Integrating Spaced Repetition in a Math Course Redesign

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Abstract

Professors often see that students do not remember key concepts from prerequisite courses. This could be due to students' studying habits of cramming information right before exams. Cramming is the worst way of learning math. So, what can we do to help students with learning how study and to approach a great deal of concepts and skills that math courses contain? In this presentation, I'll discuss implementation of spaced repetition or distributed practice strategy in a math course redesign. I'll use Calculus I and/or college algebra to show great positive results.

“I Teach Students, Not Subjects.” Moje 1985

When you teach students, focus on how to help the students become a better version of themselves at the end of the course.

“ **Learning results from what the student does** and thinks and only from what the student does and thinks. **The teacher can advance learning only by influencing what the student does to learn**.”

(Herbert Simon, 2001)

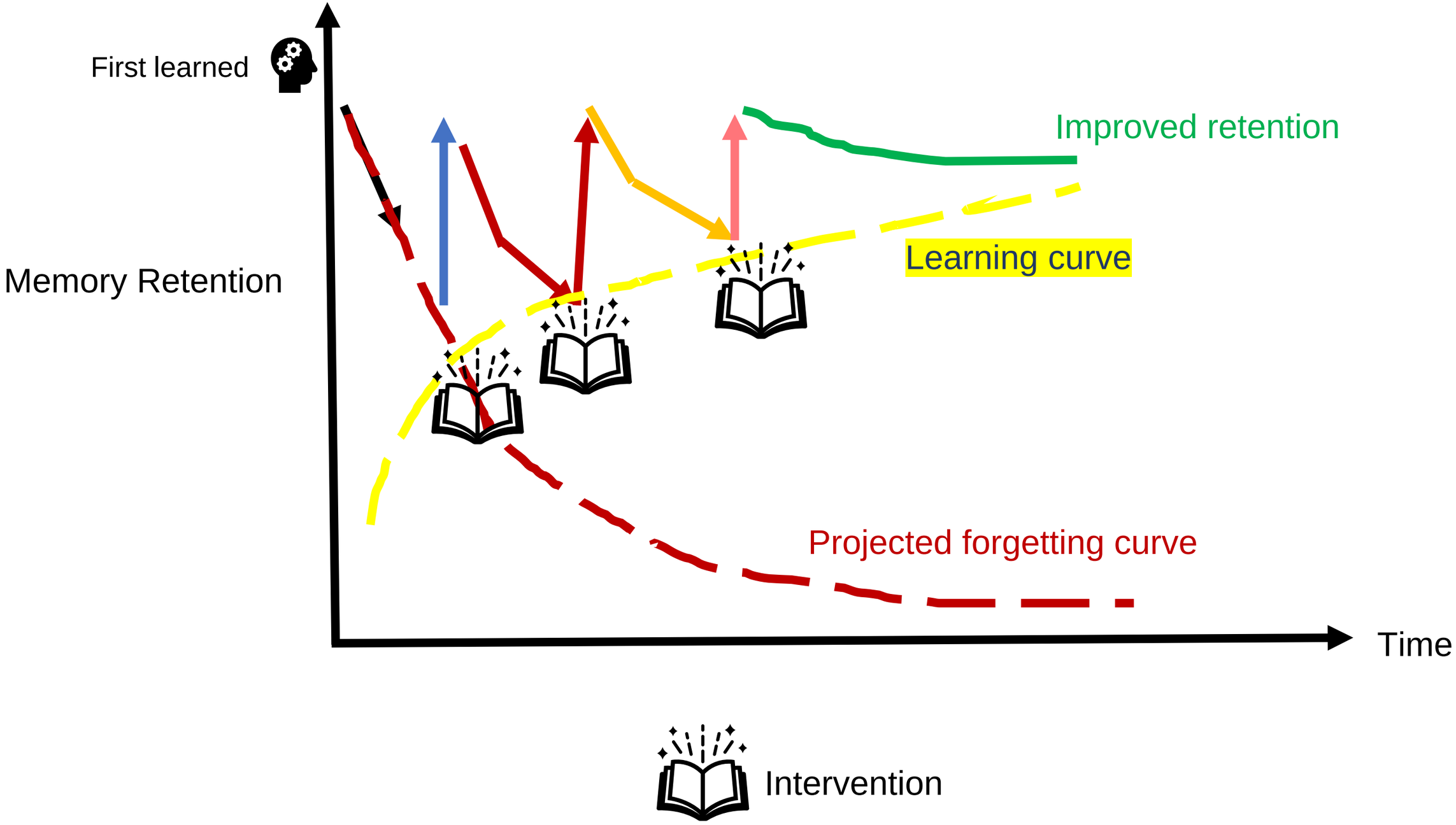
“it’s not teaching that causes learning. **Attempts by the learner to perform cause learning**, dependent upon the **quality of feedback and opportunities to use it**. “

