766686254
  Max. = 306.0
  Min. = 71.0
```



Inter-Group Curricular Complexities



Inter-Group Curricular Complexities



Pay attention to:

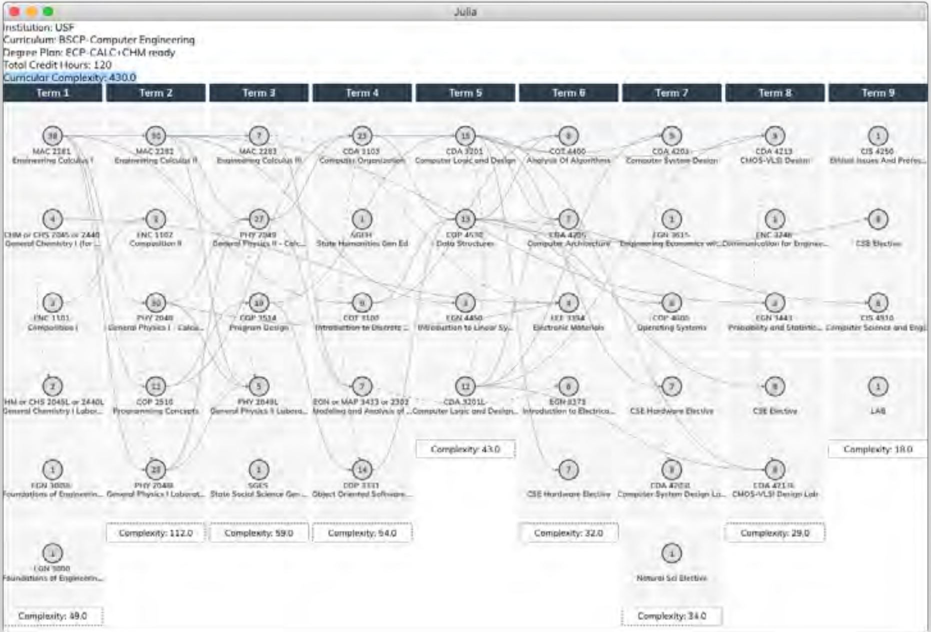
- Overall complexity score
- Existence of long chains of prerequisites — more than 6, or 7 long
- Few free electives in the program
- Delay of general education requirements into the junior/senior years
- Existence of “bottleneck” courses, i.e., courses with:
  - (a) lots of prerequisites so that they are not easy to get to, and
  - (b) a prerequisite for multiple other courses, so they can’t be delayed too long.

Curricular Study: University of South Florida Curricular Review

Notebook: CA-Notebooks site → Wright State Engineering Reform Study

- Ten different degree programs were considered.
- The curricula of all programs were analyzed using the curricular analytics toolset:
  - The "standard" degree plan for each program was created using these curricula.
  - For some programs we also created degree plans that include different math and chemistry starting points.
