

What goes through the mind of a faculty member who wants to revamp an entire chemistry curriculum?

https://z.umn.edu/xavier_umr

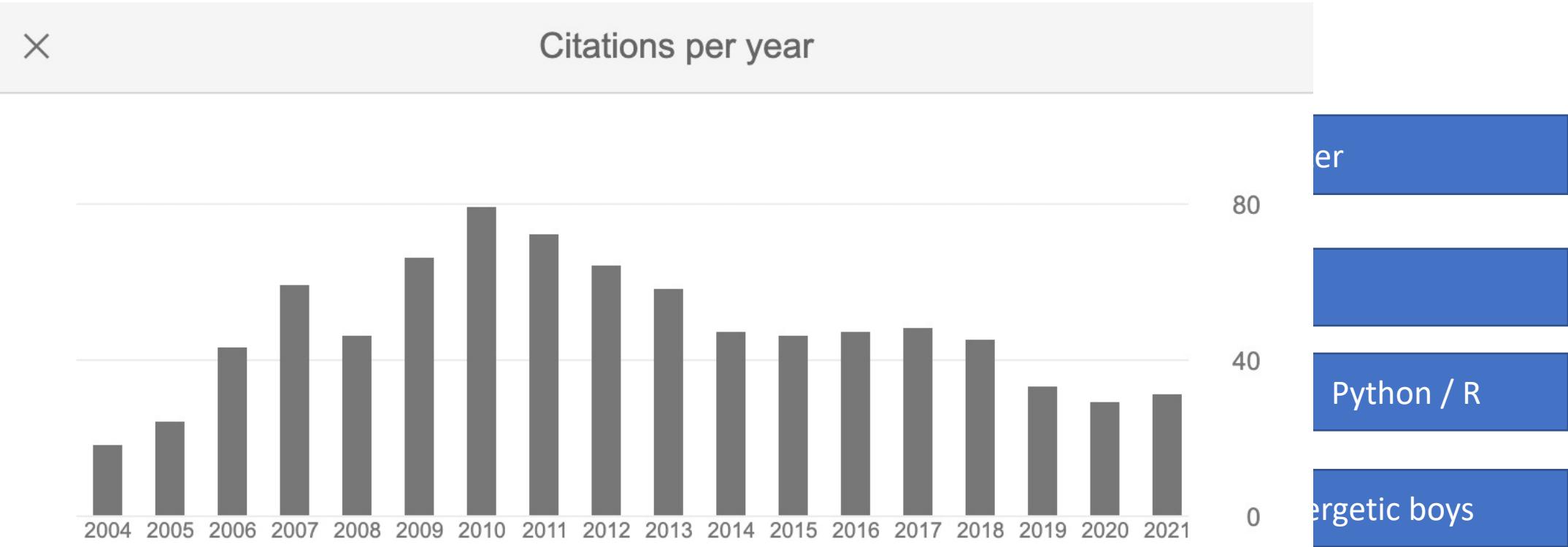
Post-tenure presentation
May 10th, 2022
Xavier Prat-Resina PhD,
Associate Professor



Xavier @ UMR - in a nutshell



1998-1999 Master of Sc Comp Chem Bologna Italy	1999- 2004 PhD in Physical Chemistry Barcelona Catalonia	2005-2006 Post-doc Enzyme simulation UW Madison	2007-2009 Post-doc II Web Chem Education UW Madison	2010 Assistant Professor Teaching GenChem and Biochem @UMR	2018 Associate Professor Revamping the curriculum
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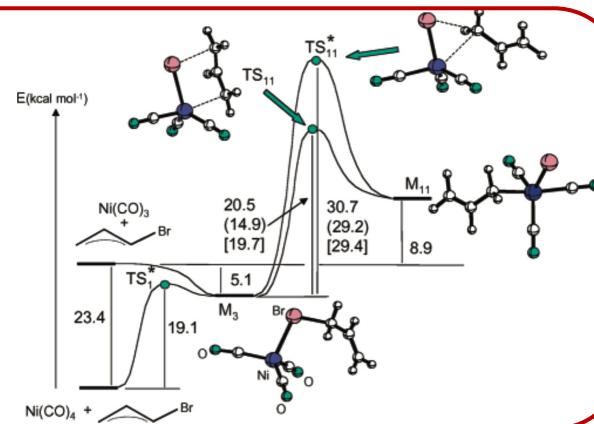
Master of Sciences at Università degli Studi di Bologna in Italy and Universitat de Barcelona:

Topic: Computational study of carbonylation of alkyl halides reactions by Nickel complexes

Method: Running DFT level calculations to find minima and transition states of the mechanism

Representative Publications: Organometallics, 19(11):2170-2178, 2000.

J. Am. Chem. Soc., 125 (34):10412-10,419, 2003.



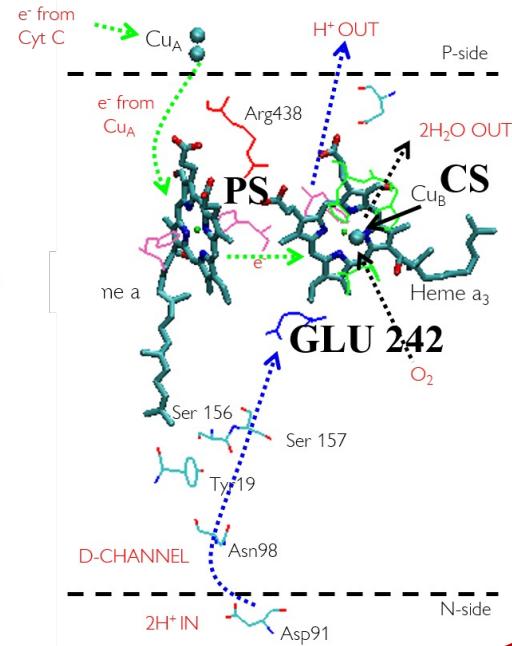
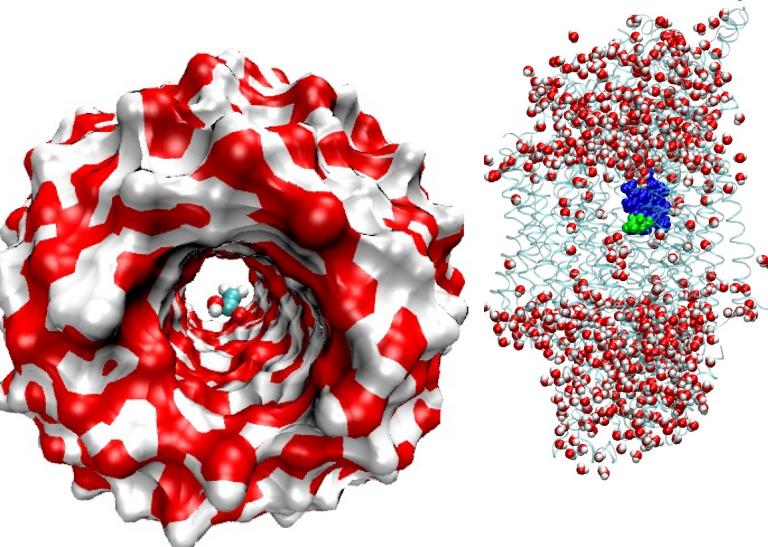
PhD at Universitat Autònoma de Barcelona in Spain and **post-doctoral** at University of Wisconsin

Topic: Development and implementation of QM/MM computational models to study enzymatic catalysis

Methods: Designing algorithms for optimization of biomolecular structures. Coding in Fortran. Free energy and statistical methods to study enzymatic catalysis. QM/MM potentials. Membrane bound proteins.

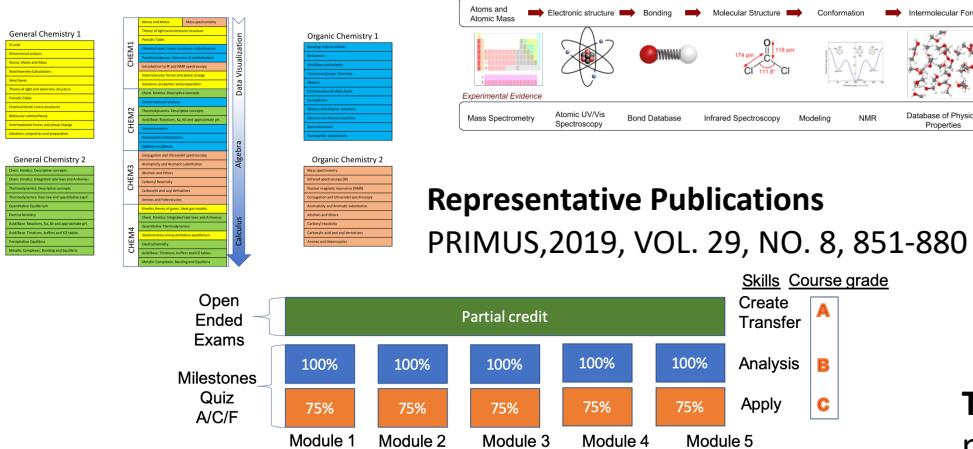
Representative Publications

- J.Phys.Chem.B, 109 (44): 21089-21101, 2005.
J. Am. Chem. Soc., 126 (5):1369-1376, 2004.
Int. J. Quant. Chem., 98 (4):367-377, 2004.
Biochemistry, 48 (11): 2468-2485, 2009
J. Am. Chem. Soc, 128, 16302-16311, 2006
J. Phys. Chem. B, 110 (13):6458-6469, 2006 Featur



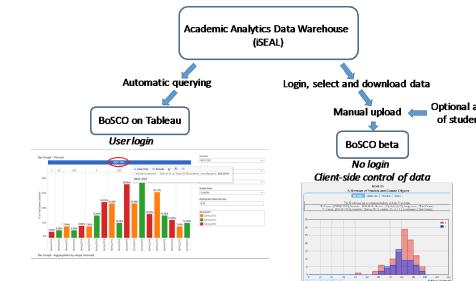
Curriculum Innovations

Topic: Merging General and Organic Chemistry. Postponing math and introducing spectra. Assessing Low and High order cognitive skills with specifications grading.



Design of Learning Analytics Tools

Topic: Developing and implementing learning analytics platforms for assessment and curriculum design

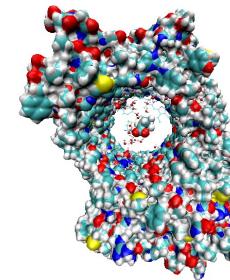


Representative Publications

J. of Learning Analytics. 3(1), 220-240, 2014

Computer Simulations of Enzyme

Topic: QM/MM simulations of enzymatic reactions catalyzing hydrolysis of carbohydrates. Using molecular dynamics and statistical mechanics approaches to calculate free energy pathways.



Representative Publications

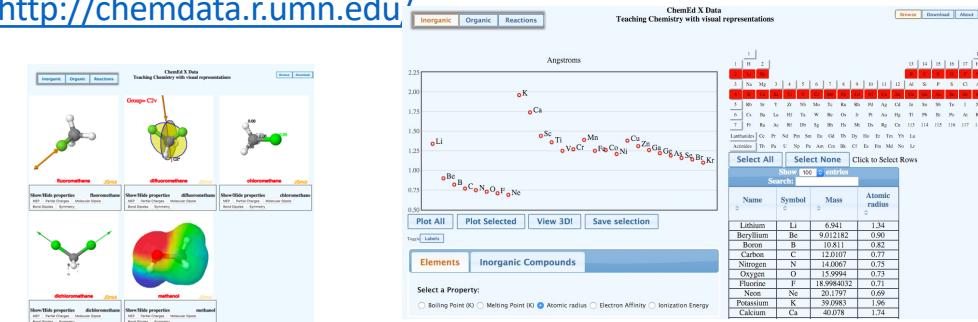
Comp & Theo Chem. 966 (1-3), 159-166, 2011
Proteins, 78(7):1774-88, 2010

Glycosylation Mechanism of Resveratrol through the Mutant Q345F Sucrose Phosphorylase Enzyme: a Computational Study. Submitted – April 2022

Design of interactive webs for chemistry learning

Topic: Using Cheminformatics tools to generate databases of physical and chemistry data. Design and assess interactive sites for data-driven exercises and high-order cognitive skills.

<http://chemdata.r.umn.edu/>



Representative Publications

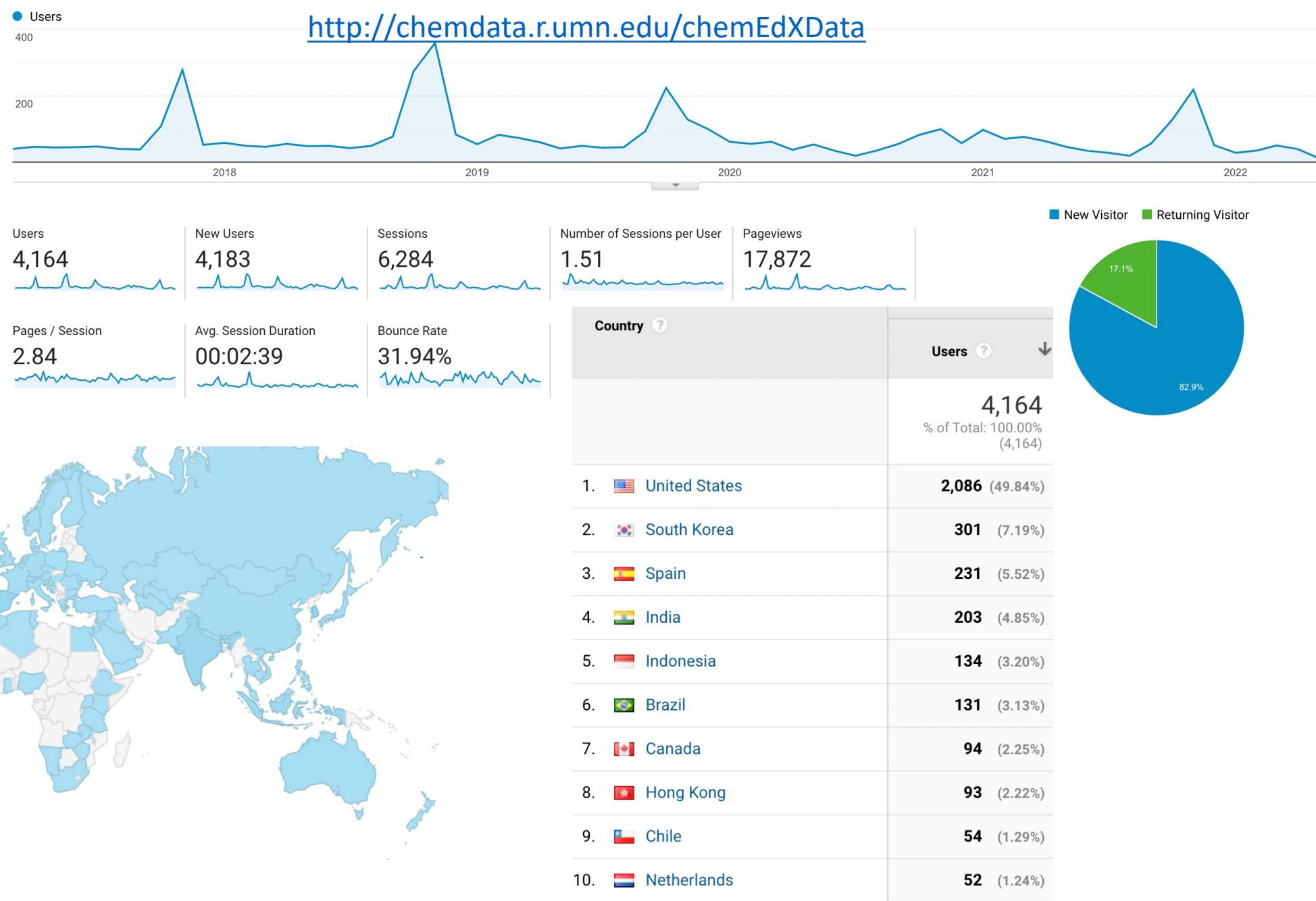
Chemistry Teacher International, 1(1). 10,2018