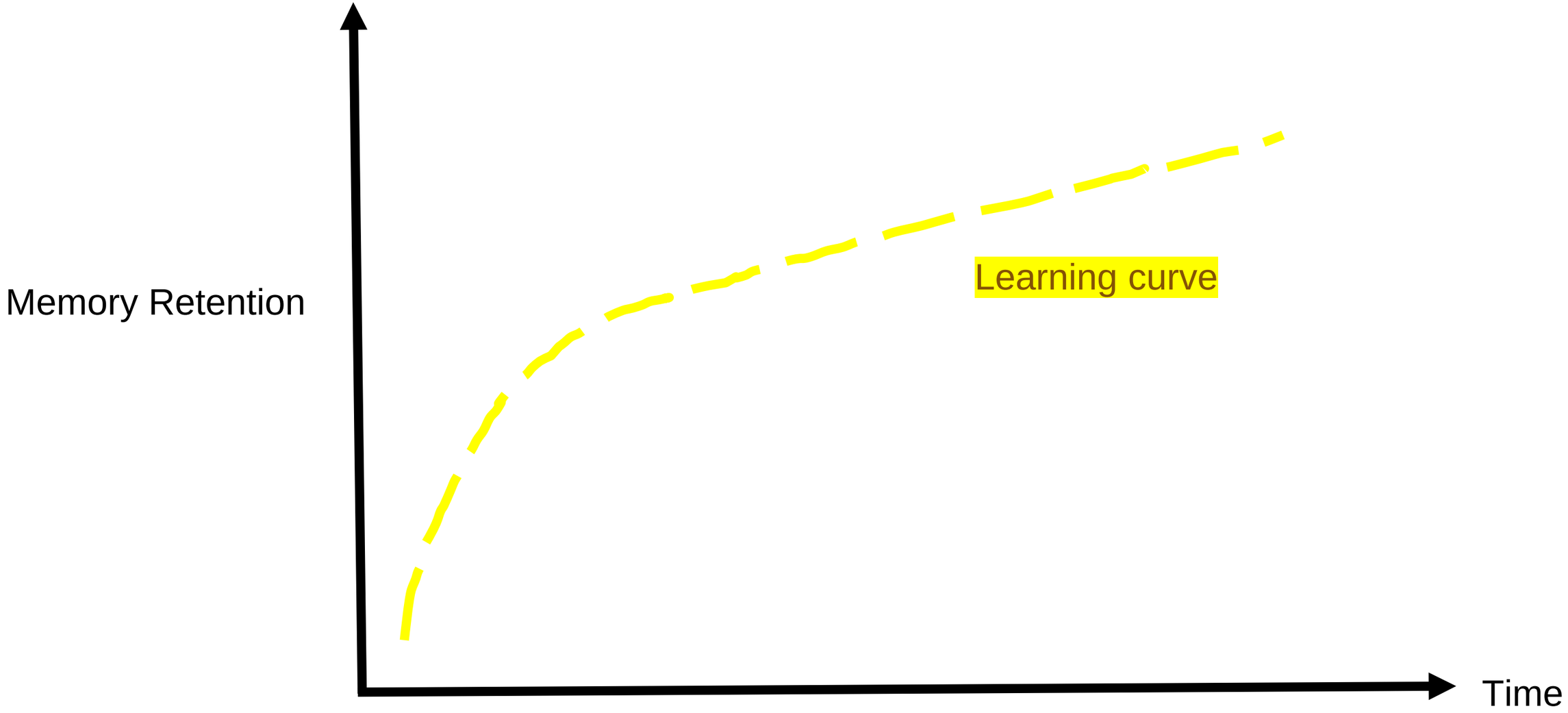
(Grant Wiggins, 1993)

Redesign & Strategy

- Redesign process is to convert a course plan for successful student outcome.

- Spaced repetition or distributed practice.
- Ebbinghaus's famous experiment of forgetting curve (1880-1885)


First learned
Memory Retention
Improved retention
Learning curve
Projected forgetting curve
Time
Intervention


