# **Curricular Analytics**



# Fall 2020 Virtual UVP Network Meeting November 12, 2020

**Curricular Analytics Workshop** 

#### 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



#### 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

# Etymology



#### 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



# BS Accounting School of Arts & Soc Sciences

124 Credit Hours

Storting in a	in Even Year Storting in an Dad year		
E No.	BB Ged	< Graph	
Semester 1			16 Coult Hours
ACCT 211 - Principles of Accounting (		i	-
ECON 265 - Principles of Economics I - Macro			THE STREET
CPTR 105 - Introduction to Computers		Department of	1000
COMM 105 - Introduction to Human Communication		·	-
ENGL 101 - Composition		-	-
NTD 105 - First-Year Experience		and a	(partyrine)
Semester 2			Lis Count House
ECON 266 - Principles of Economics II - Micro			-
ACCT 212 - Principles of Accounting II		-	
Religious Studies			and the same of
ENGL 102 - Research and Literature		-	-
MATH 110 - Probability and Statistics			-
Semester 3			16 Credit History
MKTG 310 - Principles of Marketing			THE PERSON NAMED IN
ACCT 301 - Intermediate Accounting (			-
FNCE 290 - Business Finance		Secretaria de	

# College Catalog – Degree Plan (Grid)



# BS Accounting School of Arts & Soc Sciences

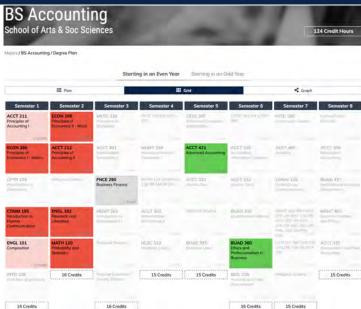
124 Credit Hours

45 Accounting / Degree Plan

		Storti	ng in an Even Year	Storting in on 0	dd Year		
	⊞ Plan		S # 11	Grid		< Graph	
Semester 1	Semester 2	Semester 3	Semester 4	Somester 5	Semester 6	Semester 7	Semester B
ACCT Z11 Priviples of Accounting (	ECON 266 Principles of Economics II - Micro	MKTG 310 Principles of Worketing	PRVC 104 DR SOCI 105	CSYS 265 Advanced Computer Applications	000P 351 OR COOP- 360	eVTD 100 Community Service	History/Social Decayes
ECON 265 Principles of Economics I - Motiro	ACCT 212 Principles of Accounting if	ACCT 301 Intermediate Accounting (	MGMT 338 Advanced Human Resources I	ACCT 421 Advanced Accounting	ACCT 325 Accounting Information Systems	ACCT 405 Au3ting	ACCT 309 Managemal Accounting
CPTR 105 Introduction to Computers	Proligious Studies	FNCE 290 Businest Finance	MATH 120 DR MATH 126 OR MATH 151	ACCT 321 bcome Tox /	ACCT 322 Income Tas II	COMM 315 Street Group Communication	BUAD 415 International Business Environment
0	1000	1200	(1000)	100	10000	j-mi	
COMM 105 Introduction to Human Communication	ENGL 102 Research and Uterature	MGMT 201 Infrieduction to Management I	ACCT 302 Intermediate Accounting 1	Religious Studies	BUAD 315 Quantitative Methods	HMNT 100 OR HMNT 270 OR HIST 126 OR HIST 257 OR HIST 276 OR HIST 283 OR PML 150 OR PML 250	MGMT 485 Business Strolegy and Policy
ENGL 101 Composition	MATH LIO Probability and Statistics	Remoun Studies	HLSC 110 Healther Living	BUAD 375 Business Low (	BUAD 360 Ethics and Professionolism in Business	LITR 227 OR LITH 232 OR LITR 236 OR LITR 135	ACCT 327 Government and Fund Accounting
100	1000	-	70-	0	l man	200	-
INTO 105 First-Year Experience	16 Credits	Physical Education VACINITY Elective	15 Credits	15 Credits	BIOL 130 Humans and Their Environment	Religious Studies	15 Credits
						11-11-11	
T6 Credits		16 Credts			16 Credits	15 Credits	

# College Catalog – Degree Plan (Grid)





# College Catalog – Degree Plan (Graph)

16 Credits

16 Credits



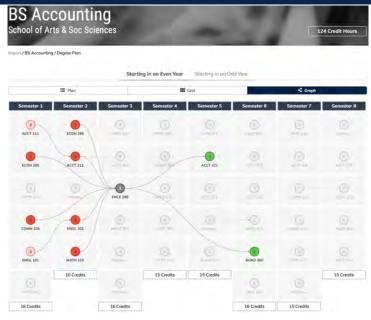


16 Credits

15 Credits

# College Catalog – Degree Plan (Graph)





#### 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

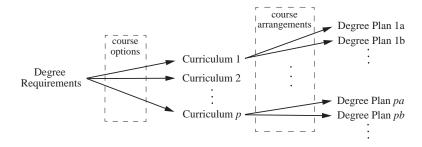
 Degree Requirements – The set of requirements that must be satisfied in order for a student to earn a degree.

```
Generally,
requirements = courses (content)
passed courses → earned units of credit
```

## Terminology



- 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.



## Curricular Analytics



- 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.

# Curricular Analytics: How It's Been Used



#### **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

<sup>\*</sup>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.