J. Chem. Educ., 91(9), 1501-1504, 2014

<https://github.com/xavierprat>

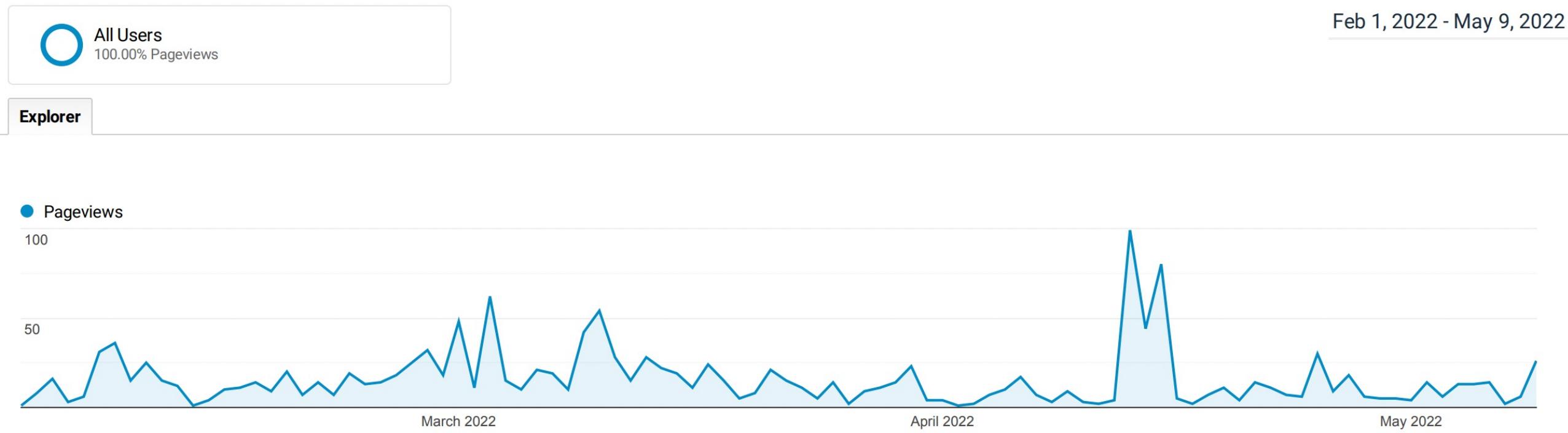


ChemEd X Data usage



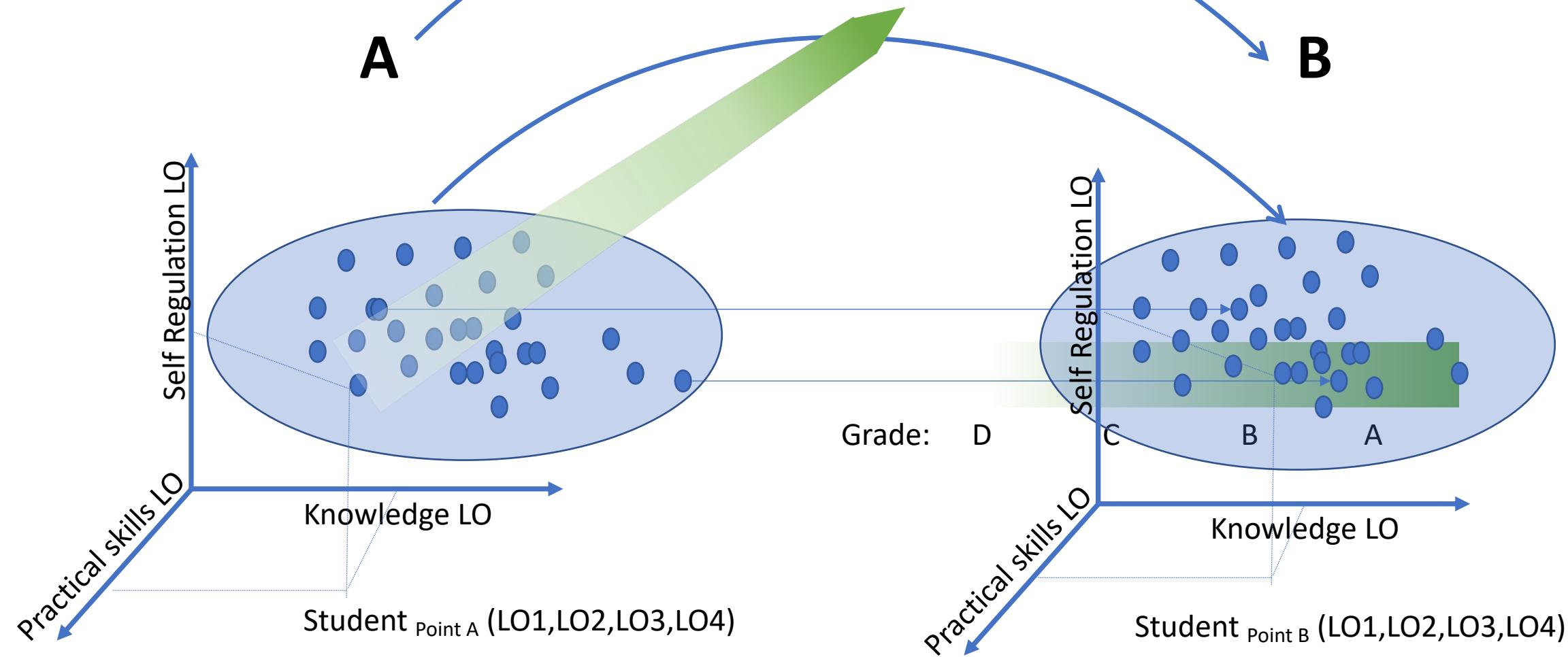
Models360 usage

<http://chemdata.r.umn.edu/models360>



What is student learning?

15 weeks?



The growth triangle



The questions that I want to answer in this talk are
→ How we can design courses to promote growth
→ How to identify the growth variables
→ How to help students grow in all directions

Practical skills:

Showing up to class on time

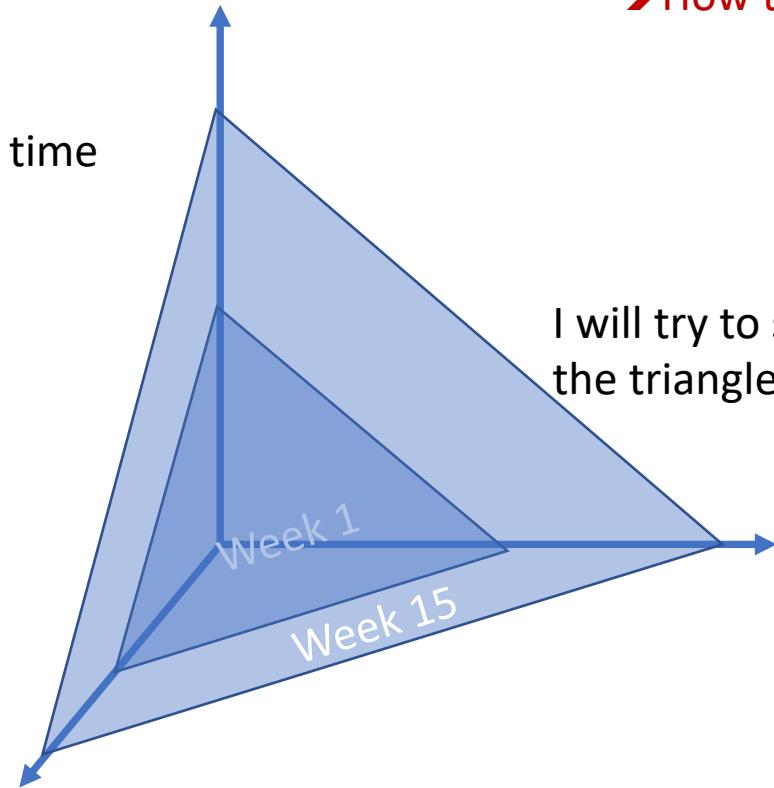
Respectful

Relatable

Interact/help others

Note taking

Time management



I will try to show that for student success,
the triangle must grow proportionally in all directions

Knowledge:

Chemical Bond

Chemical Structure

Chemical Reactivity

...

Self regulation:

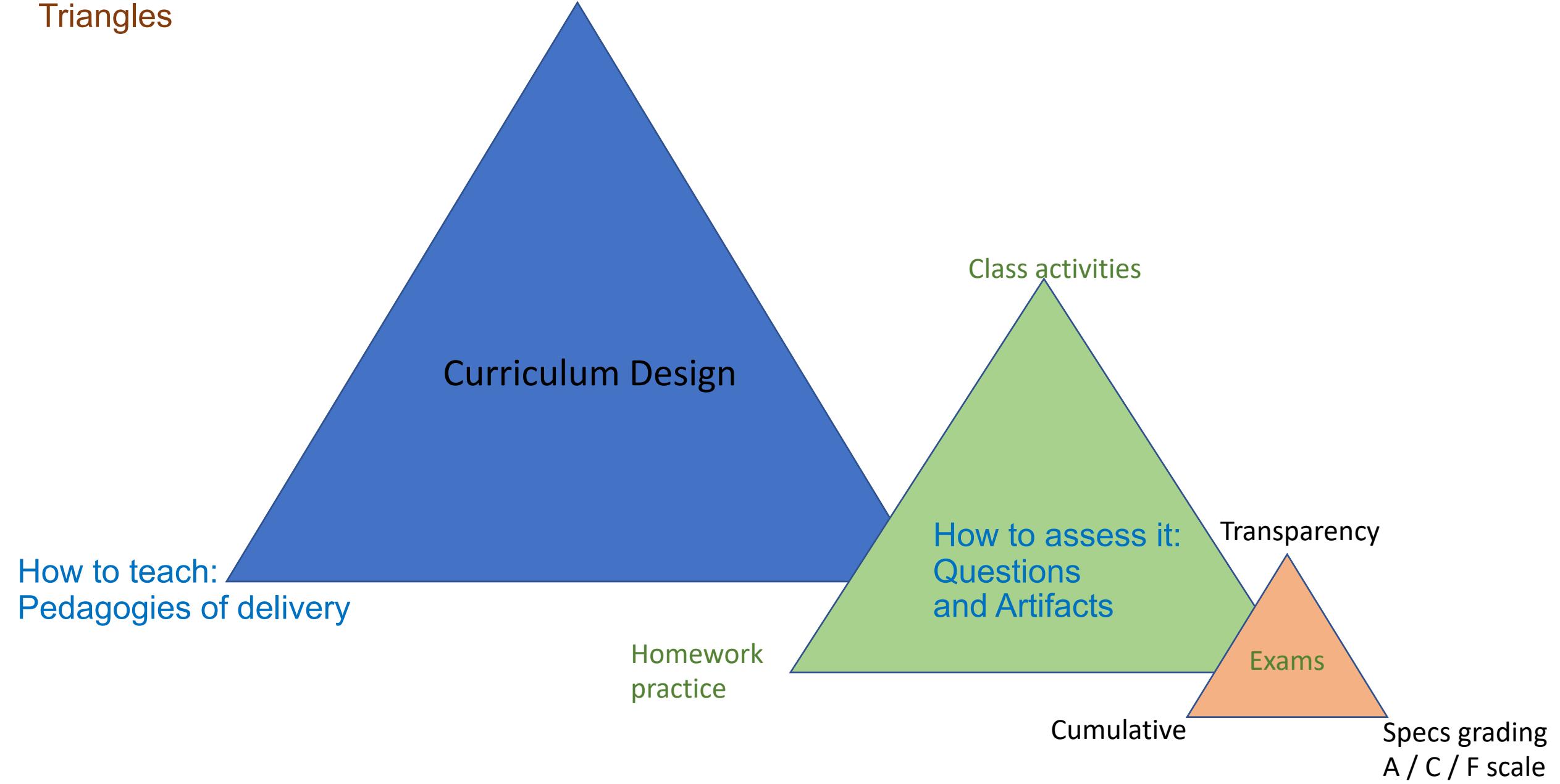
Studying skills

Self-awareness of learning

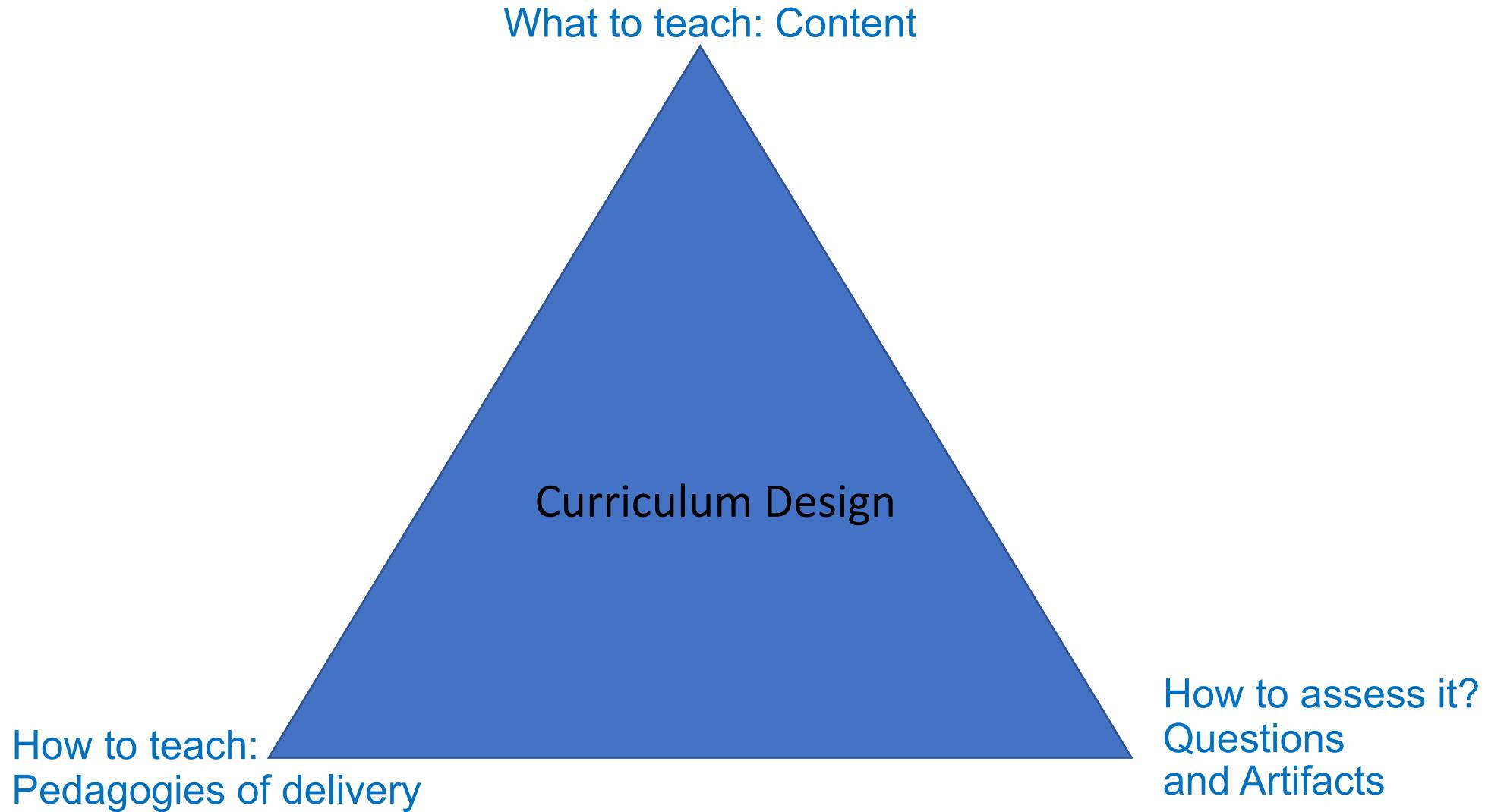
Resilience

What to teach: Content

Triangles



The first triangle

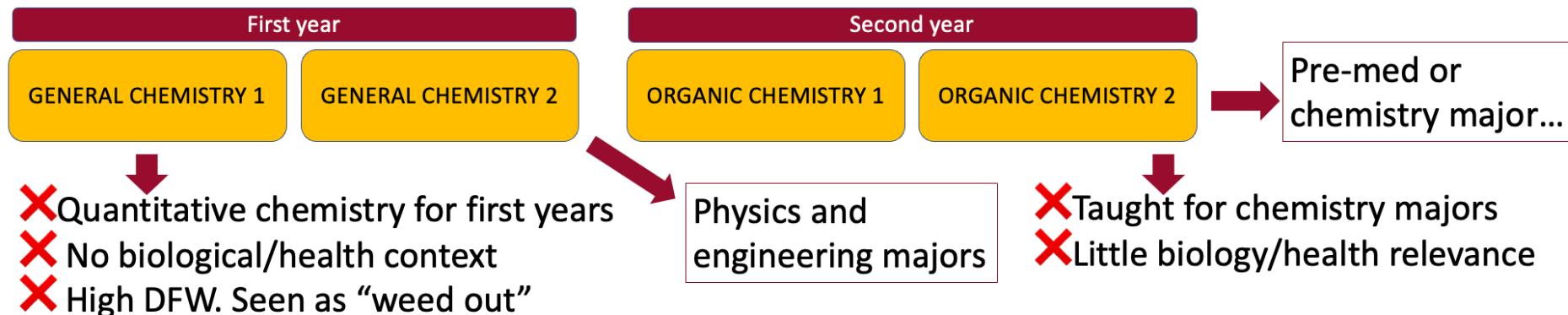


First triangle: Course content – Other institutions

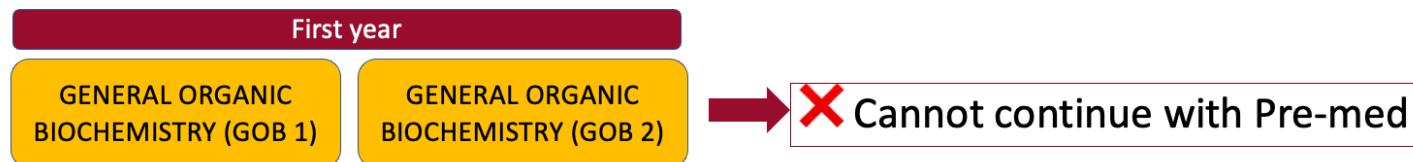
The problem elsewhere:

Nationwide the “pre-med” 4-semester chemistry sequence is a challenge

- These courses serve too many majors and its sequence cannot be changed



- Departments must create alternative paths for nursing and health professions.
But those are not accepted for pre-med as they sacrifice too much content.



First triangle: Course content – Pre2018: Organic first- GenChem second

First year

ORGANIC CHEM 1

ORGANIC CHEM 2

Second year

GENEREAL CHEM 1

GENERAL CHEM 2



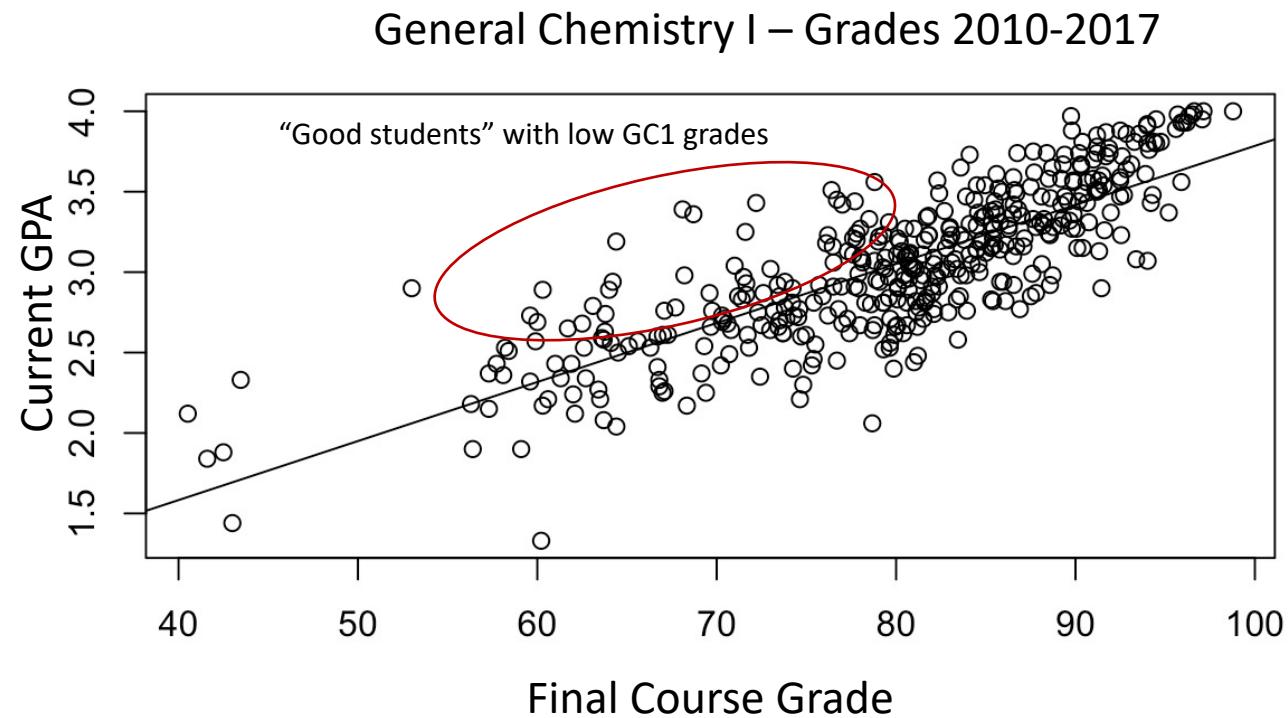
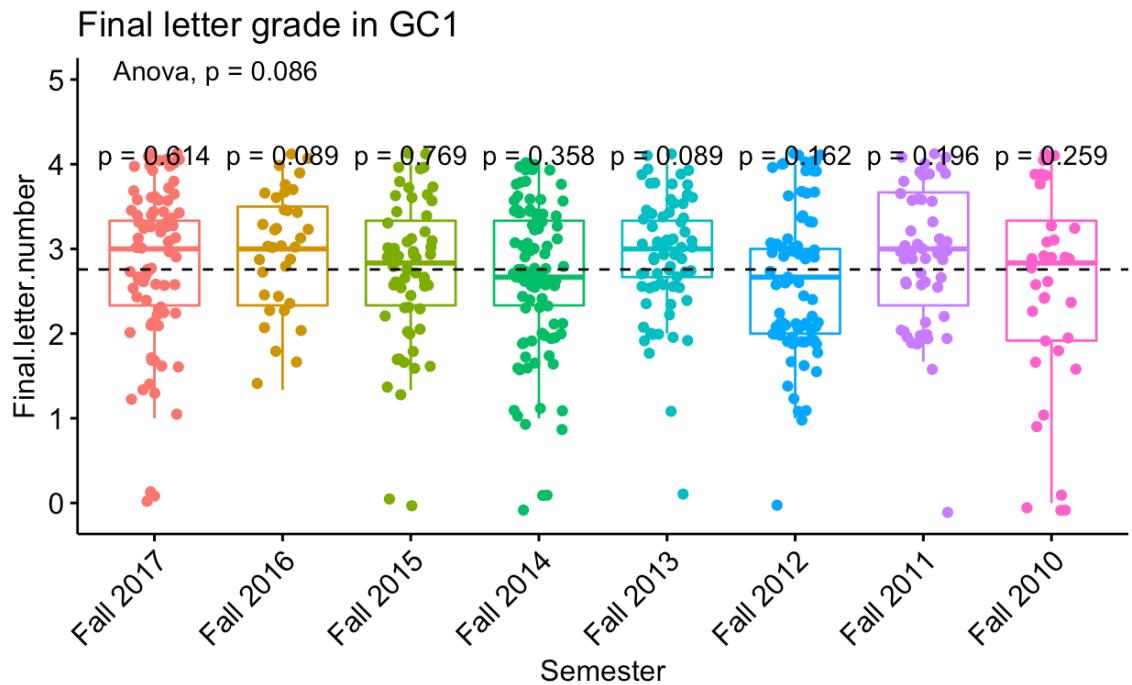
- Meets BSHP requirement
- Introduce Health science relevance
- Post-pone math to the second year

- Two teams of faculty with no contact or integration
- Does not transfer concepts or skills across courses
 - Taught as two separate Chemistry disciplines
- Math skills not addressed until 2nd year
- Fundamental Chem concepts not addressed until 2nd year

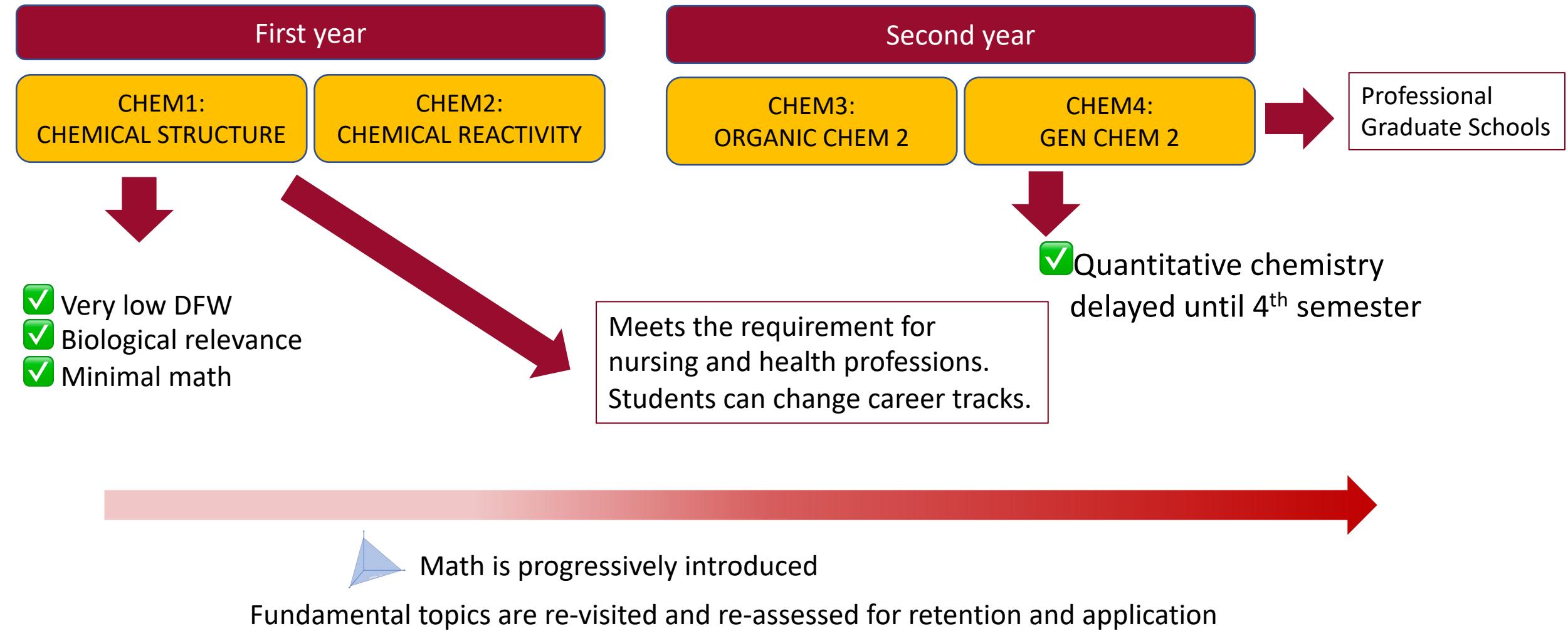
First triangle: Was “OChem first – GenChem second” working?

https://xavierprat.github.io/Blog/posts/analysis_seven_years_genchem/

- GenChem1 was a dreaded course. Even though it was for sophomores many students struggled with basic skills.
- The best predictor of success was previous GPA



First triangle: Course content – Post Fall 2018



First triangle: Course content

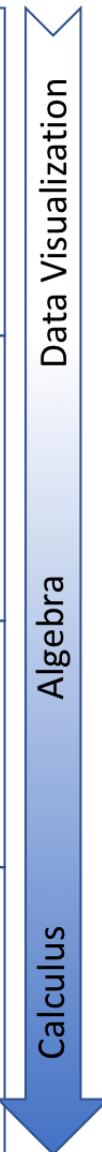
General Chemistry 1

SI units
Dimensional analysis
Atoms, Moles and Mass
Stoichiometry Calculations
Ideal Gases
Theory of light and electronic structure
Periodic Table
Chemical bond: Lewis structures
Molecular orbital theory
Intermolecular forces and phase change
Solutions: properties and preparation

General Chemistry 2

Chem. Kinetics: Descriptive concepts
Chem. Kinetics: Integrated rate laws and Arrhenius
Thermodynamics: Descriptive concepts
Thermodynamics: Hess law and quantitative equil.
Quantitative Equilibrium
Electrochemistry
Acid/Base: Reactions, Ka, Kb and approximate pH.
Acid/Base: Titrations, buffers and ICE tables.
Precipitation Equilibria
Metallic Complexes: Bonding and Equilibria

CHEM1	Atoms and Moles	Mass spectrometry	
	Theory of light and electronic structure		
	Periodic Table		
	Chemical bond, Lewis structures, Hybridization		
	Functional groups. Overview of conformation.		
	Introduction to IR and NMR spectroscopy		
	Intermolecular forces and phase change		
	Solutions: properties and preparation		
	CHEM2	Chem. Kinetics: Descriptive concepts	
		Conformational analysis	
Thermodynamics: Descriptive concepts			
Acid/Base: Reactions, Ka, Kb and approximate pH.			
Stereochemistry			
Nucleophilic Substitutions			
Addition to alkenes			
CHEM3		Conjugation and Ultraviolet spectroscopy	
		Aromaticity and Aromatic substitution	
		Alcohols and Ethers	
	Carbonyl Reactivity		
	Carboxylic and acyl derivatives		
	Amines and Heterocycles		
	CHEM4	Kinetics theory of gases. Ideal gas models.	
		Chem. Kinetics: Integrated rate laws and Arrhenius	
		Quantitative Thermodynamics	
		Stoichiometry and quantitative equilibrium	
Electrochemistry			
Acid/Base: Titrations, buffers and ICE tables.			
Metallic Complexes: Bonding and Equilibria			



Organic Chemistry 1

Bonding: Hybrid orbitals.
Resonance.
Acid/Base and polarity
Functional groups. Overview
Alkanes
Conformation of alkyl chains
Cycloalkanes
Alkenes and alkynes: structure
Alkenes and Alkynes reactivity.
Stereochemistry
Nucleophilic substitution.