Memory Retention
Learning curve
Time

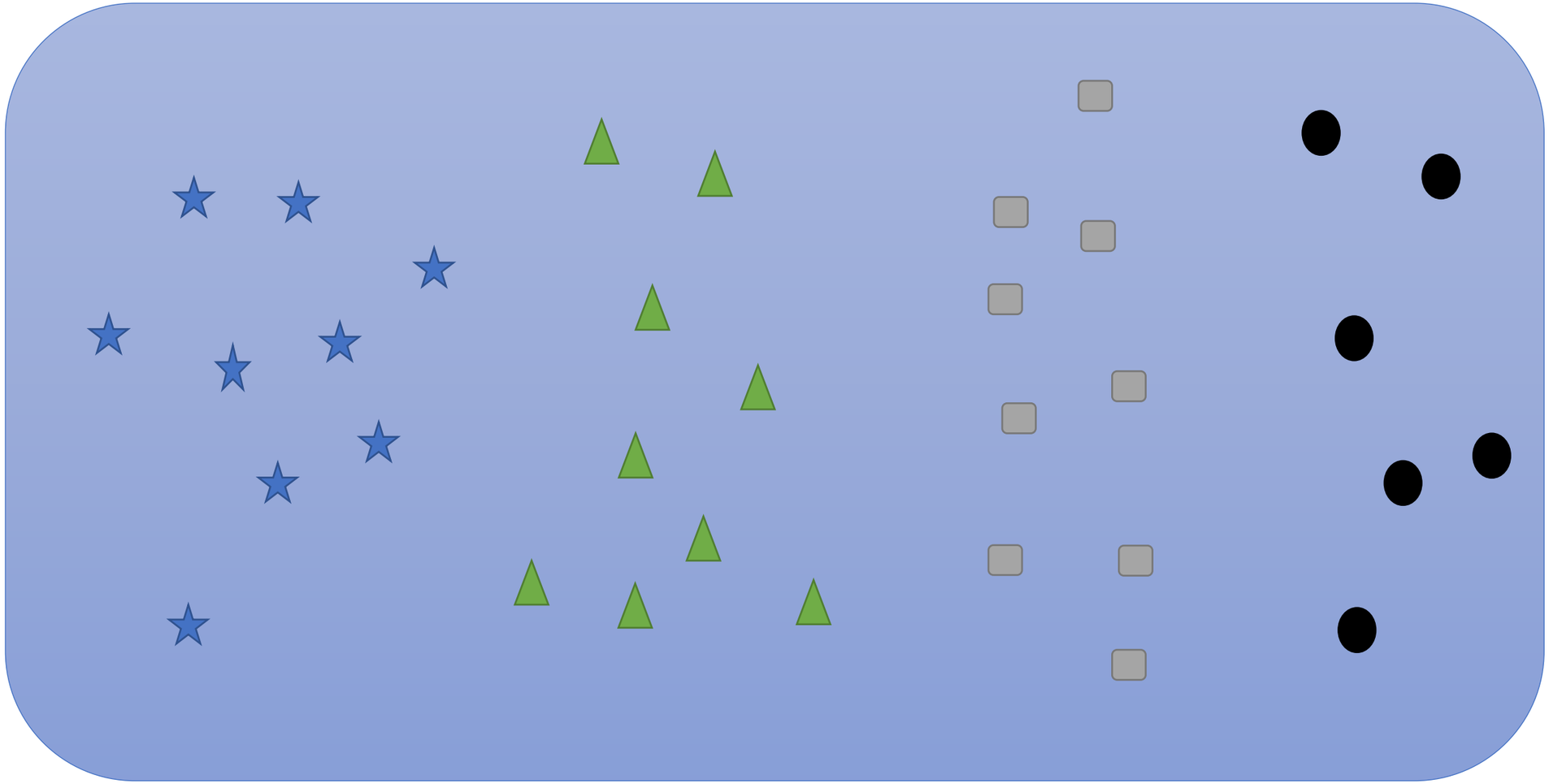
Summary of main idea

Apply spaced repetition to objectives of interest (not all).

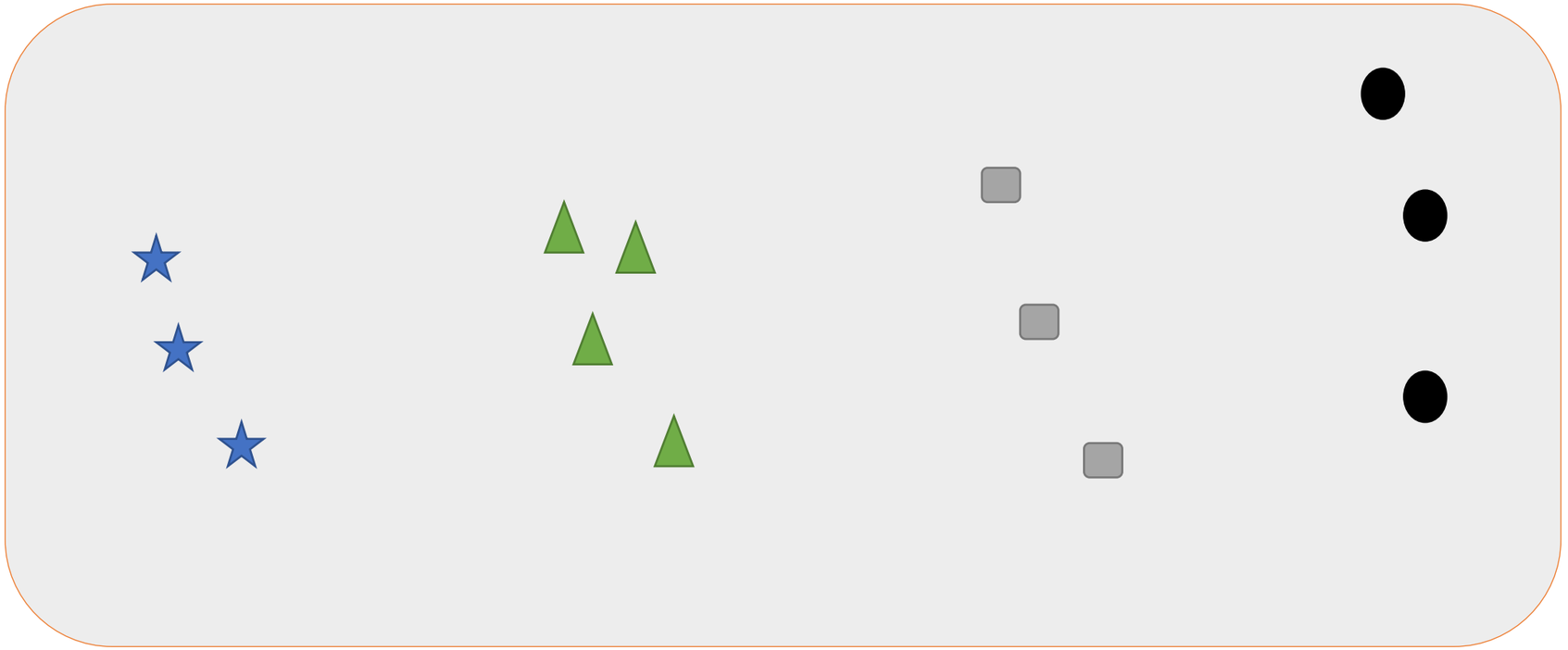
Use technology and written notes to supplement any objectives that don’t need much attention.

Improve design using course analytics after each run.

