Flat space, deep learning

Penn State University
State College, PA, 20 March 2015s

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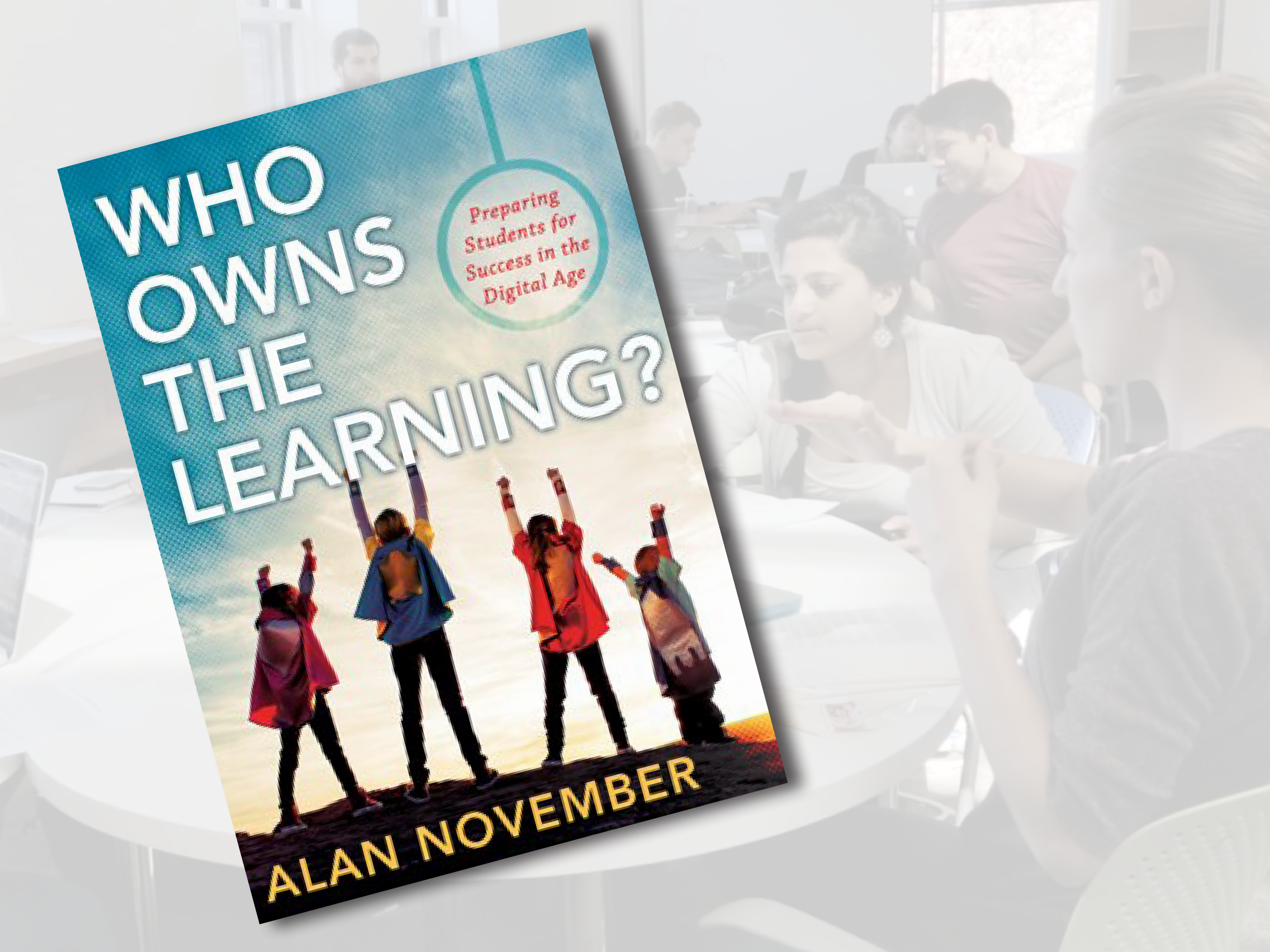
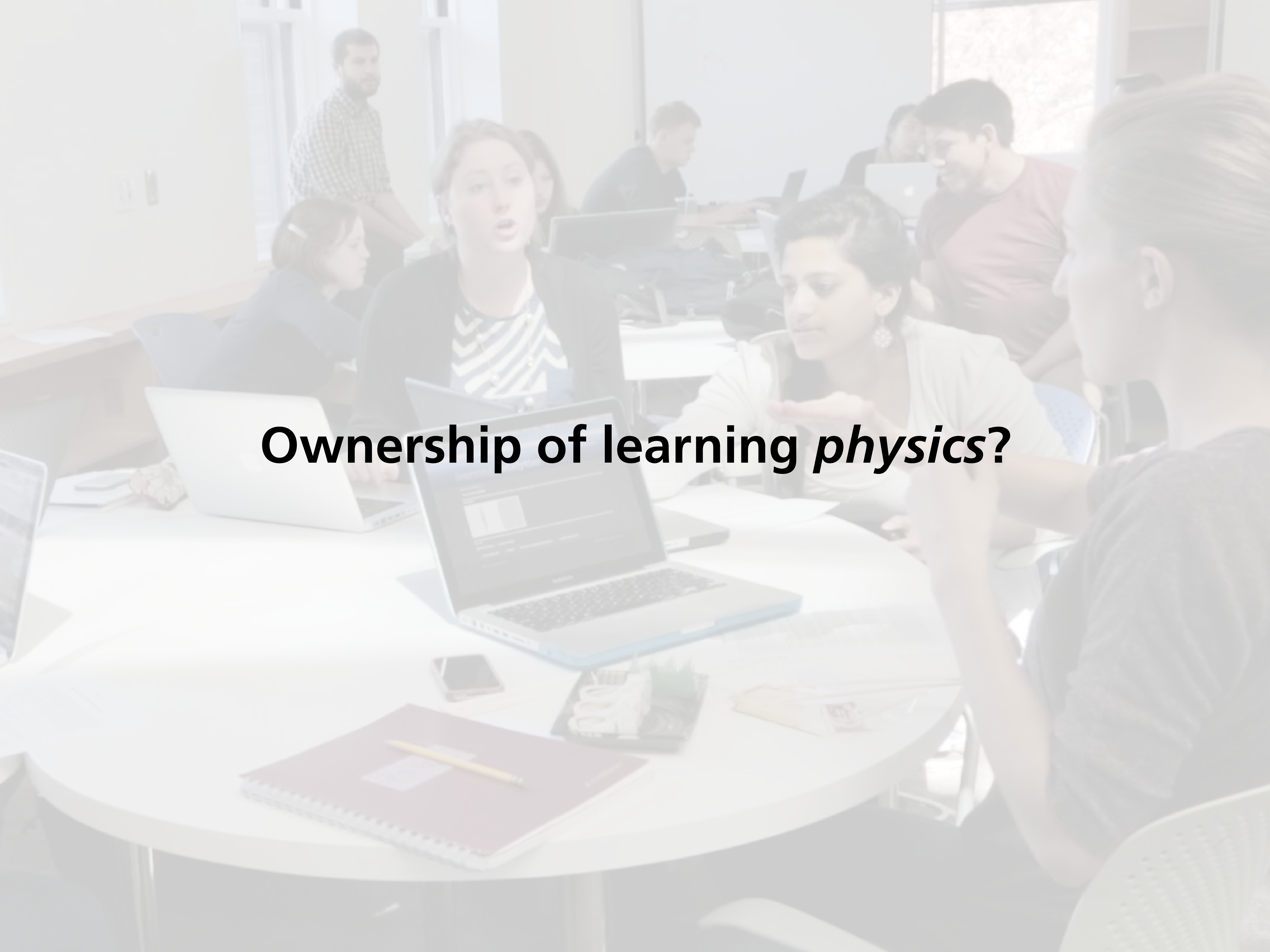
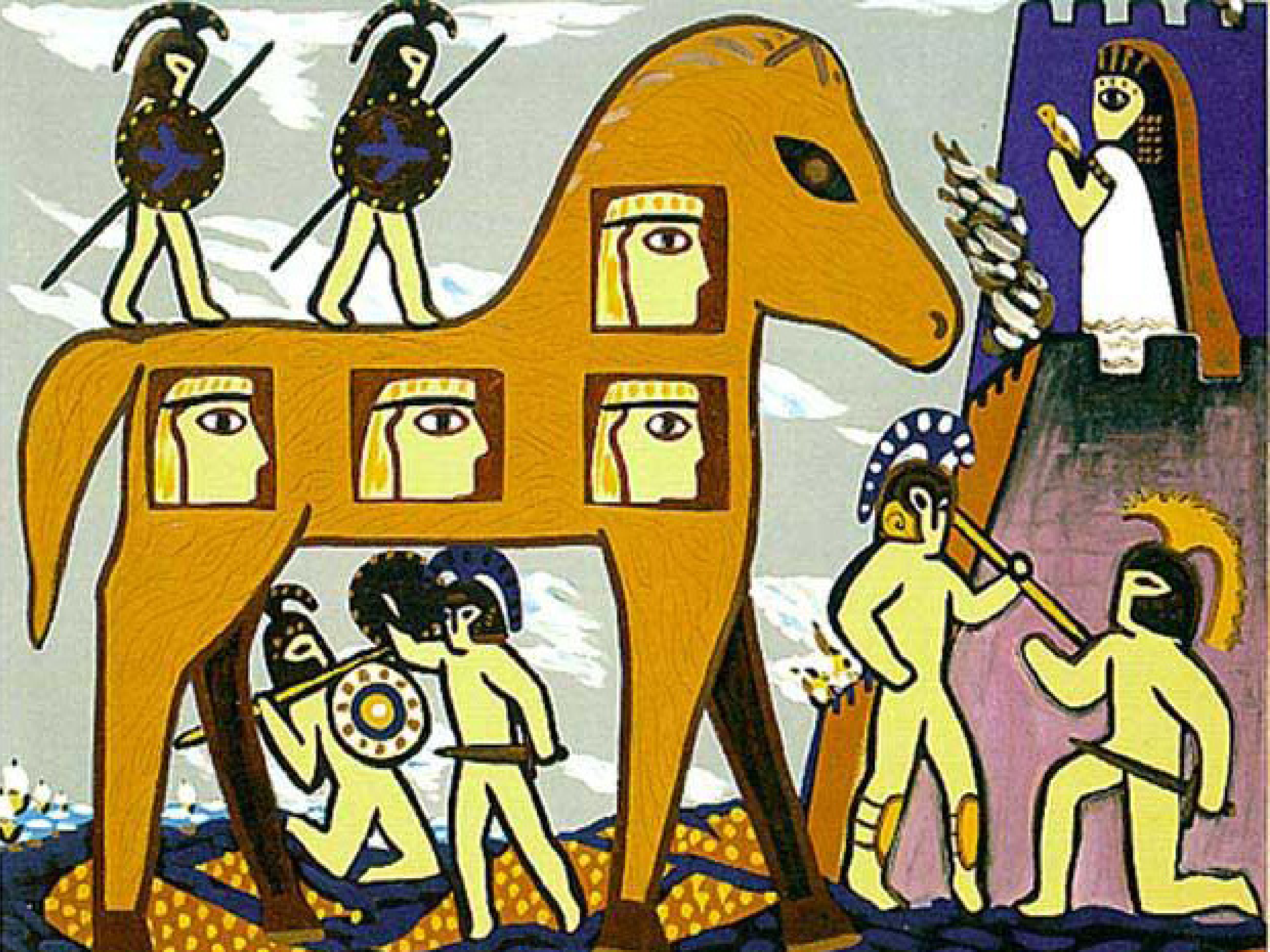

WHO
OWNS
THE
LEARNING?
Preparing Students for Success in the Digital Age
ALAN NOVEMBER

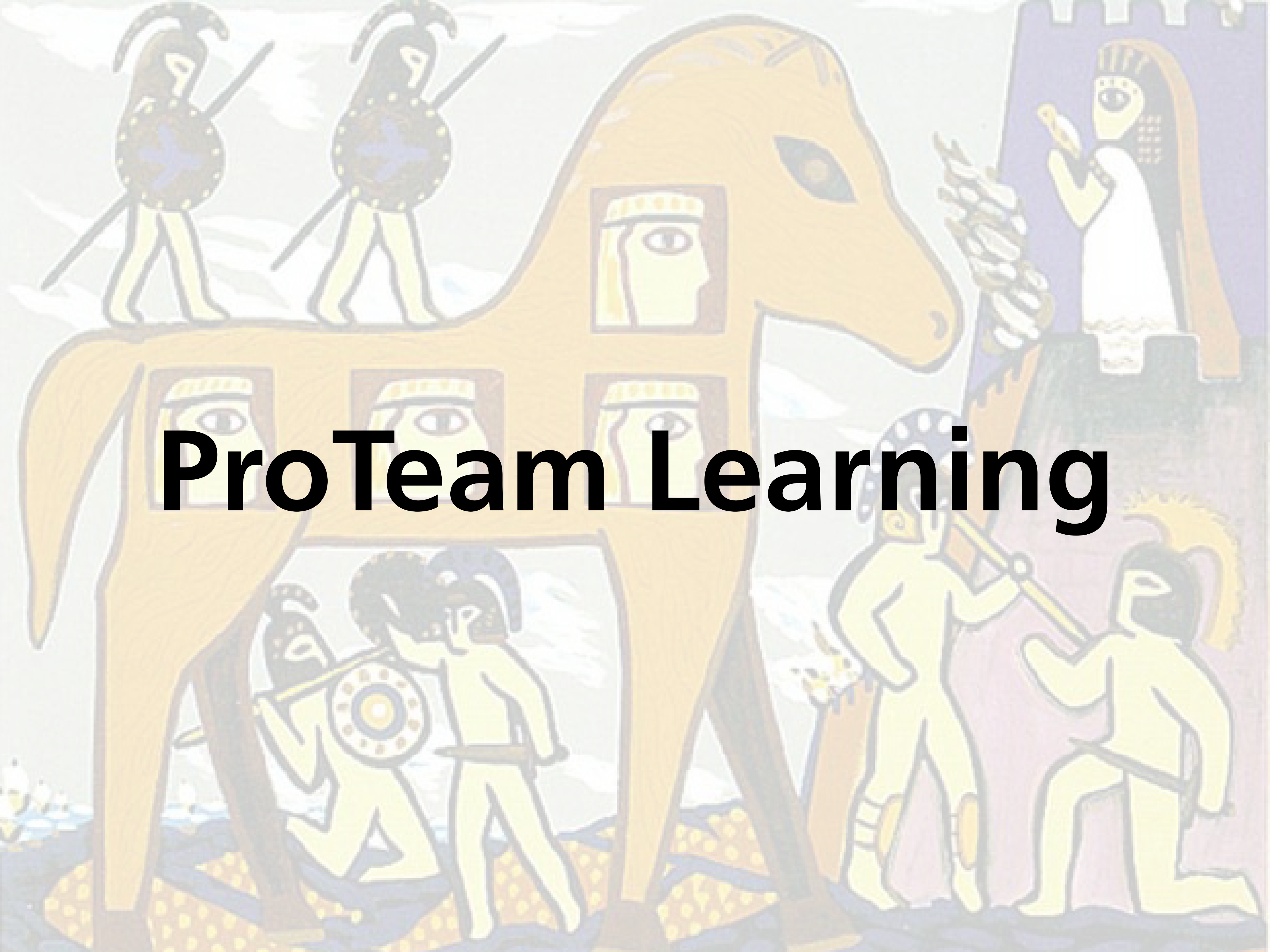
Ownership of learning *physics*?





team & project-based approach

ProTeam Learning

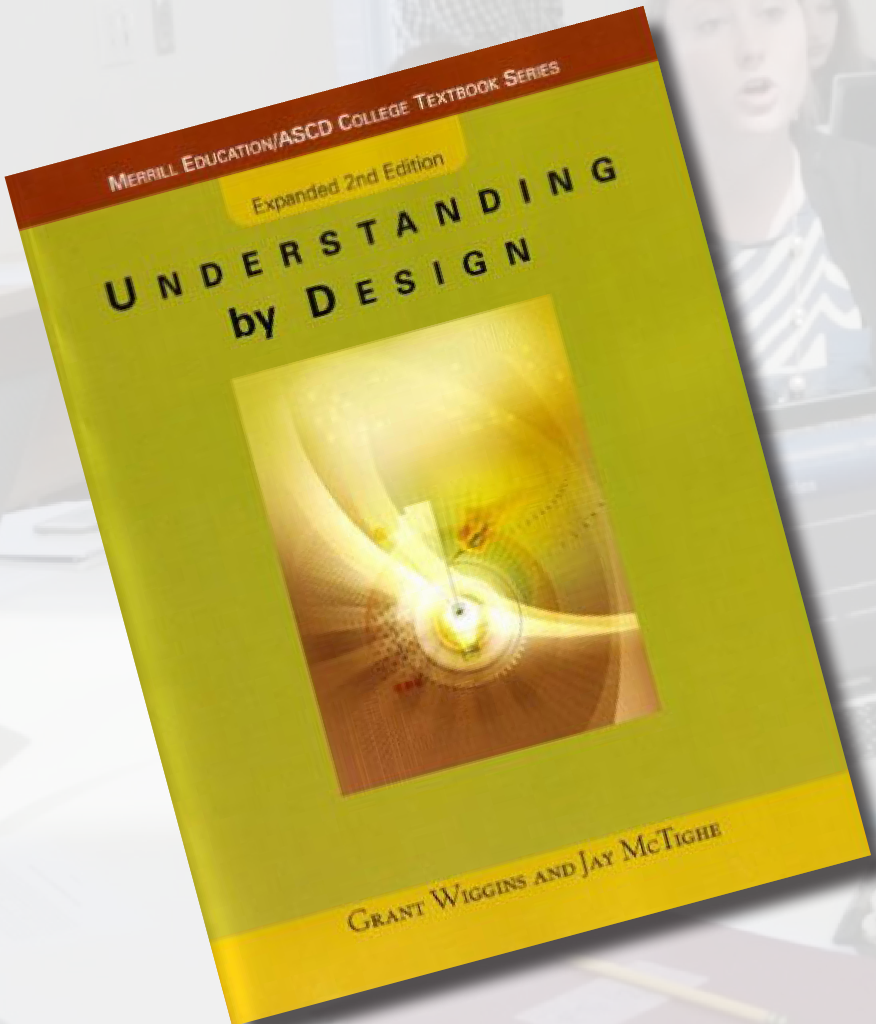


1 design

1 design
2 approach

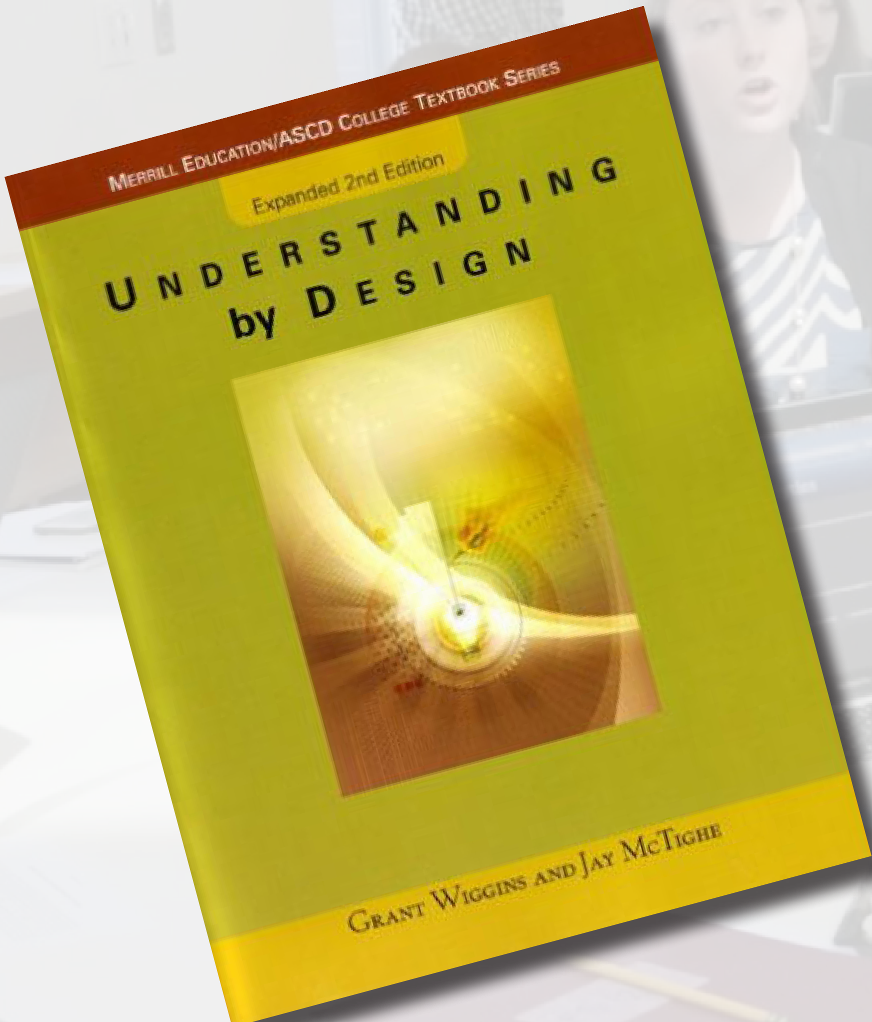
1 design 2 approach 3 results

Setting learning goals



Grant Wiggins and Jay McTighe, *Understanding by Design* (Prentice Hall, 2001)

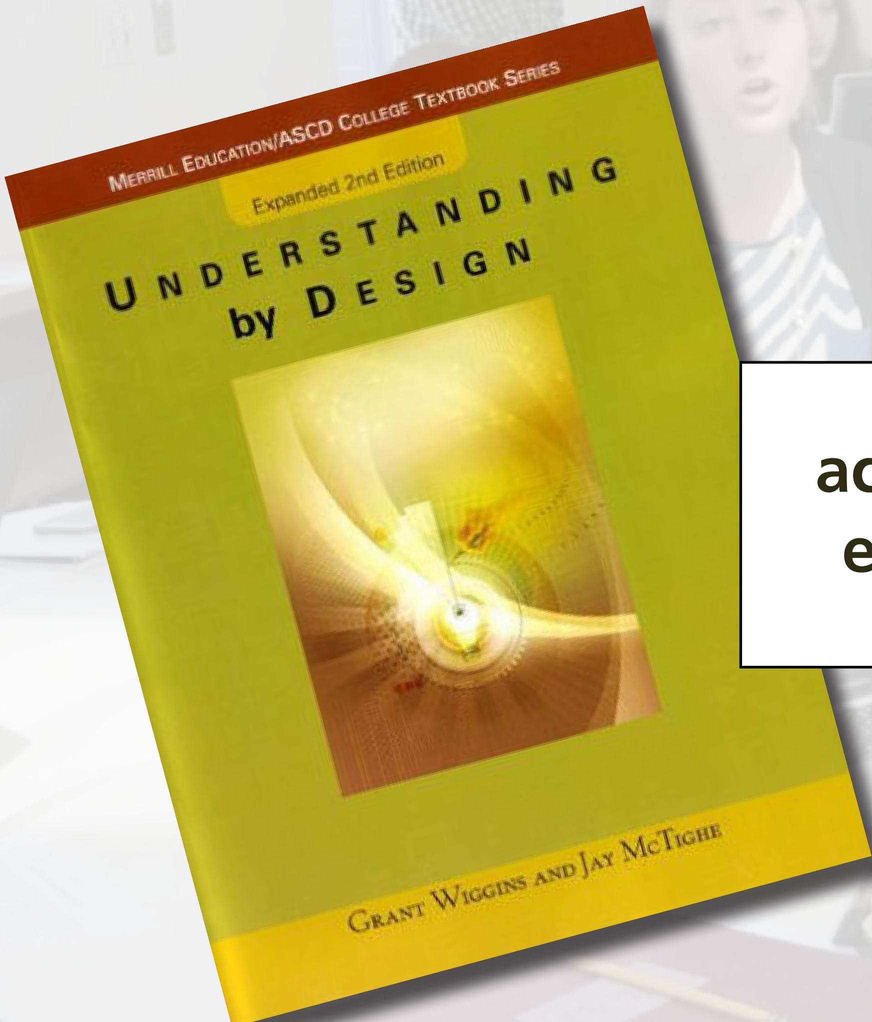
Backward design



desired outcomes

Grant Wiggins and Jay McTighe, *Understanding by Design* (Prentice Hall, 2001)