Organic Chemistry 2

Mass spectrometry
Infrared spectroscopy (IR)
Nuclear magnetic resonance (NMR)
Conjugation and Ultraviolet spectroscopy
Aromaticity and Aromatic substitution
Alcohols and Ethers
Carbonyl reactivity
Carboxylic acid and acyl derivatives
Amines and Heterocycles





One single chemistry team

First triangle: Pedagogies of delivery

What is the right combination?

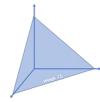
Reading /
Listening

Practicing /
Doing

Before Class

During Class

After Class

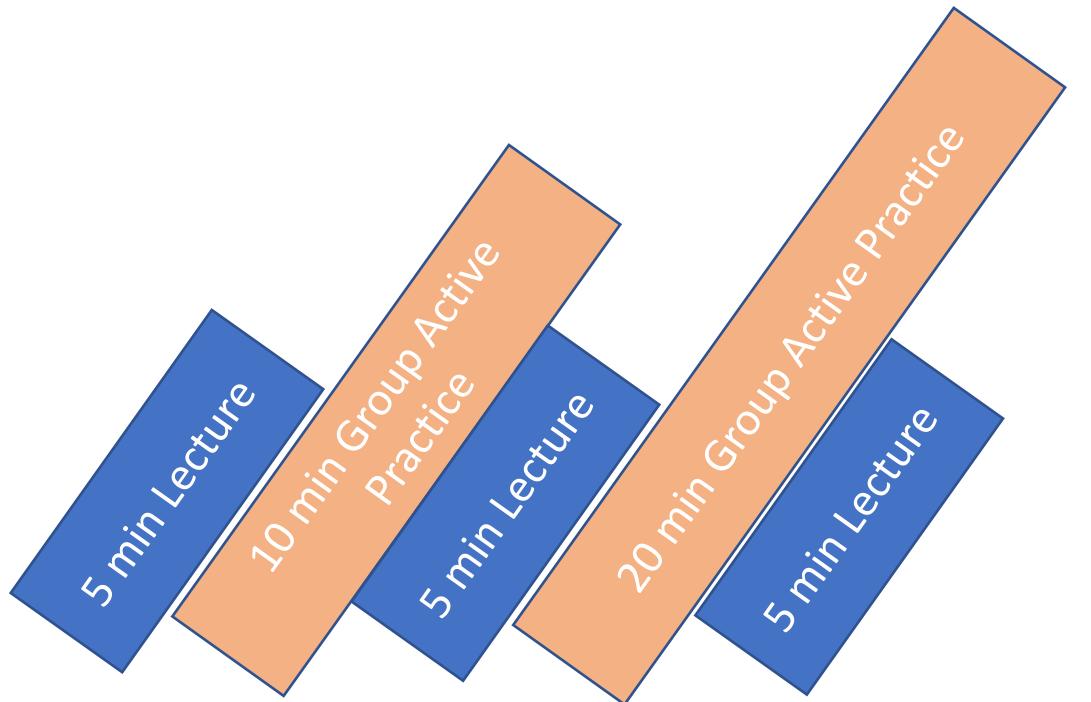


Helping students learn how to college through pedagogies of delivery:
Preclass is graded on A/C/F: If they miss more than 30% they automatically fail the course

Videos
Assigned
~3 videos
~8 min/video

Video common
structure:
Explain Principle
Practice principle

Pre-class questions

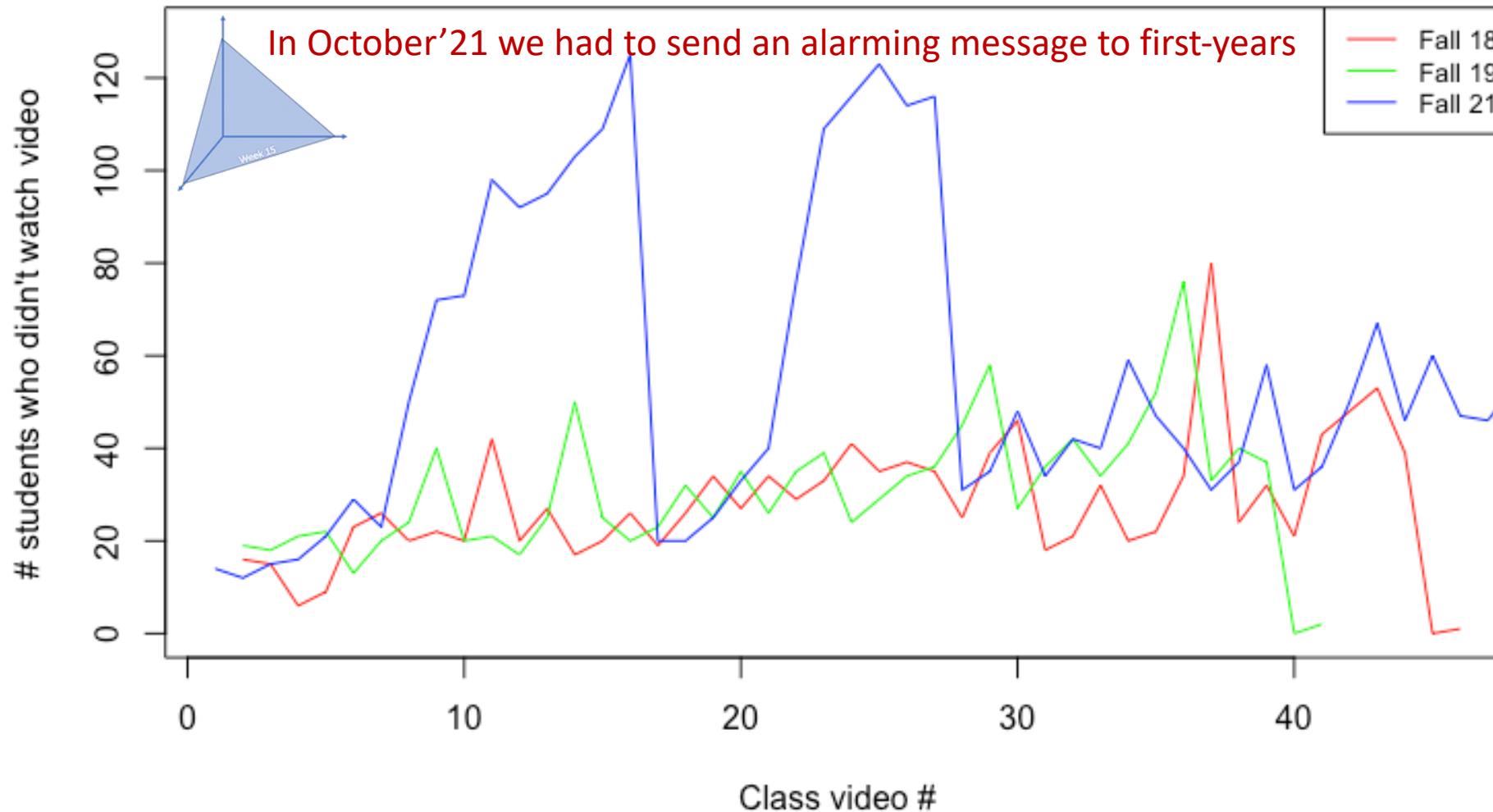


Milestone questions as
Homework to help them
prepare for exams

From initially lower-level to later higher-level all assignments must be aligned.

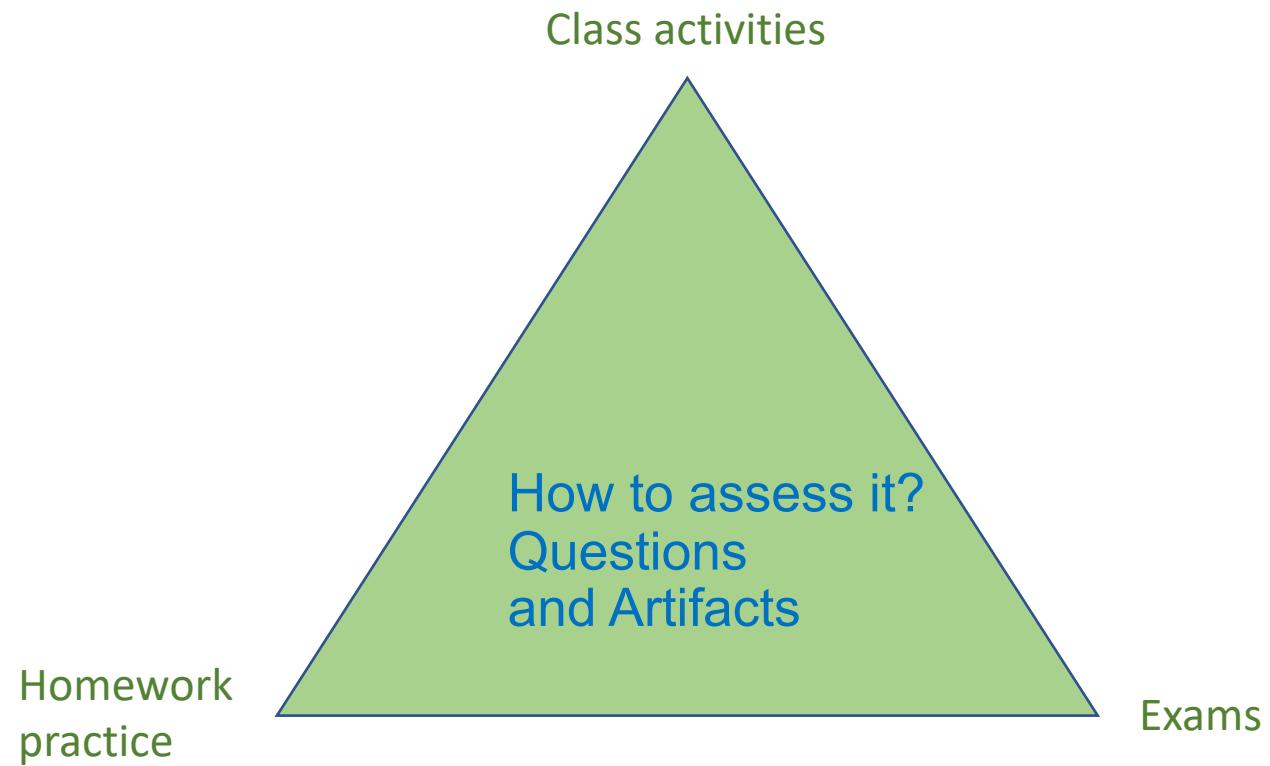
First triangle: Pedagogies – Did the flip model work? Did they watch the videos?

Since 2018 we've had about 200 students per semester



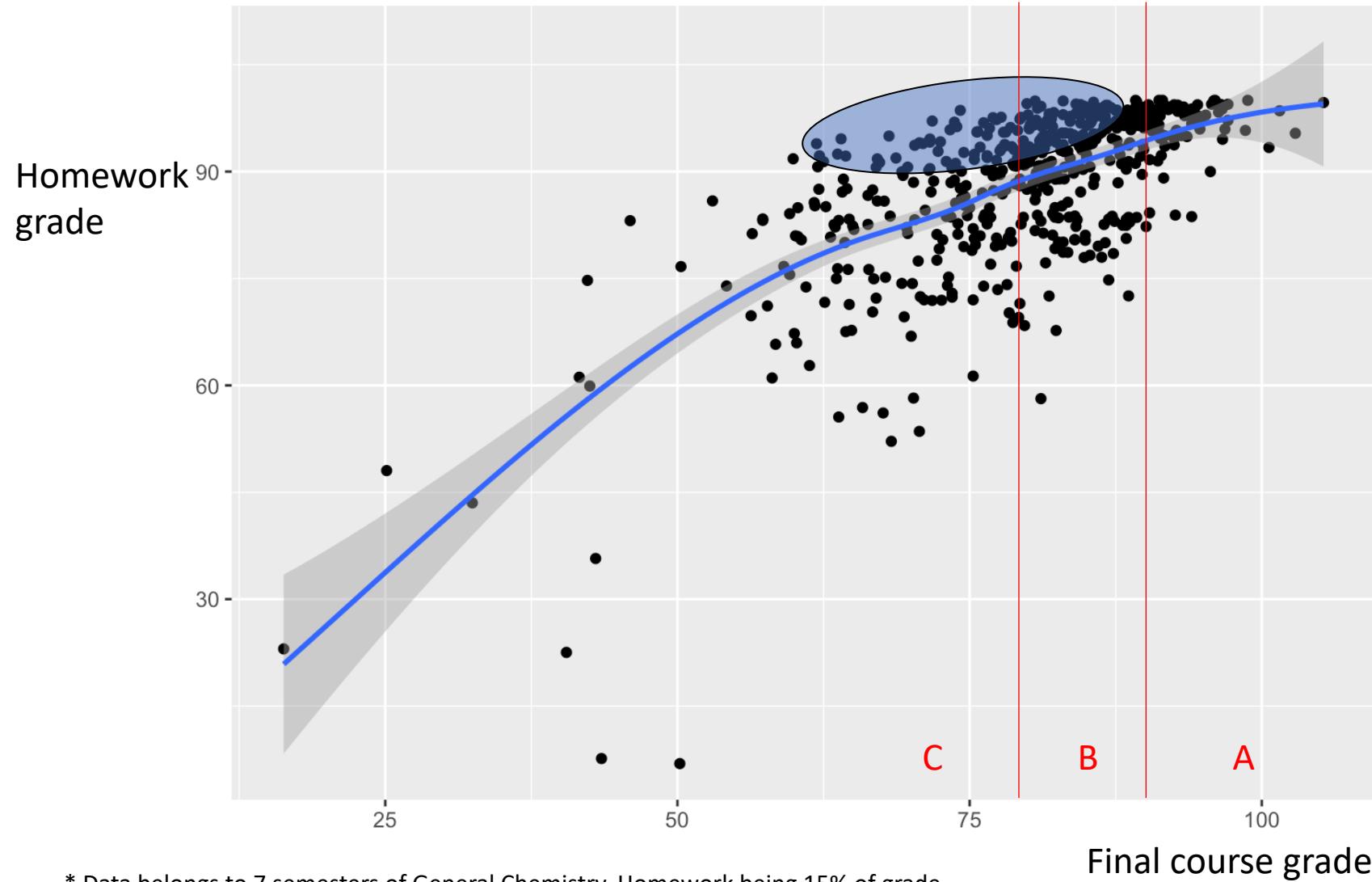
Later we'll talk about how watching videos correlates with course performance

The second triangle



Second triangle: aligning activities

Lots of students get almost 100% in homework but it does not align with their course grade or their exam grade.



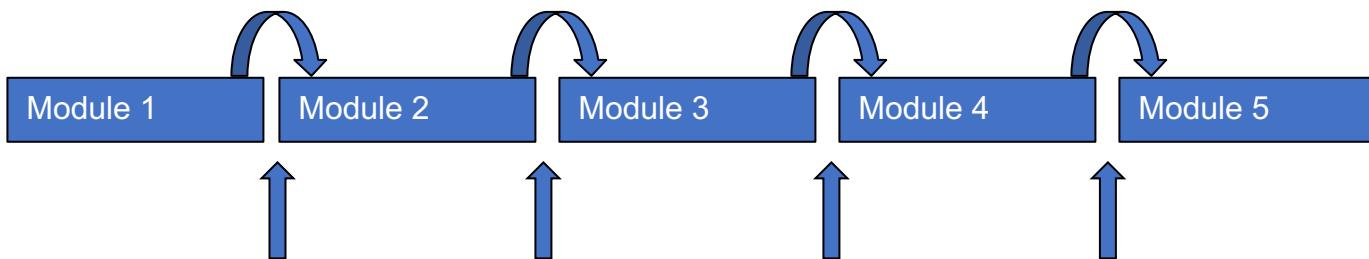
We saw a misalignment between practice and exams.