Method: Categorize Learning Objectives



Method: Sample from the Categories



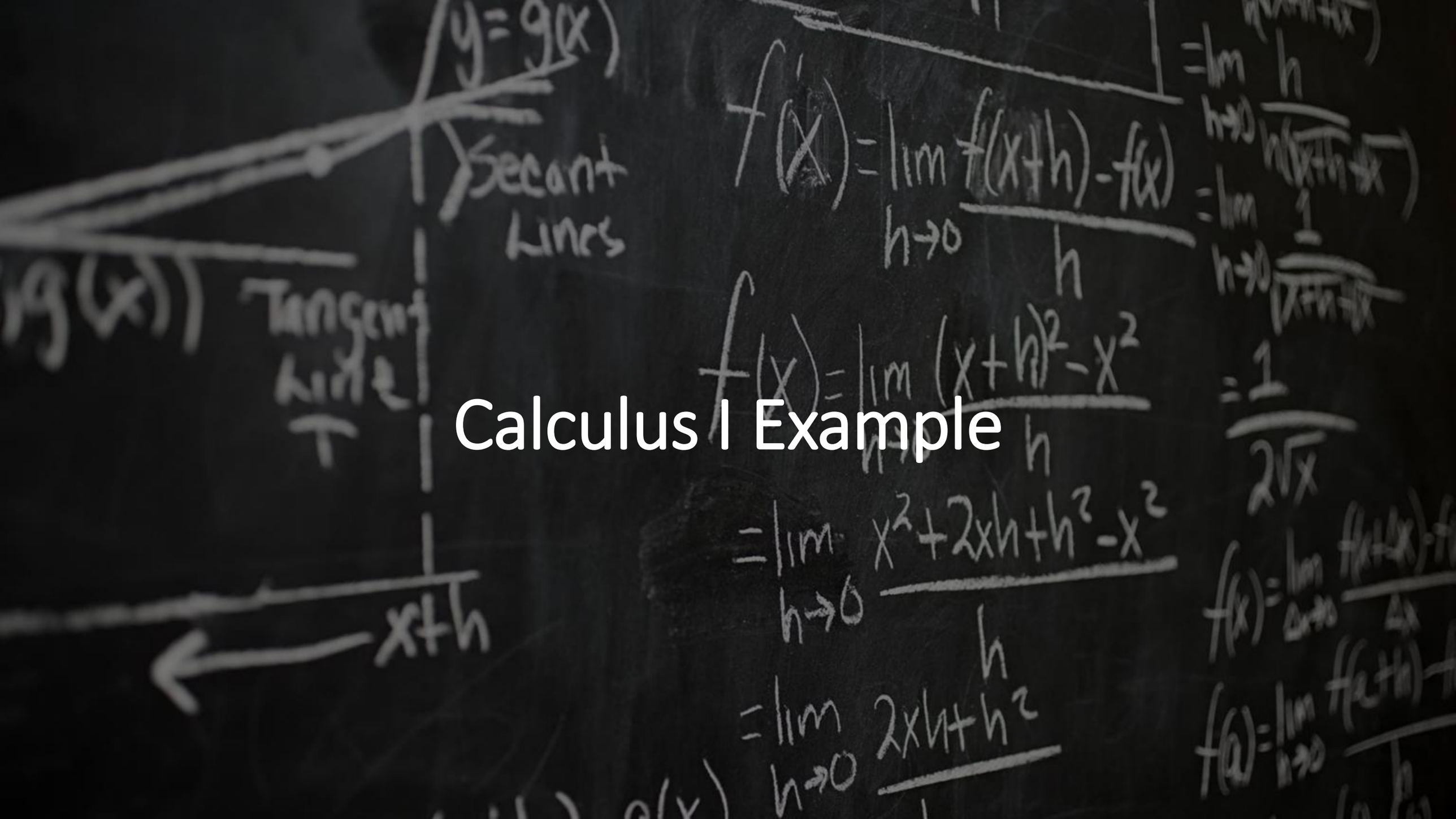
Method: Apply Criterion

1. Direct: What's important in the course? (survey) Or

2. Backward: Remediation, what's important to be successful in subsequent course? (survey) Or

3. Data analysis: Diagnostic (pretest) – convenient for lower level: Intermediate/college algebra, Or

- Data analysis for new iterations: Course Analytics from previous or finished runs.



Calculus I Example

Calculus I: Learning Outcomes

Understand the concept of limit of a function.

Be able to calculate limits.

Understand and apply the concept of continuity of functions.

Understand the concept of limit at infinity and evaluate them.

Understand the concept of horizontal asymptote, and the relationship between the horizontal asymptote and limit at infinity.

Understand the definition of derivative and be able to apply it to compute the derivative of a function.

Understand the relation between average rate of change and instantaneous rate of change.

Differentiate functions using appropriate differentiation rules.

Calculus I: Learning Outcomes

Calculate derivatives using implicit differentiation.

Solve application problems involving related rates and optimization.

Understand and be able to apply the concepts of linear approximation and of differential.

Apply differentiation to problems about maximum and minimum values.

Understand the proofs of the Mean Value Theorem and Rolle's Theorem and be able to apply them.

Recognize indeterminate forms of limits and know when and how to use l'Hospital's rule to evaluate them.

Be able to sketch a curve using asymptotes, critical points, intervals of increasing and decreasing, inflection points and concavity.

Understand the concept of antiderivative.

Understand the relation between area under curves and integration using Riemann sums and the Fundamental Theorem of Calculus.

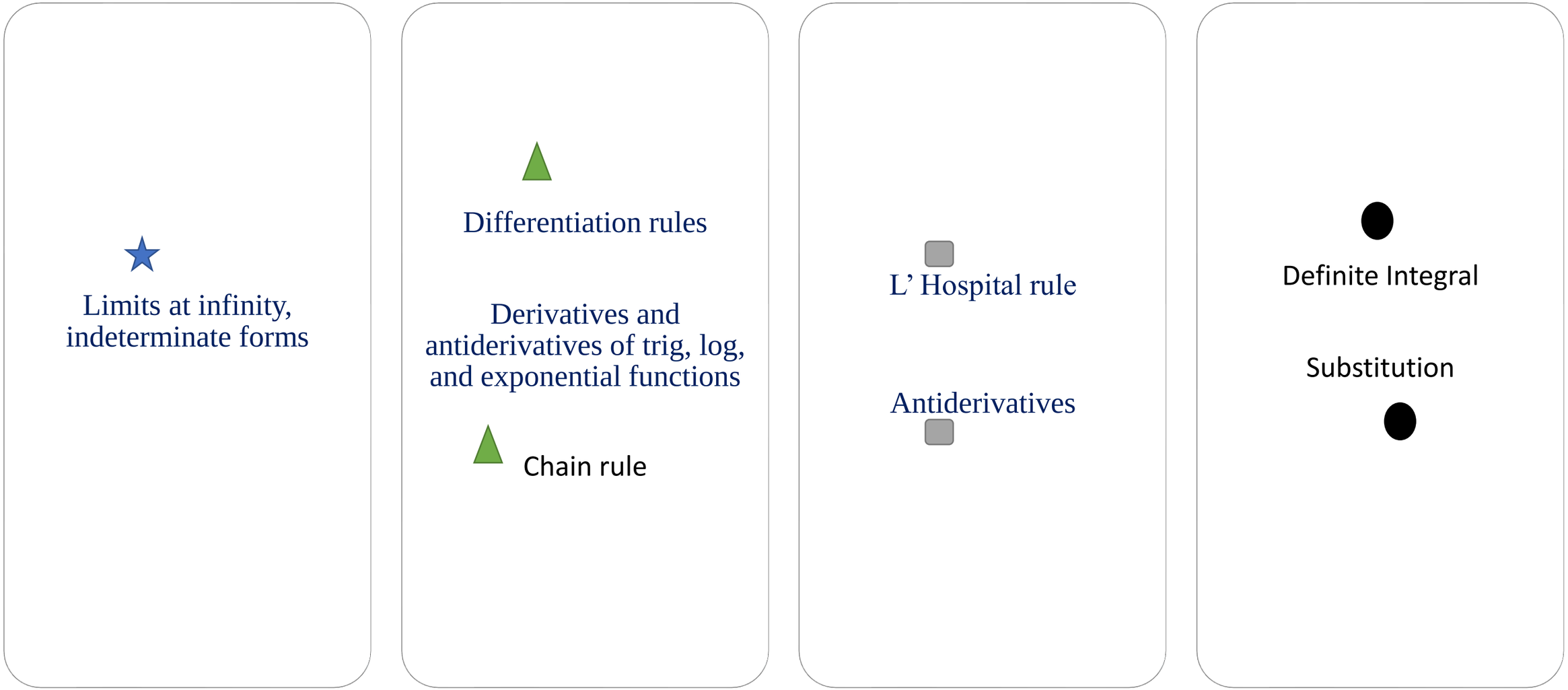
Solve basic integration using reverse differentiation rules and the Substitution Rule.