- Met with five departments (covering eight degree programs) to review curricular maps, curricular analytics metrics and degree plans.

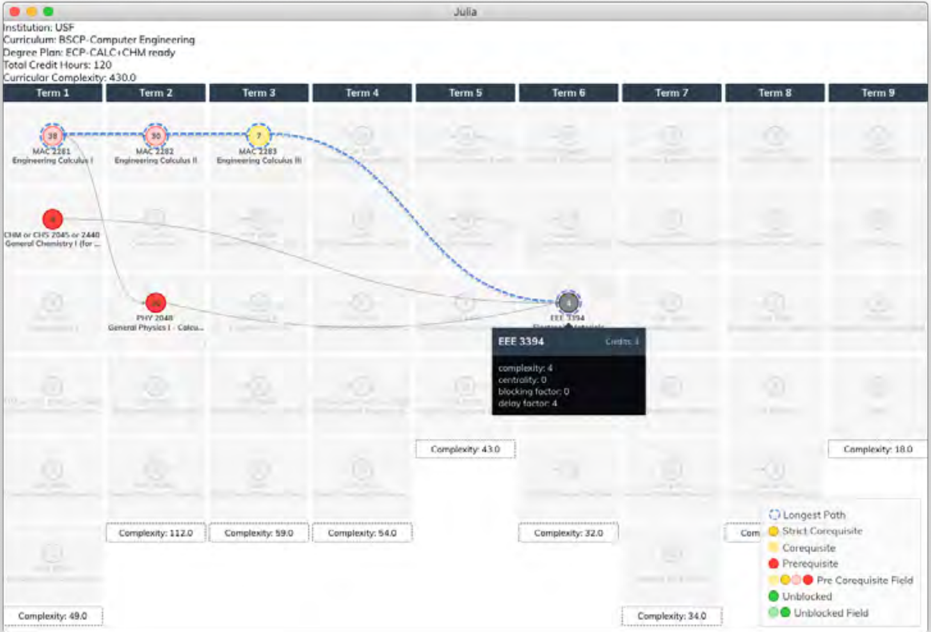
Computer Eng Program – Math Prepared



Computer Eng Program – Math Prepared

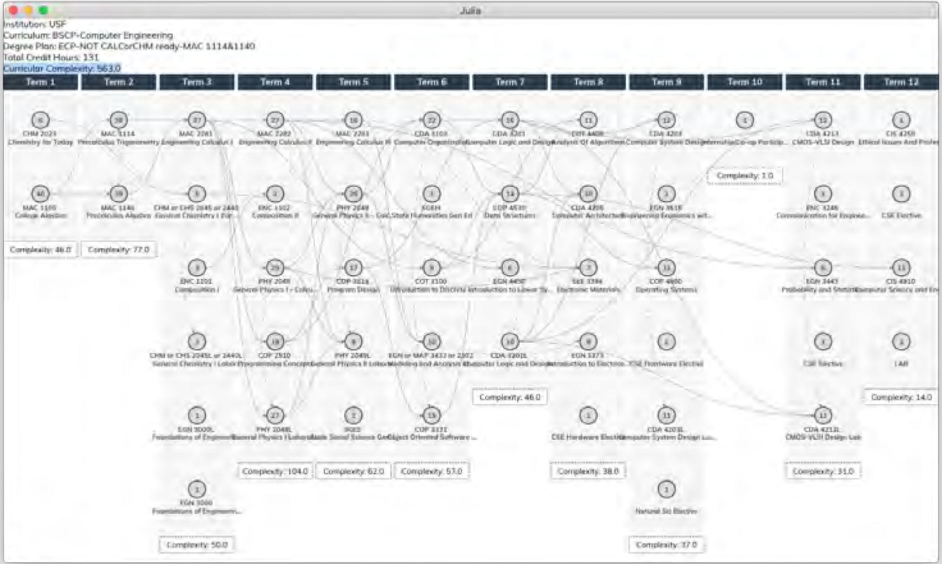
Computer Eng Program – Math Prepared

Computer Eng Program – Math Prepared

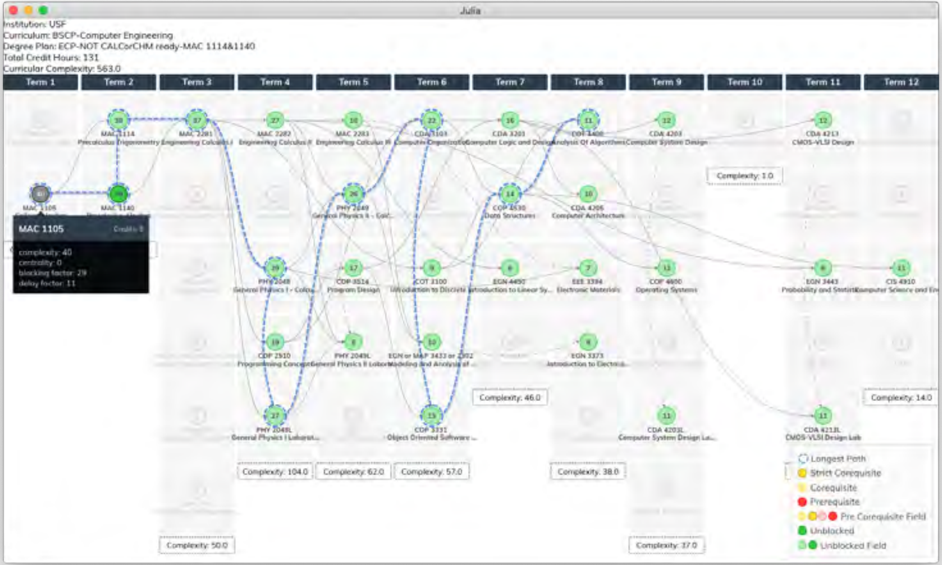


Computer Eng Program – Not Math Prepared

THE UNIVERSITY OF ARIZONA



Computer Eng Program – Not Math Prepared



Computer Eng Program – Not Math Prepared

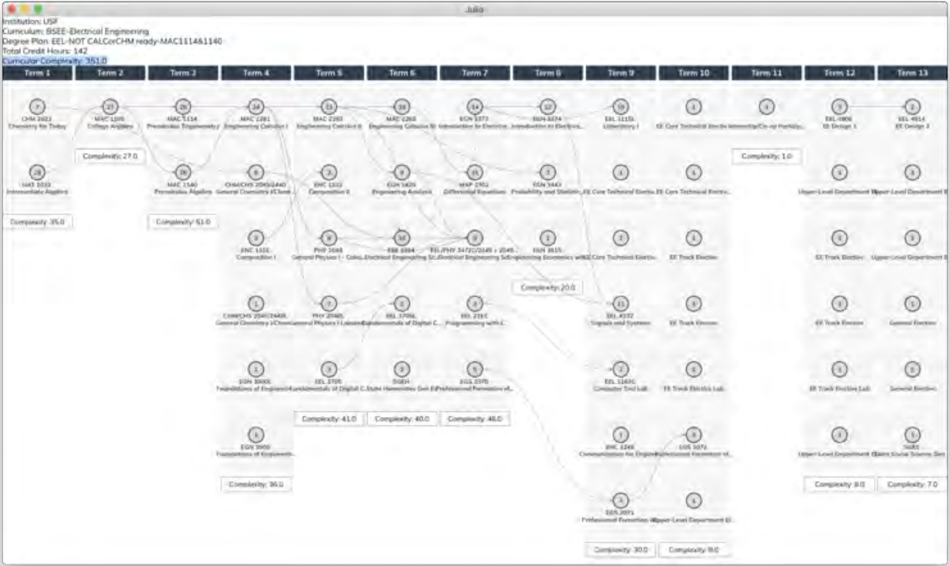
Electrical Eng Program – Math Prepared

Electrical Eng Program – Math Prepared

THE UNIVERSITY OF ARIZONA

Electrical Eng Program – Not Math Prepared

THE UNIVERSITY OF ARIZONA

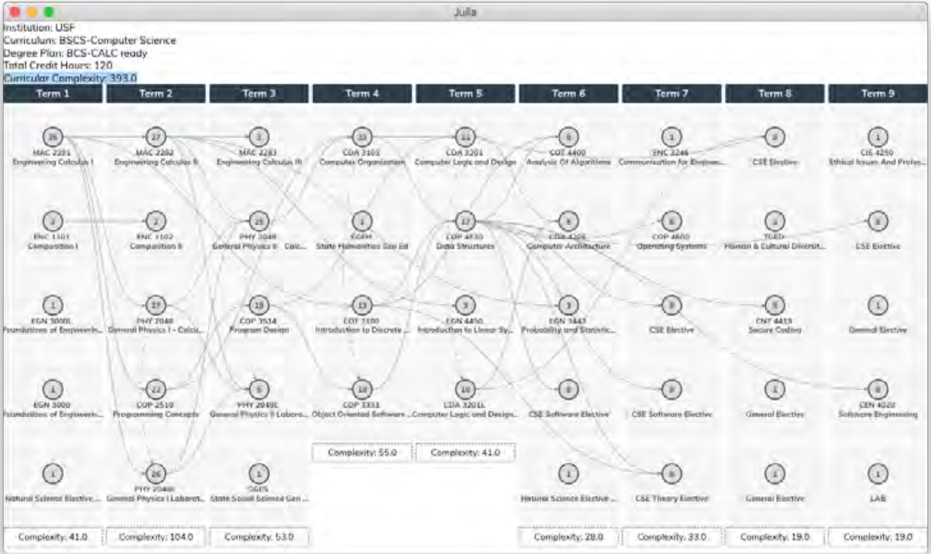


Electrical Eng Program – Not Math Prepared

THE UNIVERSITY OF ARIZONA

Computer Sci Program – Math Prepared

THE UNIVERSITY OF ARIZONA



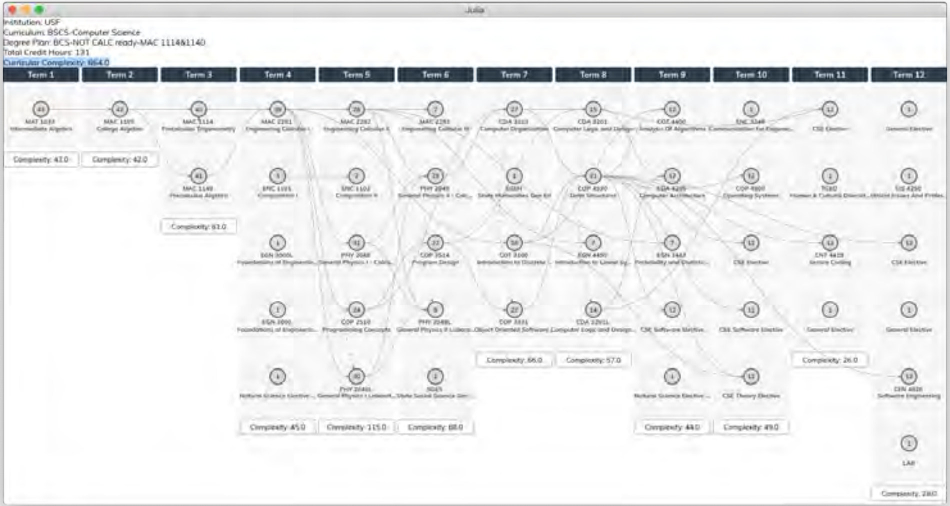
Computer Sci Program – Math Prepared

THE UNIVERSITY OF ARIZONA

Computer Sci Program – Math Prepared