Students complete homework for the points but not for the help to prepare for exams.

* Data belongs to 7 semesters of General Chemistry. Homework being 15% of grade.

Second triangle: aligning activities – What is the problem? A possible solution.

The course is designed so that one module builds on the next one



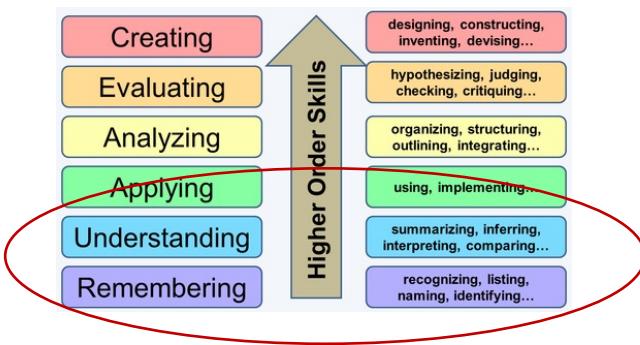
Problem:

- ➔ During Module 5 some students forgot Module 1
- ➔ Students study “hard questions” without having mastered the easy ones.

Possible solution:

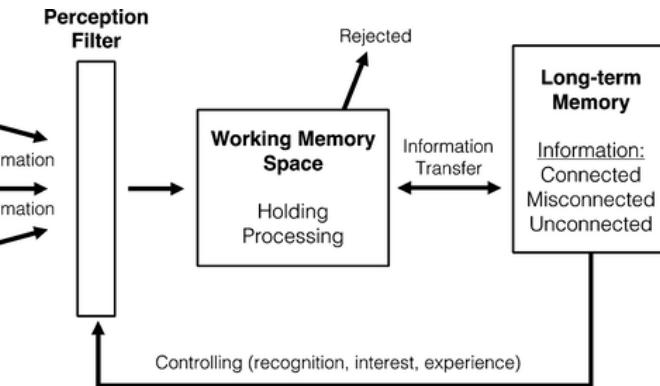
- ➔ At the end of each module, we need to setup “checkpoints” or milestones.
- ➔ Make it clear to students what low-level skill must be mastered to prepare for open-ended exams.

Second triangle: aligning activities - What is a milestone?



Pedagogical Characteristics

Aimed at lower-level skills that should help students prepare for “open-ended” or higher-level skills



Through repetition students are expected to lower their cognitive load and “chunk” connected concepts to be applied to higher-level.

Logistical Characteristics

- The question pool is available online. Students can practice as much as they want. It’s automatically graded.
- The question pool is also assigned as homework so that students can connect practice with assessment
- Students can only obtain 100% (if score is > 80%), 80% (if score is between 70 and 80) or 0% (if score is < 70%)
- It can be thought as “proctored homework” and they have several attempts to get the highest grade.



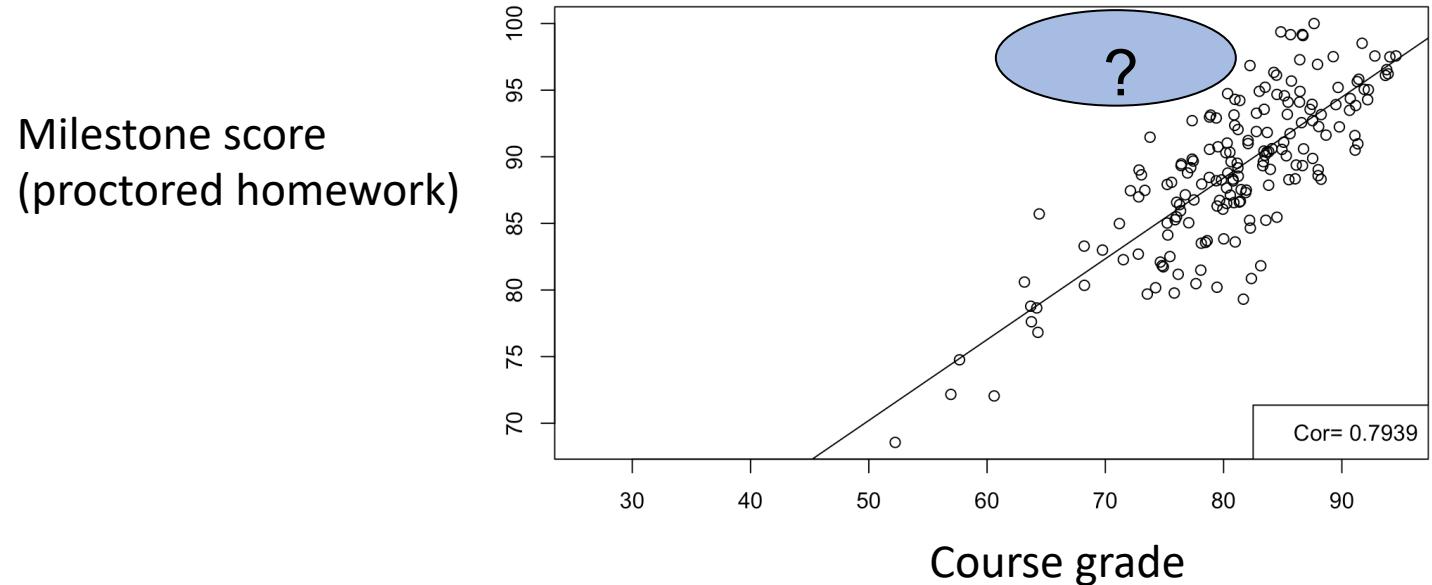
Helping students learn how to college with milestones graded on A/C/F :

It sends a clear message about what to focus on.

Positive reinforcement: Students who pass with a C all their milestones automatically pass the course.

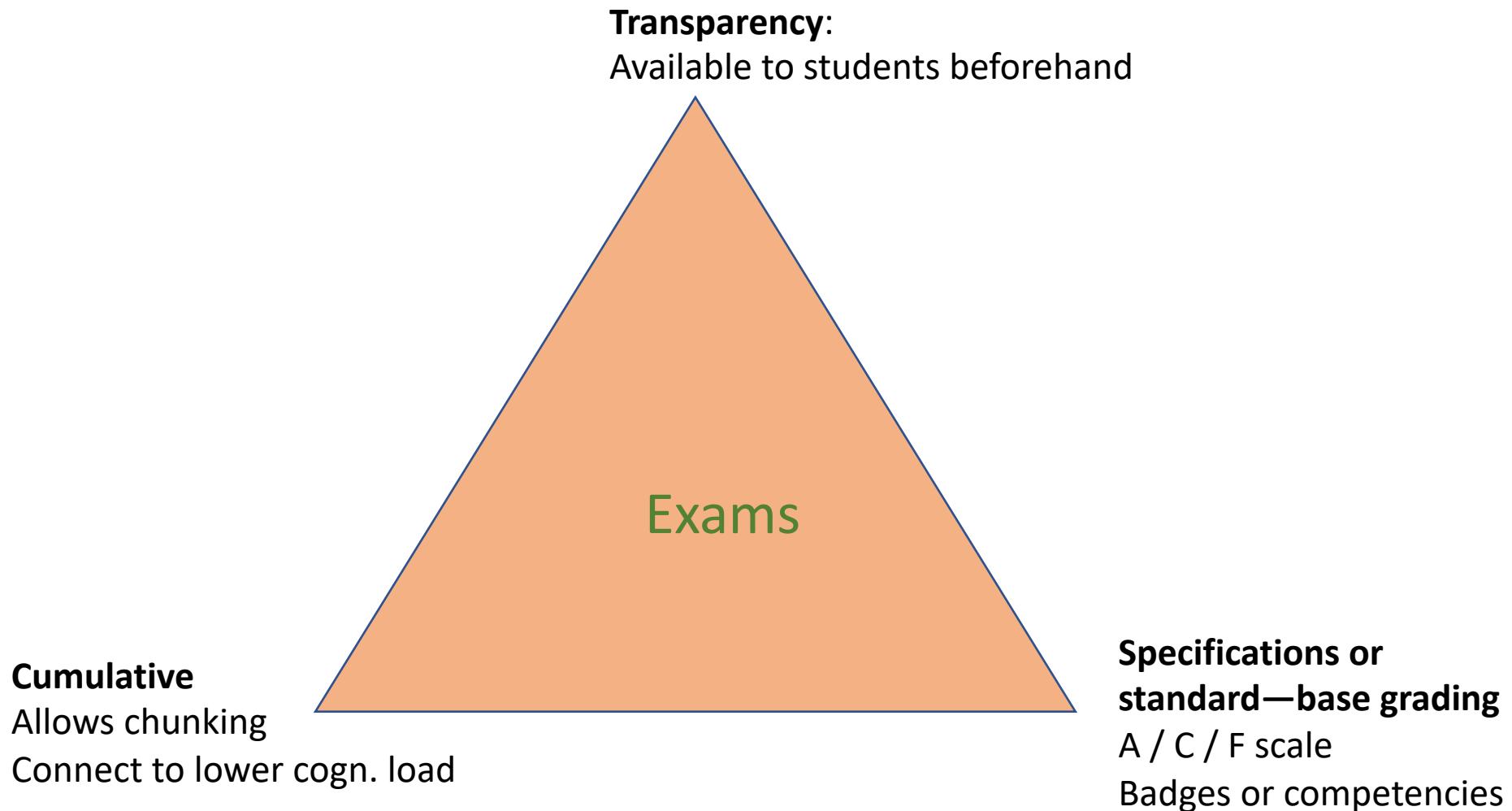
Second triangle: aligning activities - What is a milestone?

→ Better alignment between practice and course grade



Data from first semester of Fall 2019

The third triangle



Third triangle: Assessment – Analyzing Milestone Performance

All the analysis is available online

For CHEM1 Milestone analysis

http://chem.r.umn.edu/chem1331/milestone_analysis_f21.html

For GenChem2 Milestone analysis

http://chem.r.umn.edu/chem2335/milestone_analysis_s22.html

You can also check the R code

```
buildHeaders <- function(numberOfQuestions){  
  colHeaders = c()  
  #build headers  
  for (n in seq(numberOfQuestions)){  
    colHeaders = c(colHeaders,paste("q",as.character(n),sep = ""))  
  }  
  return(colHeaders)  
}  
  
variationWithinQuestionTypes <- function(ml,pat){  
  #compare each question with the average  
  totcol = ncol(ml)  
  numcol = (totcol-2-10)/2  
  aveQ = data.frame( matrix(ncol=3 ,nrow=0) )  
  indivQ = data.frame( matrix(ncol=0 ,nrow=nrow(ml)) )  
  for (q in seq(10,totcol-2,2)){  
    #q is the number, q-1 is the title  
    qtitle = colnames(ml)[q-1]  
    if ( grepl(pat,qtitle)){  
      thisQ = c(  
        colnames(ml)[q-1],  
        mean(ml[,q],na.rm=TRUE),  
        length( na.omit(ml[,q]))  
      )  
      aveQ = rbind(aveQ,thisQ)  
      indivQ[qtitle] = ml[,q]  
    }  
  }  
  results = list("indi" = indivQ, "ave" = aveQ)  
  return(results)  
}  
  
printVariationWithinQuestions <- function(indivQ,ndig){
```

Third triangle: Assessment – Analyzing Milestone Performance

- ➔ Pre and post-COVID cohort analysis
- ➔ Measuring resilience
- ➔ Do they just memorize the questions?
- ➔ High discriminatory index questions
- ➔ What practical skills students need to master?
- ➔ Helping students retain previous content

Third triangle: Assessment - The post-COVID times



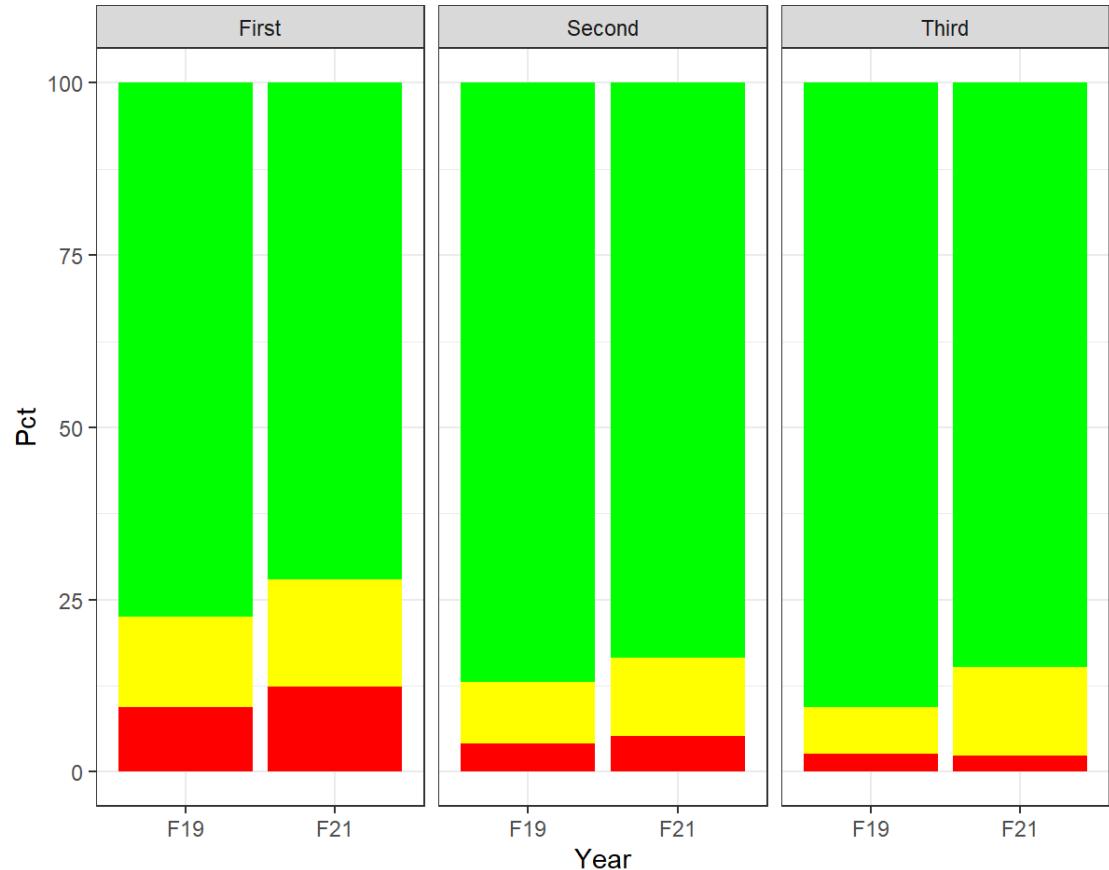
↑  r/Professors · Posted by u/exhaustedfignewton  2 hours ago 