Backward design



acceptable evidence ◀ **desired outcomes**

Grant Wiggins and Jay McTighe, *Understanding by Design* (Prentice Hall, 2001)

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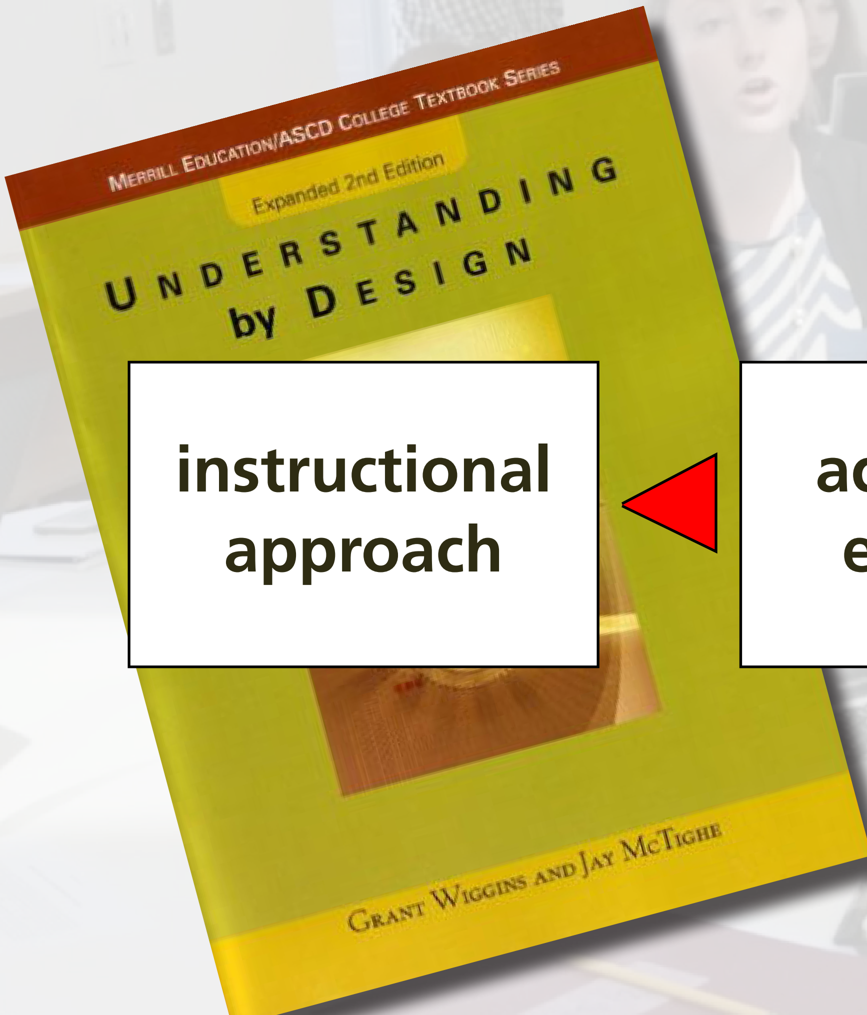


instructional approach ◀ acceptable evidence ◀ desired outcomes

Grant Wiggins and Jay McTighe, *Understanding by Design* (Prentice Hall, 2001)

competencies

course goals

COURSE GOALS

After successful completion of this course, you will be able to... (wit

- Use independent study and research to tackle a problem
- Apply the scientific method to advance your knowledge and to desi
- Use a variety of techniques to get a handle on problems: repres
  perform ord of magnitude estimates, use dimensional analysi
  symmetries, evaluate limits, and/or relate the problem to cases w
- Set up, solve, and interpret relevant equations
- Know how to evaluate the correctness of a solution
- Explain assumptions made in a model and know how to justify
- Analyze a system, explain why it works, and how to optimize
- Use information to build a case for a specific design or measu
- Describe how a measurement is performed and the limitati
- software to control simple experiments and accumulat
- dentify sources of uncertainty, and minimiz
  easurement in order to develo
  ts and presentat

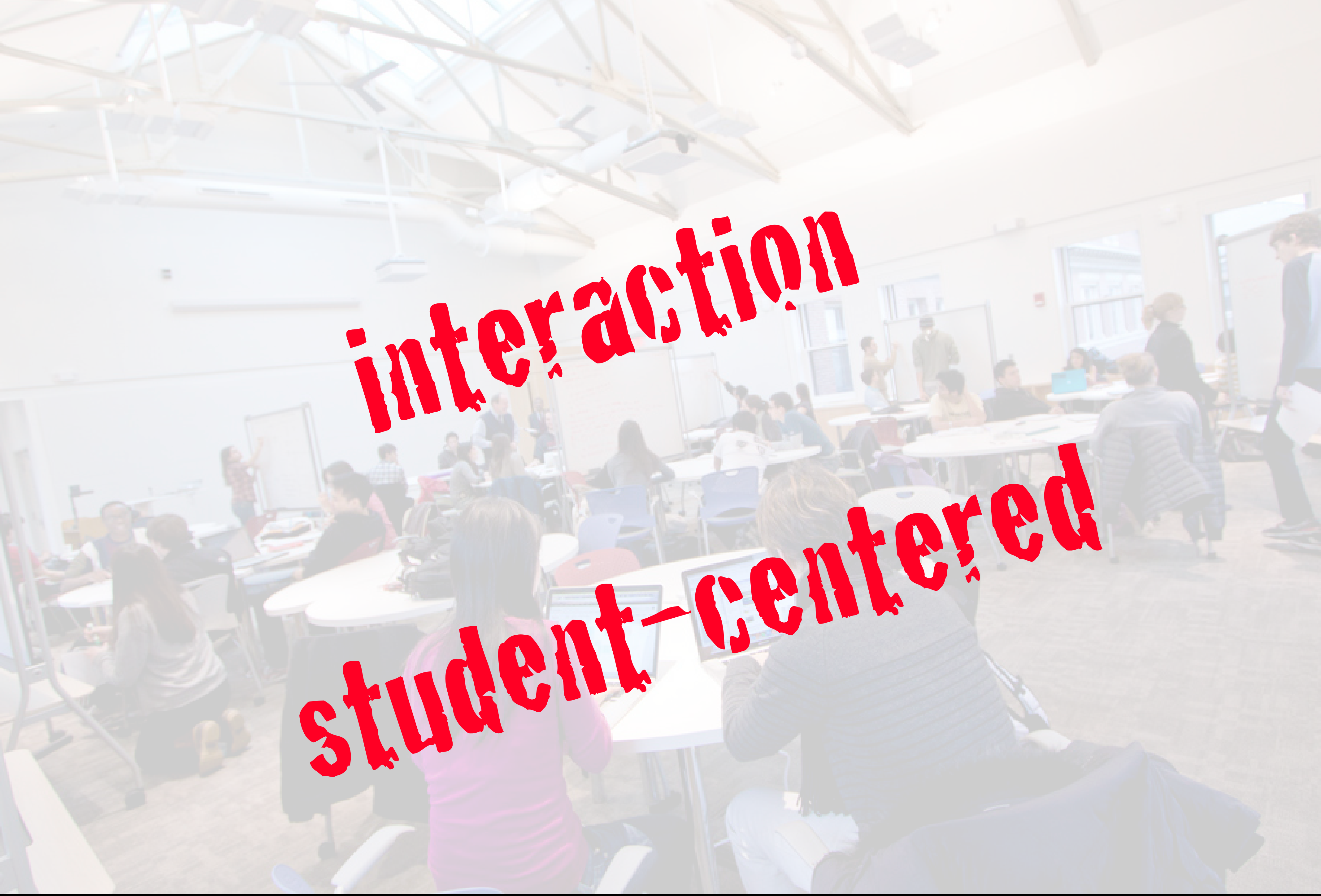
content-specific goals

http://bit.ly/ap50visitor

1 design

1 design

1 design



1 design

1 design 2 approach

CLASS

1st exposure

ROOM

deeper understanding

1 design

2 approach

CLASS → **ROOM**

1st exposure — deeper understanding

ROOM → **CLASS**

1st exposure — deeper understanding

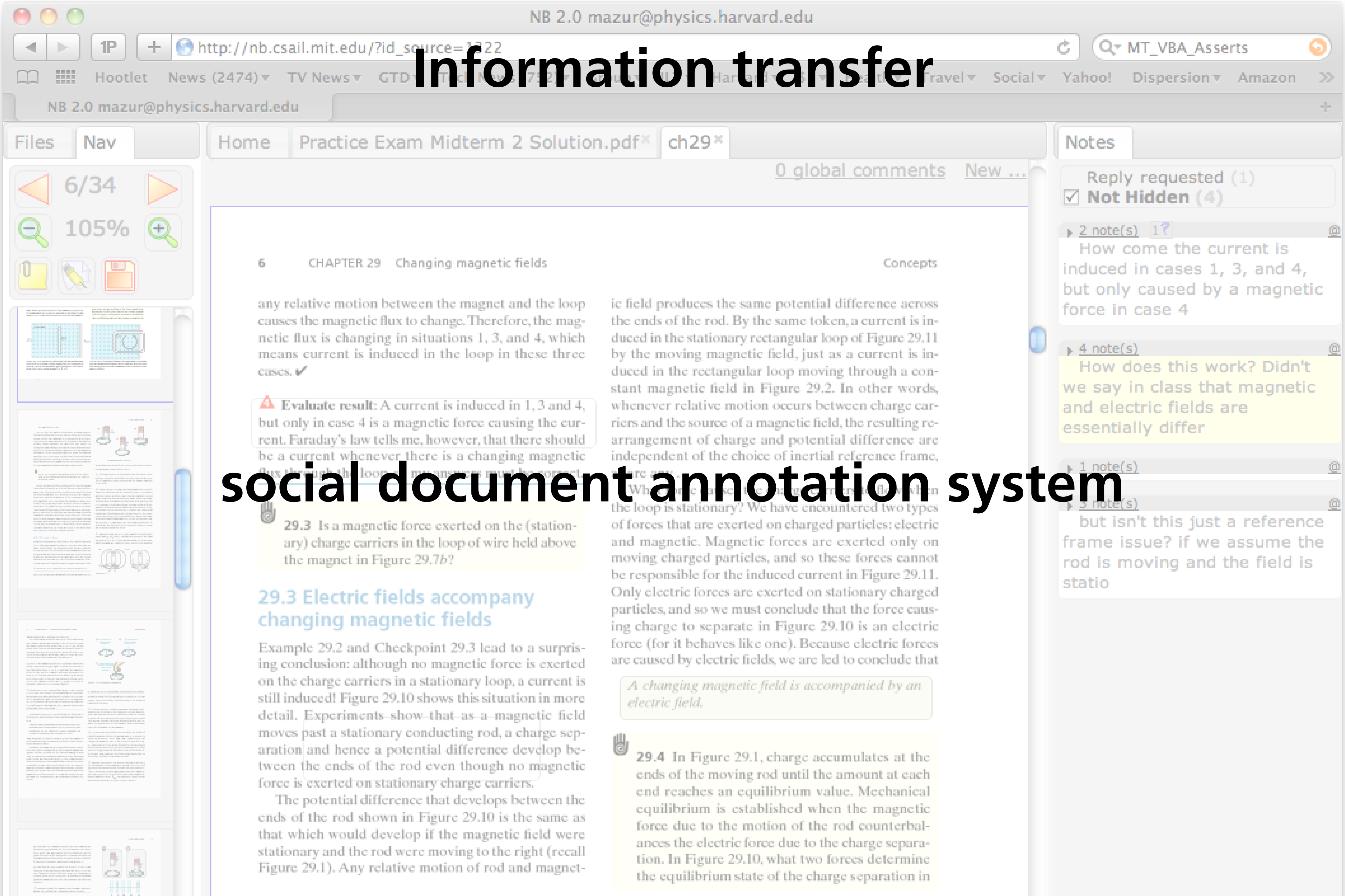
1 design **2** approach

❶ design ❷ approach

Three major components:

- information transfer (out of class)
- in-class activities
- projects

Information transfer

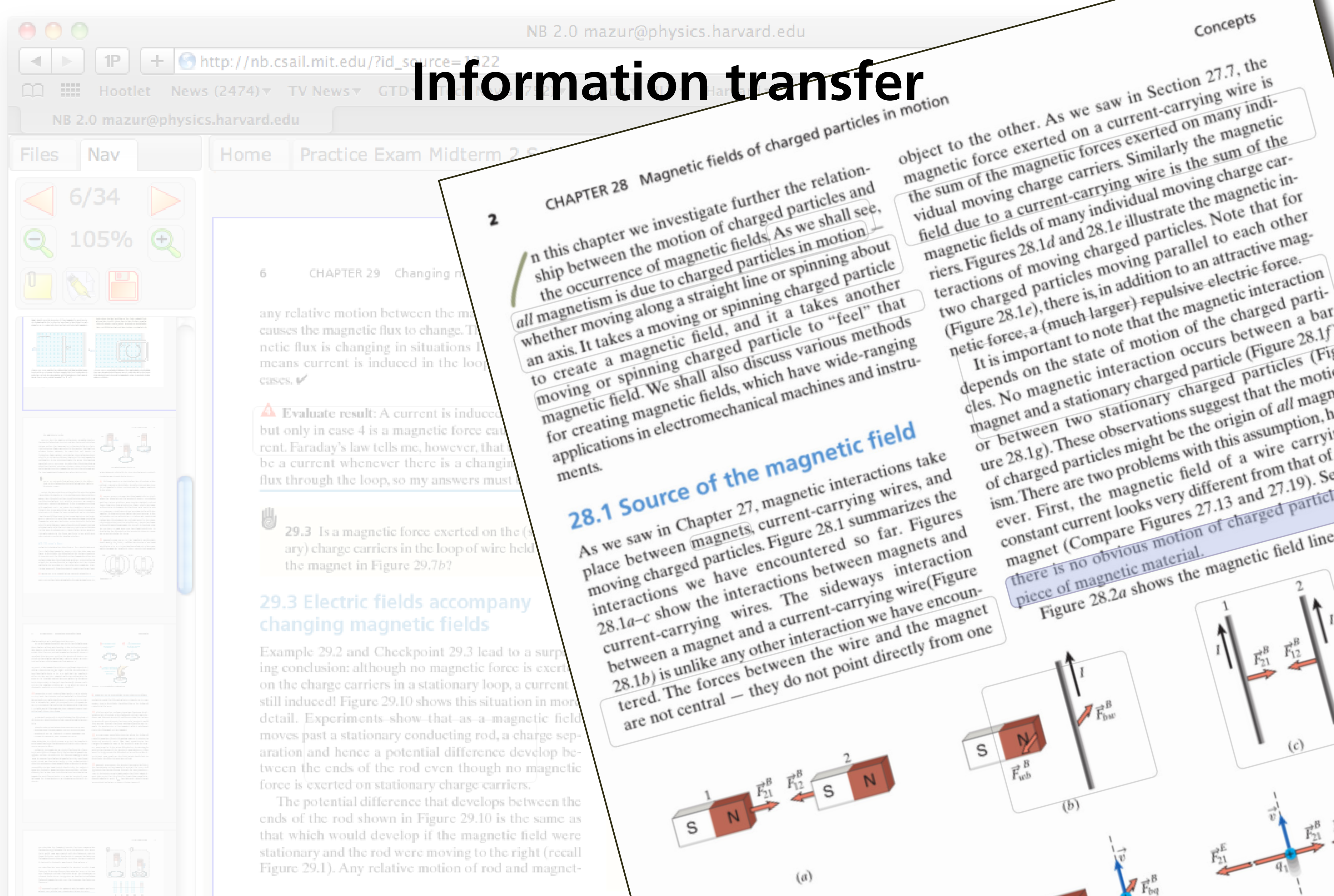


social document annotation system

1 design

2 approach

Information transfer



1 design

2 approach

Information transfer

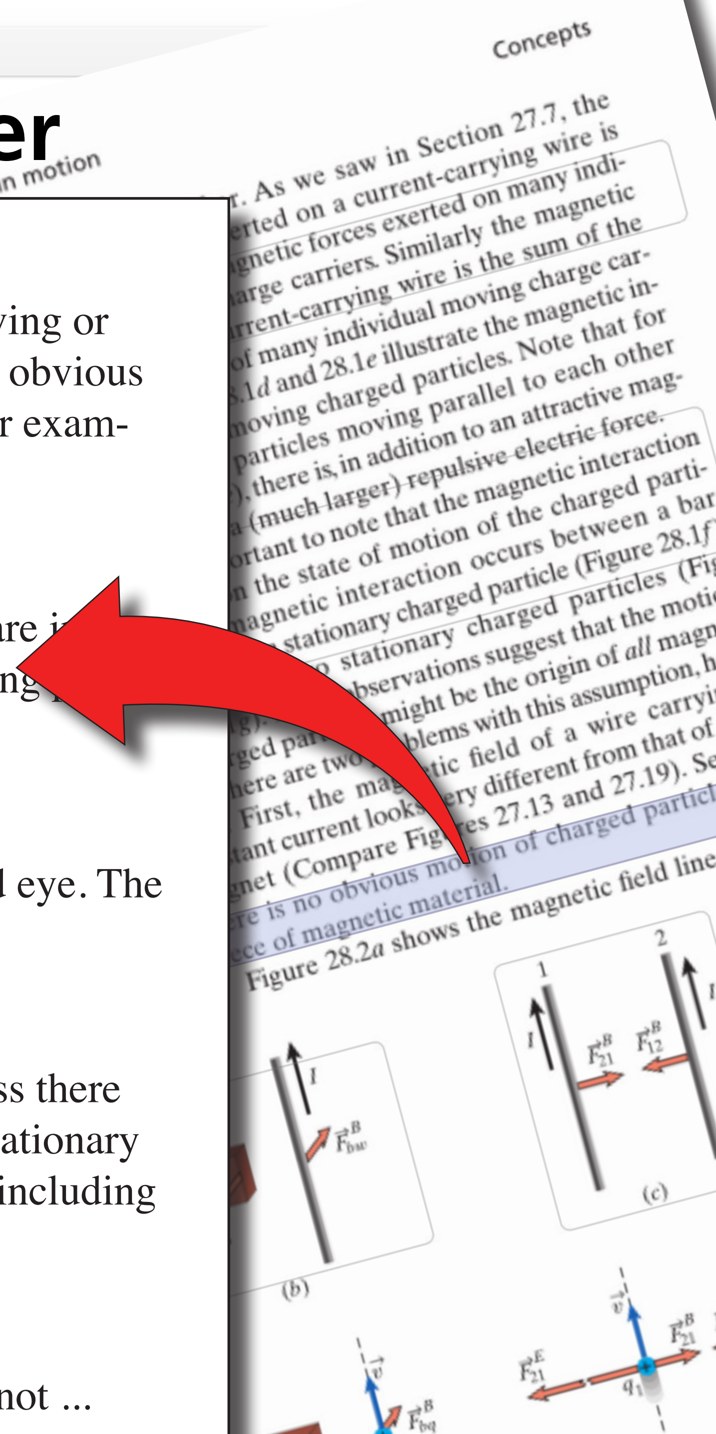
Student 1 – 25 Feb, 04:55PM
Yeah, this is where I'm confused. From the first paragraph: "It takes a moving or spinning charged particle to create a magnetic field..." however there is no obvious motion of charged particles in a piece of magnetic material (bar magnet for example?). How does this reconcile?

Student 2 – 26 Feb, 08:29PM
Maybe they are trying to say that there is no OBVIOUS motion, but they are i... moving via a current. Therefore, it meets their definition that it takes moving ... ticles to create a magnetic field

Student 3 – 2 Mar, 09:00AM
I agree that the motion is not "obvious" in that it is not visible to the naked eye. The cause must be atomic.

Student 2 – 2 Mar, 11:37AM
Oh the answers to this question kind of address my question above - I guess there isn't a force if the particle is stationary, but since even when an object is stationary (thus no obvious motion), there is a magnetic force. It's when everything, including the particles, are stationary that there is no obvious motion.

Student 4 – 4 Mar, 01:05PM
Is there ever a situation in reality where everything, even the particles are not ...



1 design 2 approach

Information transfer

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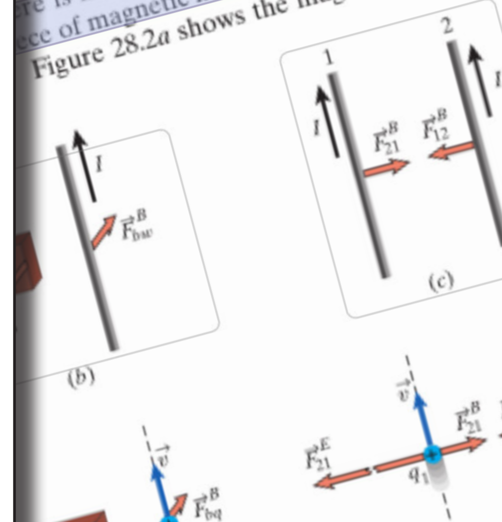


over 20,000 annotations!

1 design 2 approach

Information transfer

AP50 Spring 2015

Annotation Rubric

Your annotations of the textbook on NB will be evaluated on the basis of quality, quantity, and timeliness, as shown below. Your goal in annotating each chapter is to demonstrate *timely and thoughtful reading of the text*. When we look at your annotations we want them to reflect the effort you put in your study of the text. It is unlikely that that effort will be reflected by just a few annotations per chapter, unless your annotations are unusually thoughtful and stimulate a deep discussion. About 7–20 *thoughtful* annotations per chapter spread out over the chapter is about right, but keep in mind that quality is more important than quantity!

About 4 days after the deadline of the last chapter in each unit, we will provide an overall assessment of your annotations in that unit using the usual three-point scale (0–3), by combining your annotation scores for the three categories.

Quality The textbook replaces the lectures (us reading the textbook to you) so that we can do more interesting things in class. Therefore it is important you read the text thoughtfully and attempt to lay the foundation for the work in class.