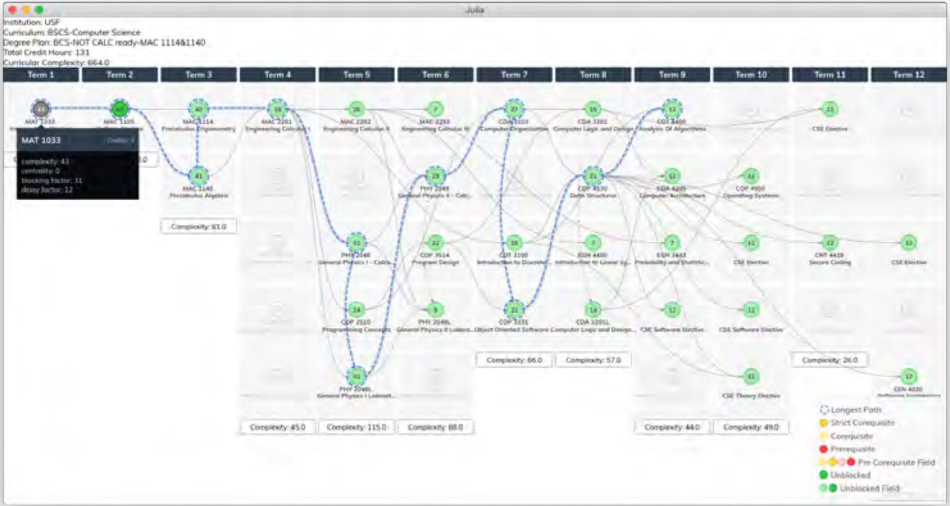
THE UNIVERSITY OF ARIZONA

Computer Sci Program – Not Math Prepared

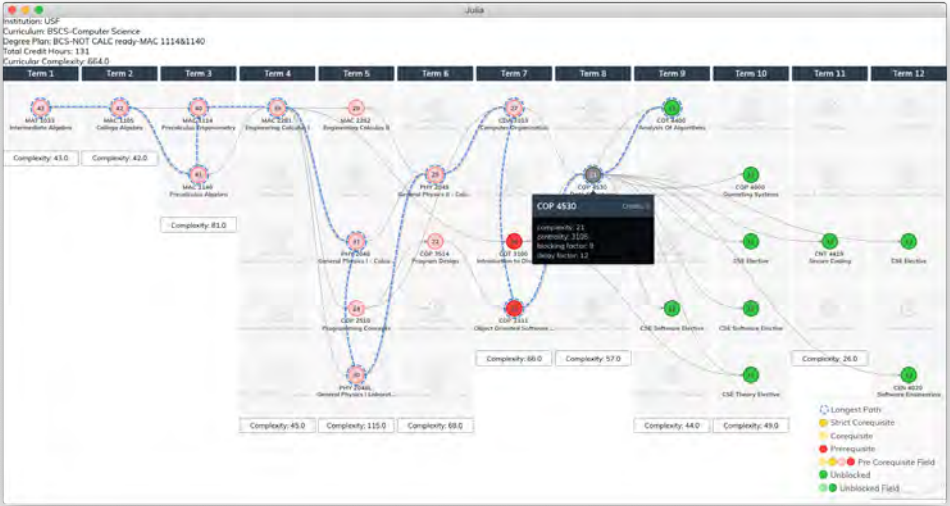


Computer Sci Program – Not Math Prepared

THE UNIVERSITY OF ARIZONA



Computer Sci Program – Not Math Prepared



Outcomes to date:

- The Computer Engineering program became the only such program in the state with a 120-credit-hour curriculum.
- Several other programs have restructured pre-requisites in ways that have reduced structural complexity.

Future outcomes:

- A number of programs are now engaged in faculty-based curriculum reviews—we expect that other programs will create 120-credit-hour curricula.
- Programs in Computer Science Engineering are planning course revisions (that essentially involve a rearrangement of where student learning outcomes are attained). The net effect involves breaking up long pathways and reducing bottlenecks.
- Electrical Engineering is creating test cases and running curricular analyses on them in order to investigate different possible curricula for best serving the students they admit.