73   Is anyone else dealing with high failure rates in lower-division courses this semester?

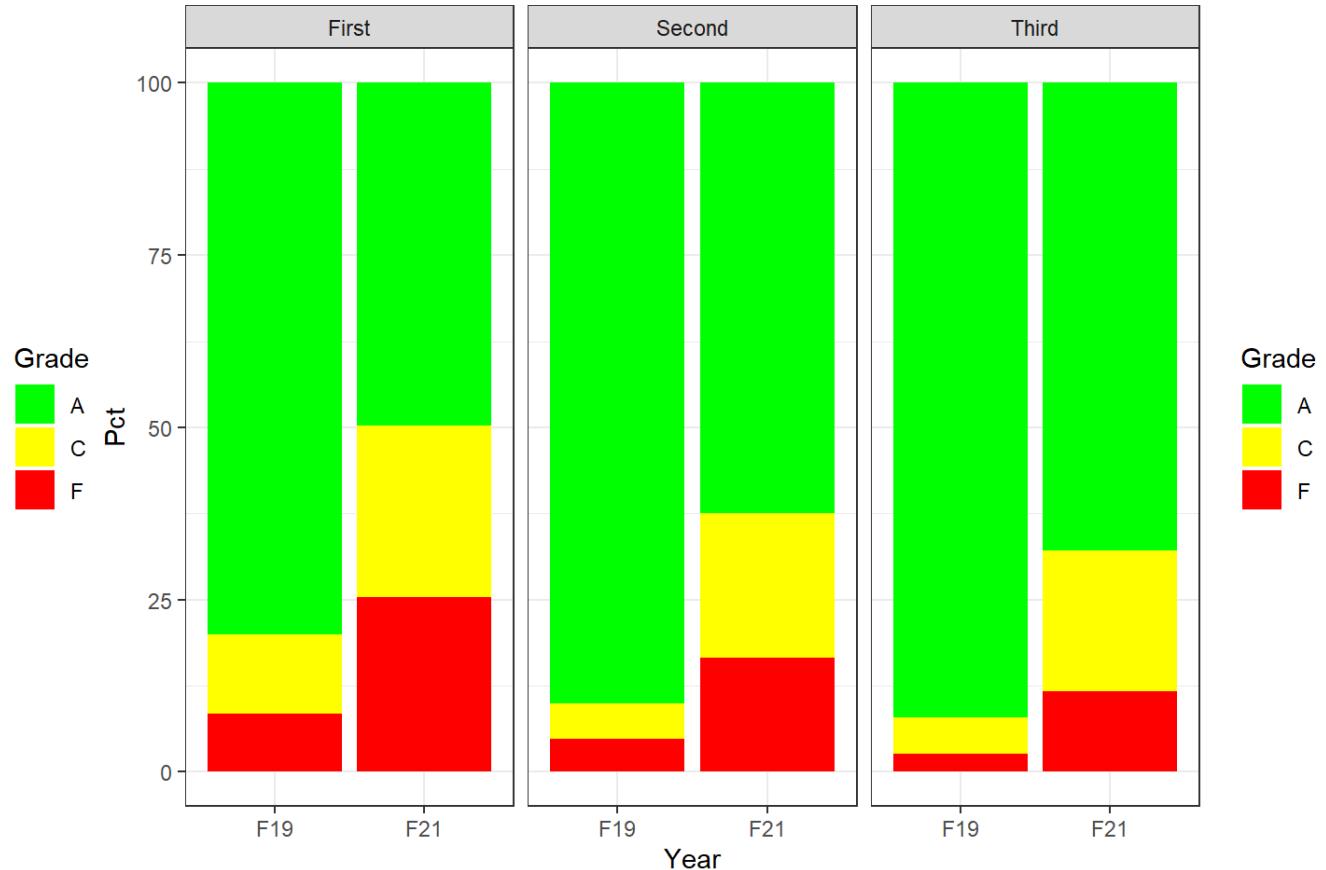
I have been teaching the same online, asynchronous lower-division course for years now. This semester, however, I have **so many** students failing due to doing almost no work (and barely, if ever, reaching out about it).

Third triangle: Assessment - Comparing pre-Covid and post-Covid years

Milestone 1: end of September

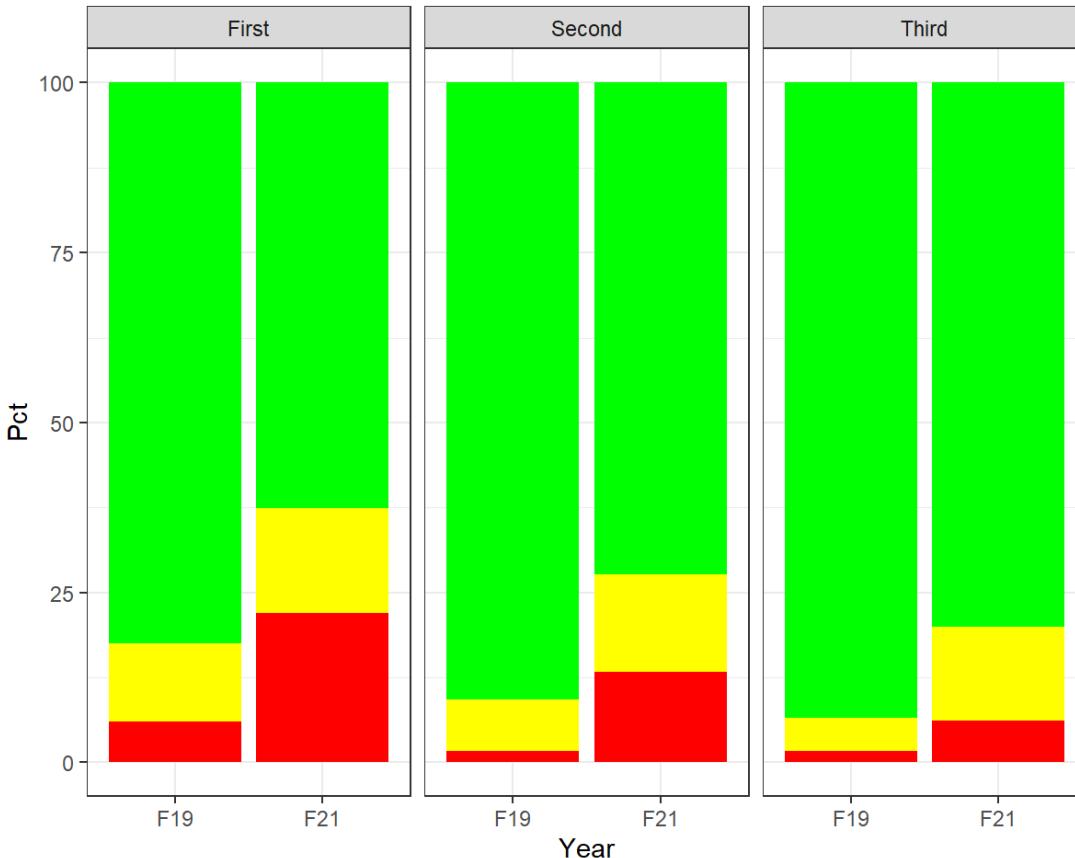


Milestone 2: mid October

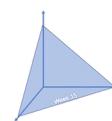
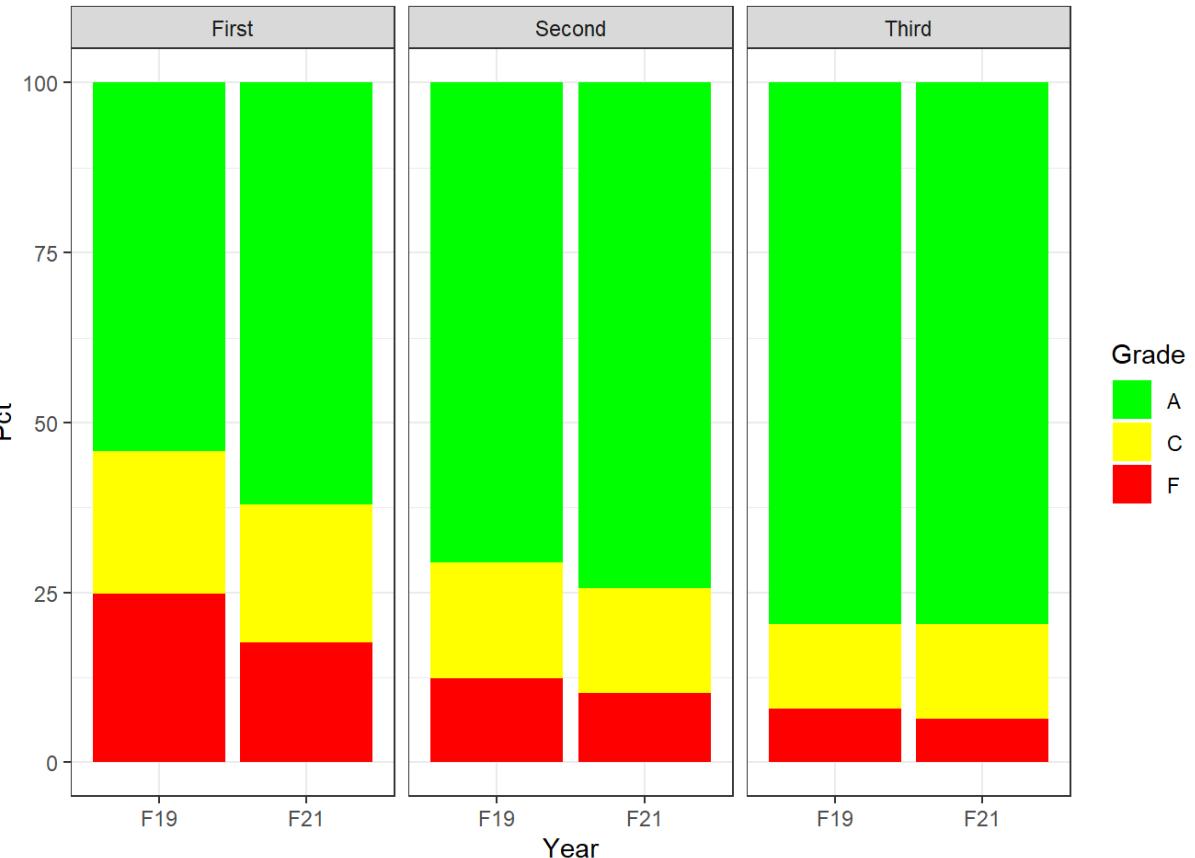


Third triangle: Assessment - Comparing pre-Covid and post-Covid years

Milestone 3: mid November



Milestone 4: beginning of December



Thanks to early signals of failure several people changed behavior or dropped the course. By the end of the semester pre and post-covid cohorts performed similarly, or even better.

Third triangle: Assessment - Comparing pre-Covid and post-Covid years

Milestone 1

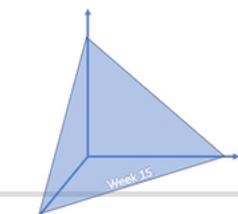
Students settling
before 3rd attempt (F21
/ F19)

	Score < 70 (F21)	Score < 70 (F19)	70 < Score < 80 (F21)	70 < Score < 80 (F19)
Settled in 1st attempt	3	2	7	4
Settled in 2nd attempt	0	3	13	5
Total	3	5	20	9

Milestone 2

Settled in 1st attempt	2	3	14	2
Settled in 2nd attempt	5	0	11	4
Total	7	3	25	6

Milestone 3



Three or four times as many students settled in F21 compared to F19.
We could say that lack of resilience has dramatically increased

Settled in 1st attempt	4	2	7	3
Settled in 2nd attempt	3	0	7	2
Total	7	2	14	5

Third triangle: Assessment - Comparing pre-Covid and post-Covid years

Milestone 4

# Students settling before 3rd attempt (F21 / F19)	Score < 70 (F21)	Score < 70 (F19)	70< Score < 80 (F21)	70< Score < 80 (F19)
Settled in 1st attempt	3	1	11	4
Settled in 2nd attempt	4	4	7	5
Total	7	5	18	9

Third triangle: Assessment – Analyzing Milestone Performance

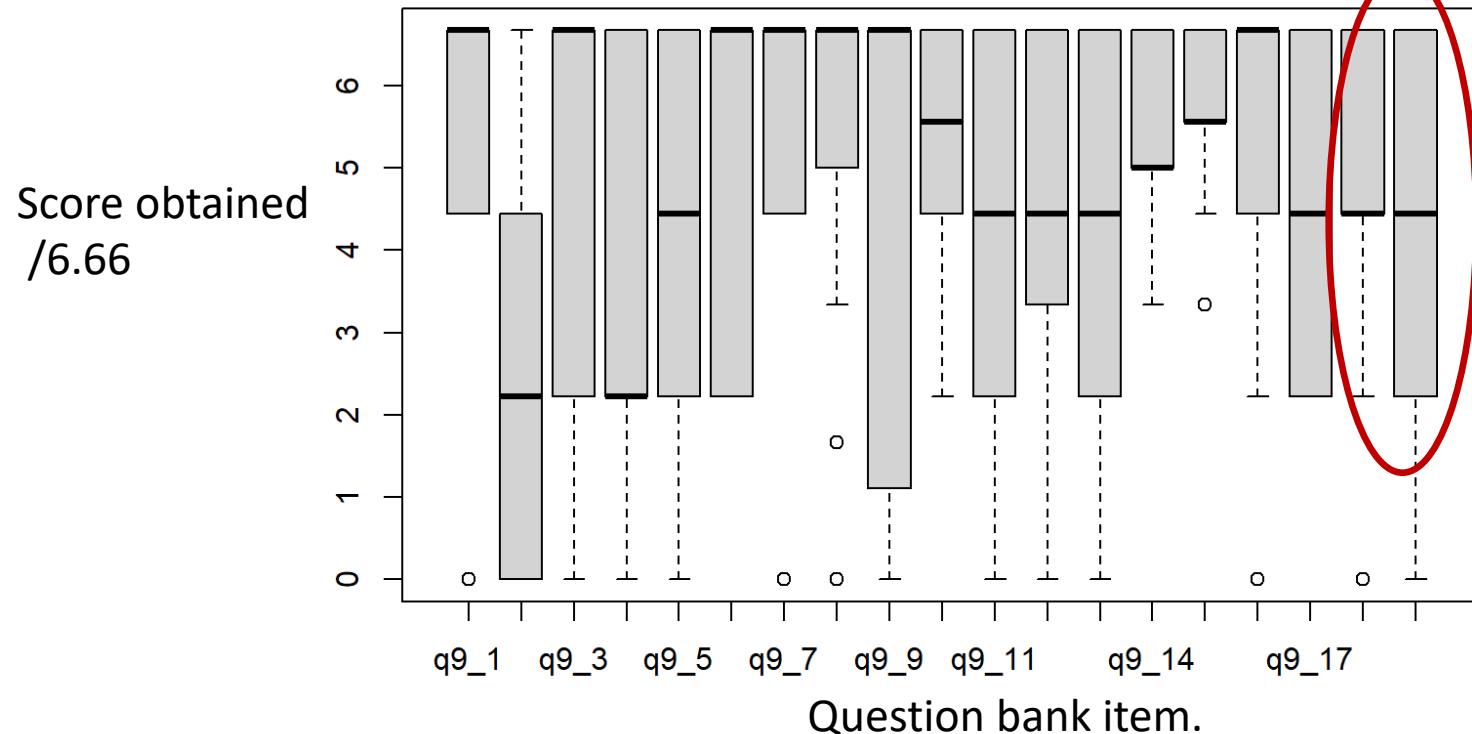
- ➔ Pre and post-COVID cohort analysis
- ➔ Measuring resilience
- ➔ Do they just memorize the questions?
- ➔ High discriminatory index questions
- ➔ What practical skills students need to master?
- ➔ Helping students retain previous content

Third triangle: Assessment – Do they just memorize the questions?

What if we add questions they've never seen before.