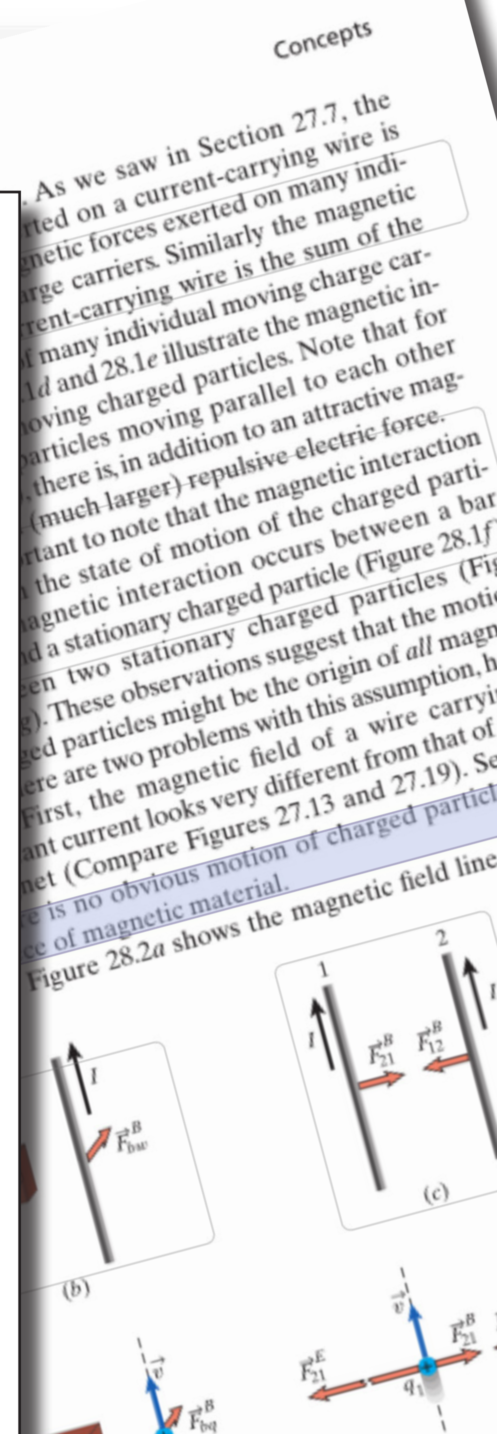
2 = Demonstrates thorough and thoughtful reading AND insightful interpretation of the chapter
1 = Demonstrates reading, but no (or only superficial) interpretation of the chapter
0 = Does not demonstrate any thoughtful reading of the chapter

See the examples on the next page to see the quality criterion applied to sample annotations.

Quantity To lay the foundation for understanding the in-class activities, you must at least familiarize yourself with the entire chapter — not just the first few pages.

2 = 7–20 thoughtful annotations that cover each section of the chapter
1 = 7–20 thoughtful annotations, but not each section is annotated
0 = 6 or fewer annotations

Timeliness The work done in class depends on you having done the reading in advance, so completing the reading on schedule is important. Your annotations can be questions, comments, or responses to existing questions or comments. Responses are allowed up to three days beyond the posted



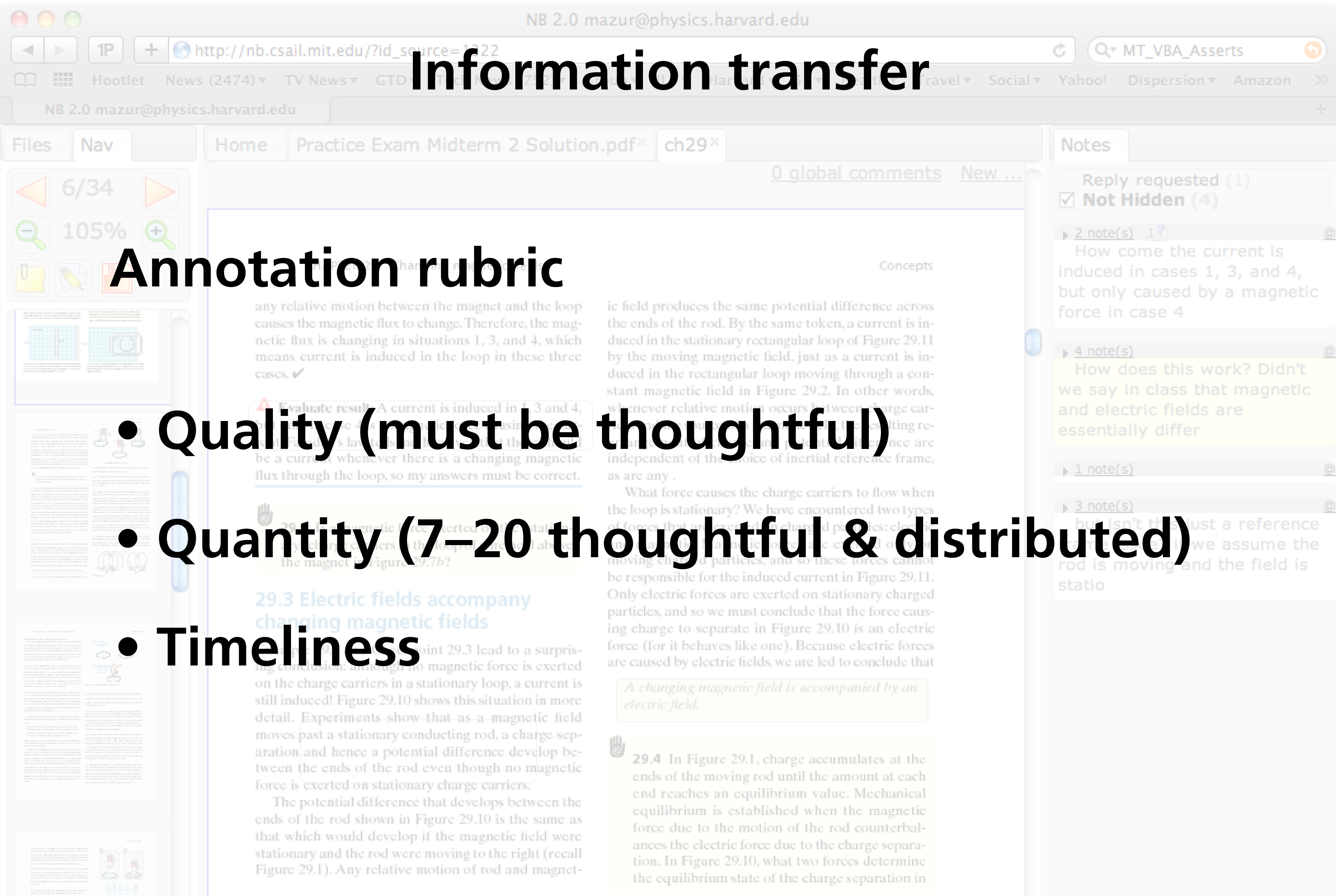
1 design

2 approach

Information transfer

Annotation rubric

- **Quality (must be thoughtful)**
- **Quantity (7–20 thoughtful & distributed)**
- **Timeliness**



❶ design ❷ approach

Information transfer

READING SCHEDULE

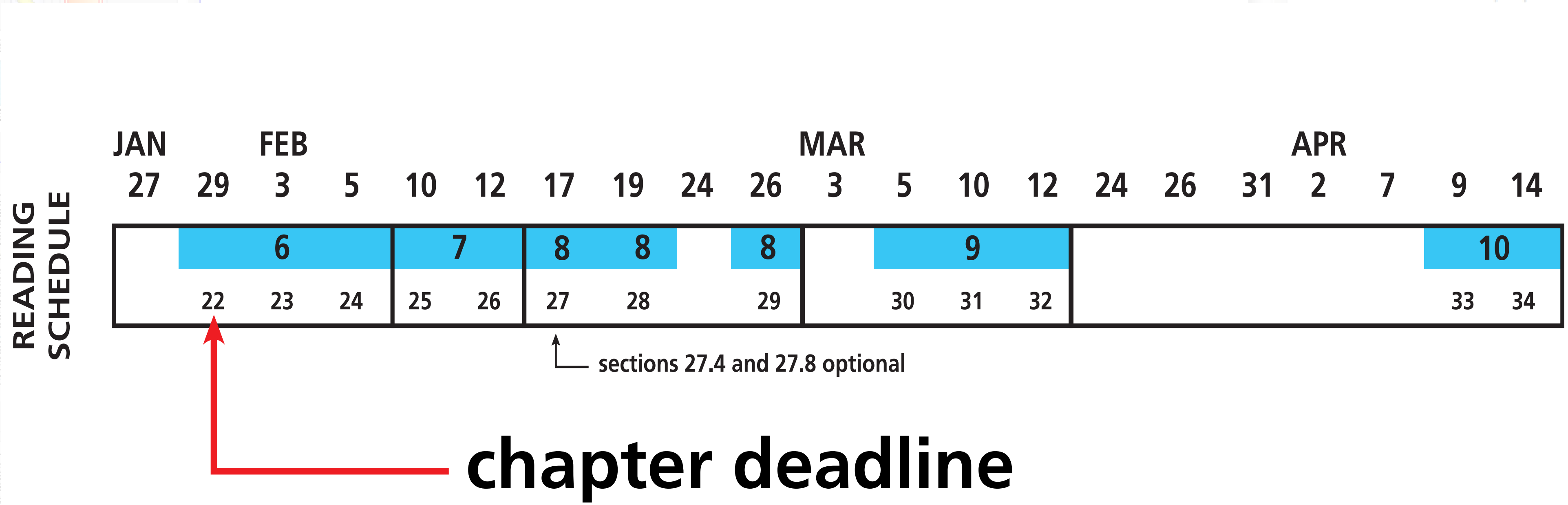
	JAN		FEB								MAR							APR			
Date	27	29	3	5	10	12	17	19	24	26	3	5	10	12	24	26	31	2	7	9	14
Chapter		6	6	6	7	7	8	8		8		9	9	9						10	10
		22	23	24	25	26	27	28		29		30	31	32						33	34

sections 27.4 and 27.8 optional

1 design

2 approach

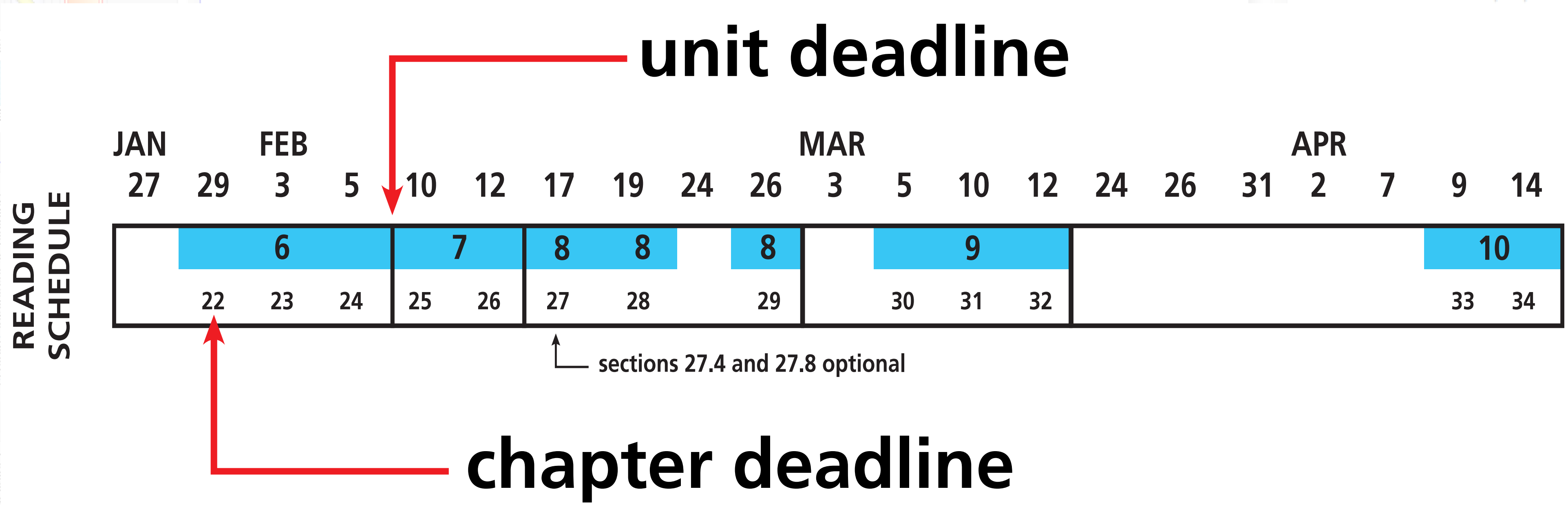
Information transfer



1 design

2 approach

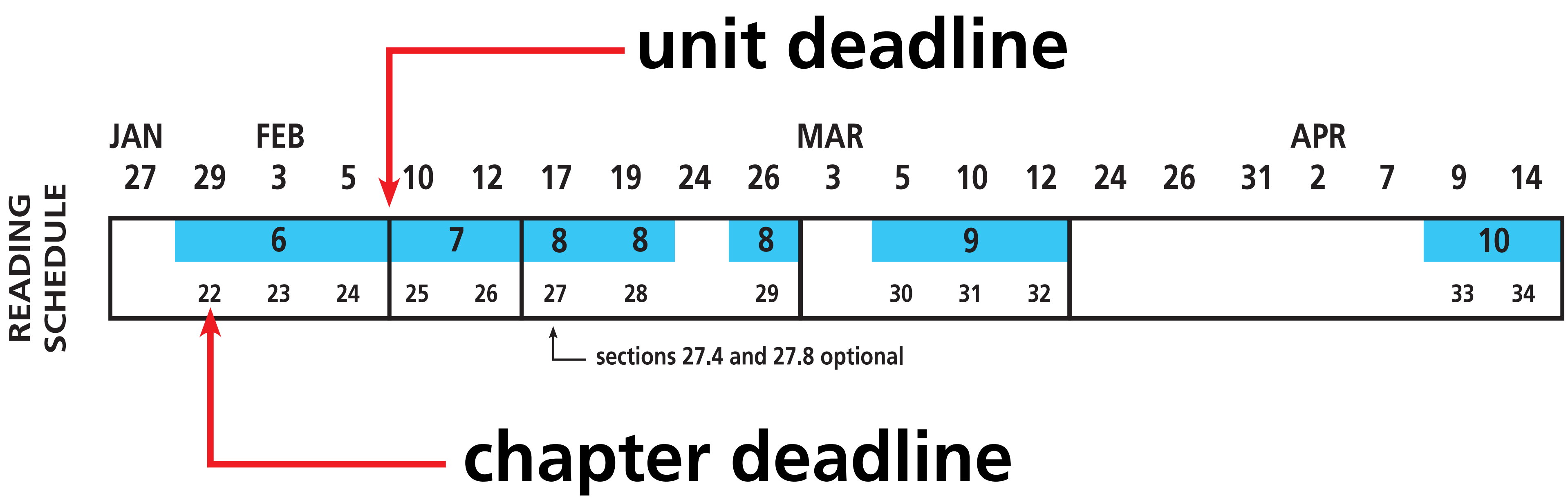
Information transfer



1 design

2 approach

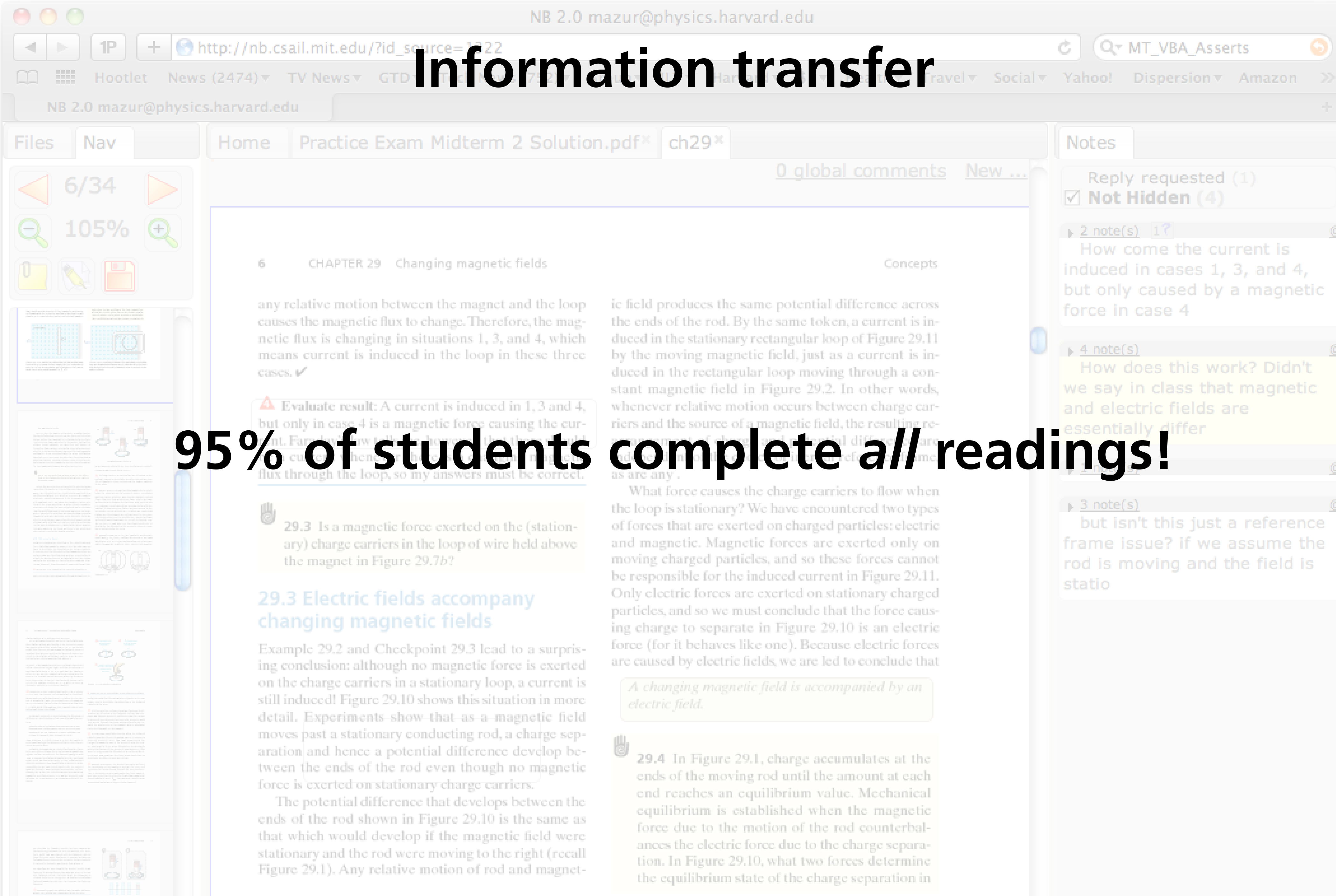
Information transfer



three extra days for answers to questions

1 design   2 approach

Information transfer

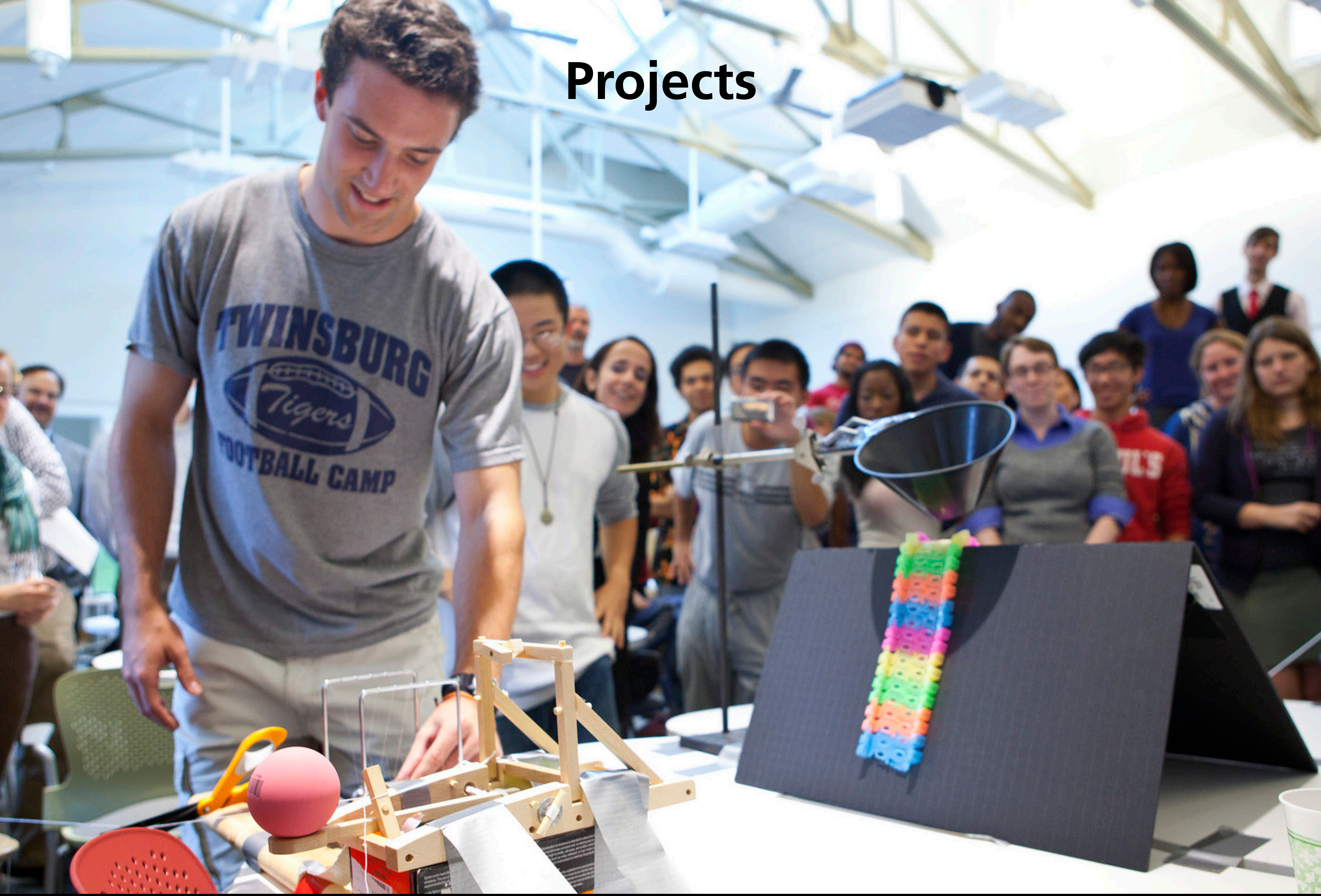


95% of students complete *all* readings!