## www.CurricularAnalytics.org



- 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



Curriculum: University of Kentucky EE Program

Degree Plan: University of Kentucky EE Program 4-year Plan

Total Credit Hours: 131

Term 1	plexity: 228.0 Term 2	Term 3	Term 4	Term 5	Term 6	Term 7	Term 8
EGR 101 tring Explorate	EGR 103 Eggineering Exploration	MA 213 L. Calculus III	MA 214 Colculus IV	EE 415G	B EE 468G ro. to Engineering Elel	EE 490 EE Capstone Design B	EE 491 E Capstone Desig
EGR 102 ntals of Engin	CIS/WRD 114 repainstion and Committee	PHY 232 lecal University Phys	EE 223 ic AC Circuits	EE 4216 Signals & Systems	(1) hotive EE LaboratoryEI	1) E Tochnicol Elective &	Technical Electiv
PHY 231 University Phy	MA 114 ysic Calculus II Ger	PHV 242 Perol University Phyls	EE 287	1 filentive EE Laboratding	Ineering/Science Elde	1) E.Technical Elective RE	(1) Technical Electiv
PHY 241 University Pls	CHE 105 esterol College Chemistr	EE 211 y Circuits i jyn	CS 215 ro. ta Program Desk	EE 461G gn latro, to Electronics	Technical Elective 2M	i) oth/Statistics Elective	1) Supportive Elective
S/WRD 110 on and Conve	UNG Course + Social Science	EE 282 Bigitol Logic Design	UK Core - Humanitis	MA 320 detroductory Probability	Core - CrtizenohipUNU	1) Core - Global Dyrifongi	1) tweering/Science E
MA 113 Colimitus I	Complexity: 28.0	Complexity: 64.0	Complexity: 28.0	Technical Elective 1	Complexity: 12.0		Core - Statistical

Complexity: 52.0 Complexity: 30.0 Complexity: 7.0

### Structural Complexity – A Real Curriculum



Curriculum: University of Kentucky EE Program
Degree Plan: University of Kentucky EE Program 4-year Plan
Total Credit Hours: 131



# Structural Complexity – A Real Curriculum



Curriculum: University of Kentucky EE Program

Degree Plan: University of Kentucky EE Program 4-year Plan

Total Credit Hours: 131

Term 1	Term 2	Term 3 Term 4	Term 5	Term 6	Term 7	Term 8
0	. 9	MA 213 Calculus III	EE 415G Electromechanicstr	EE 468G htro. to Engineering Ele_		
0	-9/	PHY 752 PHY 752 eneral University Physic AC Circuits	EE 421G Signals & Systems	0.	m	(3)
PHY 231 al University Phys	MA 114 sic. Calculus II G	PHY 242 PHY 242 Feneral University Physic	0	0		
0	.0	EE 211 Credits.	B EE 461G Intro. to Electronics	w		
9	0	centrality: 112 complexity: 13 blocking factor: 5 delay factor: 8	9.	0	(1)	
MATI3 Calculus I	Complexity: 28.0	Complexity: 64.0 Complexity: 28		Complexity: 12.0	Complexity: 7.0	
omplexity: 52.0			Complexity: 30.0			Complexity: 7.

#### www.CurricularAnalytics.org Tour

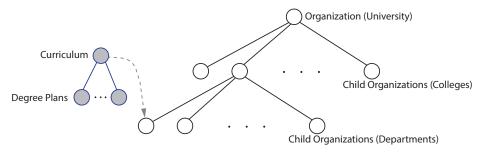




# Web App – Organizations



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.

## Curricular Analytics: Practice



#### 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

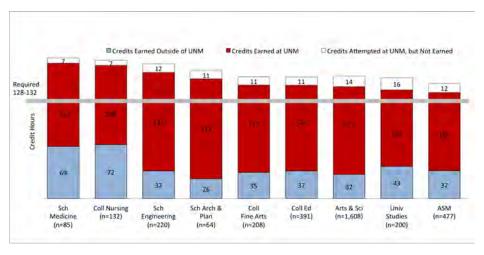
- Collected the degree plans associated with all programs at all institutions of higher education in the State of Kentucky (see: KYDegreePlans.com.
- Statewide ability to compare and contrast curricula.
- Ongoing work to create an automated transfer articulation system using degree plan optimization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

# Curricular Study: University of New Mexico

#### Excess Credit Hours



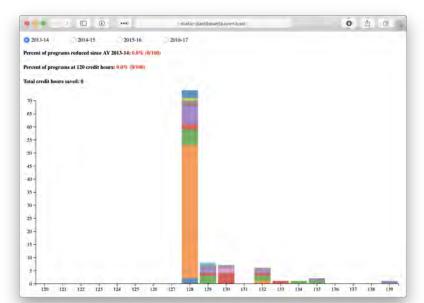
#### Avg. credit hours, UNM bachelor's recipients, 2011-12 AY:



## Reduction in Program Credit Hours



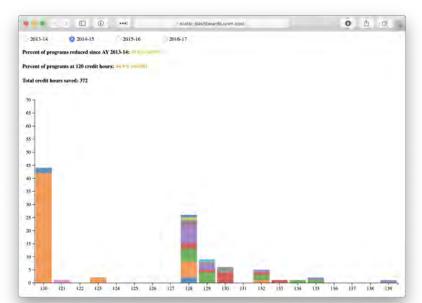
#### University of New Mexico —



## Reduction in Program Credit Hours



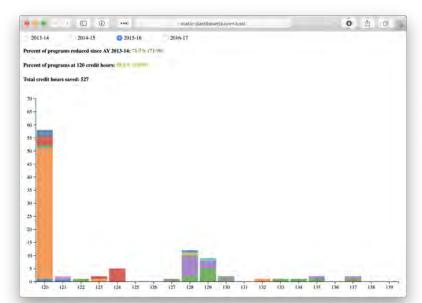
#### University of New Mexico —



## Reduction in Program Credit Hours



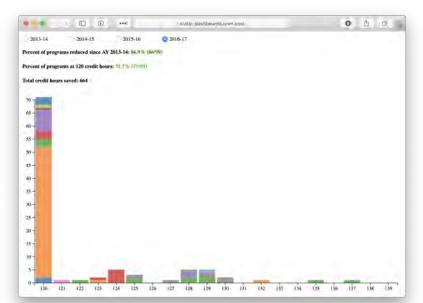
#### University of New Mexico —



## 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:  $12.6\% \rightarrow 35\%$ 

$$\sim$$
 300% 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

# Complexity vs. Quality



- 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.



Curricular Comp	olexity: 118.0 Term 2	Term 3	Term 4	Term 5	Term 6	Term 7	Term 8
(1) CHEM 2090	-(10) PHYS 1112	9 PHYS 2213	PHYS 2214	(1) ECE FOUND	ECE FOUND	CDE	ECE ELECT
15 MATH 1910	12 MATH 1920	8 MATH 2930	5 MATH 2940	5 ECE 3400	ECE FOUND	ECE ELECT	ECE ELECT
(1) ENGRI	G CS THIX	6 ECE 2100	ENGRD 2XXX OUT	TSIDE ECE TECH EDI	TOSIDE ECE TECH EA	TECSIDE ECE TECH ELI	ECT ECE ELECT
() PE	WRITING SEMINAR	ECE 2300	S ECE 2200 ADV	ISOR APPROVEDABLE	1) SESTOR APPROVED E	LECTLiberal Studies	Liberal Studies
WRITING SEMINAR	(i) PE	1 Liberal Studies	1 Liberal Studies	(1) Liberal Studies	1) Liberal Studies	Complexity: 4.0	Complexity: 4.0
Complexity: 19.0	Complexity: 30.0	Complexity: 28.0	Complexity: 19.0	Complexity: 9.0	Complexity: 5.0	1	



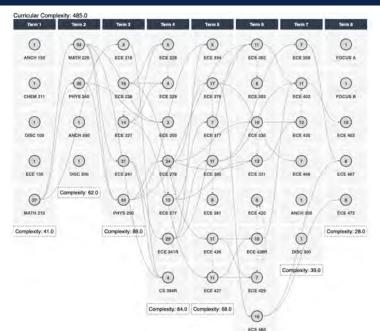
Curricular Comp Term 1	lexity: 118.0 Term 2	Term 3	Term 4	Term 5	Term 6	Term 7	Term 8
9	PHYS 1112	9 PHYS 2213	PHYS 2214		(D) positions	0	
MATERIAN	MATH 1920 Credits: 4	8 MATH 2930	MATH 2940	ECE 3400	(i) Extrans	9	(3) January
centrality: 0 complexity: 15 blocking factor: delay factor: 5		ECE 2100	4 ENGRD 2XXX	0	0	0	
0	0		ECE 2200		0	0	
0		0	0	0	(D)	Complexity: 4.0	Complexity: 4.0
Complexity: 19.0	Complexity: 30.0	Complexity: 28.0	Complexity: 19.0	Complexity: 9.0	Complexity: 5.0		

Curricular Complexity: 118.0



Term 1	Term 2	Term 3	Term 4	Term 5	Term 6	Term 7	Term 8
0	PHYS 1112	9 PHYS 2213	-O		0	0	(D) menor
(15) MATH 1910	MATH 1920	8 MATH 2930	2	ECE 3400			(a)
	0	ECP\$100	MANAGE EN STORE D	0	0	0	0
0	0	centrality: 15 complexity: 6 blocking factor: delay factor: 5	Credits: 4	0	0	0	0
	0	D	0	0		Complexity: 4.0	Complexity: 4.0
Complexity: 19.0	Complexity: 30.0	Complexity: 28.0	Complexity: 19.0	Complexity: 9.0	Complexity: 5.0		







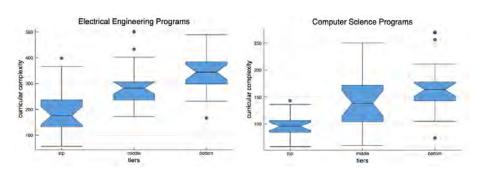






# Complexity vs. Quality





- 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 → 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
  - 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).