Overall, demonstrate stronger problem solving and critical thinking skills.

Be able to organize and communicate their work in a coherent way, using correct notation.

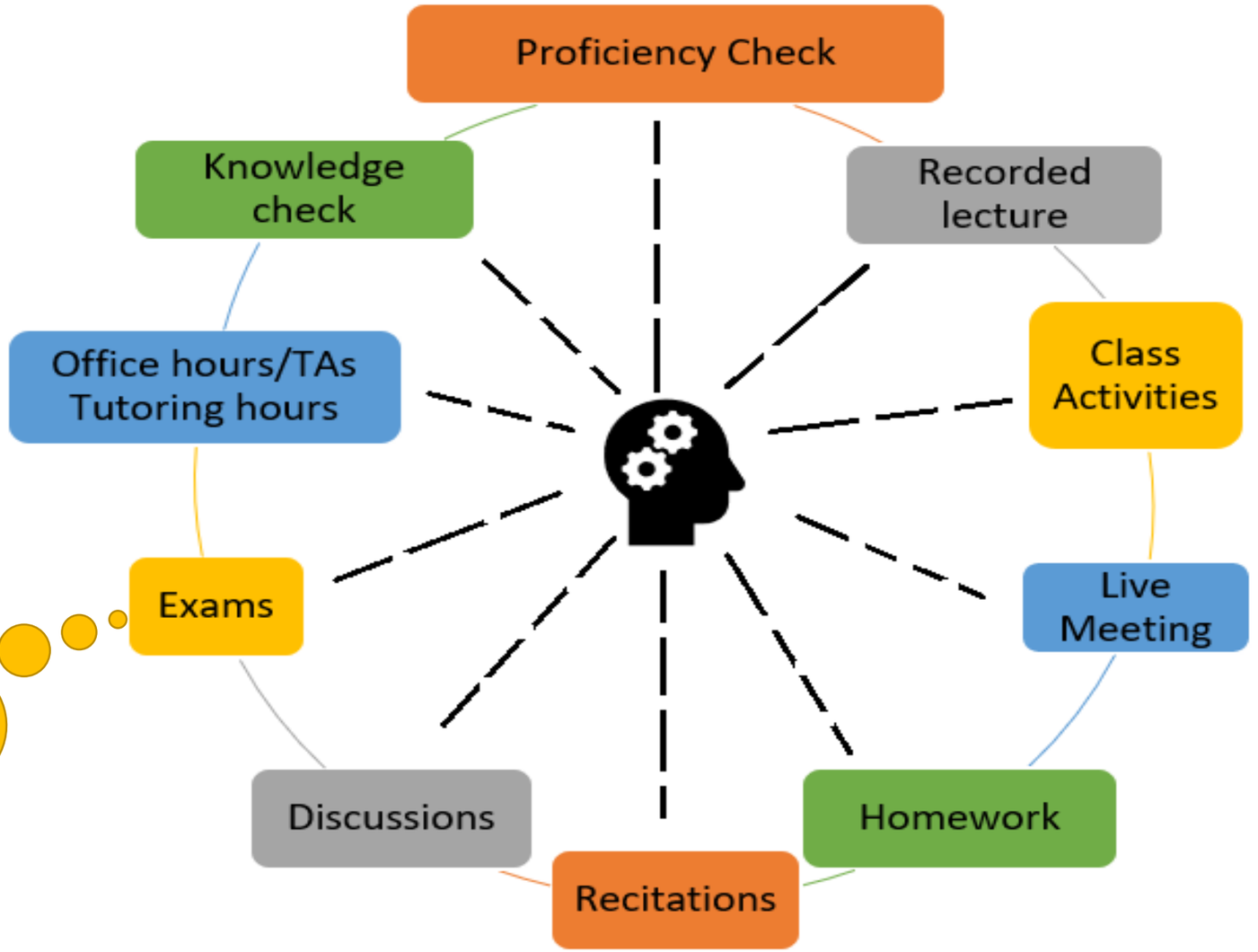
Criterion: What's important in the course? (Survey)

Criterion: Backward (Calc II > Calc I) (Survey)



How to integrate?

Planning Interventions on intervals



Mid term exams
use previous exams
questions concerning
spaced repetition

How to integrate?

Adjust Grading with reduction of high-stake assignments 2021

Assignment	Weight
Homework (due 11:00 pm)	13%
Calculus Proficiency Check	5%
Calculus Knowledge Check	5%
Lecture Activities (due 6:00 pm)	7%
Four Exams	50%
Recitation and orientation activities, Discussions	15%

Cramming is the worst way to learn math.