1 design

2 approach

Projects



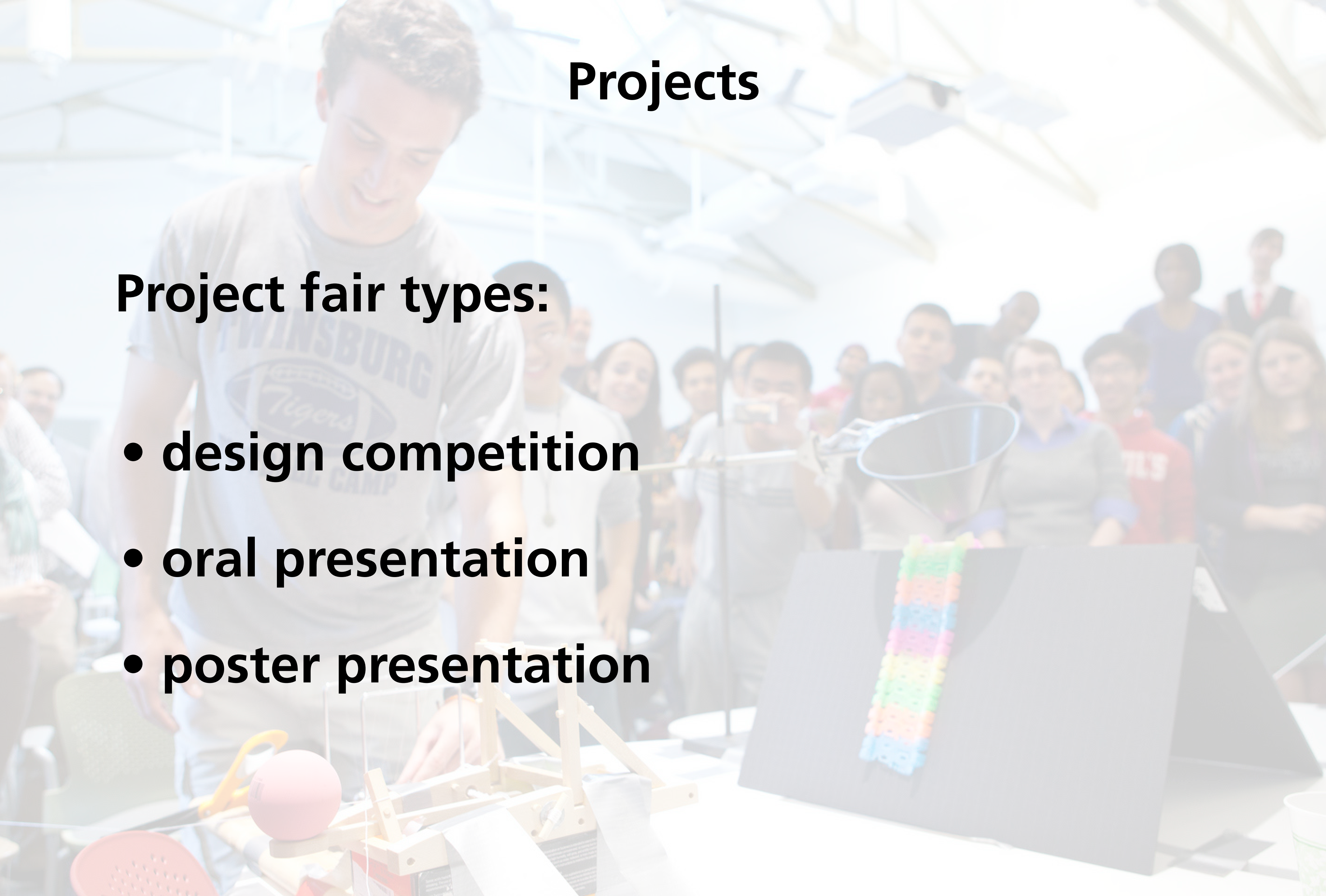
1 design

2 approach

Projects

- 1 projects/month (6 over 2 semesters)
- new team formation for each project
- projects not prescriptive, but open-ended
- 3 types of project “fairs”
- external evaluators

Projects



Project fair types:

- design competition
- oral presentation
- poster presentation

Projects

Rule-based team formation using GroupEng

www.GroupEng.org

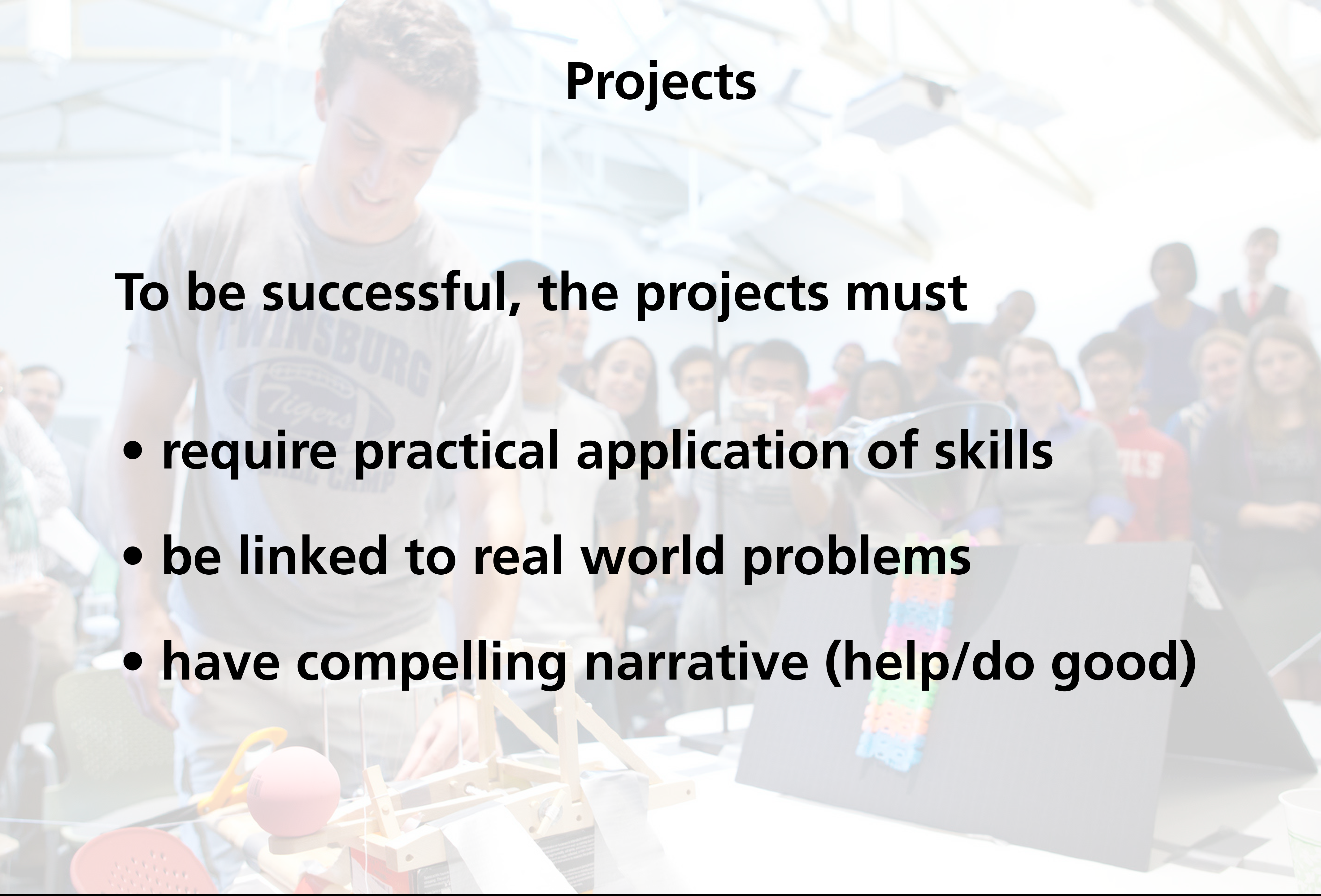
❶ design ❷ approach

Projects

Rule-based team formation using GroupEng

- gender
- year
- self-efficacy & learning attitude
- class performance
- exlude previous team mates

www.GroupEng.org



Projects

To be successful, the projects must

- require practical application of skills
- be linked to real world problems
- have compelling narrative (help/do good)

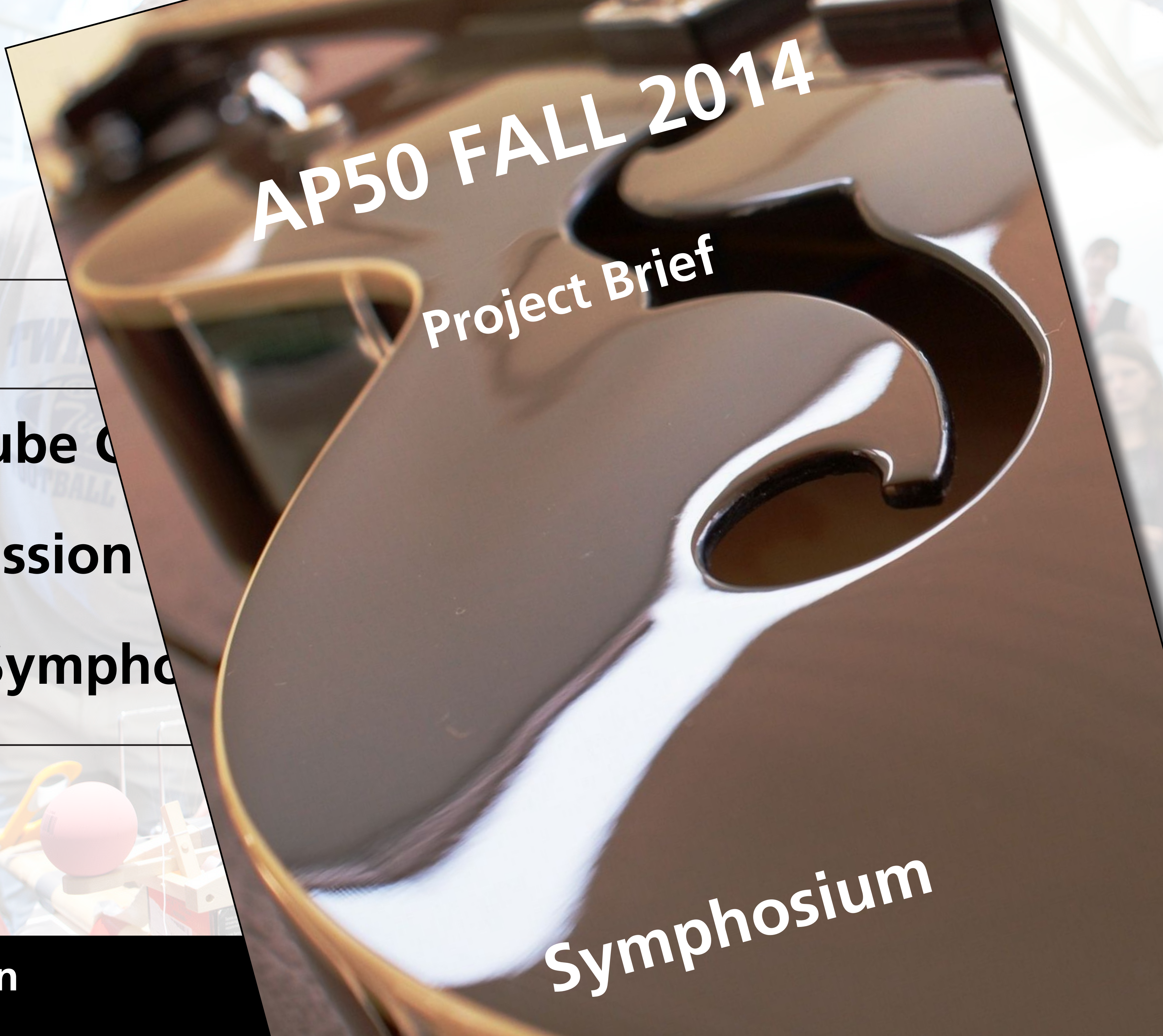
Projects

Fall	Spring
Rube Goldberg	Ecotricity
Mission to Mars	Crack-a-Thon
Symphosium	inSPECT Fair

Rube G

Mission

Sympho



1 design

1 design

2 approach

Projects

1 design

2 approach

Projects

Build a beautifully sounding instrument from recycled parts

1 design

2 approach

Projects

Build a beautifully sounding instrument from recycled parts

- musical range
- *Q*-factor
- harmonic spectrum
- sound level
- tuning stability

Projects

Milestones:

- team contract
- proposal
- fair
- report
- team, peer, and self assessment

Projects

Milestones:

- team contract (at beginning)
- proposal
- fair
- report
- team, peer, and self assessment

Projects

Milestones:

- team contract (at beginning)
- proposal (+1 week)
- fair
- report
- team, peer, and self assessment

Projects

Milestones:

- team contract (at beginning)
- proposal (+1 week)
- fair (+3 weeks)
- report
- team, peer, and self assessment

Projects

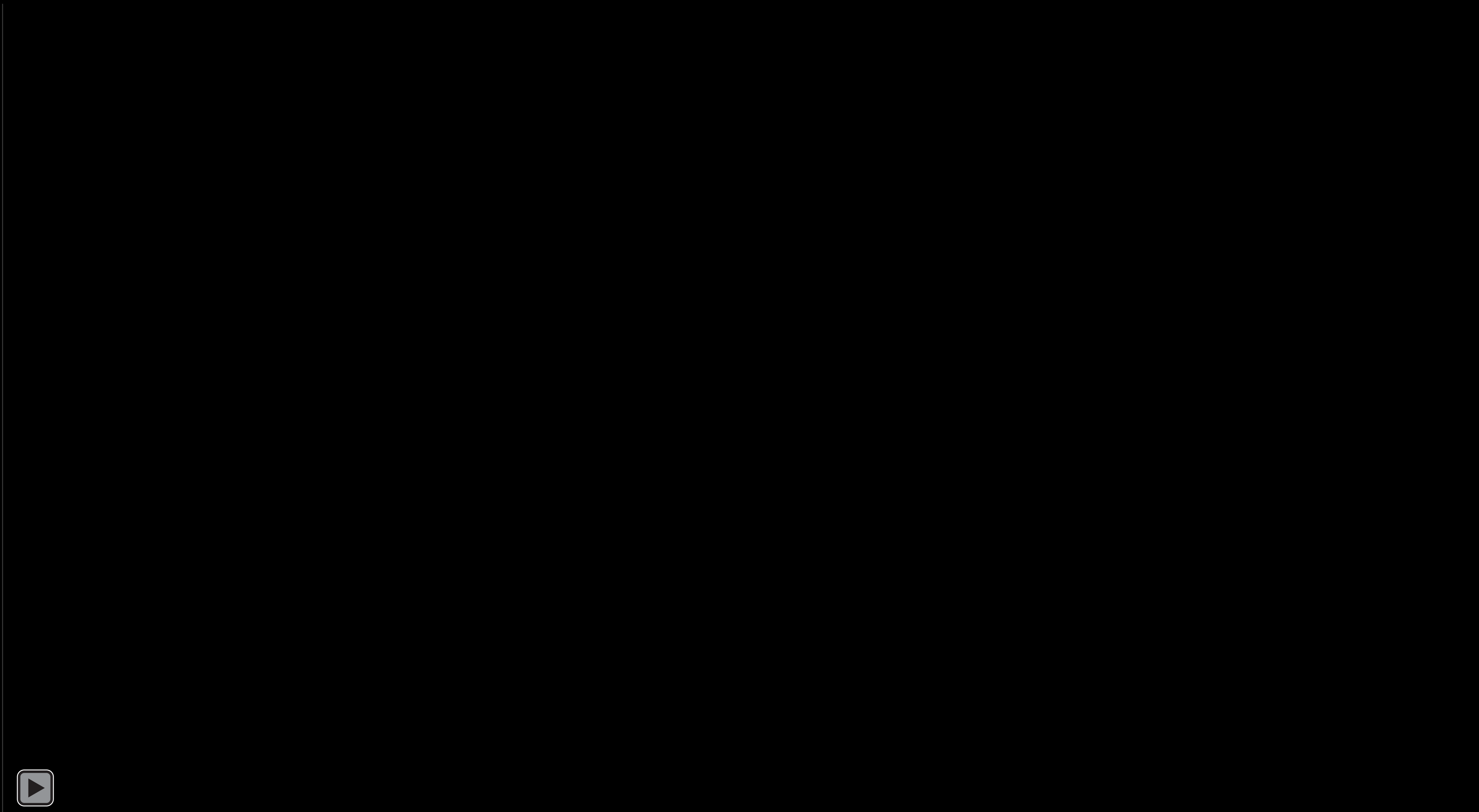
Milestones:

- team contract (at beginning)
- proposal (+1 week)
- fair (+3 weeks)
- report (+1 week +3 days for revision)
- team, peer, and self assessment

Projects

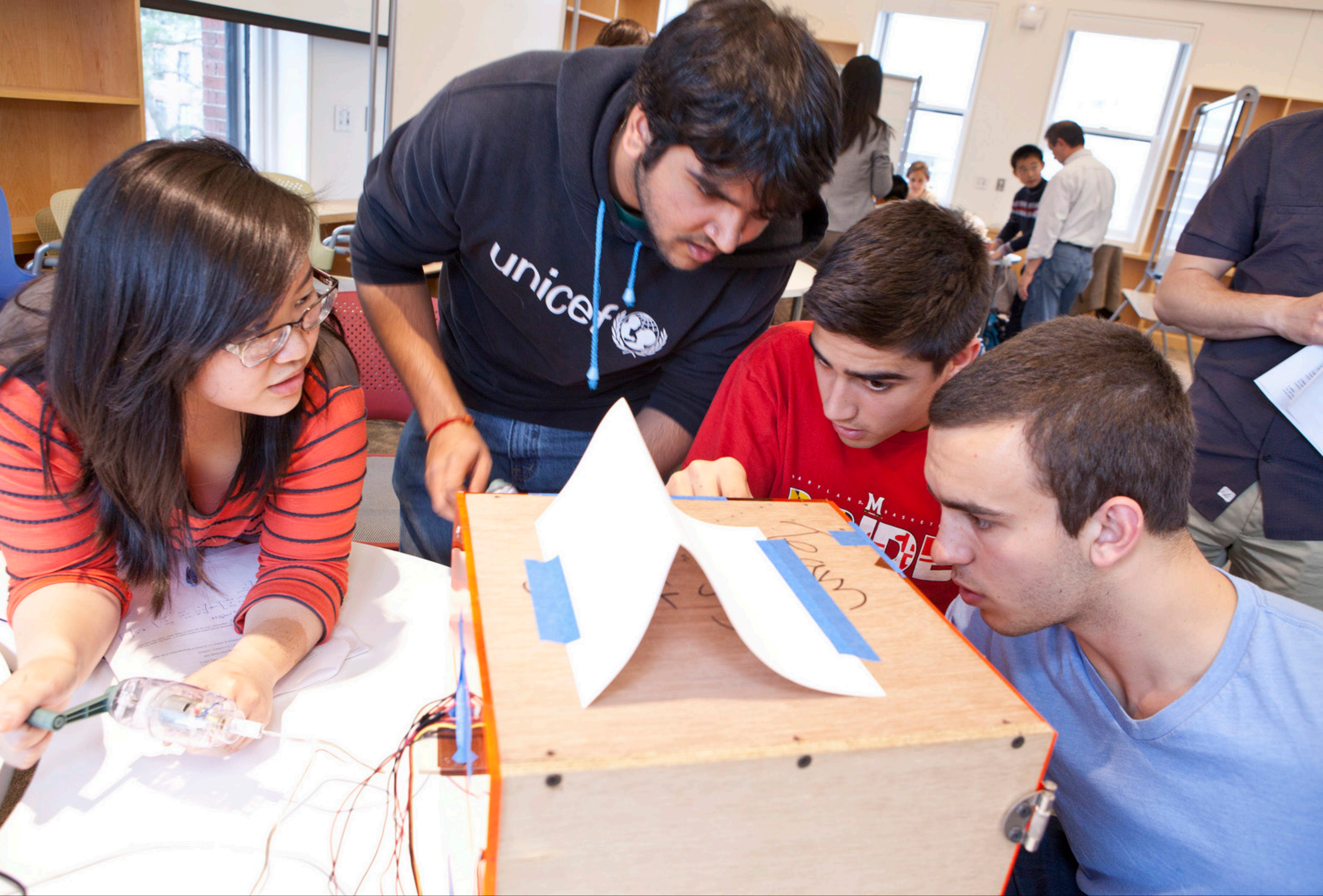
Milestones:

- team contract (at beginning)
- proposal (+1 week)
- fair (+3 weeks)
- report (+1 week +3 days for revision)
- team, peer, and self assessment (at end)



1 design

2 approach



1 design

2 approach

competition instead of

social good/empathy as motivator

1 design **2 approach**

1 design 2 approach

In-class activities

In-class activities

2 weekly 3-hour class periods

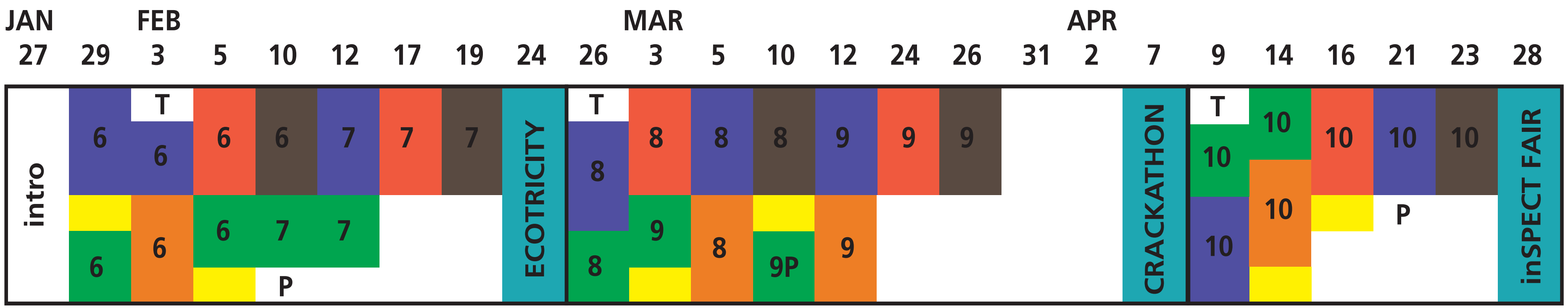
In-class activities

blend of 6 “best practices”