- South Dakota State University
- University of Idaho
- University of Nevada-Reno
- University of Wyoming
- Utah State University

## 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

MECH 338 -> MECH 498B

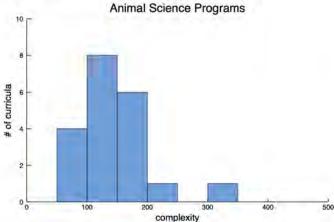


#### Colorado State University, Curriculum: Mechanical Engineering credit hours = 129. number of courses = 39Blocking Factor entire curriculum = 143max. value = 26, for course(s): MATH 160Centrality entire curriculum = 680max. value = 81, for course(s): PH 141 Delay Factor entire curriculum = 176.0max. 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 = 319.0max. 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 ->

# Intra-Group Curricular Complexities

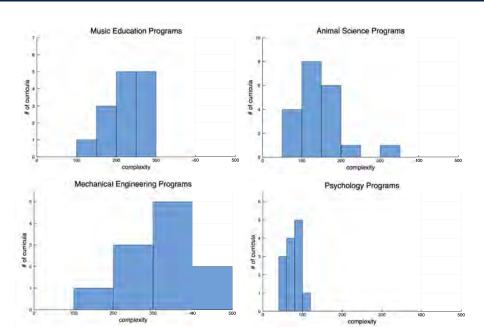


```
Metric -- complexity
Number of curricula = 20
Mean = 139.25
STD = 13.248702766686254
Max. = 306.0
Min. = 71.0
```



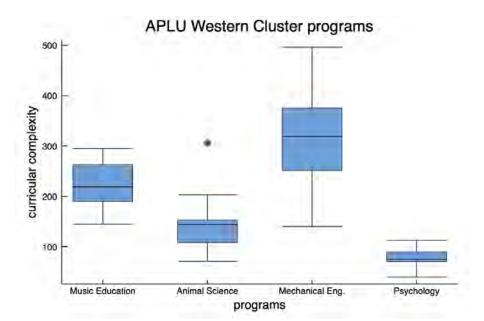
# Inter-Group Curricular Complexities





# Inter-Group Curricular Complexities





#### CSU Provost Guidance



#### 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

# Curricular Analytics: USF College of Engineering



- 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.



rriculum: BSCP-Com gree Plan: ECP-CALC ol Credit Hours: 120	C+CHM ready							
ncular Complexity: 4 Term 1	Term 2	Term 3	Term 4	Term 5	Term 0	Term 7	Term 8	Term 9
MAC 2381 mirresting Colculus V	MAC 2282 Ensireming Calculas II	UAC 1283 Engineering Colculus III.	COA 3103 Compage Organization	CDA 3/201 Computer Loyic and Desi	COT 4400 an Abgryss Of Algorithms	COA 4203 Concouter System Design	CDA 4213 CMOS-VLSI Desimi	CJS 4250 Ethicul issues And Po
A or CHS 2005 or 2440 ered Chemistry I (for	FNC 116Z Compesition II	Proy Zoko Demond Province II - Colo	AGES State Hamonities Cen Ed	CUP 45:36 Eatly Structures	Shi 420; Congular Architecture	Englanding Economics with 1	ENC 3248	CSS blaction
Contract I	Phyr 2048 seneral Physica I Calca.	- Car 1534 Frigran Design	COT 11.05 Introduction to Discrete :	EEN 4440 UNICODATION TO LINOW SY	ASS 135A Electronic Moterlais	con aton Constend Systems	CCN YAAT Prisonelty and Statistic.	CITS 4910 Completer Science and
or CHS 2045L or 2440L and Chamilistry ( Labor	COP 2516 From arm in Concepts	PHY 2048L General Physics I Labora_	EON or MAP 3423 or 2382 Modeling and Amotycle ofC	CDA 3201L- computer Largic and Design	EGIF 23.75 n. Infreduction to Electrica.	CSE Handware Elective	CSE Election	1
FICH TOTAL FICH TOTAL Intelligence of Engineerin _ G	PITY 2048 Prey 2048 Impries I Laborat	State Social Science Gen _	DDP 3531 Object Oriented Software	Complexity: 43.0	CSE Hardware Declary	CDA 47-EEL Computer System Design Lo.	CNOS-VLSI Design Leis	Complexity: 18
(QN 1000 Outliens of Engineerin	Complexity: 112.0	Complexity: 59.0	Complexity, 54.0		Complexity: 32.0	Notural Sci Electiva	Complexity: 29.0	
Enmplexity: 49.0						Complexity: 340		