Math Preparation – Wright St. Study

- The degree plans for most STEM disciplines require Calculus I in the first semester of the first year.

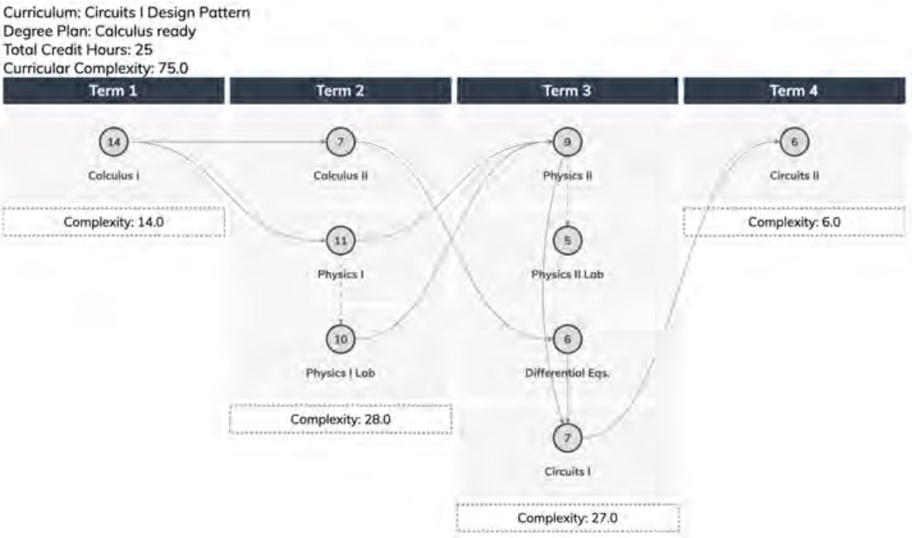
- What happens if students are not Calculus I-ready when they arrive?
  - In many cases they are told to:
    "get yourself Calc-ready, and then come back to talk with us."

  - For some students, this is the same as telling them:
    "change your major."

- How many capable students do we lose to STEM disciplines because of this?

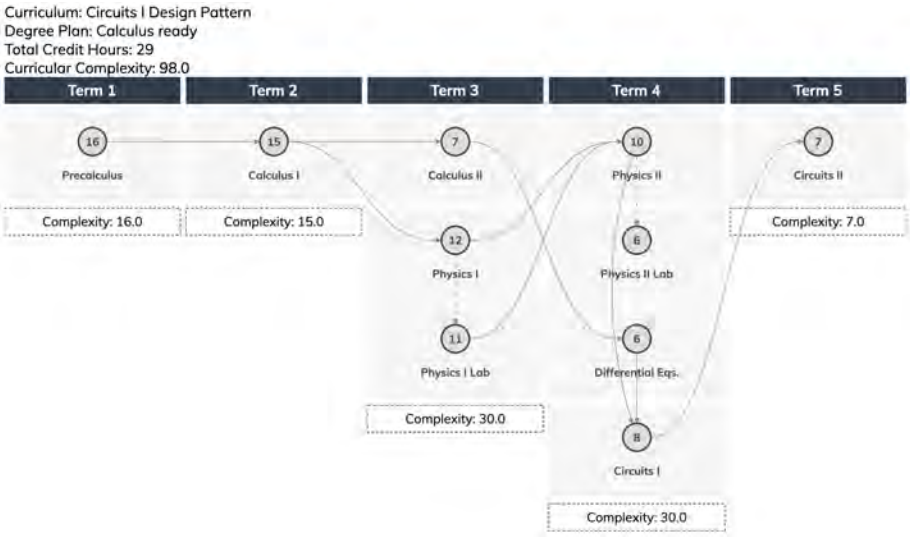
- Can we adapt our curricula to better serve these students?

Curricular Design Pattern – Calculus Ready



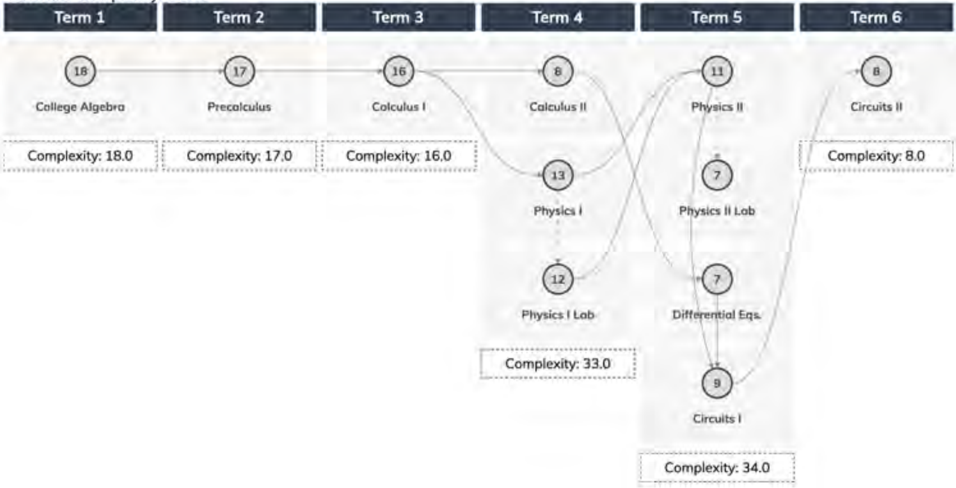
Curricular Design Pattern – Precalculus Ready

THE UNIVERSITY OF ARIZONA



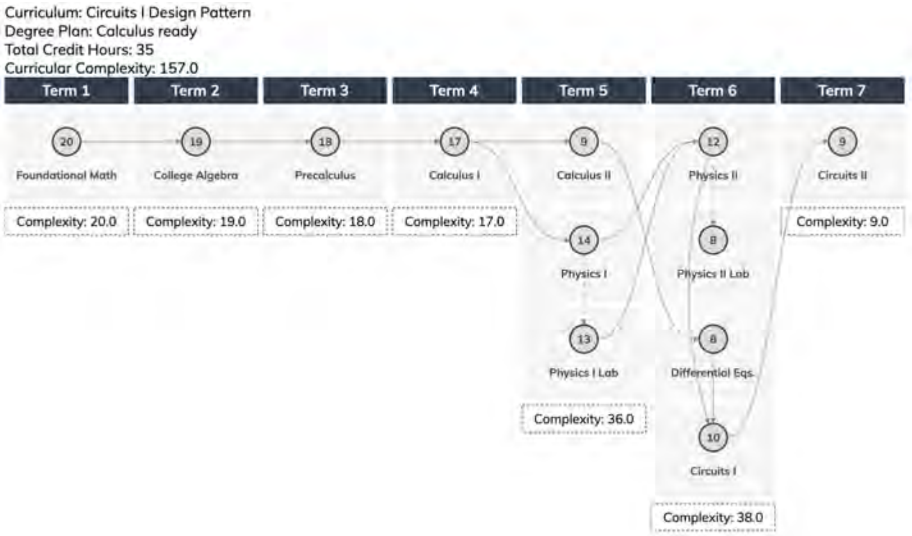
Curricular Design Pattern – College Algebra Ready

Curriculum: Circuits I Design Pattern
Degree Plan: Calculus ready
Total Credit Hours: 32
Curricular Complexity: 126.0

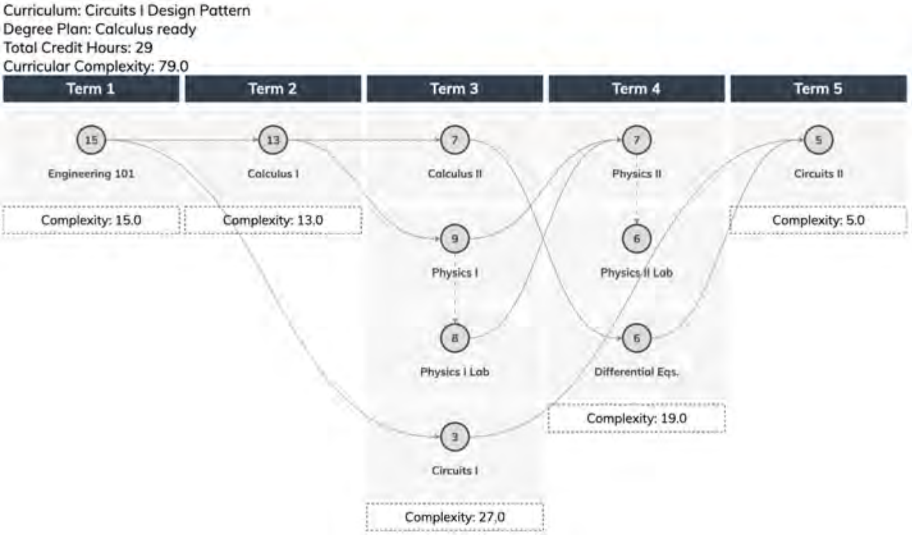


Curricular Design Pattern – Foundational Math

THE UNIVERSITY OF ARIZONA



Curricular Design Pattern – Engineering 101



Simulation Assumptions:

- Students not calculus ready.
- Instructional complexity is the same for both patterns
- At most three courses in the pattern per term.
- When a class is not passed, it is attempted again in the next semester.