How to integrate?

Adjust Grading with reduction of high-stake assignments 2022

Assignments	Percentage	Notes
Adaptive Homework	20%	Two lowest scores are dropped
Calculus Proficiency Initial Check Calculus Knowledge Check	6%	
Lecture Activities (See full schedule for due dates)	15%	Two lowest scores are dropped
Recitation Activities (TBA), Orientation Activity & Discussions (See full schedule for due dates)	5%	In recitation Orientation and Discussions are online/Webcourses One lowest score is dropped
Exam 1 due 2/4/22 - Recitation period Exam 2 due 3/4/22-Recitation period Exam 3 due 4/8/22 - Recitation period	36%	In recitation classroom per schedule See full schedule for included topics. Exams will include topics from previous exams for repetition. Best two scores are used, or lowest score is dropped
Final Exam	18%	In classroom Cannot be dropped and does not replace another exam See full schedule for included topics. Also, selected topics from exams 1, 2, and 3 may also be included

How to integrate?

Challenge:

- Some topics appear in second have or late in the course
- Introduce early in some form that allow to build and repeat

- Use prior knowledge
- Optimization using vertex can be introduced earlier
- Limits at infinity can be introduced early using graphs and transformations
- Integration can be introduced on the first day as a distance problem
- Chain rule with power rule
- Our students come knowing L’Hospital rule, they aren’t sure about indeterminate form.


Results

Data analysis: Course Analytics from previous run Fall 2021
Top 10, % of Students Struggled (end up mastering)

	Struggled	Mastered	Didn't Master
Determine the differentiability of piecewise functions	59%	86%	14%
Combine the product and quotient rules	55%	86%	14%
Graph the derivative of a function	56%	89%	11%
Use related rates to solve problems involving volume	53%	96%	4%
Determine the continuity of a piecewise function	39%	96%	4%
Use the chain rule with the power rule	28%	89%	11%
Explain the three conditions for continuity at a point	28%	100%	0%
Find a higher-order derivative of a sine or cosine function	23%	95%	5%
Use the chain rule with the product or quotient rule	15%	89%	11%
Distinguish between three kinds of discontinuity	13%	98%	2%

Data analysis: Course Analytics from previous run Fall 2021
Top 10, Easiest (Mastered easily)

	% Struggled	% Mastered
Find the limit of a polynomial or rational function using limit laws and direct substitution	0	100%
Use the constant, constant multiple, and power rules	0	96%
Evaluate limits graphically	2	100%
Understand the limit of a function and evaluate a limit from a table	2	100%
Find absolute extrema	3	76%
Find the derivative of other trigonometric functions	5	95%
Define a vertical asymptote	7	98%
Understand differentiability and when a function does not have a derivative	11	100%
Find the derivative of a natural logarithmic function using properties of logarithms	11	96%
Use related rates to solve problems involving area	15	93%

Results Spring 2022

How are things going so far with this course? 71% great

Do you think you will review a past review even if it was not required that week for an assignment or an exam? 50% yes

Lecture activities helped me with time management and quick practice. 89% yes

Discussions are not common in math courses, but they intend to help you write or research and learn from writing and classmates. 50% agree

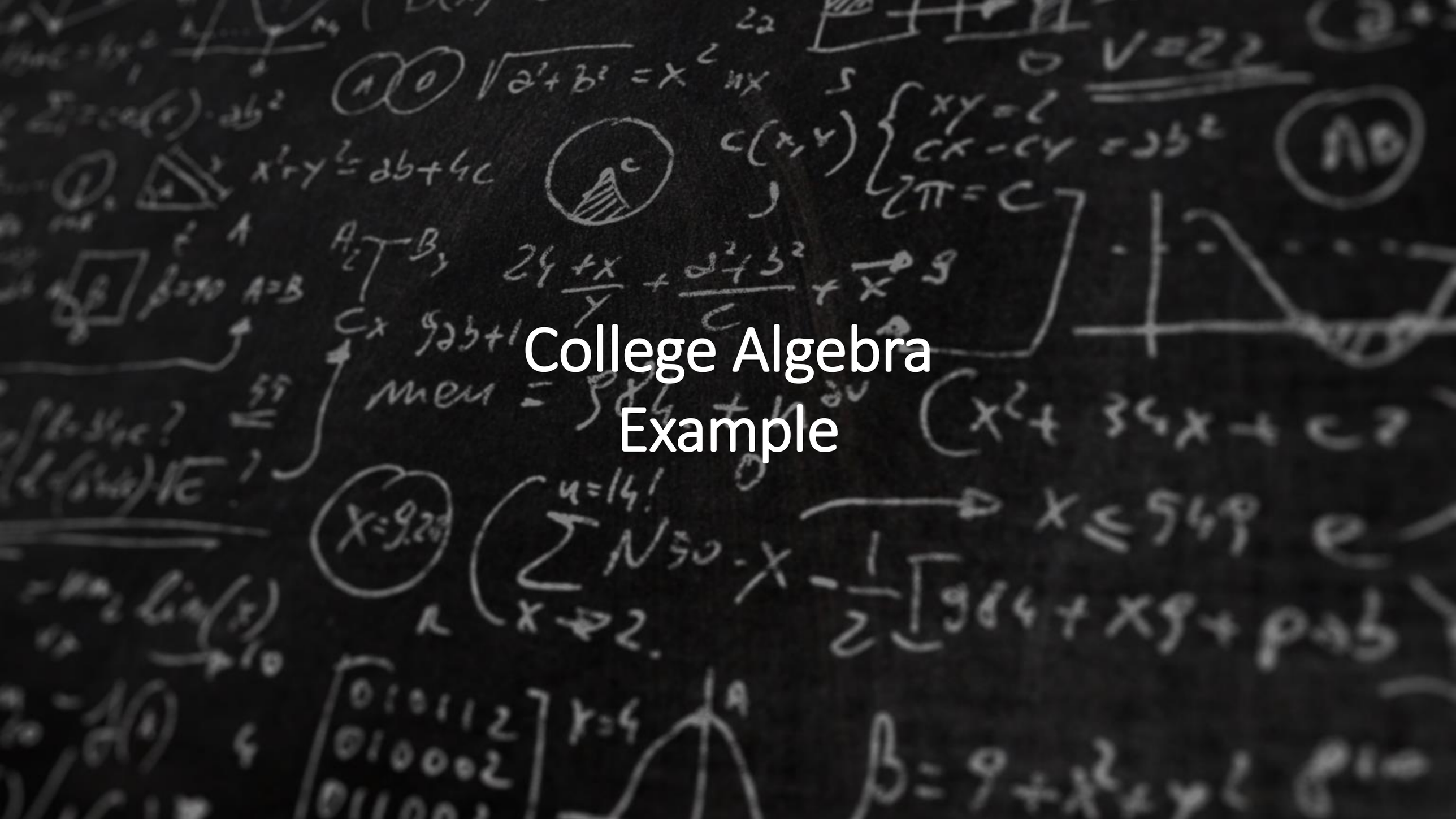
Important Results for Exploratory Study 2022