Same wording

All students took these two new questions
that were not available for practice
And yet, students performed equally well.

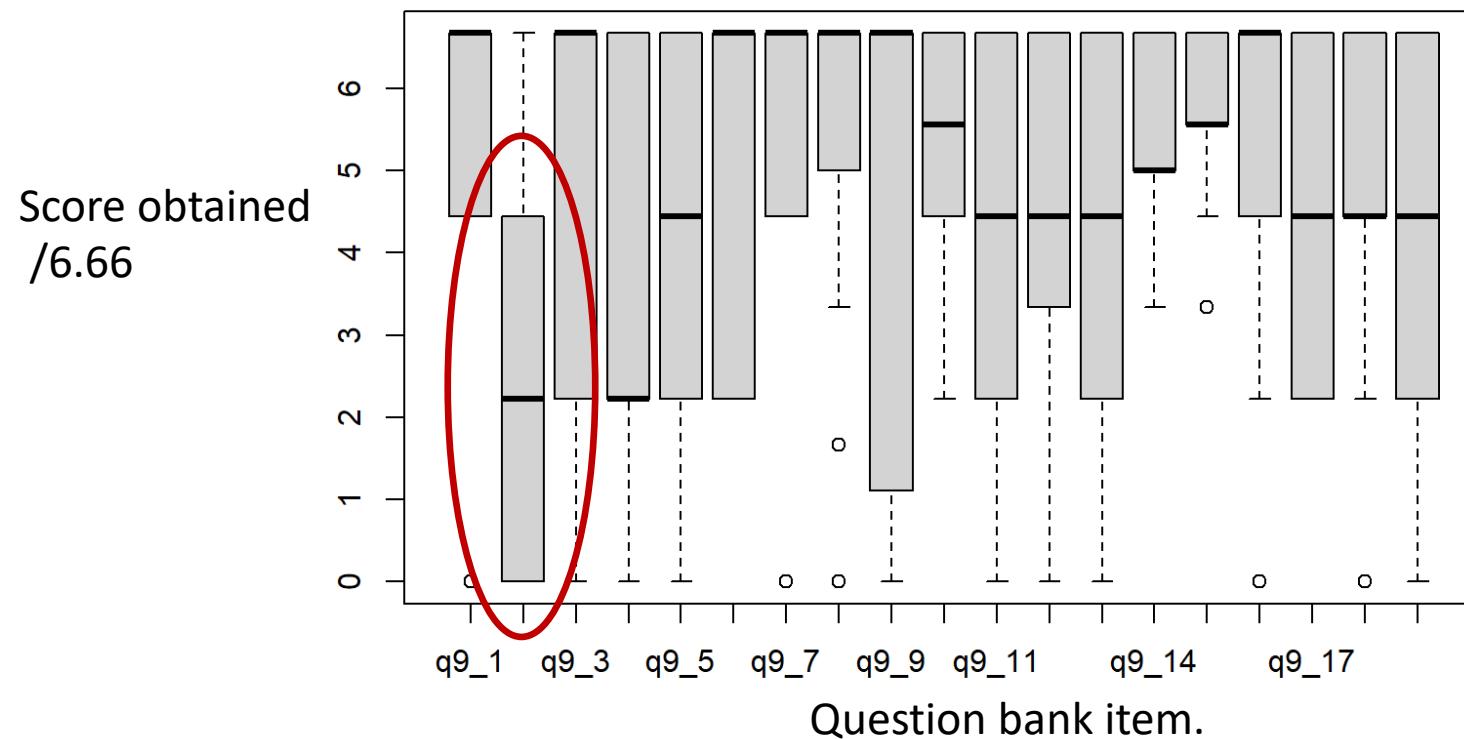


Third triangle: Assessment – Analyzing Milestone Performance

- ➔ Pre and post-COVID cohort analysis
- ➔ Measuring resilience
- ➔ Do they just memorize the questions?
- ➔ High discriminatory index questions
- ➔ What practical skills students need to master?
- ➔ Helping students retain previous content

Third triangle: Assessment – Identifying common pitfalls

One question in the milestone exam has several variations, it has the same wording, but the answers are different.
(different molecules, different numbers...etc)



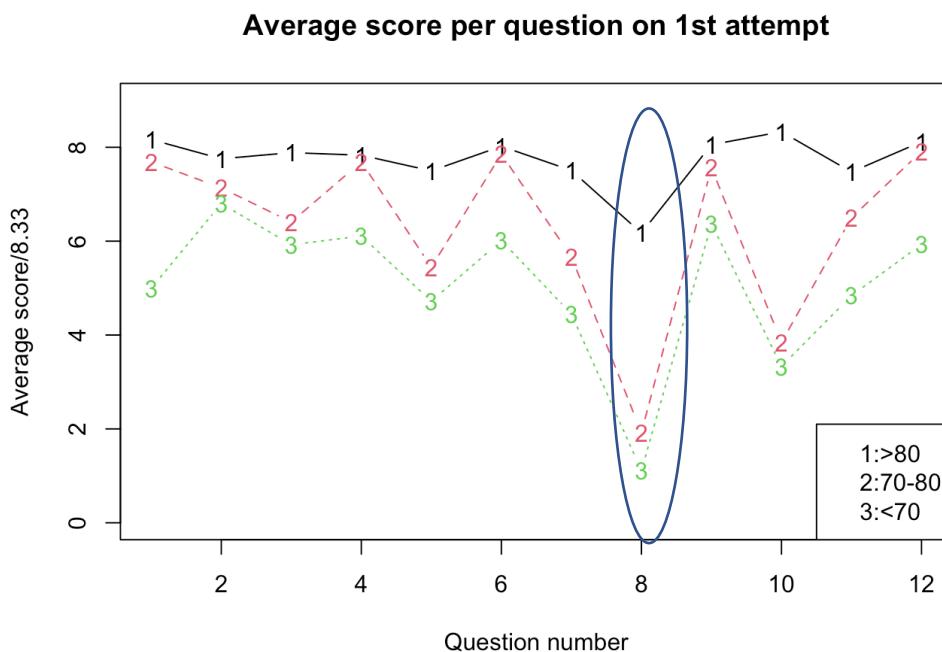
Students who got this question performed significantly lower
So, should this question be removed because it's unfair? It depends.
In this case the question was mostly taken by “low-performers”.

Third triangle: Assessment – Identifying common pitfalls



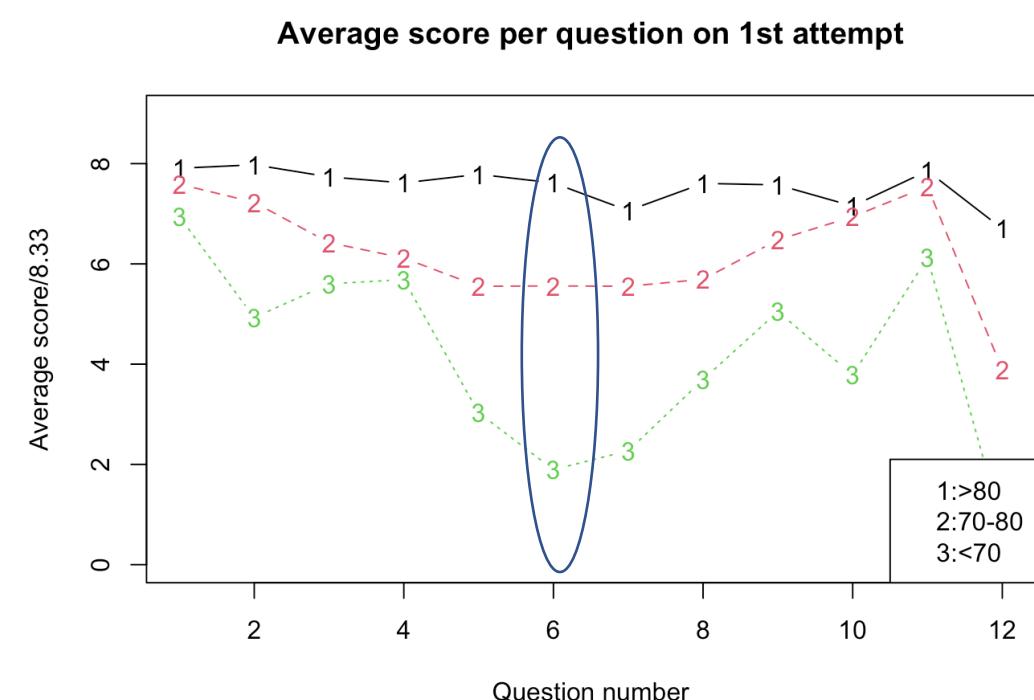
- Questions with a high discriminatory index
- Help predict college performance
- Informs students about pitfalls

There are questions that hard for everyone



Milestone 2 – Spring 2022 – GenChem2

There are questions that are harder only to low-performers.



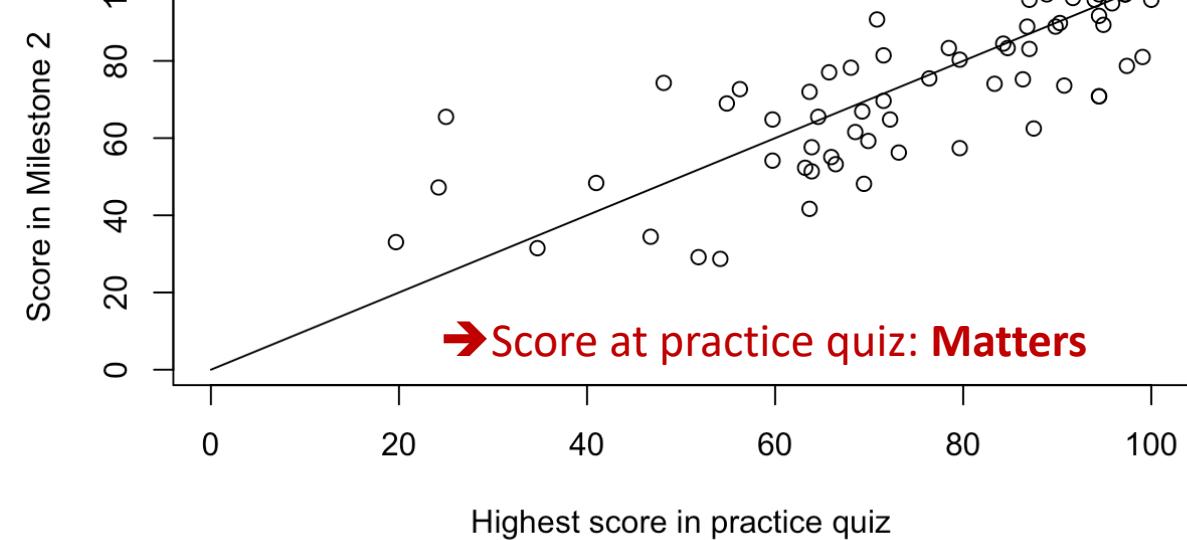
Milestone 5 – Spring 2022 – GenChem2

Third triangle: Assessment – Analyzing Milestone Performance

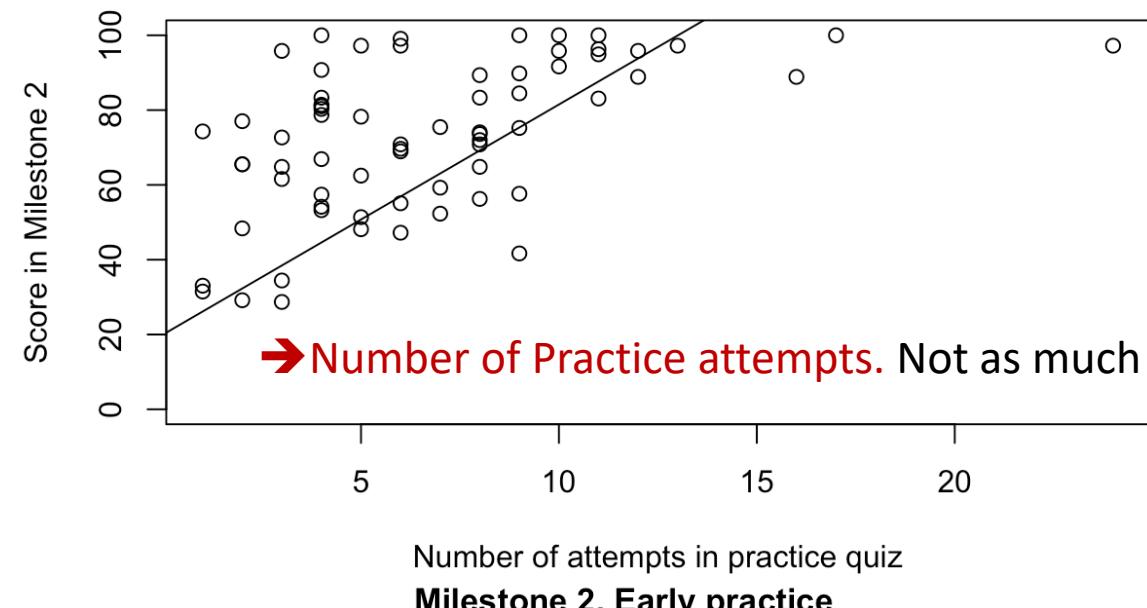
- ➔ Pre and post-COVID cohort analysis
- ➔ Measuring resilience
- ➔ Do they just memorize the questions?
- ➔ High discriminatory index questions
- ➔ What practical skills students need to master?
- ➔ Helping students retain previous content

What kind of practice helps enhancing performance?