- Success: completion within 7 terms.

Use historic pass rate data:

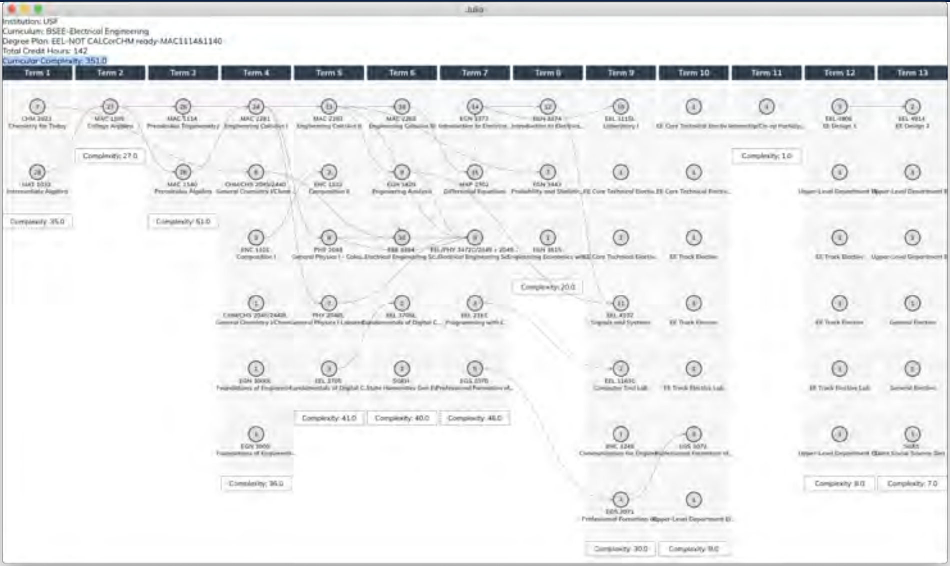
- Traditional: 79% success
- Alternative: 88% success

90% pass rate in ENG 101:

- Alternative: 98% success

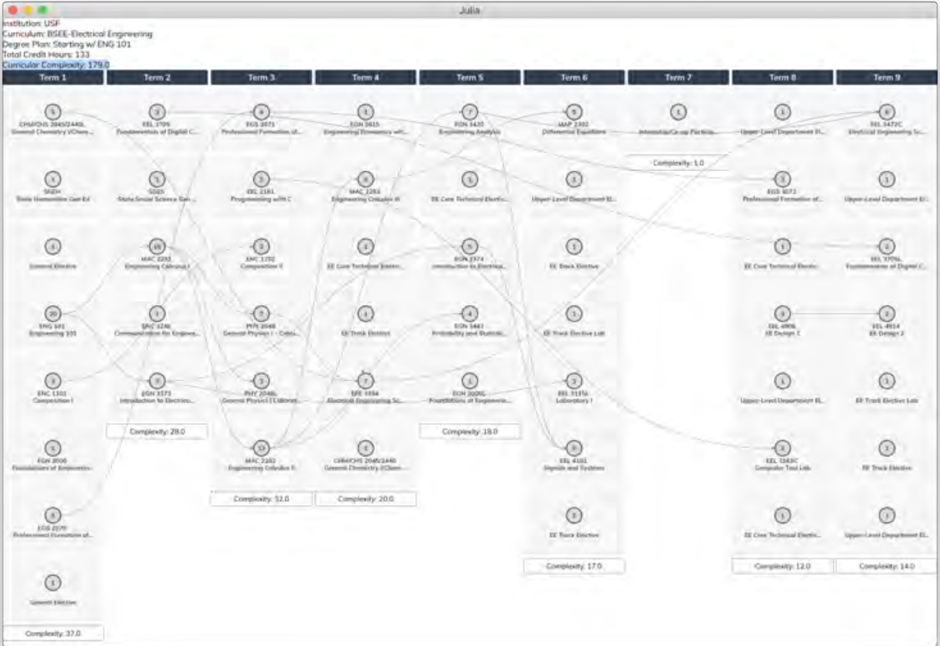
EE Program – Not Math Prepared (Revisited)

EE Program – Not Math Prepared (Revisited)



EE Program – Not Math Prepared (Revisited)

THE UNIVERSITY OF ARIZONA



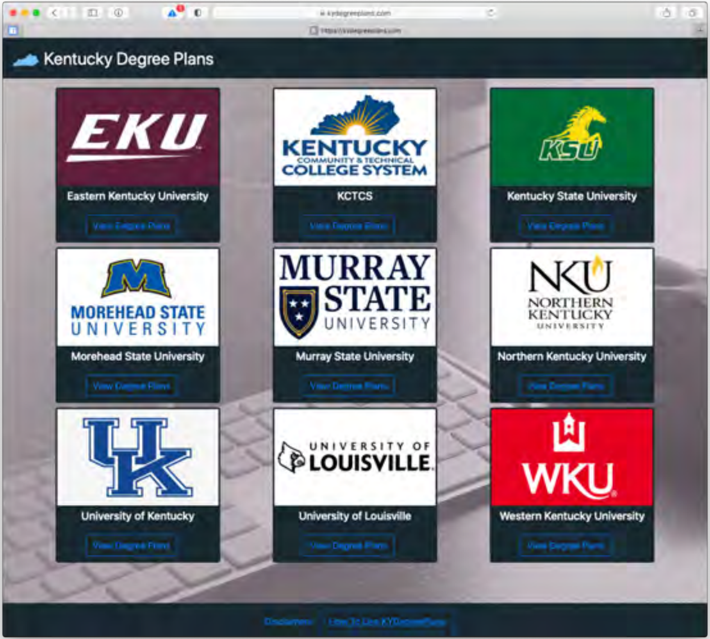
EE Program – Not Math Prepared (Revisited)

THE UNIVERSITY OF ARIZONA

EE Program – Not Math Prepared (Revisited)

Curricular Study: Kentucky Council on Postsecondary Education

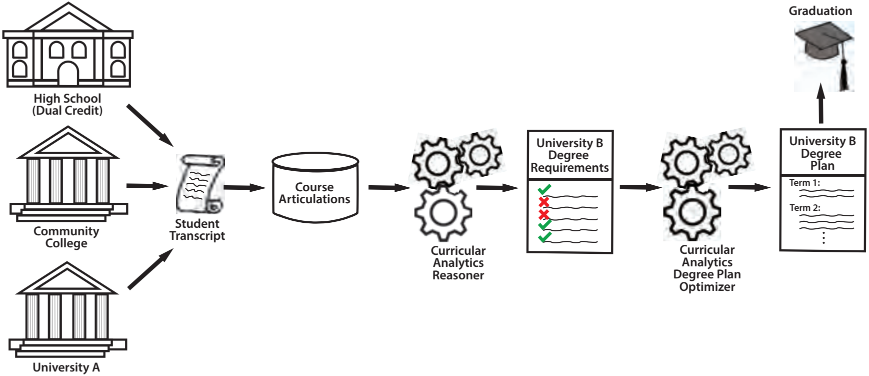
Statewide Degree Plans



Statewide Degree Plans

Statewide Transfer Articulation

The overall process flow:



Personalized Degree Plans

THE UNIVERSITY OF ARIZONA

A program creates a single degree plans that works for all students:

A program creates a single degree plans that works for all students:

...but Emilio didn't test into Calculus I, the math starting point in the degree plan.

Personalized Degree Plans

A program creates a single degree plans that works for all students:

... and Julie is bringing in 31 credit hours of AP and dual credit coursework.

A program creates a single degree plans that works for all students:

... Ana is transferring from Tri-City Community College with credits from her AS degree.

Personalized Degree Plans

A program creates a single degree plans that works for all students:

... Pia withdrew from two classes last semester and is no longer "on plan."

Personalized Degree Plans

A program creates a single degree plans that works for all students:

... Byron is changing majors but still wants to finish in four years.

Personalized Degree Plans

A program creates a single degree plans that works for all students:

All of these student deserve degrees adapted to their individual needs

Personalized Degree Plans

A program creates a single degree plans that works for all students:

All of these student deserve degrees adapted to their individual needs ... allowing them to complete on time.

Motivation: Create customized degree plans that improve the chances of student success.

- Generic plans that satisfy various “nice” properties.
- Initial plans tailored to students with particular backgrounds.
- Plans customized to individual students:
  - revised plans for student no longer “on track,”
  - plans that takes into account prior coursework (AP, dual credit, etc.).
- Plans that separate toxic course combinations, and group synergistic courses.

Personalized Plans

We specified an **Integer Linear Programming** problem for creating optimized plans.