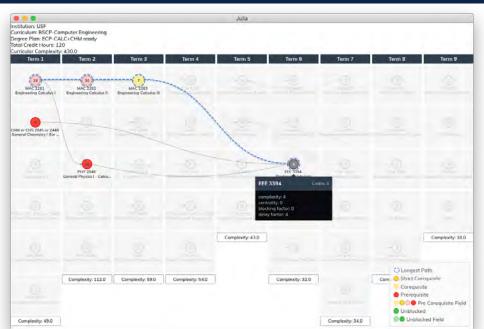




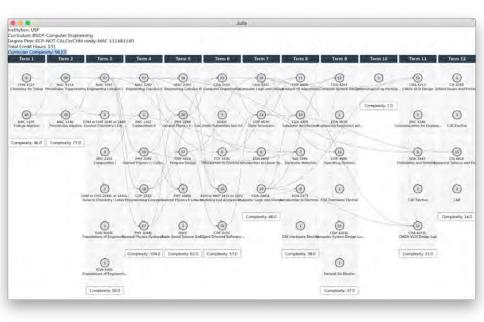




















# Electrical Eng Program – Math Prepared



itution: USF neukum: BSEE-Electrics prie Plan: EEL-CALC+C si Credit Hours: 128									
Term 1	Term 2	Term 3	Term 4	Term 5	Term 6	Term 7	Term 8	Term 9	Term 10
MAC (28)	Mic 1283 Depositing Delating 9	ANC 2281 Engineering Calculus III	(S) 100/207 Introduction in Electron.	EGN 3174 Introduction to Sincerbos.	III. FEETIN	EX Core Tradescal Corp.	(3) Helipping Co-sp Portogo.	ES Design 1	III Proget 7
CHINCHO JOHNJAMO	Tomposition 6	Use have been a family of	(II) MAP EPEL	TOT SALE Transactivy and Contact		DI Core Tribbinos Director.	Complexity: LS	Oppositional Department (II	0
BWC LIFE Companies	Per 2048 Description 1 - Colo.	III IIIA December Degreeming St.	BILL SMITTE Demonstration of Sec.	EGN MES.	(I) Core Technool Gents-	(S) (If Small Families		(5) (5) Invite Gentler	(i)
S HARLSHS ZONNYJANIZ. COST COMMUNICATION	Print JOAN. Committed Propriets I Laborate.	Total Print. Processor Asia, of Copped C.	(3) Programmi = (8) I	Complexity: 12.0	PIL 4101/ Signal and Systems	(3) Id Took Factor		(3) (6) Truck Gentleri	(3)
O STATE LINES.	The Street Property Co.	GEN State Number State Still	THIS JOHE Protestional Formation of		HI MARKE Designation Treat Liab	to Track Deploys last		Di Trouk Directory Lab	0
FOR 2000 method of Cognosting	Complexity 29.0	Complexity: 28.0	Complexity 34.0		THE TOTAL CONTRACT			Upon Front Common III.	O Today
Complexity 31.0					WA 2011 Professional Tomoston In.	(1) Upper-Level Department EL.		Companity, 8.0	Compressity: 7.5
					Complexity: 23.0	Complexity: 9.0			

# Electrical Eng Program – Math Prepared





# Electrical Eng Program – Not Math Prepared



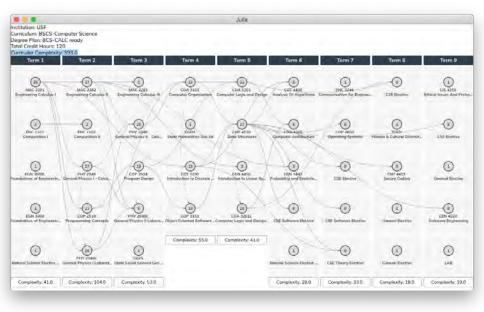
oution: USF						hilo						
oution: USP evulum: BSEE-Electrical Er ee Plan EEL-NOT CALCO I Credit Hours: 142 cular Complete by 351.0 form 1	rCHM rego		Term &	Term S	Term 6	Term 7	Term 0	Tirm 9	Trem 10	Term 11	Term 12	Term 13
OH DRES SHEET COMMEN	200	(B) MACTEM	MAC (1991 A September 1	BAC 2781 Englacemy Course 8	MIE (2HI	(G)	ENDY MATE	BH. 18150	GI Core Sentential Standard	①	Est. 1906 Ut Design 1	III. ones
Complex Comple	es; 27 0.	IN LINE PROPERTY AND ADDRESS OF THE PARTY AND	ONLOW ZONG AND	OF US	Gar sales Proposering Analysis	(B)	(SAY) MAG	(E) Comp Technology Election	El Care Technical Forces	Complexity, 10	0	(a)
quenty 3%0		Company 510	SNC 195E Composition 1	Prof 3088 second Physica 1 - Coles.	(a)	IL MAN SATIONAN - 20	EL BANKS	(I) Mail Core Tradescol Sortio	(I) Dock Electron		(I) (I) Truck Blockey (A)	0
			Commence of the Control	O Providence of the Control of the C	- (1) III. 37004	m zne	Complexity 204	(I) (II) A 1777 (III) A 1777	(I) (I) Year (I)		(I) has form	0
			TOA SONS	ED. 3100 STORAGE OF TOWNS C	Souni Souni	SOL 2500	1	to use	(E) The Street Street Code		ER York Frontier, Lab	0
			EGN 2000	Complexity: 41.0	Complexity: 40.0	Complexity 46.0		O Des	USS 1071		①	0
			Consisting 94.0					O SEALERS	(i)		Complexity BIT	Complexity
								Complexity 300	Complexity II.C			

# Electrical Eng Program – Not Math Prepared











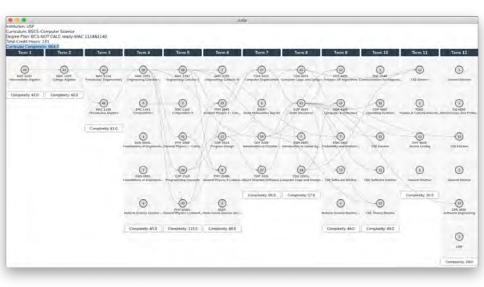






# Computer Sci Program – Not Math Prepared





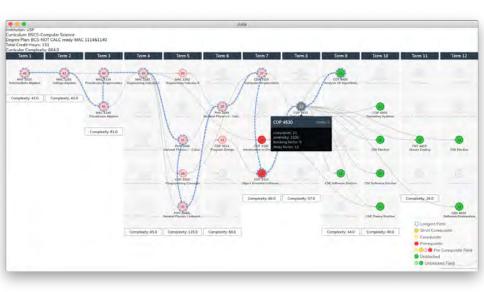
## Computer Sci Program – Not Math Prepared