Spaced repetition or distributed practice is used in this course by bringing previous questions from previous exams/assignments. It helped me with remembering them.

95% agree, 2% disagree. 4% no comment

I'm confident I can talk about Calculus in public.

84% Agree



College Algebra Example

Combining Keller's Plan with Spaced Repetition

- Spaced repetition based
  - on Data analysis:
    - Diagnostic (pretest)
    - Weekly analytic reports

- PSI or Keller's Plan:
  - Modularized content,
  - Prepare written material,
  - Pacing,
  - Mastery,
  - Human proctor.
- Monitor time on task.
- Adaptive system.

Overall Target Course Success (ABC) by Prerequisite Course Attempt Source

MAC 1105 College Algebra

students from UCF

overall success in

subsequent or target course

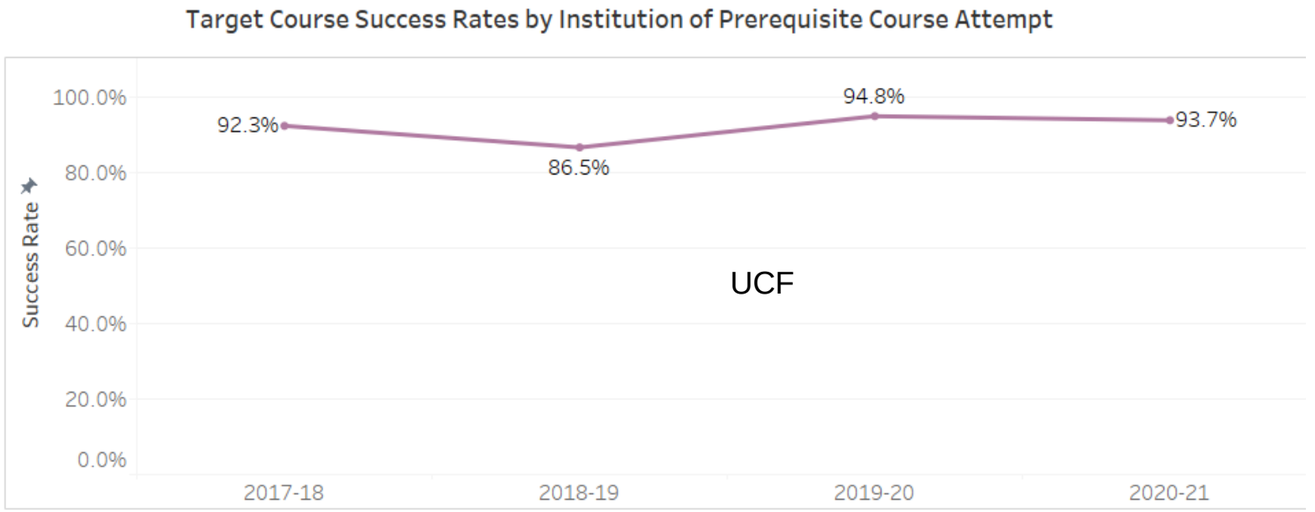
MAC 1140 Precalculus Algebra

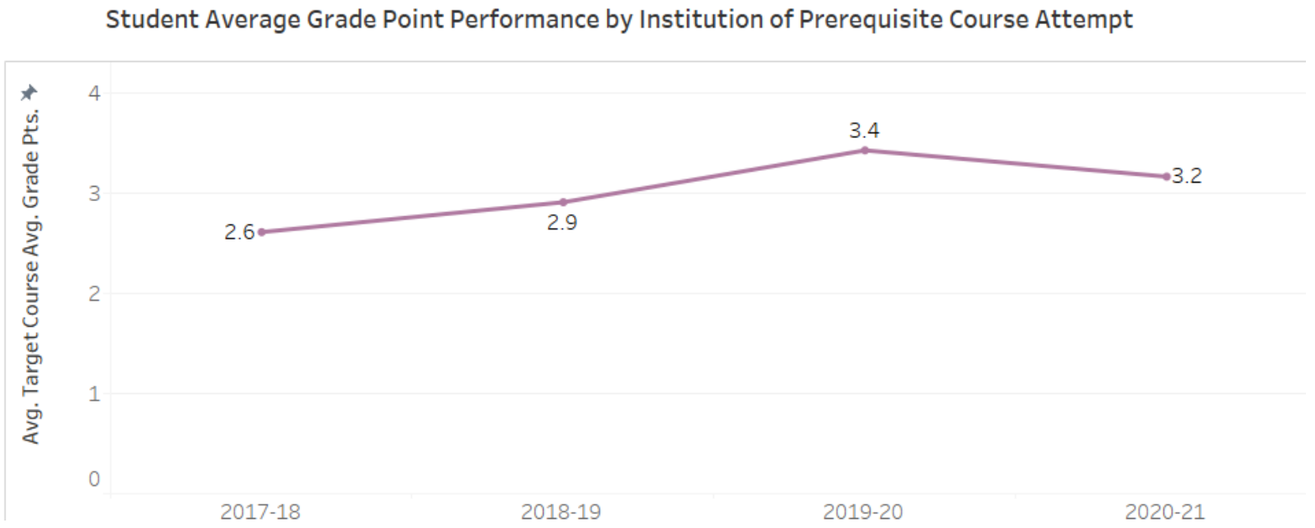
is 91.9%, higher when

Compared to students

who transferred in college algebra or used another way, 80.6%.