1 design

2 approach

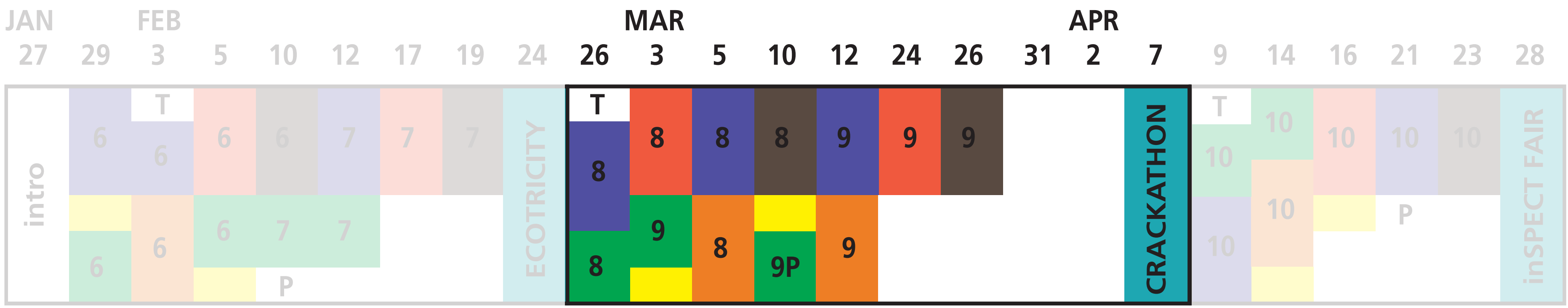
In-class activities



1 design
2 approach

In-class activities

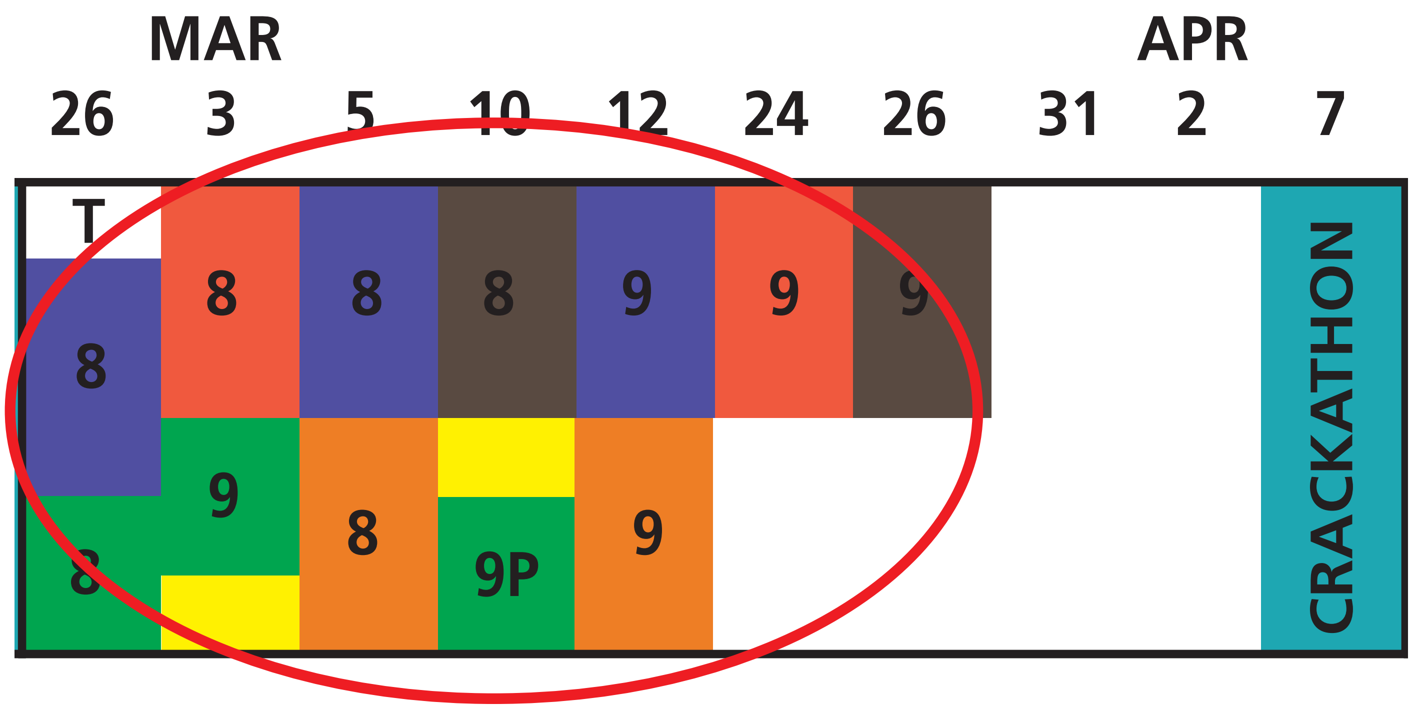
one project



❶ design ❷ approach

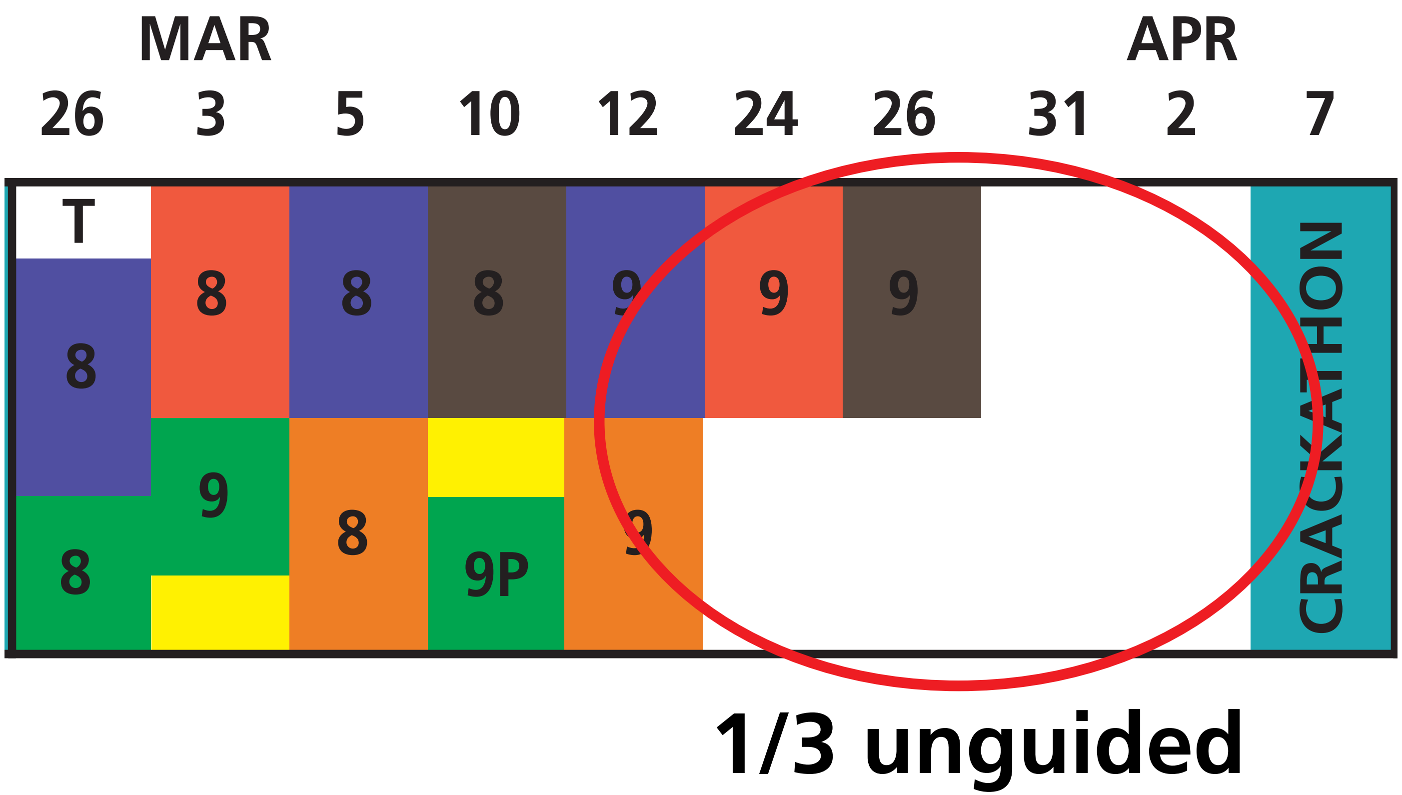
In-class activities

2/3 scaffolded, guided



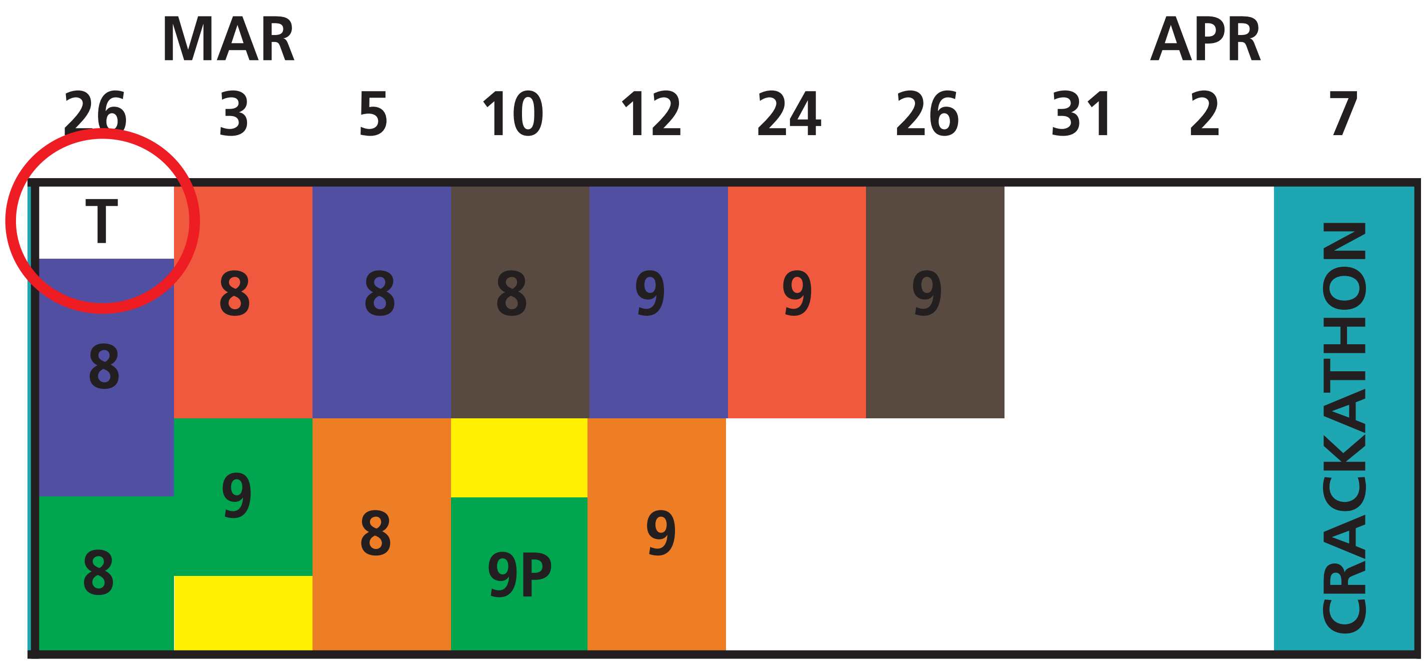
1 design
2 approach

In-class activities



In-class activities

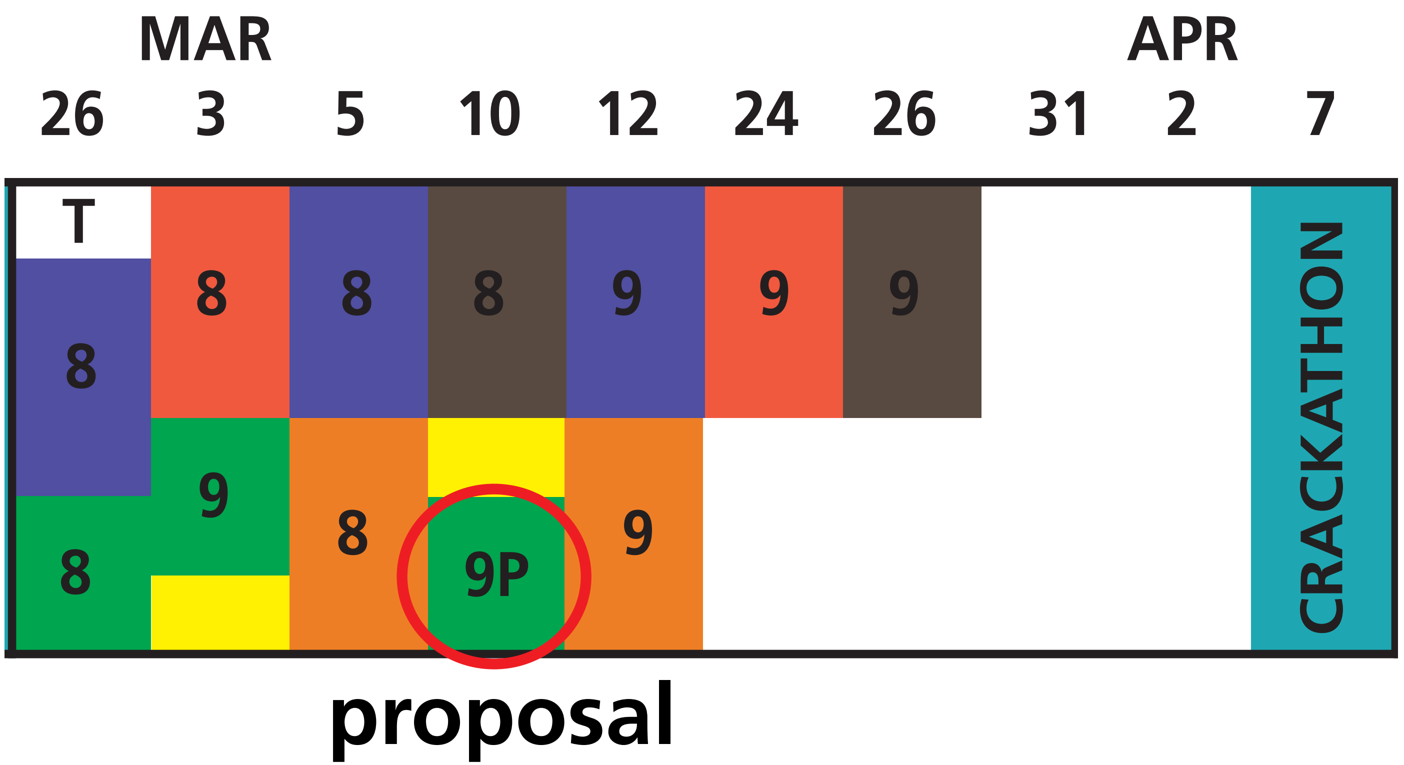
team intro



1 design

2 approach

In-class activities



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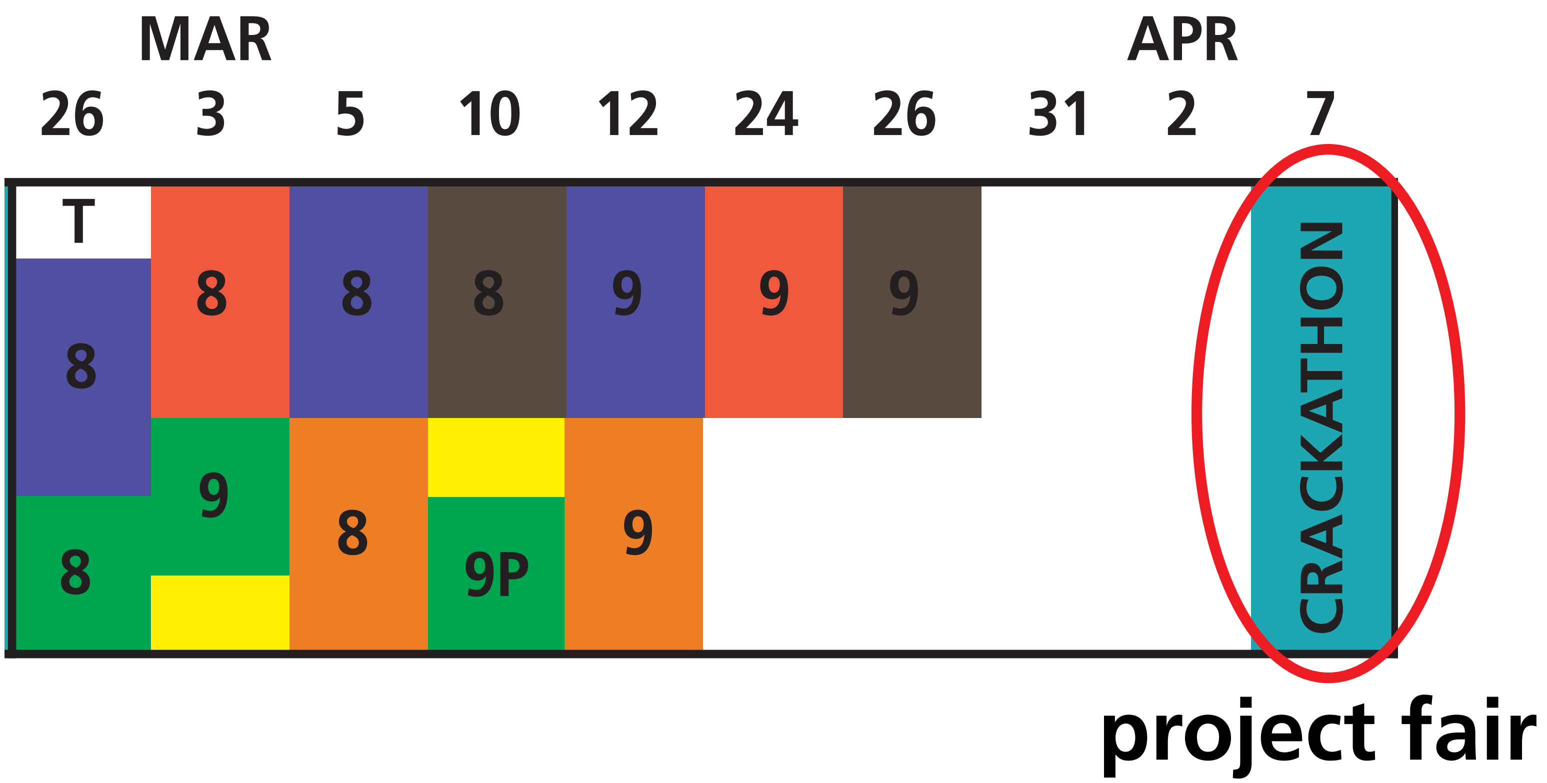

In-class activities

understand

LC: Learning Catalytics — 90 min

- Instructor poses question
- Answer alone
- Discuss in team
- Answer again

bring device

Tutorial — 60 min

- Work on worksheet with team
- Explore concepts
- Discuss with staff

apply

EA: Estimation Activity — 30 min

- Estimate quantities
- Develop individual strategy
- Discuss and solve as team

EDA: Experimental Design Activity — 90 min

- Conduct experiment with team
- Take measurements
- Analyze data
- Carry out simulations

bring device

evaluate

Problem Set & Reflection — 90 min

- Work problems alone BEFORE class
- Discuss with team, mark up
- Self-assess & turn in

RAA: Readiness Assurance Activity — 90 min

- Part 1: solve problems alone
- Open book, open internet
- Part 2: solve with team

bring device

1 design

2 approach

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1 design   2 approach

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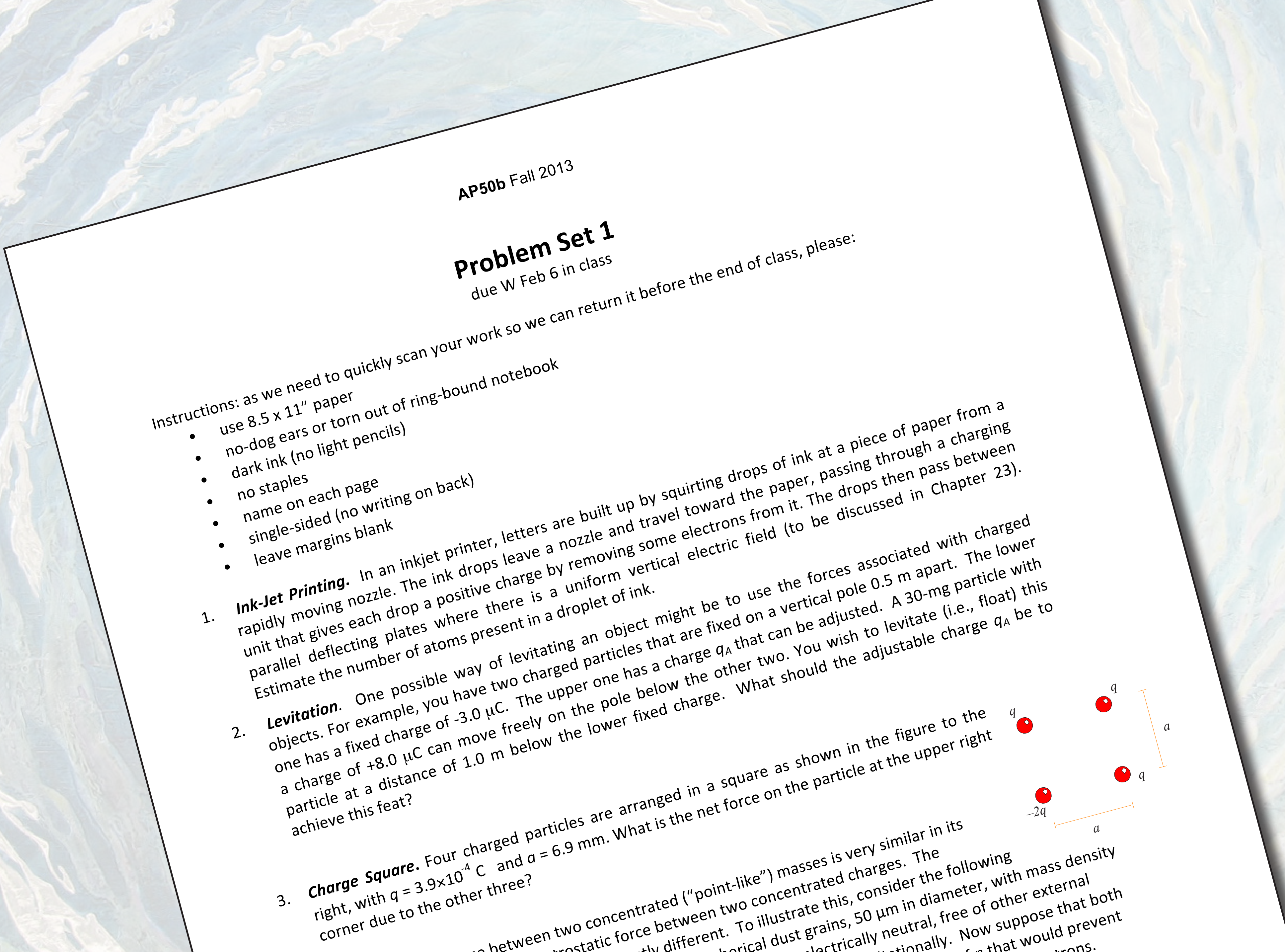


AP50b Fall 2013

Problem Set 1

due W Feb 6 in class

Instructions: as we need to quickly scan your work so we can return it before the end of class, please:

- use 8.5 x 11" paper
- no-dog ears or torn out of ring-bound notebook
- dark ink (no light pencils)
- no staples
- name on each page
- single-sided (no writing on back)
- leave margins blank