# Computer Sci Program – Not Math Prepared





# USF College of Engineering



#### 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



Curriculum: Circuits I Design Pattern Degree Plan: Calculus ready

Total Credit Hours: 25

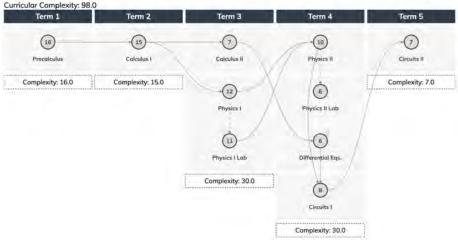
Curricular Complexity: 75.0 Term 2 Term 3 Term 1 Term 4 Calculus II Calculus i Physics II Circuits II Complexity: 14.0 Complexity: 6.0 Physics I Physics II Lab Physics I Lab Differential Eas. Complexity: 28.0 Circuits I Complexity: 27.0

#### Curricular Design Pattern – Precalculus Ready



Curriculum: Circuits I Design Pattern Degree Plan: Calculus ready

Total Credit Hours: 29

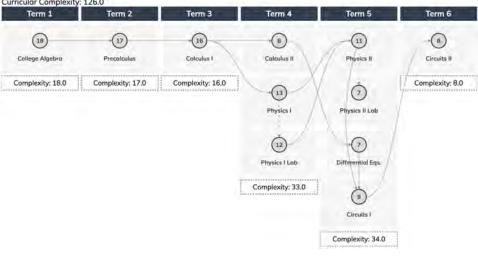


# Curricular Design Pattern – College Algebra Ready 🕮 of ARIZONA

Curriculum: Circuits I Design Pattern

Degree Plan: Calculus ready Total Credit Hours: 32

Curricular Complexity: 126.0

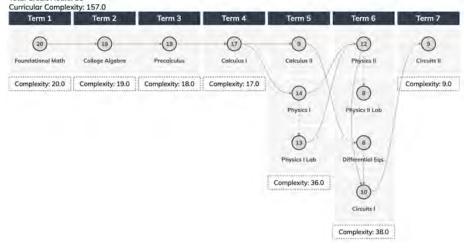


#### Curricular Design Pattern – Foundational Math



Curriculum: Circuits | Design Pattern Degree Plan: Calculus ready

Total Credit Hours: 35



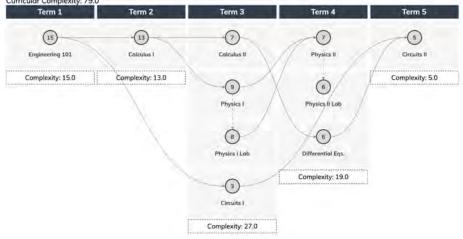
#### Curricular Design Pattern – Engineering 101



Curriculum: Circuits I Design Pattern Degree Plan: Calculus ready

Total Credit Hours: 29

Curricular Complexity: 79.0



#### Curricular Design Pattern: Simulation



#### **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



ditation: USF medium: BSEE-Electric gree Plan: EEL-CALC+I tol Credit Hours: 128 mission: Complexity: 18 Terms 1	CHM ready	Term 3	Term 4	Term 5	Term 6	Term 7	Term 8	Term 9	Term 10
MAC 2281 Engineering Consulty (	MAN THE DESCRIPTION OF THE PERSON OF T	AMIC EQUI Engressing Calcula, III	(II) 100/3171 Introduction in Districts	EGN 2524 Introduction to Electrica.	Int. Filth	EX Care Transcent Seaton.	(3) Interpologica de Perroqu	(I)	(1) (1) 41)4 (1) Openin 2
CHINCHO SOMIVEMED	THE LINE	BAN BAS Department Amount	WF INII	Title SALE Transactive and Suppose.	0	(I) In the Telephol Rects.	Completely LS	(a)	0
EMC LIST.	Provi 2048 Control Proposit 1 - Colo	HIS INA Discussed Exponency St.	IN 1975 Decrease becomes Sc.	I SON METS. Engineering Engineering will.	(If Case Technood Gards	if the further		(If these Gorthei	(S)
MARINE EDWINSON	PHY JUNE. Segretal Physics I Laborat.	Turning of Organic C.	THE TANK I	Complexity 12.0	TIS, 4102/ Signal mort Septemen	(a) Id backfurthe		(3) (6) Treak Similari	(3) Income limited
STAN SECONOMINA	The Street Translation of Display Translation	Cape Management San Mil	gilla Jeste Pyolegiacod Formalion of		- (2) IBL SERVE Democrate Tree Lade	(1) In Total Develop Jale		(b) (b) Thesis Directory Lab	(i)
EGN 2000 paratitude of Engineering	Complexity 29.0	Complexity: 28.0	Complexity: 34.0		THE TOTAL CONTRACTOR	100 mg		Upper I and Description (II.	G)
Completely 31.0					WA 2011 Professional Formacian M.	(1) Opport Cover Department Co.		Companity: 8.0	Composity: 7.
					Complexity 23.0	Complexity: 9.0			