MAC 1140 Precalculus Algebra
2017-2021





Overall Target Course Success (ABC) by Prerequisite Course Attempt Source

MAC 1105 College Algebra

students from UCF

overall success in

subsequent or target course

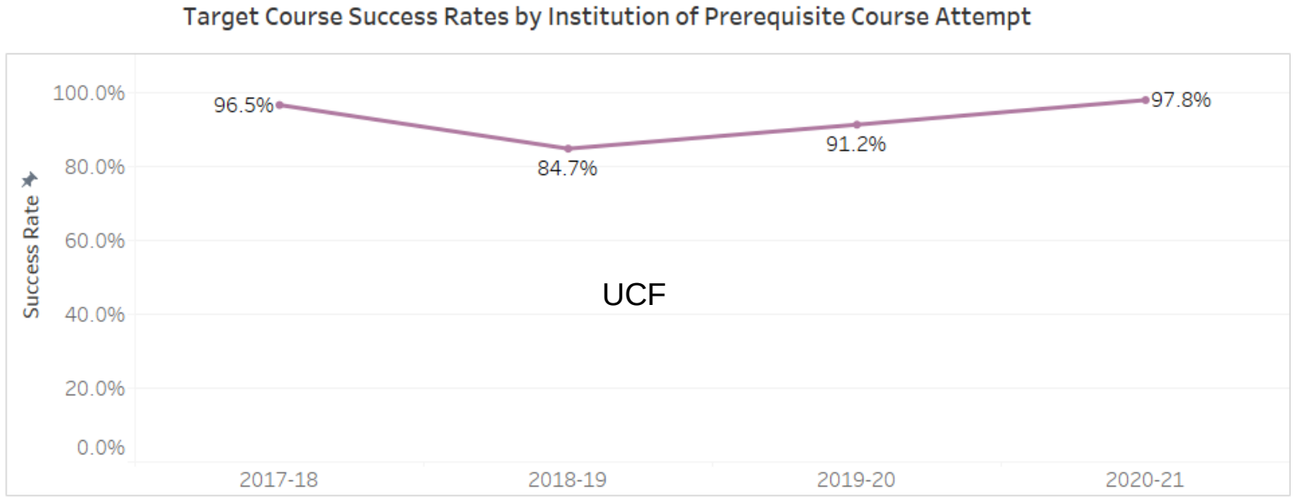
MAC 1114 College Trigonometry

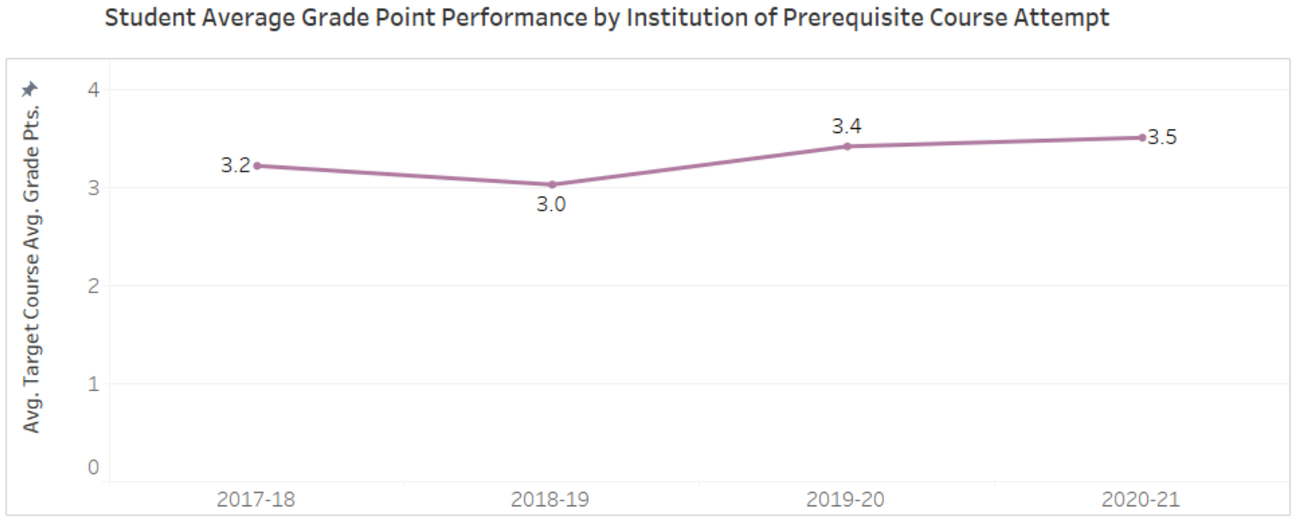
is 92.8%, higher when

Compared to students

who transferred in college algebra or used another way, 86%.

MAC 1114 College Trigonometry
2017-2021





Final Thoughts

- Use first day of class to justify reasons behind design. Ask students for input.
- Work on human connection from the first day.
- Include relevance.
- Assign roles if groups are used.
- Post materials early.
- Using LMS and Conference technology (Zoom/Teams).
- Embed undergraduate or graduate assistant in meetings.
- Have activities for students to connect ideas or explore to create new ideas.
- Give prompt feedback.
- Facilitate collaboration, engagement, peer evaluation and/or peer reflection
- Facilitate environment in which students should feel secure to communicate
- Adopt flexibility and empathy.
- Model the behavior that you want to see: Curiosity, use of textbook, solving more problems, ect.

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Thank you!