It's an assignment problem –

$$
\text{courses}\quad
\begin{array}{c}
\\ 1 \\ 2 \\ 3 \\ \vdots \\ n
\end{array}
\overset{\text{terms}}{\begin{bmatrix}
1 & 2 & & m \\
0 & 1 & & 0 \\
1 & 0 & & 0 \\
0 & 0 & \cdots & 1 \\
\vdots & \vdots & & \vdots \\
1 & 0 & & 0
\end{bmatrix}}
$$

Problem Specification –

$$\min f(x),$$
$$\text{subject to: a bunch constraints.}$$

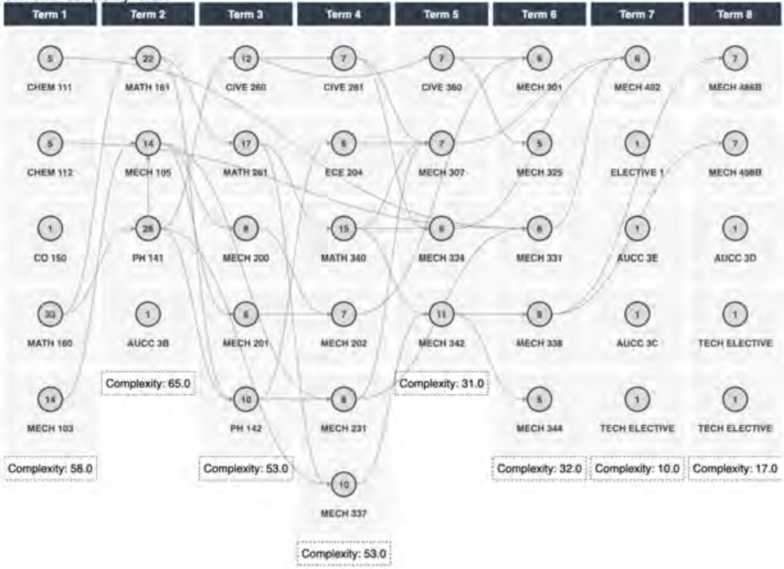
where $f(x)$ is an objective function we need to specify.

Personalized Plans

- Constraints related to prerequisite satisfaction must be satisfied.
- Additional constraints may be specified by the user in order to stipulate:
  - Coursework that has already been completed.
  - Courses that must be taken in a particular term (e.g., fall or spring)
  - Courses that must be taken in consecutive terms.
  - Courses that should or should not be taken together (toxic course avoidance).

Example – Baseline Plan

Institution: Colorado State University
Curriculum: Mechanical Engineering
Degree Plan: 4-Year Plan
Total Credit Hours: 129
Curricular Complexity: 319.0



Colorado State University, Curriculum: Mechanical Engineering

Curriculum: Mechanical Engineering

Degree Plan: 4-Year Plan

total credit hours = 129

number of terms = 8

max. credits in a term = 20, in term 4

min. credits in a term = 13, in term 6

avg. credits per term = 16.125, with **std. dev. = 2.088**

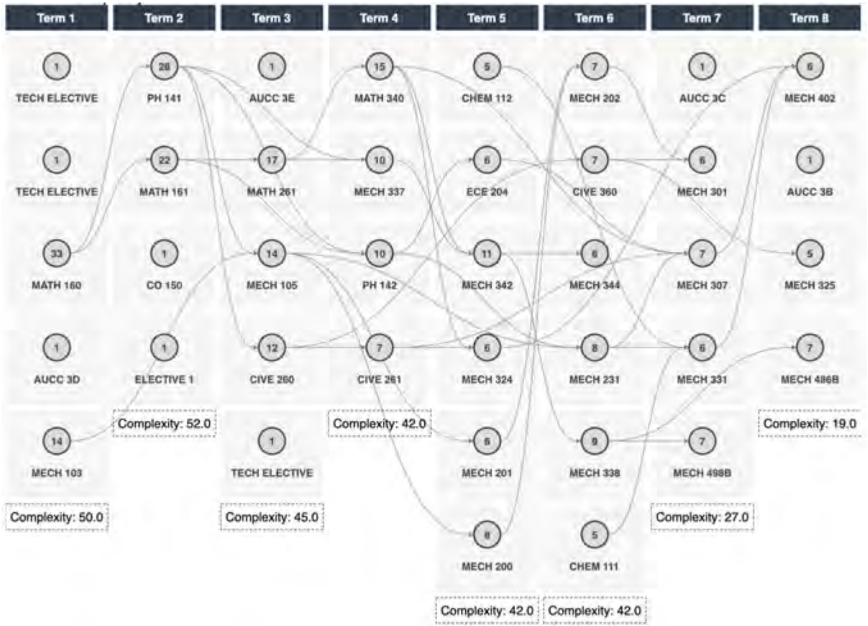
Balanced Curriculum Objective

Goal: create degree plans that have roughly the same number of credit hours in every term.

$$f(x) = \min \left(\sum_{i=1}^{m} \sum_{j=1}^{m} |\theta_i(x) - \theta_j(x)| \right),$$

m = number of terms,
θ_i = number of credit hours in term i.

Balanced Curriculum Objective



Balanced Curriculum Objective

Example Plan – Balance Objective

Colorado State University, Curriculum: Mechanical Engineering

- Curriculum: Mechanical Engineering
- Degree Plan: 4-Year Plan
  - total credit hours = 129
  - number of terms = 8
  - max. credits in a term = 17, in term 6
  - min. credits in a term = 16, in term 1
  - avg. credits per term = 16.125, with **std. dev. = 0.331**

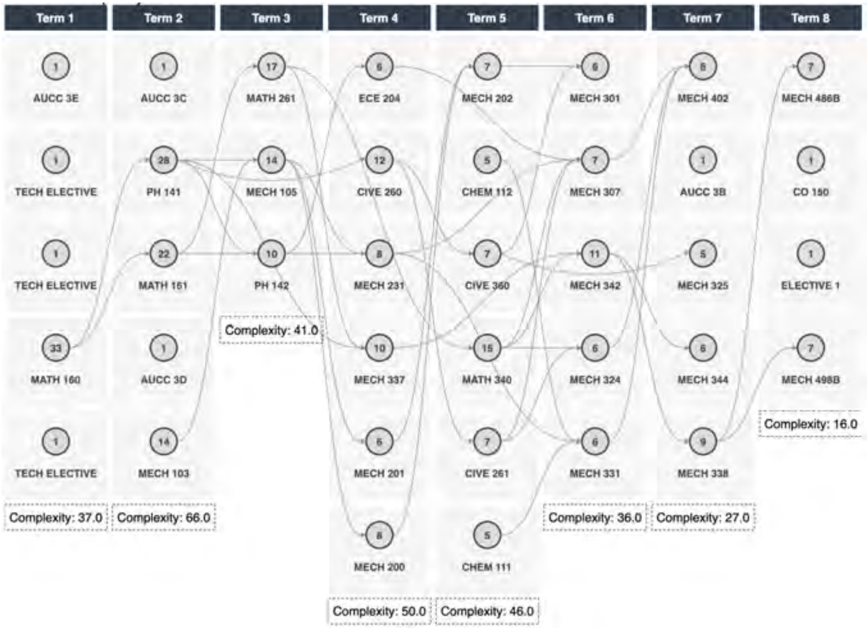
Requisite Distance Objective

Goal: create degree plans where the pre- and co-requisites for every course are as close as possible (in the degree plan) to the course that requires them.