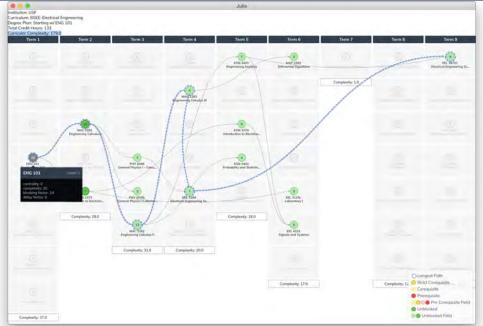


0	(6)	0	0	99	0	@	0	0	0	0	(E)
								Eli Corp Technolog Stemps	annesty Co. of Parkit		EX Deside
Complexity; 27.0.	MARC 1340) Promission Algebra Ga	Osacon zorużaci com Com zorużaci	Dec 1223	Can Mas Frequenting Analysis	MOP 2163 Differential Equation	(SAY SAG) Franchisty and Dississe	/E Core bashesed tierte	(I) Ope Technical Forms	Complexity, 1.0	0	(1)
	Complexity 610	SNC 165E Composition 1 on	Profit School Profit School	(a)	Limer Sarziczskii - 254 Domon Baylanii - 354	E HAN BEEN	(I) Mail Core Truchescol Search	If Peak Discour		EX Truck Blockiny May	0
	9	(I)	Prior Zhang med Physica I Laurence	III. JOHN	m. 7015	Complexity 200	III. 4557 Separate and Systems	(I) (I) Youk (Issue)		(II) (III hash Florense	0
	14	(I) 10h 10xx	ID. 3700	50001	303.200		Em. Lient	(E) Treed Pleasable Loads		(E) Track Floation Lab	(1)
		G EGY 1000	Complexity 41.0	Complexity: 40.0	Complexity 45.0	١,	(1) (1) (1) (1) (1) (1) (1) (1) (1) (1)	1005 10074		<u>()</u>	O Suda
		Consisting M.D.					(S)			Complexity BIS	Complexit
	College Andrews	Auto-Classes National Processing Proceedings of the Computation of the	Wild Title  Wild T	Supplements of the control of the co	UNC TAIL MC TA	Complexity, \$2.50  Section proteins processing Segmentary Conducts Segment Segme	We Case 1 May 124 (1997)  Completely 1270  We Case 1 May 124 (1997)  W	SUPC TEST MACK T	Side Class   Mod 251   Mod 252   Mod	We file 1 Me (2) 1 Me	SUCTION SUCTIO

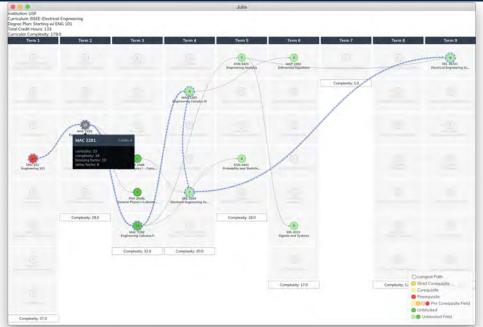


Term 3	Term #	Term 5	Term 6	Trem 7	Term 8	Term 9
103 3673 Produced Port of	Esta 1615	FISH SASS Bases Assessed	S MAY 2352 Differential Countries	(1)	Union Lavel Experiment PL	BILL MAZE Sireful diregioning
Programming solar C	Succession Contains in	(I) Et Care Serbergel Eberle.	(3) Hepot Level Discontraved M.	Complexity: L0	Fool Mari	(3) Napor Level Departmen
ANG TITLE	(I)	(S)	(I) Data District		El Cost Technologi Baselo	100, 3200A.
Cemel Physics - Celebra	Gr. Tomb Chesters	ESh 1441 Franchity and Outres	(3) (8) York Street Latt		Day, efforts, all Constant C	ER Design 2
Per Male Green Provid Fullows	UP 1914 Absorbed from sering Sc.	Ecol 30005 Fourthfolios at Taggeterre	EST 1156 Indiceptory I		Usang-Lorent Uniquentical pt SL.	(3) Elit Transil Eliterature So
MAC 2282 Ingineering Colonies E	CORNECT SOME CARD	Compressity 18.0	Ett. 4102 Septiment and Explains		EEL DESIGN Companier Total Links	(3) NE Truck Education
Complexity: 12.0	Complexity 20.0		IX Tours Electrics		El Cree Technical Cherin.	0
			Complexity 17.0		Complexity 12.0	Complexity, \$4.0
				III Theor Edicates	III Burst Electron	III has literas III Con National Gentu-







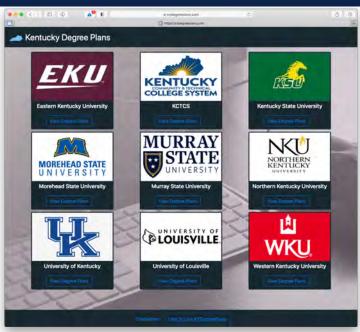


#### Kentucky Council on Postsecondary Education

**Curricular Study:** 

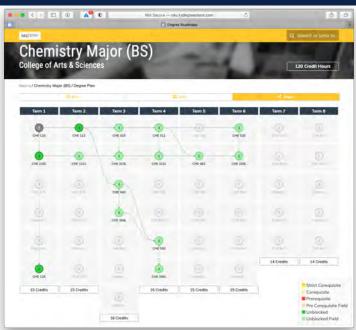
#### Statewide Degree Plans





#### Statewide Degree Plans



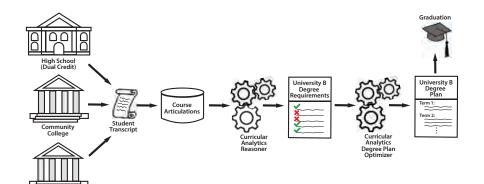


#### Statewide Transfer Articulation



#### The overall process flow:

University A





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.