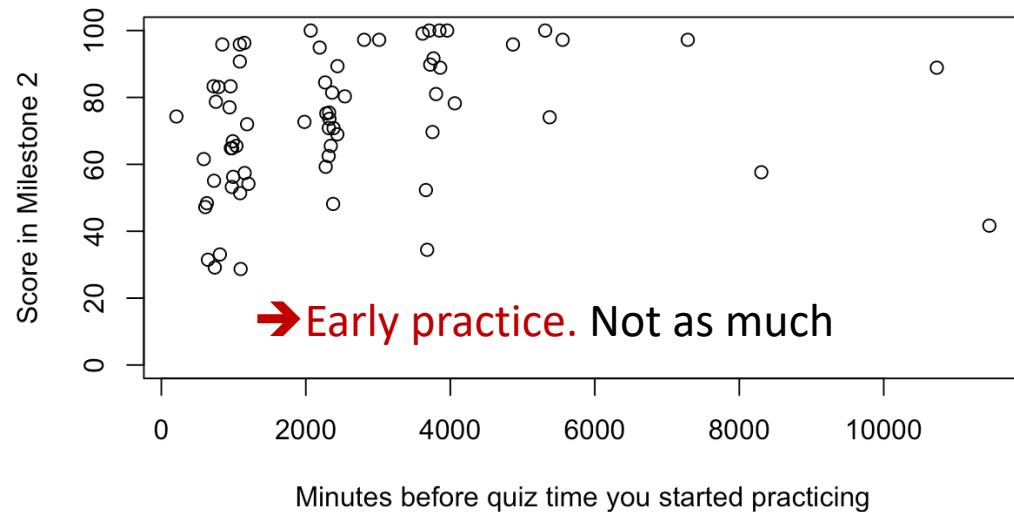
Milestone 2. Practicing score



Milestone 2. #Attempts



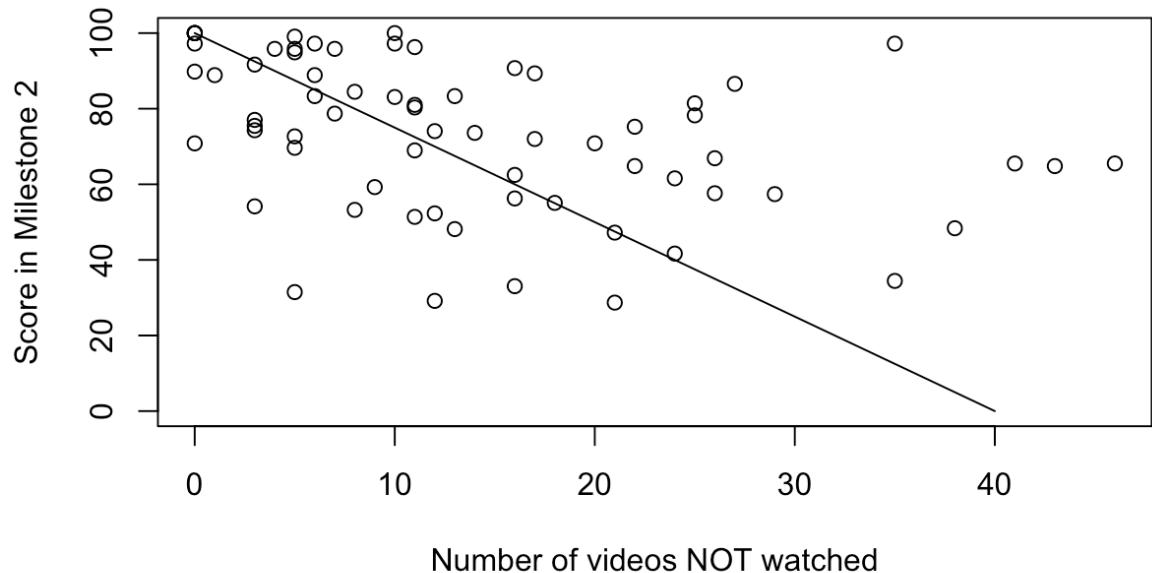
Milestone 2. Early practice



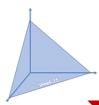
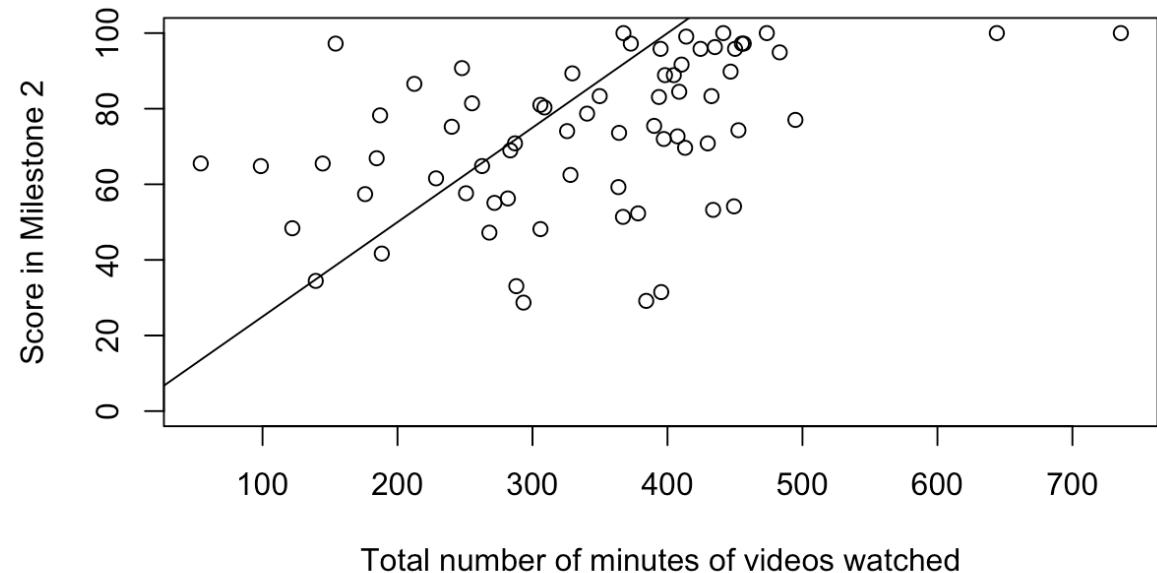
- Practice at least 3 times
- Obtain a passing grade in your practice
- Applicable to sophomores (GenChem2)

What kind of practice helps enhancing performance?

Milestone 2. Missed videos



Milestone 2. Minutes of videos watched



- With some outliers. Skipping videos correlates with low performance.
- Watching the whole video is a necessary condition to do well in milestones.

Third triangle: Assessment – Analyzing Milestone Performance

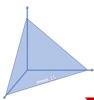
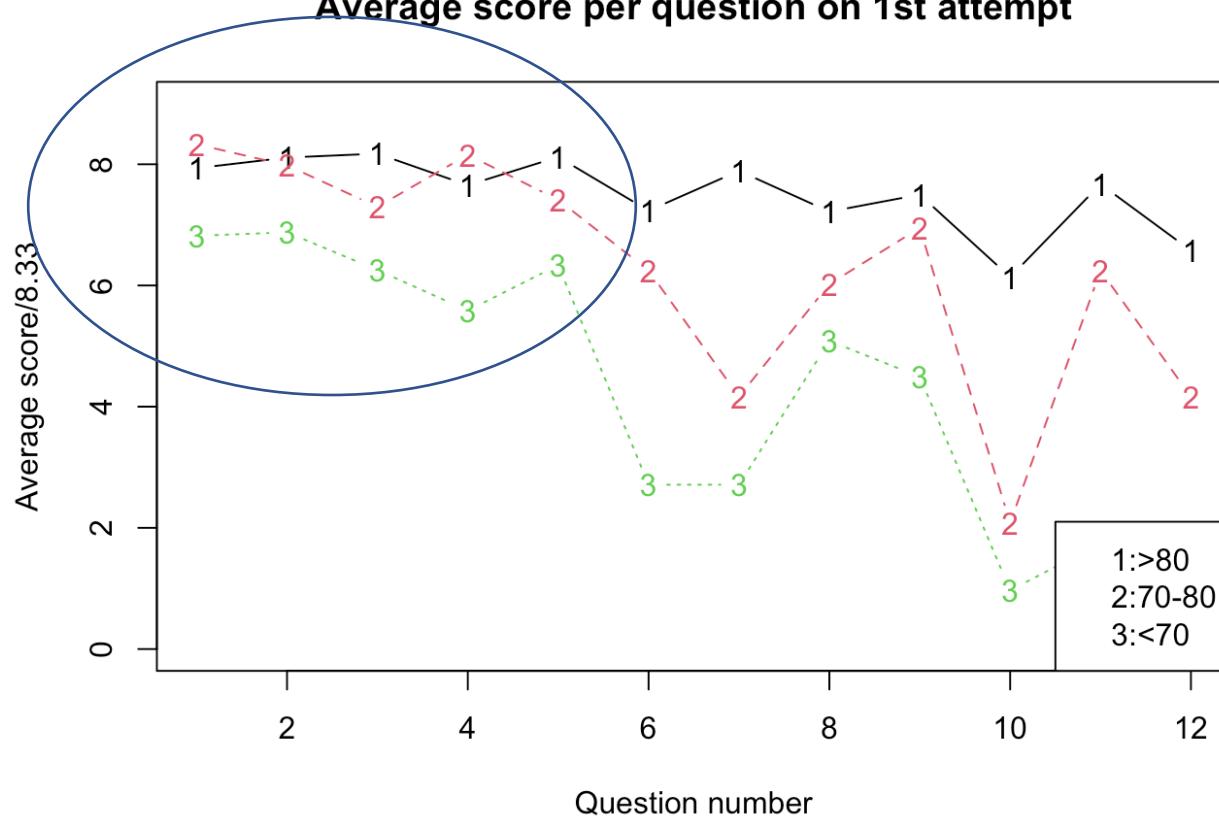
- ➔ Pre and post-COVID cohort analysis
- ➔ Measuring resilience
- ➔ Do they just memorize the questions?
- ➔ High discriminatory index questions
- ➔ What practical skills students need to master?
- ➔ Helping students retain previous content

Third triangle: Assessment – Cumulative

Previous semester questions

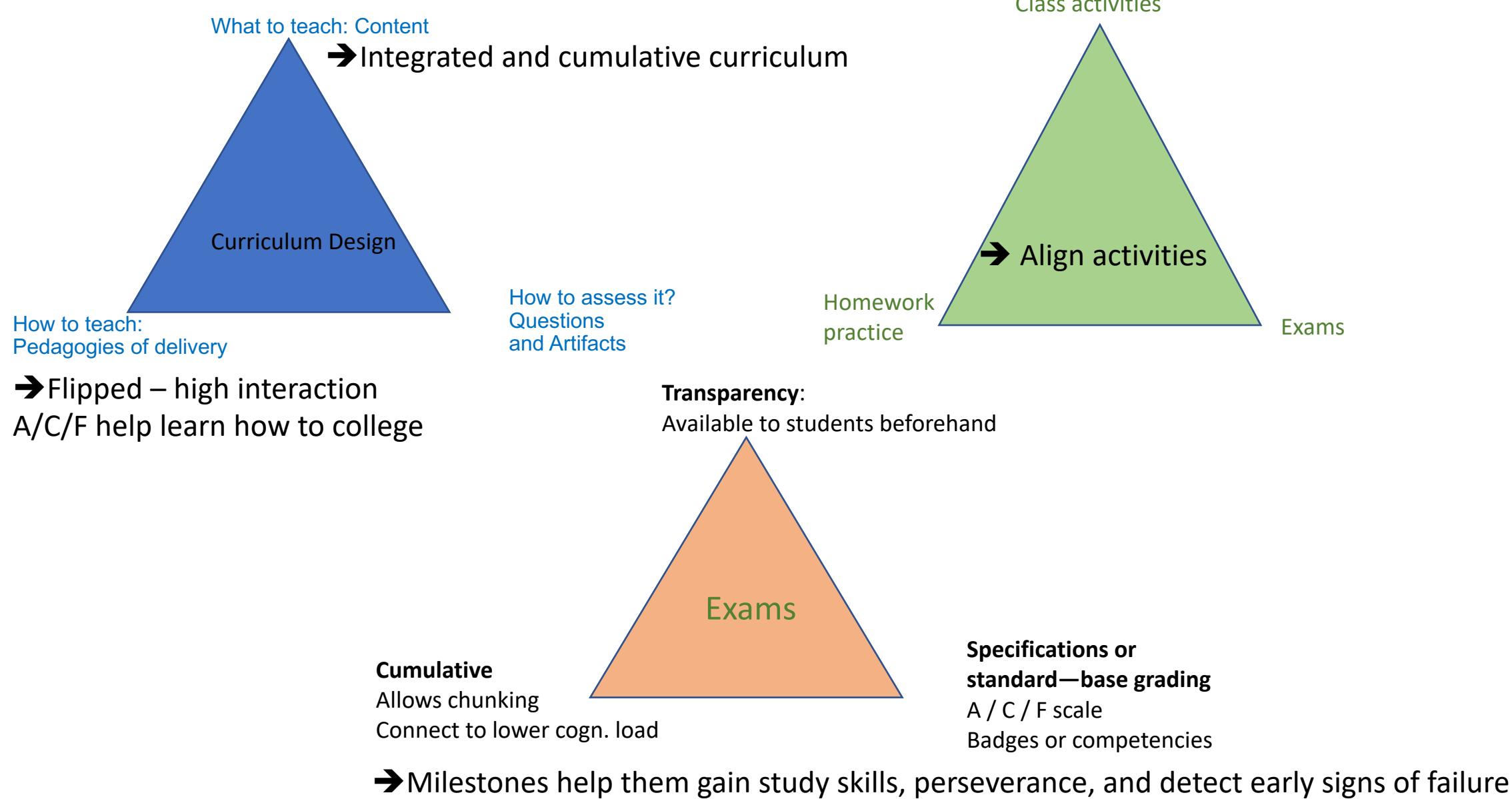
Average score per question on 1st attempt

CHEM2335 - 4 semesters later



→ Through repetition, students master previous content including previous years content

Conclusions on Curriculum Design



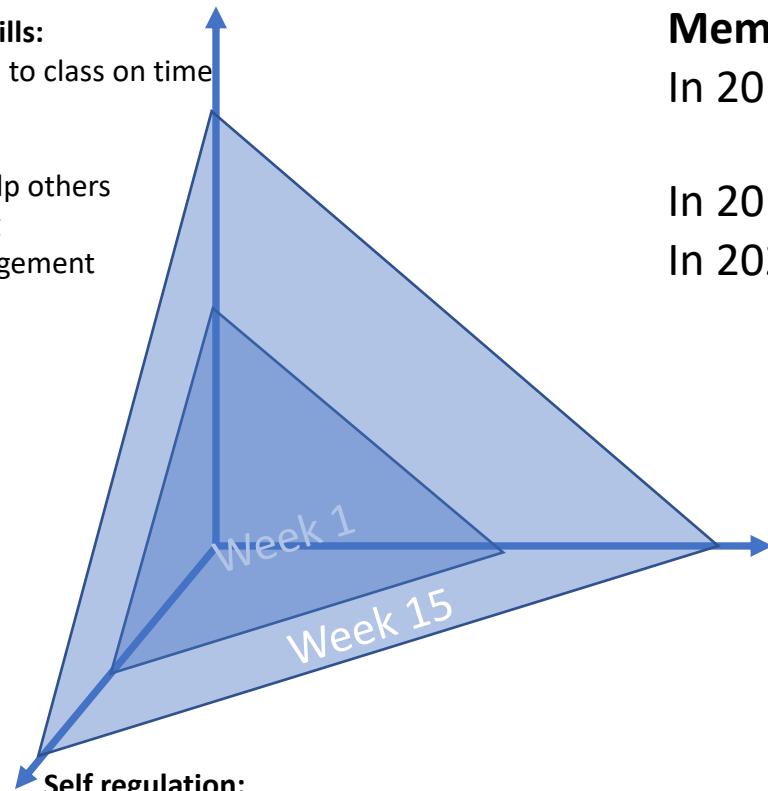
Conclusions on helping students grow in all directions.

→ We have identified “good skills” that correlate with student success

How should we motivate students to acquire those skills?

Practical skills:

Showing up to class on time
Respectful
Relatable
Interact/help others
Note taking
Time management



Self regulation:

Studying skills
Self-awareness of learning
Resilience

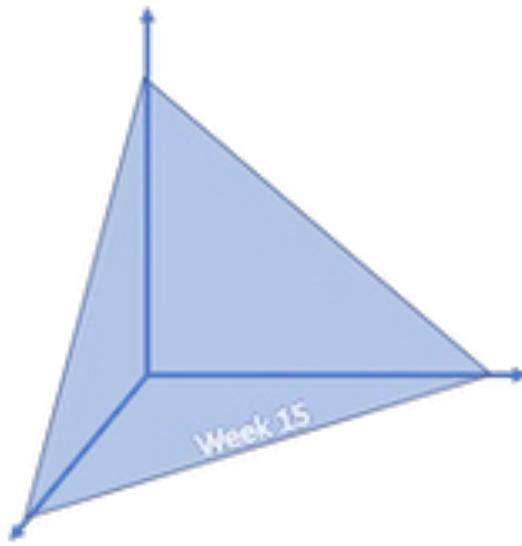
Memory lane:

In 2014 I proposed SLICE (Showing Longitudinal Interactions of Course Events)
(<http://chem.r.umn.edu/bosco/slice/>)

In 2017 through the Academic Innovation Group [I proposed badges](#) in “good skills”

In 2021 through [NextGenMed we proposed badges](#)





Thanks