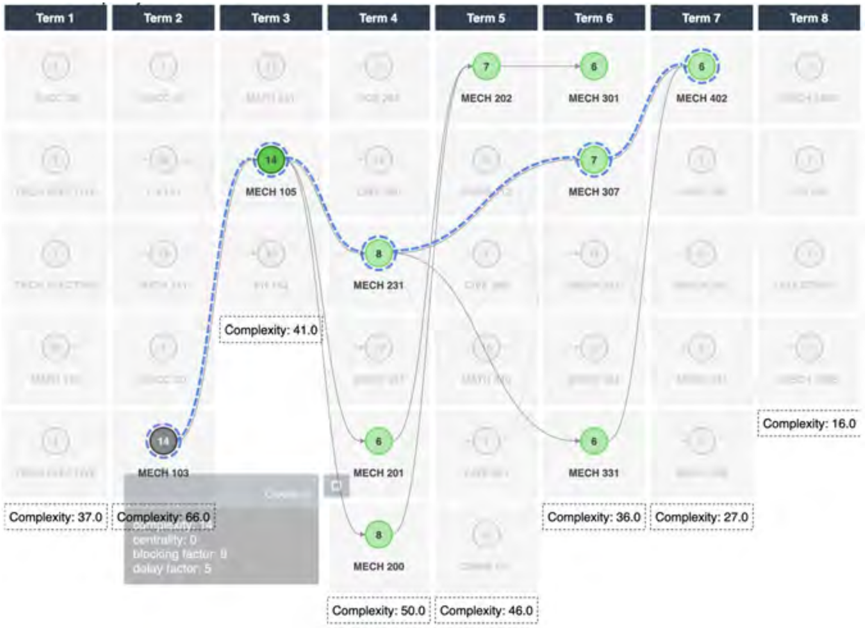
$$f(x) = \min\left(|T_j(x) - T_i(x)|\right) \quad \forall e = (i, j) \in E.$$

$G = (V, E) =$ curriculum graph,
$T_i =$ term that course i appears in the plan.

Requisite Distance Objective



Requisite Distance Objective



Colorado State University, Curriculum: Mechanical Engineering

Curriculum: Mechanical Engineering

Degree Plan: 4-Year Plan

total credit hours = 129

number of terms = 8

max. credits in a term = 18, in term 2

min. credits in a term = 12, in term 3

avg. credits per term = 16.125, with **std. dev. = 2.027**

- The toolbox supports multi-objective optimization, allowing more than one objective function to be optimized simultaneously.
  Problem Specification –

$$\min\{f_1(x), f_2(x), \ldots\},$$
$$\text{subject to: a bunch of constraints.}$$

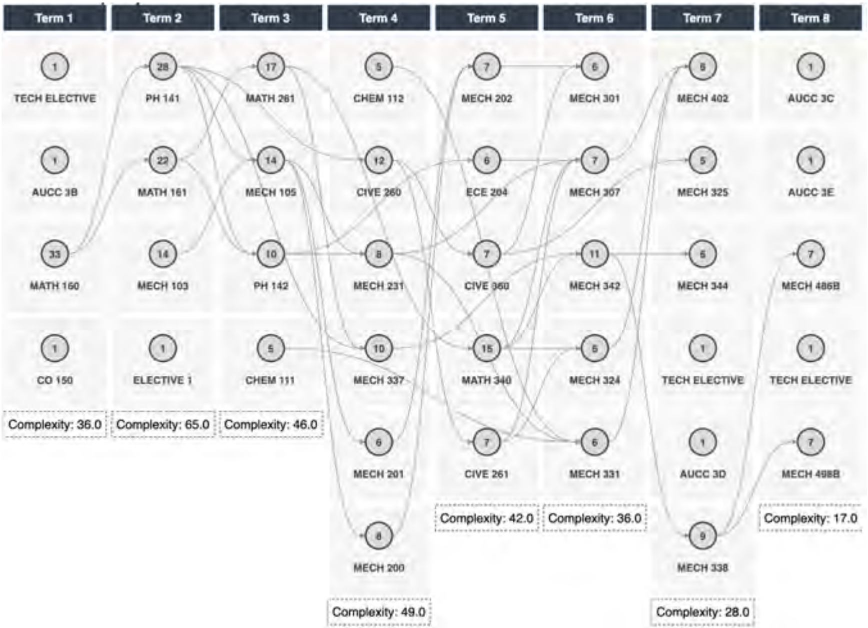
- Currently three objective functions are supported, including toxic course combination avoidance.

- Toxic course combination avoidance (quadratic) objective function:

$$f(x) = \min\left(\sum_{t=1}^{m}\sum_{i=1}^{n}\sum_{j=1}^{n}\aleph_{ij}\cdot x_{it}\cdot x_{jt}\right).$$

  where $-1 \leq \aleph_{ij} \leq 1$ denotes the toxic impact course i has on course j if they are taken together in the same term.

Requisite Distance and Balance Objectives



Requisite Distance and Balance Objectives

Colorado State University, Curriculum: Mechanical Engineering

Curriculum: Mechanical Engineering

Degree Plan: 4-Year Plan

total credit hours = 129

number of terms = 8

max. credits in a term = 17, in term 6

min. credits in a term = 16, in term 1

avg. credits per term = 16.125, with **std. dev. = 0.331**

Questions?