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.



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."



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



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



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



All of these student deserve degrees adapted to their individual needs



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.

#### Personalized Plans



**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 -

#### Problem Specification -

$$\min f(x)$$
, 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 Comp	lexity: 319.0						
Term 1	Term 2	Term 3	Term 4	Term 5	Term 6	Term 7	Term 8
5 CHEM 111	(22) MATH 161	(2) CIVE 260	CIVE 281	CIVE 360	MECH 361	MECH 402	MECH AREB
(5) CHEM 112	14 MECH 105	MATH 201	6 ECE 204	MECH 307	(§) MECH 325	ELECTIVE 1	MECH 408B
CO 150	28 PH 141	MECH 300	(15) MATH 340	(B) MECH 324	MECH 331	AUCC 3E	ALICC 3D
MATH 160	(1) AUCC 38	MECH 201	MECH 202	(1) MECH 342	MECH 338	AUCE 3C	TECH BLECTIVE
14) MECH 183	Complexity: 65.0	10 PH 142	€ MECH 231	Complexity: 31.0	MECH 344	TECH ELECTIVE	TECH ELECTIVE
Complexity: 58.0		Complexity: 53.0	10 MECH 337		Complexity: 32.0	Complexity: 10.0	Complexity: 17.0

Complexity: 53.0

#### Example Plan – Baseline



#### 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,  $\theta_i =$  number of credit hours in term i.

# Balanced Curriculum Objective



Term 1	Term 2	Term 3	Term 4	Term 5	Term 6	Term 7	Term 8
TECH ELECTIVE	28 PH 141	AUCC RE	(15) MATH 340	CHEM 112	MECH 202	AUCC 3C	MECH 402
TECH ELECTIVE	- (22) MATH 161	17) MATH 261	10 MECH 337	6) ECF 204	(7) CIVE 360	(E) MECH 301	AUCC 3B
33) MATH 160	(1) CO 150	14) MECH 105	10) PH 182	11) MECH 342	6 MECH 344	7 MECH 307	5 MECH 325
AUCC 3D	ELECTIVE 1	12 CIVE 260	(7) CIVE 261	€ MECH 324	8 MECH 231	6 MECH 331	→ (7) MECH 4868
14 MECH 103	Complexity: 52.0	1 TECH ELECTIVE	Complexity: 42.0		9 MECH 338	7 MECH 498B	Complexity: 19.0
Complexity: 50.0		Complexity: 45.0		MECH 200	(5) CHEM 111	Complexity: 27.0	
					Complexity: 42.0		

## 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.

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

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

 $T_i = \text{term that course } i \text{ appears in the plan.}$ 

## Requisite Distance Objective



Term 1	Term 2	Term 3	Term 4	Term 5	Term 6	Term 7	Term 8
AUCC 3E	AUCC 3C	17) MATH 261	6 ECE 204	MECH 202	MECH 301	B MECH 402	→ (7) MECH 486B
TECH ELECTIVE	28 PH 141	14 MECH 105	CIVE 260	5 CHEM 112	MECH 307	AUCC 3B	CO 190
TECH ELECTIVE	(22) MATH 161	10 PH 142	8 MECH 231	CIVE 360	11) MECH 342	MECH 325	ELECTIVE 1
(33) MATH 160	AUCC 3D	Complexity: 41.0	10 MECH 337	15 MATH 340	6 MECH 324	6 MECH 344	7 MECH 498B
TECH ELECTIVE	14) MECH 103		6 MECH 201	CIVE 261	6 MECH 331	MECH 338	Complexity: 16.0
Complexity: 37.0	Complexity: 66.0	0	0	0	Complexity: 36.0	Complexity: 27.0	6
			MECH 200	CHEM 111			

## Requisite Distance Objective





## Example Plan – 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

## Multi-objective Optimization



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

# Requisite Distance and Balance Objectives



Term 1	Term 2	Term 3	Term 4	Term 5	Term 6	Term 7	Term 8
TECH ELECTIVE	28 PH 141	17) MATH 261	(5) CHEM 112	MECH 202	MECH 301	MECH 402	AUGC 3C
AUCC 18	22 MATH 161	MECH 105	(12) CIVE 280	6 ECE 204	7 MECH 367	5 MECH 325	AUCC 3E
33 MATH 160	14 MECH 103	10 PH 142	B MECH 231	7) CIVE 960	11) MECH 342	MECH 344	→ (7) MECH 486B
© CO 150	ELECTIVE 1	(5) CHEM 1311	10 MECH 337	15 MATH 340	6 MECH 324	TECH ELECTIVE	TECH ELECTIVE
Complexity; 36.0	Complexity; 65.0	Complexity: 46.0	6 MECH 201	CIVE 261	6 MECH 331	AUCC 3D	7 MECH 4988
			+ 8 MECH 200	Complexity: 42.0	Complexity: 36.0	9 MECH 338	Complexity: 17.0
			Complexity: 49.0			Complexity: 28.0	

# Requisite Distance and Balance Objectives





# Example Plan – Requisite Distance & Balance Objection Burden Stone

#### 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?