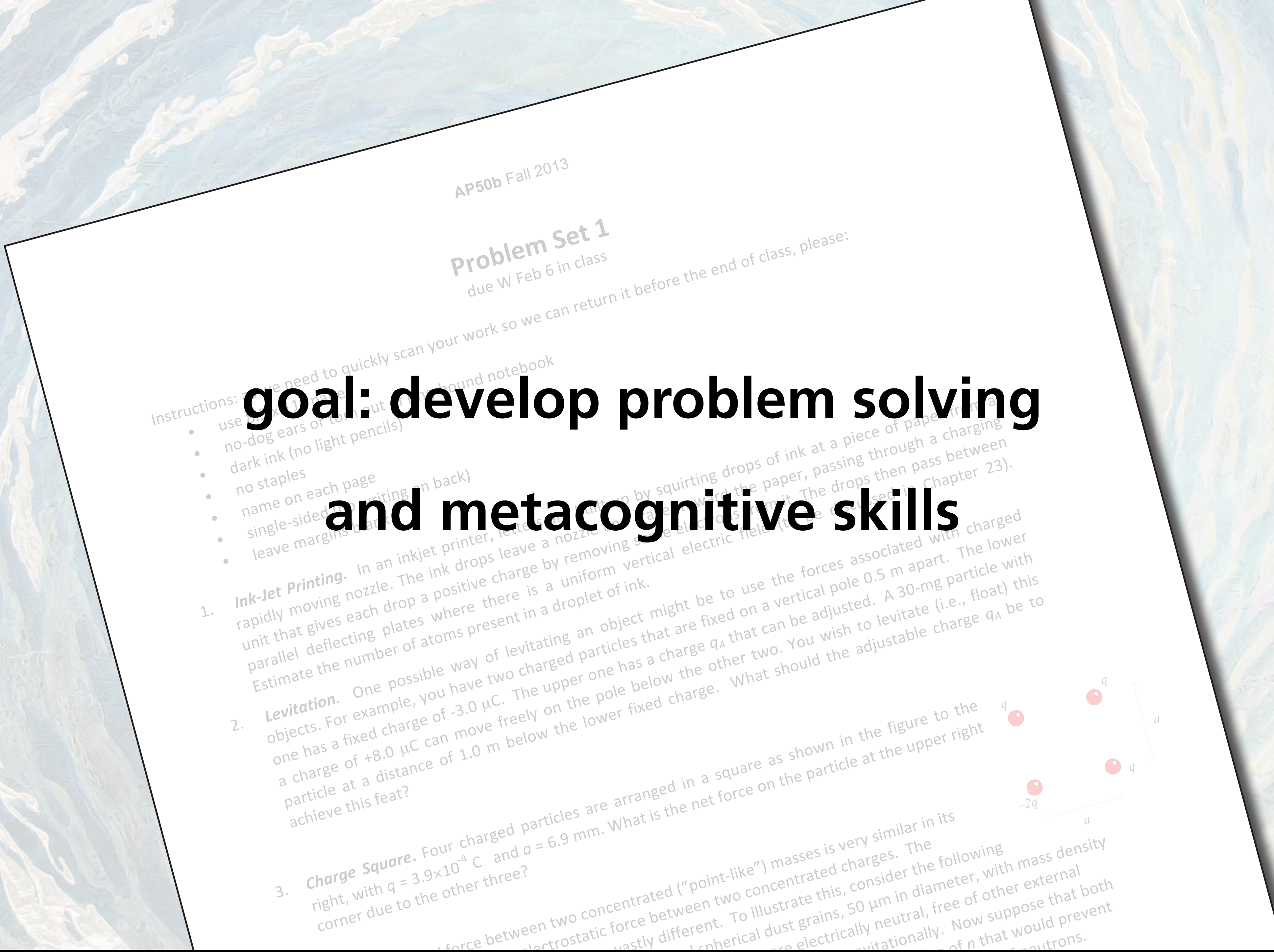
1. ***Ink-Jet Printing.*** In an inkjet printer, letters are built up by squirting drops of ink at a piece of paper from a rapidly moving nozzle. The ink drops leave a nozzle and travel toward the paper, passing through a charging unit that gives each drop a positive charge by removing some electrons from it. The drops then pass between parallel deflecting plates where there is a uniform vertical electric field (to be discussed in Chapter 23). Estimate the number of atoms present in a droplet of ink.

2. ***Levitation***. One possible way of levitating an object might be to use the forces associated with charged objects. For example, you have two charged particles that are fixed on a vertical pole 0.5 m apart. The lower one has a fixed charge of -3.0 μC. The upper one has a charge q_A that can be adjusted. A 30-mg particle with a charge of +8.0 μC can move freely on the pole below the other two. You wish to levitate (i.e., float) this particle at a distance of 1.0 m below the lower fixed charge. What should the adjustable charge q_A be to achieve this feat?

3. ***Charge Square.*** Four charged particles are arranged in a square as shown in the figure to the right, with $q = 3.9\times10^{-4}$ C and $a = 6.9$ mm. What is the net force on the particle at the upper right corner due to the other three?

…force between two concentrated ("point-like") masses is very similar in its …lectrostatic force between two concentrated charges. The …vastly different. To illustrate this, consider the following …spherical dust grains, 50 μm in diameter, with mass density …re electrically neutral, free of other external …vitationally. Now suppose that both …of *n* that would prevent …neutrons.

1 design 2 approach



goal: develop problem solving and metacognitive skills

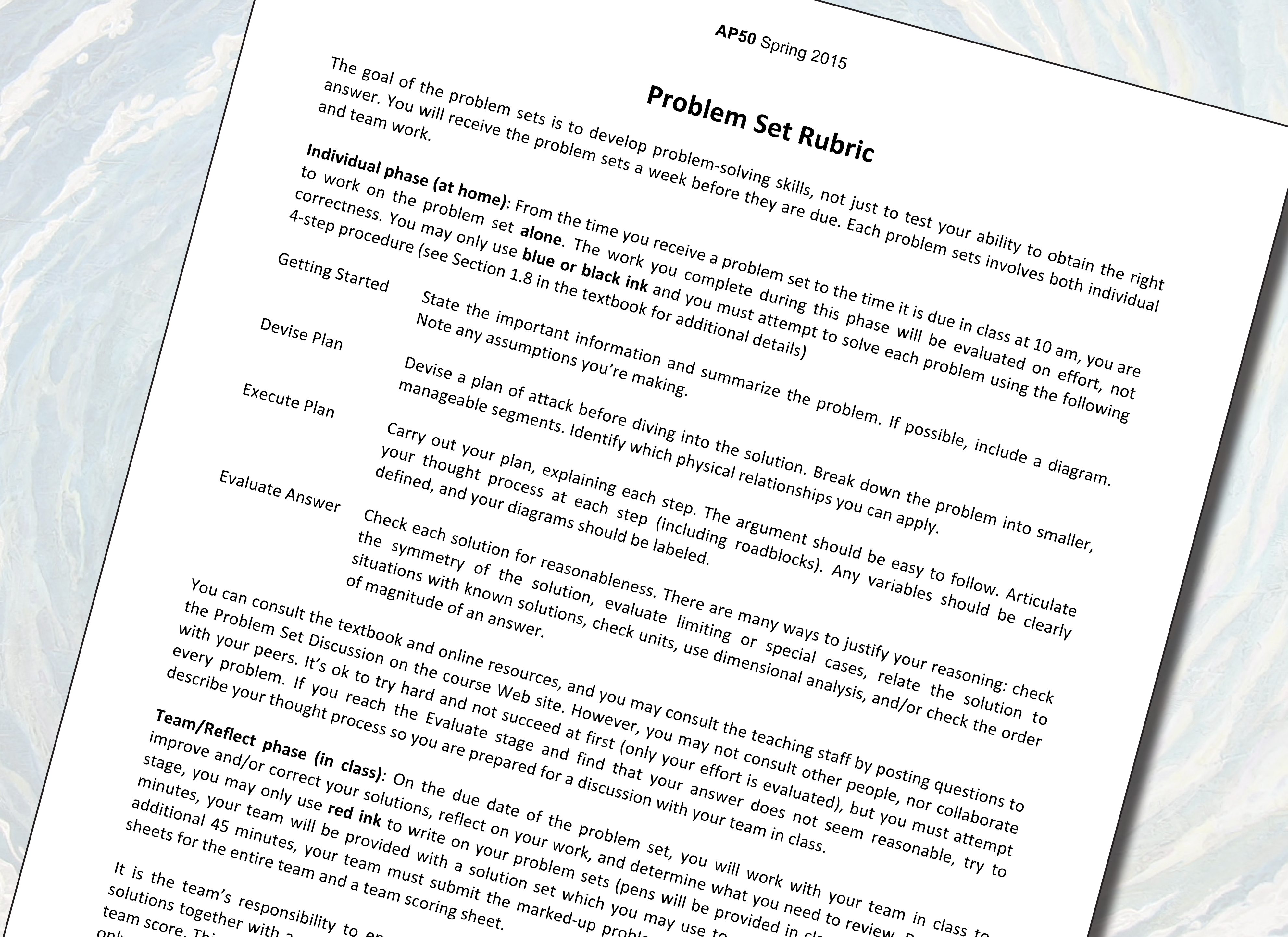
1 design

2 approach

phase	goal
solve (at home/individual)	skills development
reflect (in class/team)	metacognition

1 design

2 approach



AP50 Spring 2015

Problem Set Rubric

The goal of the problem sets is to develop problem-solving skills, not just to test your ability to obtain the right answer. You will receive the problem sets a week before they are due. Each problem sets involves both individual and team work.

Individual phase (at home): From the time you receive a problem set to the time it is due in class at 10 am, you are to work on the problem set **alone**. The work you complete during this phase will be evaluated on effort, not correctness. You may only use **blue or black ink** and you must attempt to solve each problem using the following 4-step procedure (see Section 1.8 in the textbook for additional details)

Getting Started	State the important information and summarize the problem. If possible, include a diagram. Note any assumptions you're making.
Devise Plan	Devise a plan of attack before diving into the solution. Break down the problem into smaller, manageable segments. Identify which physical relationships you can apply.
Execute Plan	Carry out your plan, explaining each step. The argument should be easy to follow. Articulate your thought process at each step (including roadblocks). Any variables should be clearly defined, and your diagrams should be labeled.
Evaluate Answer	Check each solution for reasonableness. There are many ways to justify your reasoning: check the symmetry of the solution, evaluate limiting or special cases, relate the solution to situations with known solutions, check units, use dimensional analysis, and/or check the order of magnitude of an answer.

You can consult the textbook and online resources, and you may consult the teaching staff by posting questions to the Problem Set Discussion on the course Web site. However, you may not consult other people, nor collaborate with your peers. It's ok to try hard and not succeed at first (only your effort is evaluated), but you must attempt every problem. If you reach the Evaluate stage and find that your answer does not seem reasonable, try to describe your thought process so you are prepared for a discussion with your team in class.

Team/Reflect phase (in class): On the due date of the problem set, you will work with your team in class to improve and/or correct your solutions, reflect on your work, and determine what you need to review. D... stage, you may only use **red ink** to write on your problem sets (pens will be provided in cla... minutes, your team will be provided with a solution set which you may use to ... additional 45 minutes, your team must submit the marked-up proble... sheets for the entire team and a team scoring sheet.

It is the team's responsibility to en... solutions together with a ... team score. Thi... onl...

1 **design** **2** **approach**

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1 design

2 approach

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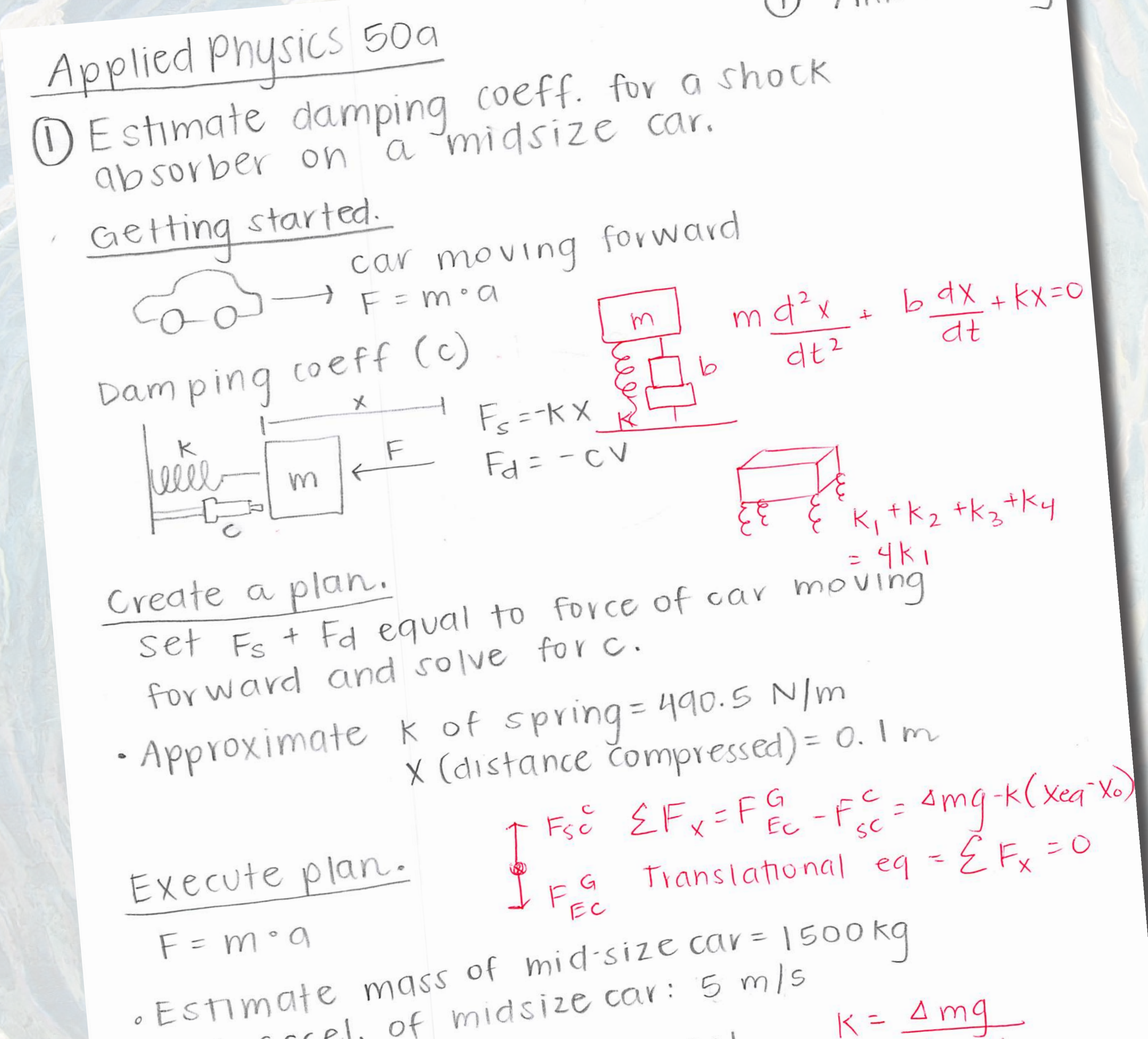
at home:

implement 4-step procedure

(evaluated on effort)

You can consult the textbook and online resources, and you may consult the teaching sta

1 **design** 2 **approach**



Applied Physics 50a

(1) Estimate damping coeff. for a shock absorber on a midsize car.

Getting started.

car moving forward

$F = m \cdot a$

Damping coeff (c)

$F_s = -kx$

$F_d = -cv$

$m \frac{d^2x}{dt^2} + b\frac{dx}{dt} + kx = 0$

$k_1 + k_2 + k_3 + k_4 = 4k_1$

Create a plan.

Set $F_s + F_d$ equal to force of car moving forward and solve for c.

- Approximate k of spring = 490.5 N/m
  x (distance compressed) = 0.1 m

$\sum F_x = F^G_{Ec} - F^c_{sc} = \Delta mg - k(x_{eq} - x_0)$

Translational eq $= \sum F_x = 0$

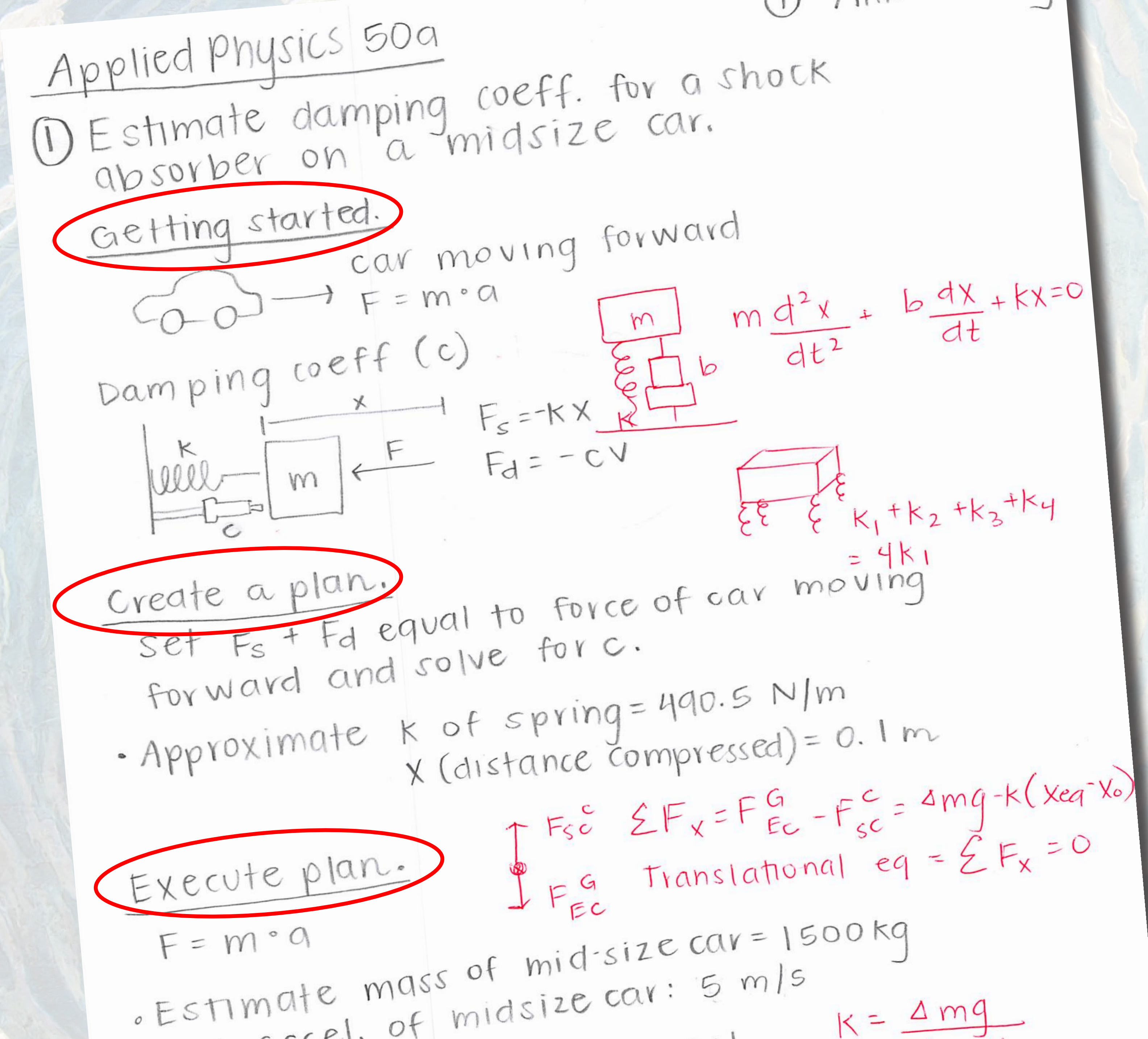
Execute plan.

$F = m \cdot a$

- Estimate mass of mid-size car = 1500 kg
- Est. accel. of midsize car: 5 m/s

$k = \frac{\Delta mg}{\dots}$

1 design 2 approach



Applied Physics 50a

① Estimate damping coeff. for a shock absorber on a midsize car.

Getting started.

car moving forward

F = m∘a

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F_{sc}^{c} $\Sigma F_x = F_{Ec}^{G} - F_{sc}^{c} = \Delta mg - k(x_{eq} - x_0)$

F_{Ec}^{G} Translational eq = $\Sigma F_x = 0$

Execute plan.

F = m∘a

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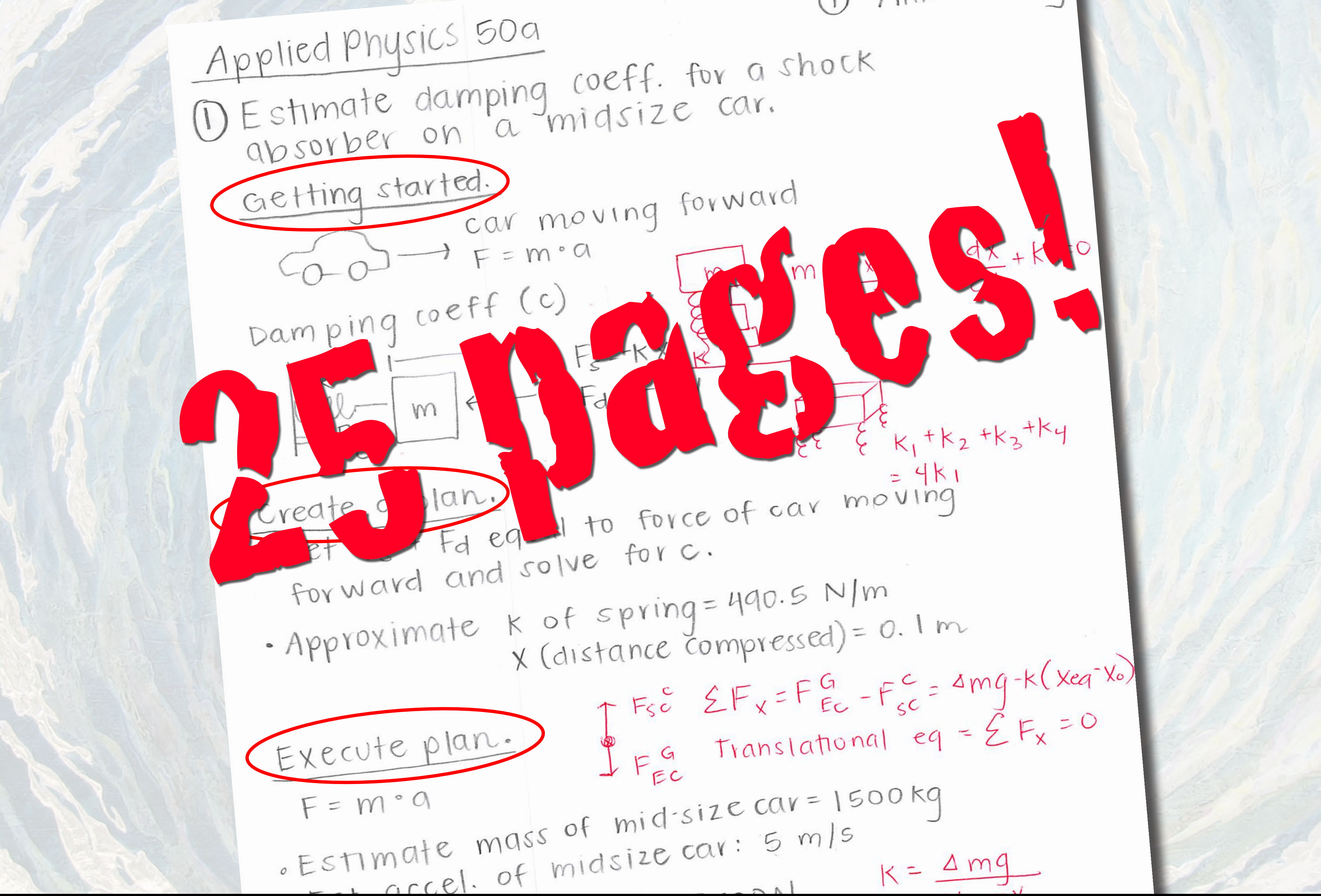
Est. accel. of midsize car: 5 m/s

$K = \frac{\Delta mg}{\ldots}$

❶ design ❷ approach



1 design

2 approach

with your peers. It's ok to try hard and not succeed at first (only your effort is evaluate every problem. If you reach the Evaluate stage and find that your answer does not describe your thought process so you are prepared for a discussion with your team in clas

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It is the team's responsibility to ensure that *all* team members hand-in complete an solutions together with a completed reflection sheet, because your team's submitted w team score. This means that if you do not put in adequate effort before the Team/Reflect only your own score, but also that of your team members. Likewise, it is important to your team marks his/her work up correctly during the Team/Reflect phase.

Important: Writing on the problem set in class in any other color but red will be considere

1 design 2 approach

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Important: Writing on the problem set in class in any other color but red will be considere

in class:

mark up/improve solutions

complete reflection sheet

1 design 2 approach

② continued.

c) Maximum transverse speed.

Use $\lambda = \frac{v}{f}$; solve for v.

d) Length would have to be λ or 1 ½ wavelength, etc.

Execute plan. ✓

a) $y = 0.2 \sin[\pi(0.5x - 100t)] = 0.5\pi(x - 200t)$

~~$x(t) = A \sin(\omega t + \phi_i$~~ $y = A \sin[k(x - ct)]$

k = wave #

c = wave speed

A = amplitude

- amplitude = 0.2 cm ✓
- ω = rotational speed = ~~0.5π~~ 200 cm/s

~~$0.5\pi = \frac{2\pi}{T}$~~ ⇒ T = ~~4~~ sec = period $\frac{1}{50}$ 0.02 sec

50 sec⁻¹ = Hz

$k = \frac{2\pi}{\lambda} \rightarrow \lambda = \frac{2\pi}{k}$

- $f = \frac{1}{T}$ = ~~¼~~ cycles/second = frequency

$\lambda = \frac{v}{f}$

$T = \frac{1}{f}$

↳ $f = \frac{v}{\lambda} = \frac{200}{4} = 50$

- $\lambda = \frac{v}{f} = \frac{\cancel{0.5\pi}\ 200}{\cancel{¼}\ 4}$ = ~~¼~~ 4 cm
- wave number = $\frac{2\pi}{\lambda} = \frac{1}{2}\pi = 0.5\pi$

k

(shifted right)

$y = 0.2 \sin[\pi(0.5x - 100(\frac{1}{200}))]$

$[\pi(0.5x - 100(0))]$

1 design **2 approach**

Problem Set Reflection

Describe what you **learned** from working on this problem set before coming to class and reviewing it in class. (Do you think you would be able to take the concepts you explored in this problem set and transfer those concepts in a whole new context?) For example, would you be able to solve a problem involving the same physics concepts, but of a form you have never seen before?). You may complete this part before coming to class in blue or black ink.

Before coming to class, I learned a lot about waves in music and frequency. i feel really comfortable with concepts of wave speed, amplitude, frequency, and period. I understand beat frequency (although I made a clerical error by forgetting to use the speed of sound (twice)). i also feel like I now understand how decibels are calculated - before, I didn't know they were exponential! I know what the concept of intensity means and how to use it.

Based on your overall experience with this problem set, describe what you need to **review**.

I definitely need to review torque! I had no idea how to use that concept for #3 and i'll probably need to go over the solutions before I really un derstand it. Similarly with the damping coefficient estimation problem → I started off in the wrong direction and never really fixed where I went wrong. I also need to review some calculus. The last time I really understood calculus was high school and it's becoming an issue.

1 design

2 approach

“I was inspired and encouraged to do these problems on my own with the promise of collaborative work [the next day]”

"I felt less pressure to find the right answer and more freedom to explore"

In-class activities

understand

LC: Learning Catalytics — 90 min
- Instructor poses question
- Answer alone
- Discuss in team
- Answer again

bring device

Tutorial — 60 min
- Work on worksheet with team
- Explore concepts
- Discuss with staff

apply

EA: Estimation Activity — 30 min
- Estimate quantities
- Develop individual strategy
- Discuss and solve as team

EDA: Experimental Design Activity — 90 min
- Conduct experiment with team
- Take measurements
- Analyze data
- Carry out simulations

bring device

evaluate

Problem Set & Reflection — 90 min
- Work problems alone BEFORE class
- Discuss with team, mark up
- Self-assess & turn in

RAA: Readiness Assurance Activity — 90 min
- Part 1: solve problems alone
- Open book, open internet
- Part 2: solve with team

bring device

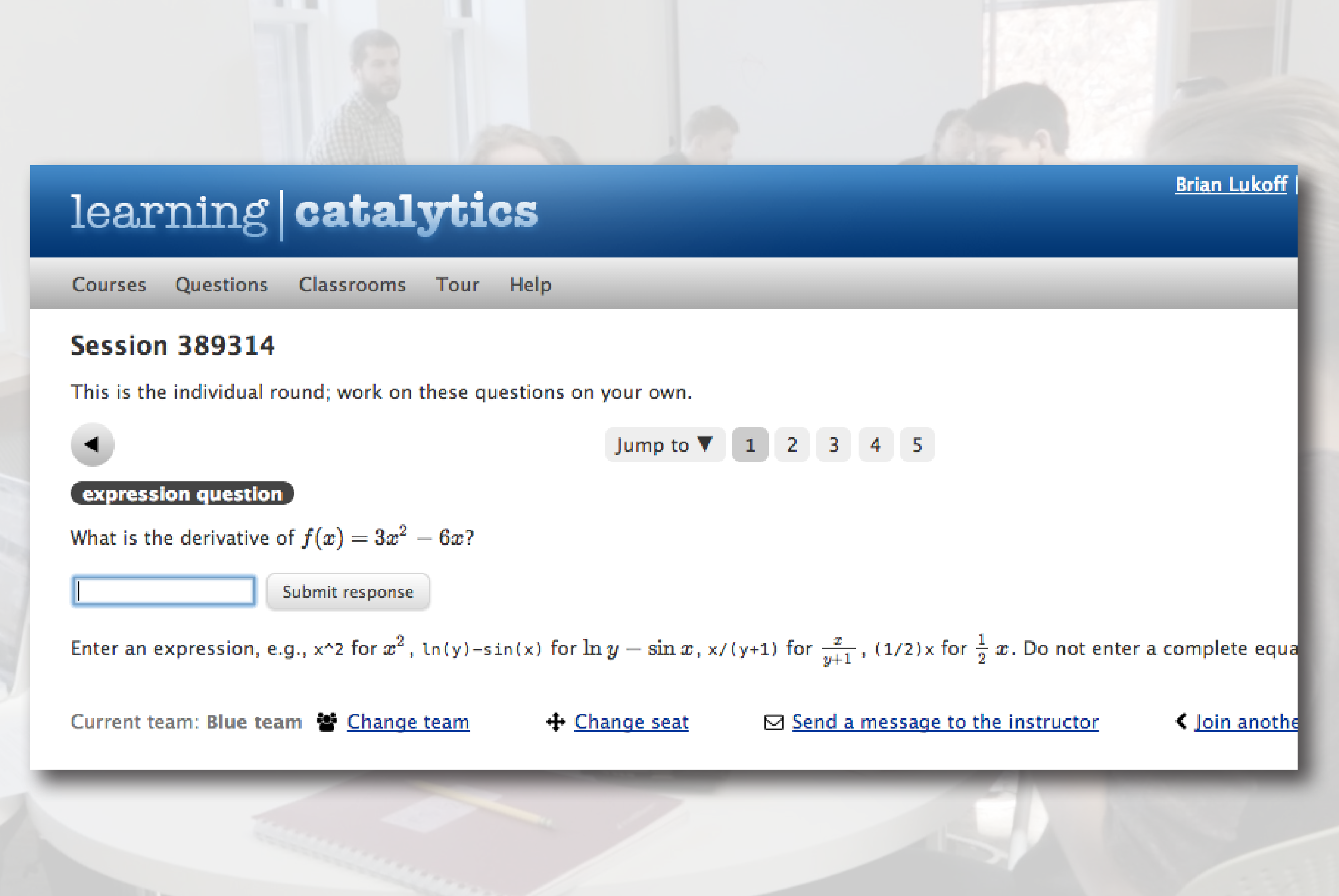
1 design   2 approach

1 design

2 approach

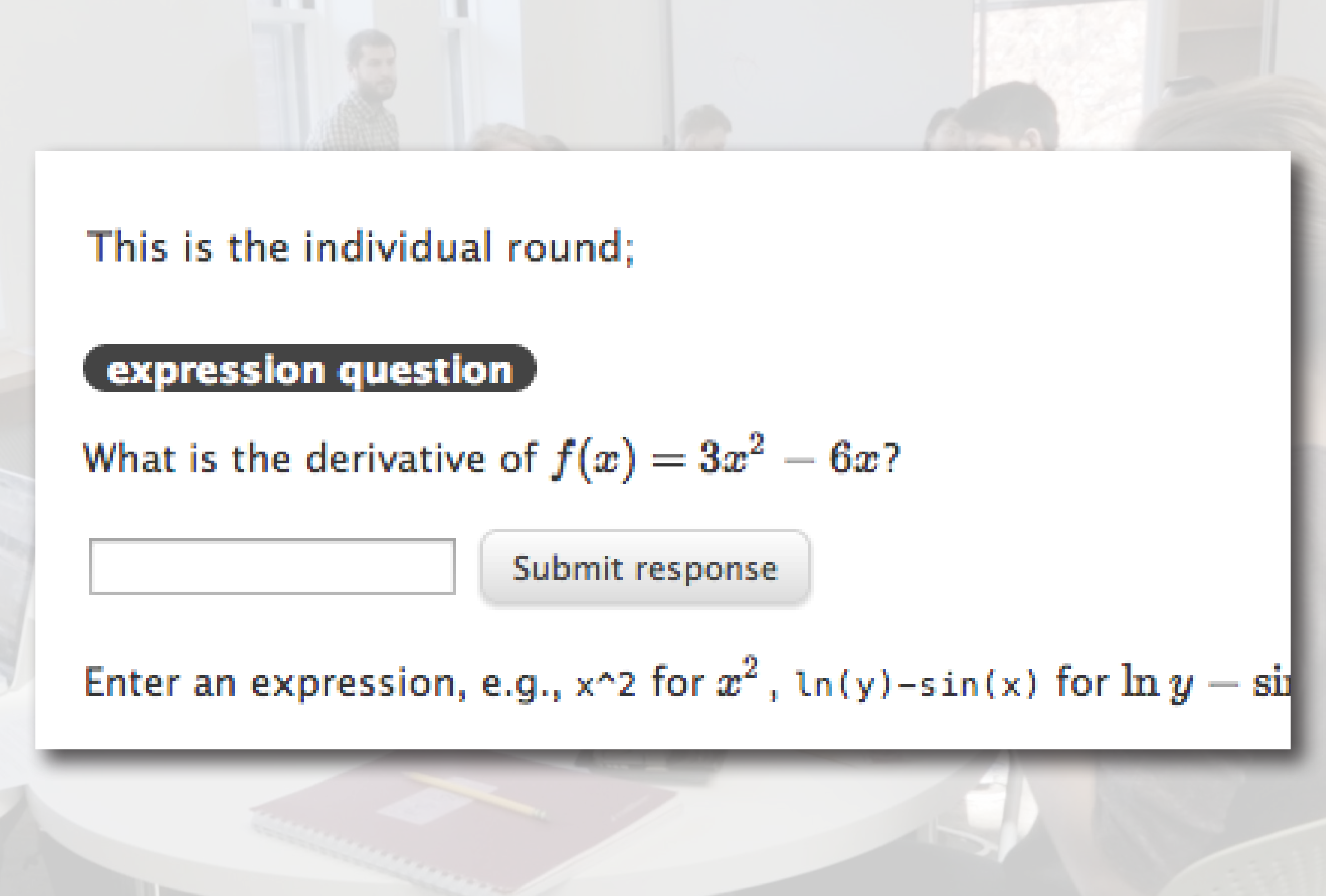
goal: formative assessment

collaborative learning



1 design

2 approach



1 design 2 approach

This is the individual round;

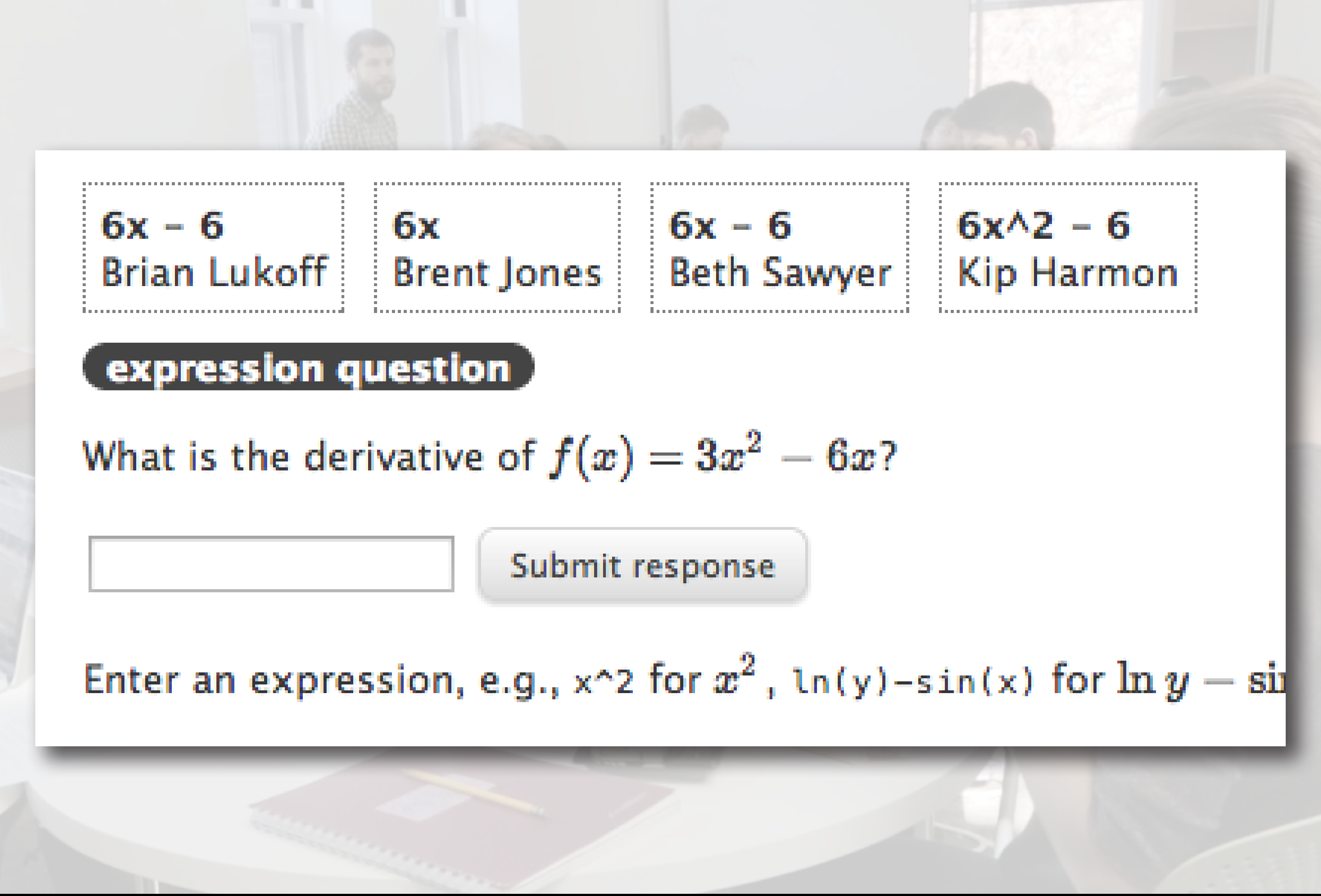
expression question

What is the derivative of $f(x) = 3x^2 - 6x$?

6x - 6 | Submit response

Enter an expression, e.g., x^2 for x^2, ln(y)-sin(x) for $\ln y - \text{si}$

❶ design ❷ approach



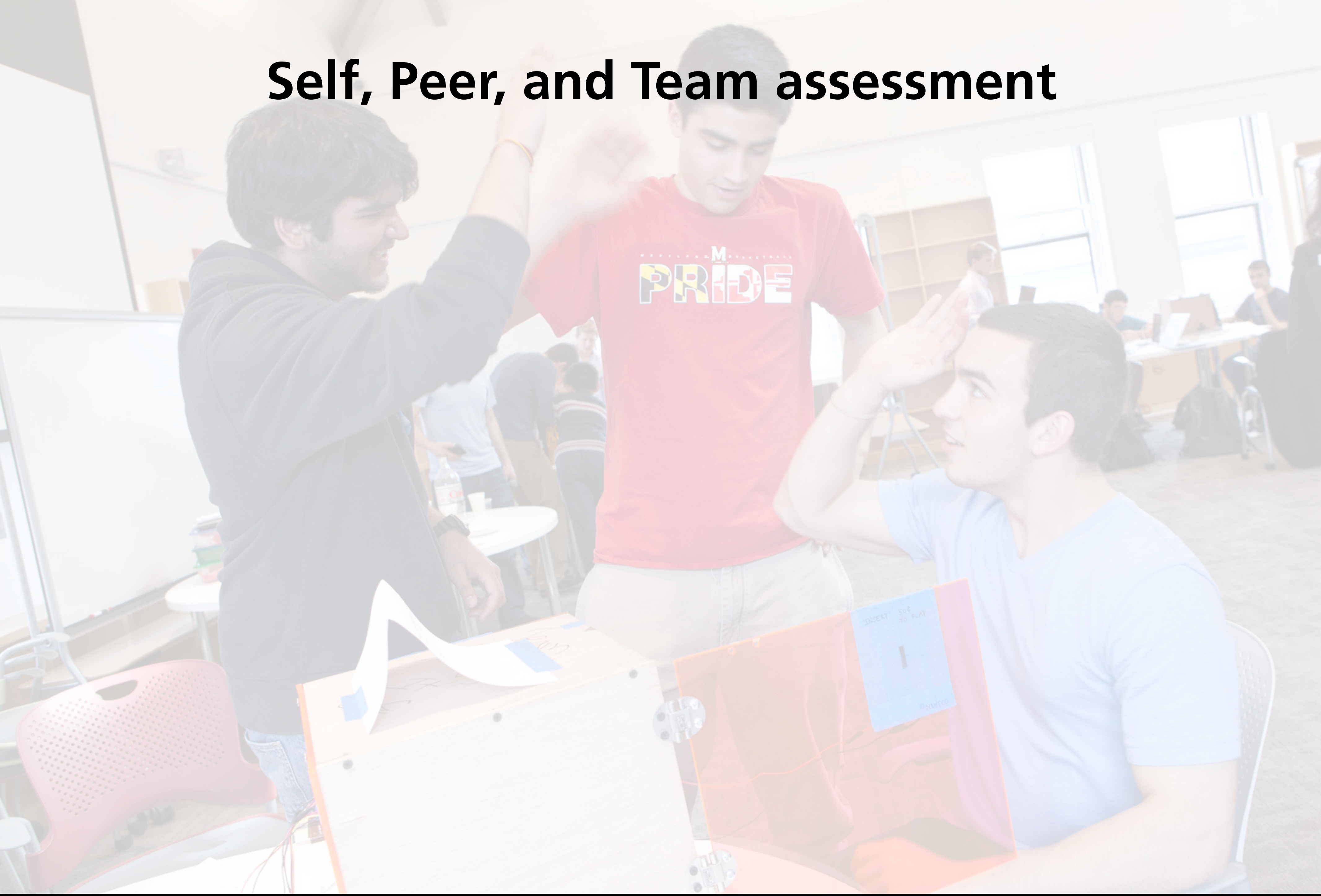
1 design

2 approach

1 design

2 approach

Self, Peer, and Team assessment



❶ design ❷ approach

Team, Peer, and Self assessment

Self Assessment

	Self Assessment (you!)	Never	Rarely	Sometimes	About half the time	Most of the time	All of the time
1.	I **participate fully** in team activities						
2.	I come to class **well-prepared** for all team activities						
3.	I **communicate effectively and respectfully** with team members: • I express my opinions respectfully and with clarity • I listen respectfully to the perspectives and contributions of others • I collaborate effectively with team members to make decisions and resolve conflicts						
4.	**Attendance**: • I am present for team activities • I am on time/punctual						
5.	I t**ake responsibility** for my own part of team work and decision-making						
6.	I am **open to change** and willing to re-evaluate my own position in light of new information from others						

7.	Please describe one thing that you think you do well, that helps to make your team more effective

1 design

2 approach

Team, Peer, and Self assessment

4. Relative contributions

How much did each team member contribute to the overall goals? Please note that the **sum of all relative contributions must be zero** — if one person did more than his/her fair share, then others must have done less.

	RELATIVE CONTRIBUTION						
	Less than fair share				More than fair share		
	Almost nothing	Much less	Somewhat less	Fair share	Somewhat more	Much more	Almost everything
Self							
Member 1							
Member 2							
Member 3							
Member 4							

❶ design ❷ approach

Team, Peer, and Self assessment

Assessment Report

	You…	Avg. Assessment by Peers	Self Assessment
1.	**Participate fully** in team activities		
2.	Come to class **well-prepared** for all team activities		
3.	**Communicate effectively and respectfully** with team members: • Express your opinions respectfully and with clarity • Listen respectfully to the perspectives and contributions of others • Collaborate effectively with team members to make decisions and resolve conflicts		
4.	**Attendance**: • You are present for team activities • On time/punctual		
5.	**Take responsibility** for your own part of team work and decision-making		
6.	Are **open to change** and willing to re-evaluate your own position in light of new information from others		

Scale: 0 = Never, 1 = Rarely, 2 = Sometimes, 3 = About half the time, 4 = Most of the time, 5 = All of the time

Your team members **praise you** for helping make your team more effective in the following ways (the quotes are in random order):

"quote 1"
"quote 2"
"quote 3"
"quote 4"

What you said you did to help make your team more effective:

"self quote"

Your team members have the following **suggestions** to help you become a more effective team member (the

1 design **2** approach

Team, Peer, and Self assessment

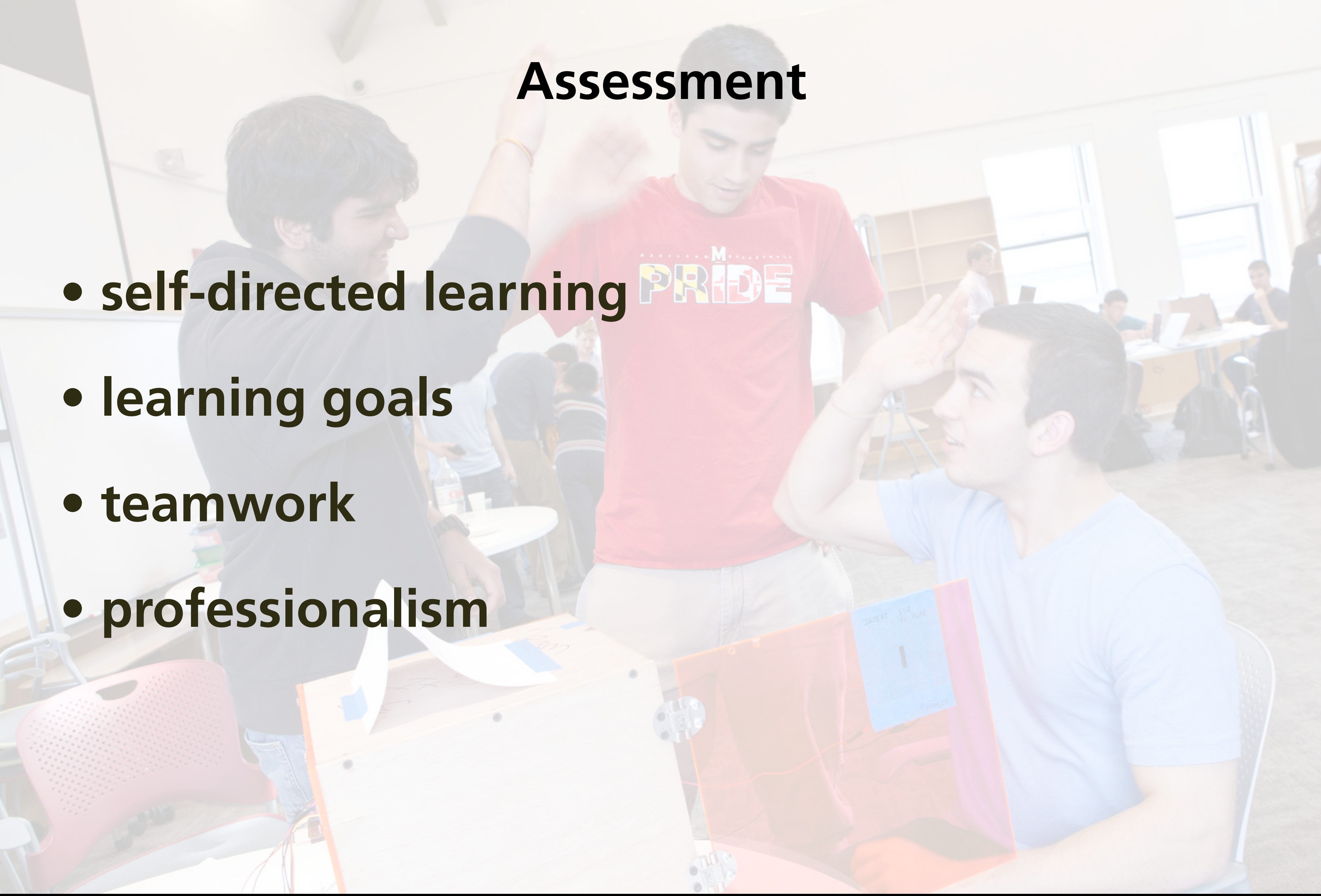
Relative contributions to team work	Average Peer Assessment	Self Assessment
You		
Team member 1		
Team member 2		
Team member 3		
Team member 4		

Scale: –3 = did almost nothing, –2 = did much less than fair share, –1 = somewhat less than fair share, 0 = fair share; +1 = somewhat more than fair share, +2 = much more than fair share, +3 = did almost everything

Scores

Your **team work score**: 0–3 (based on peers' assessment of **your** relative contributions)
Your self and peer **assessment accuracy score**: 0–3

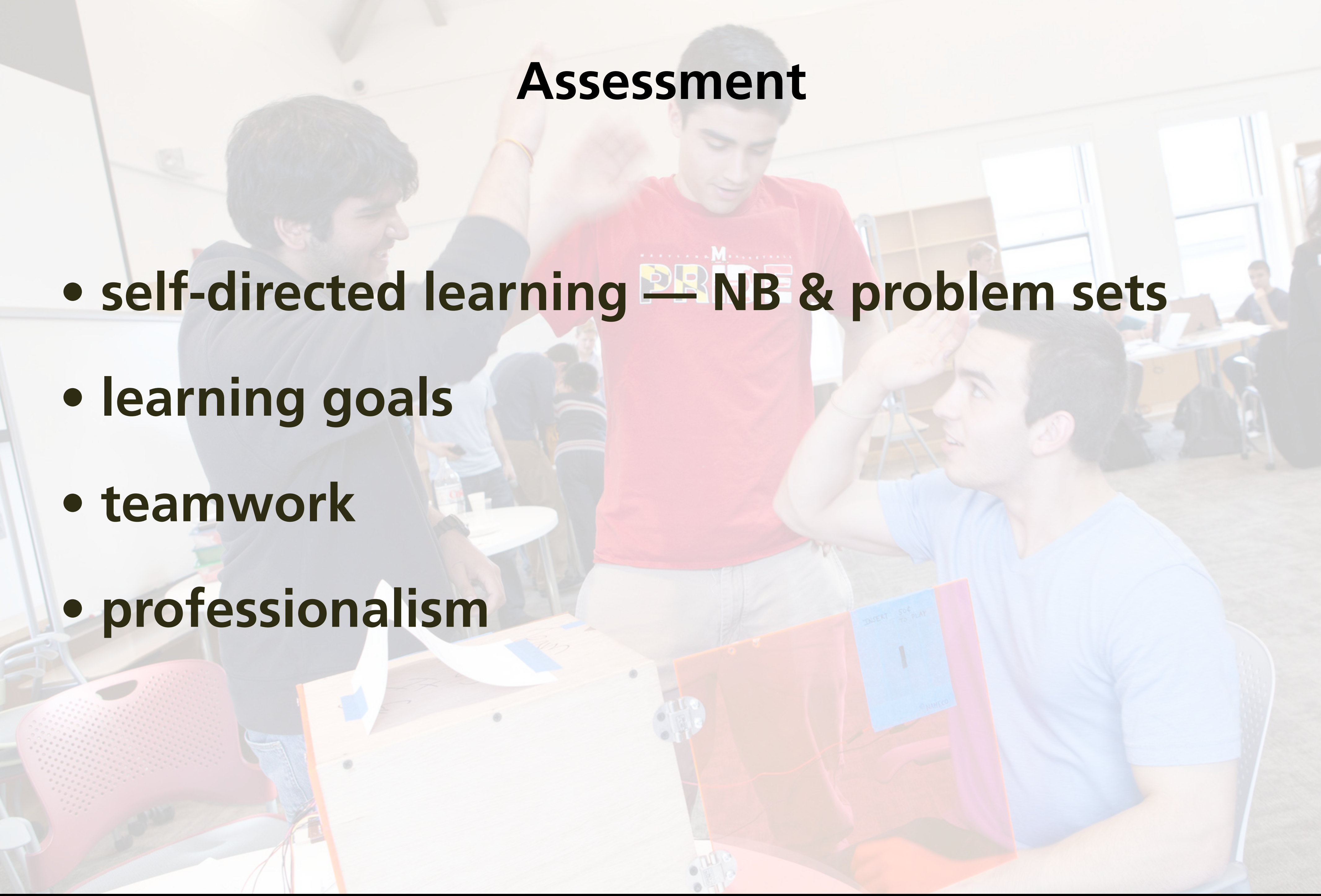
Scale: 3 = exceptional (very rarely given); 2 = meets expectations; 1 = needs improvement; 0 = deficient



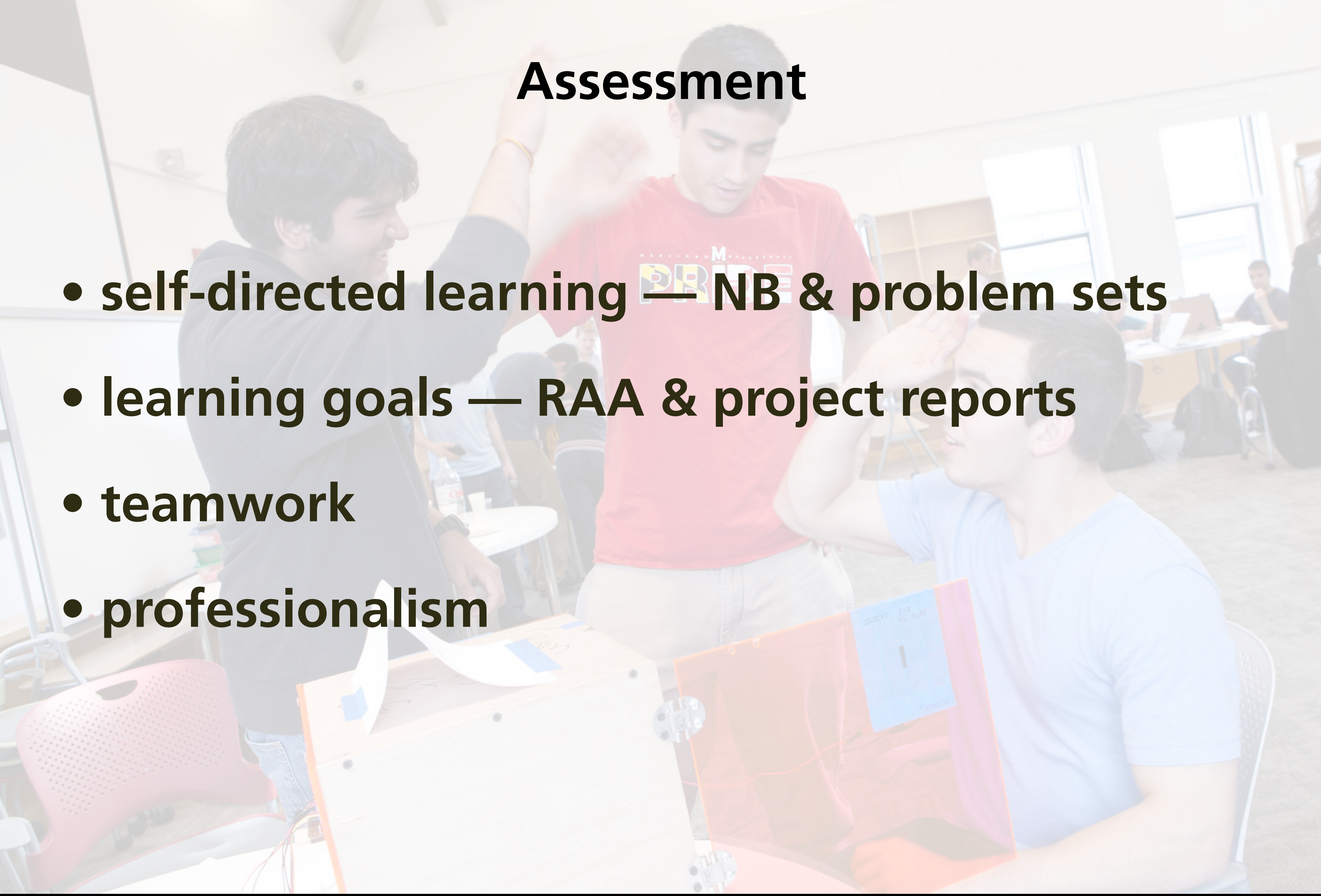
Assessment

- self-directed learning
- learning goals
- teamwork
- professionalism

Assessment

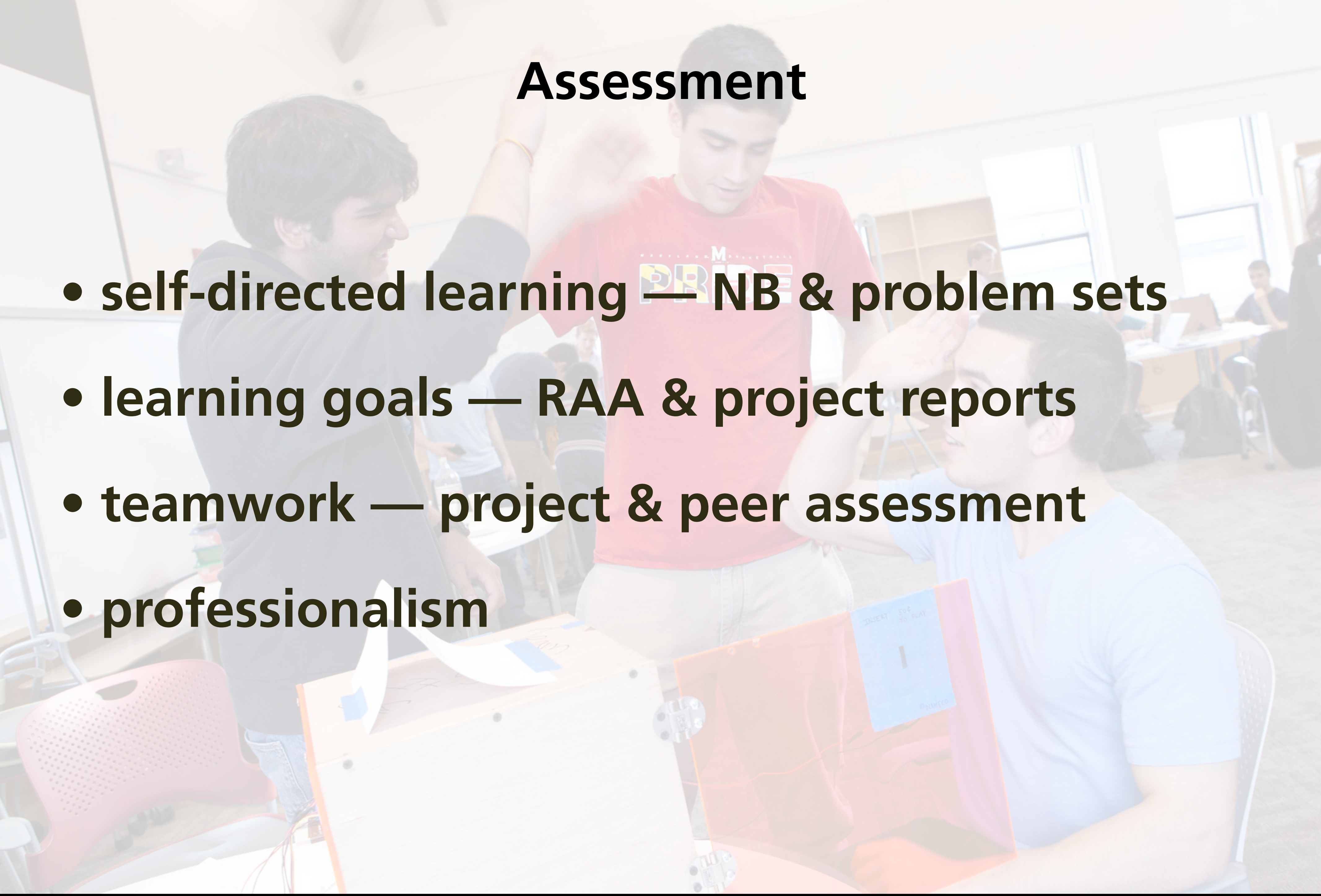


- self-directed learning — NB & problem sets
- learning goals
- teamwork
- professionalism



Assessment

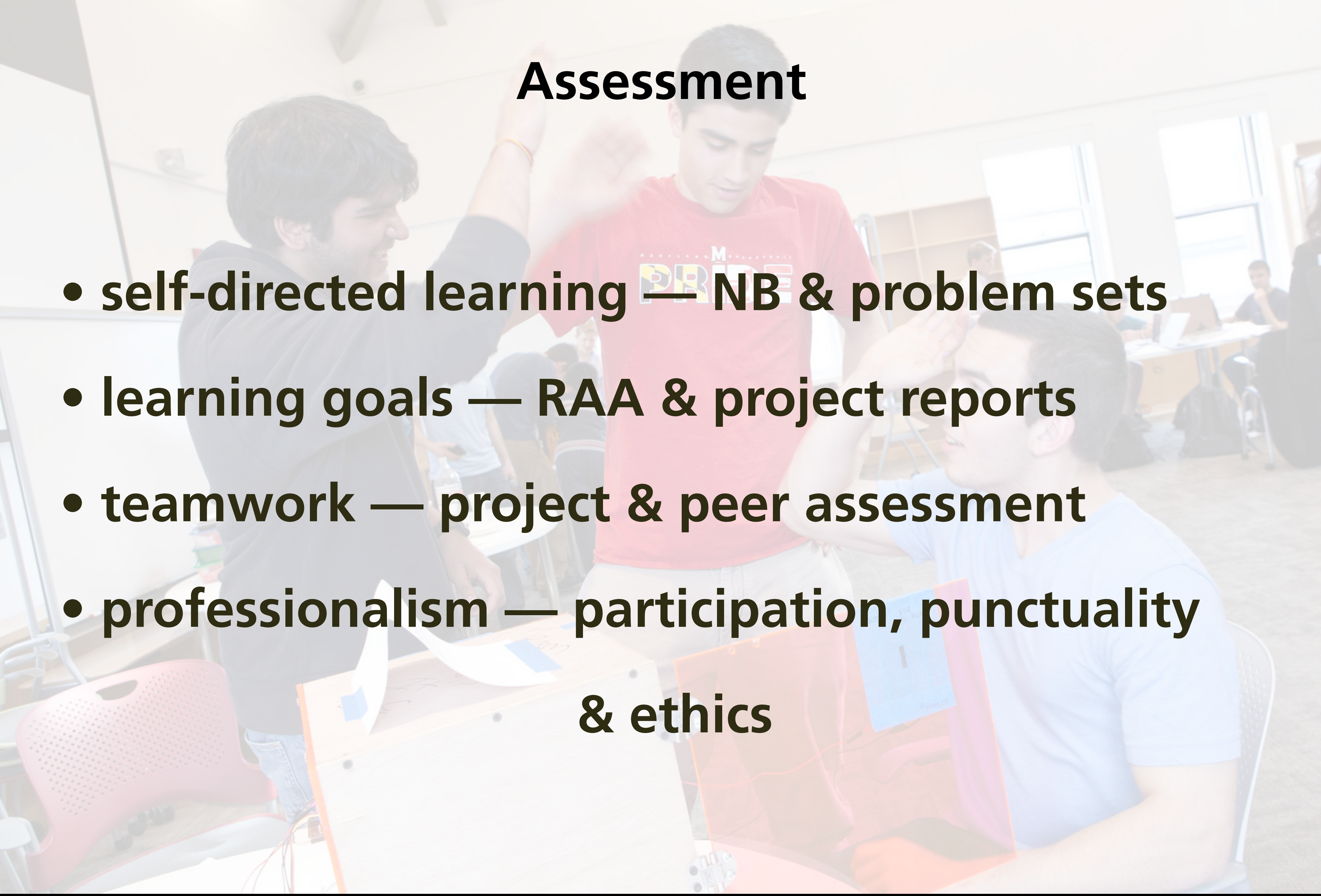
- self-directed learning — NB & problem sets
- learning goals — RAA & project reports
- teamwork
- professionalism



Assessment

- self-directed learning — NB & problem sets
- learning goals — RAA & project reports
- teamwork — project & peer assessment
- professionalism

Assessment



- self-directed learning — NB & problem sets
- learning goals — RAA & project reports
- teamwork — project & peer assessment
- professionalism — participation, punctuality & ethics

Assessment

self-directed learning

learning goals

team work

professionalism

1 design

2 approach

Assessment

Scale: 3–0

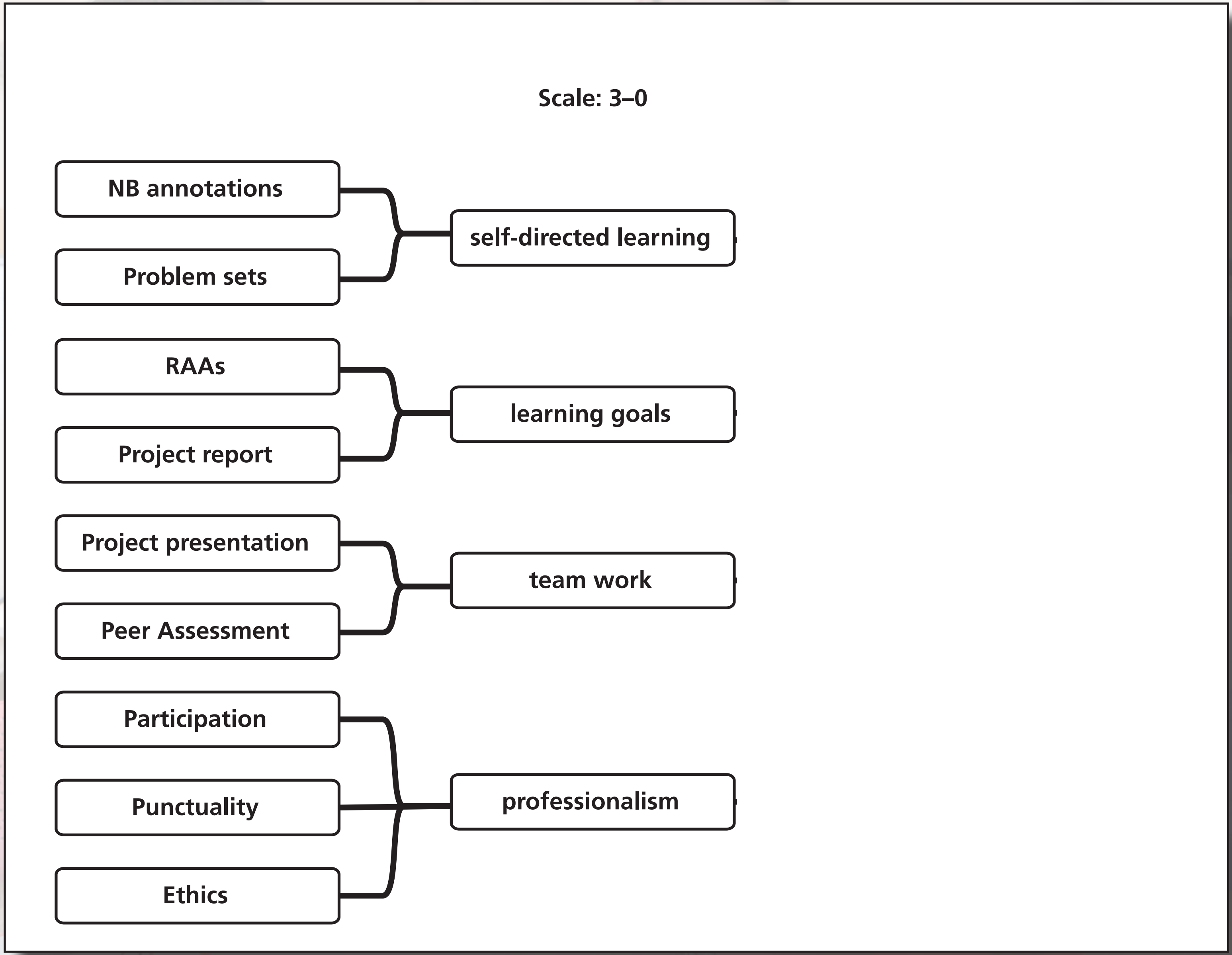
self-directed learning

learning goals

team work

professionalism

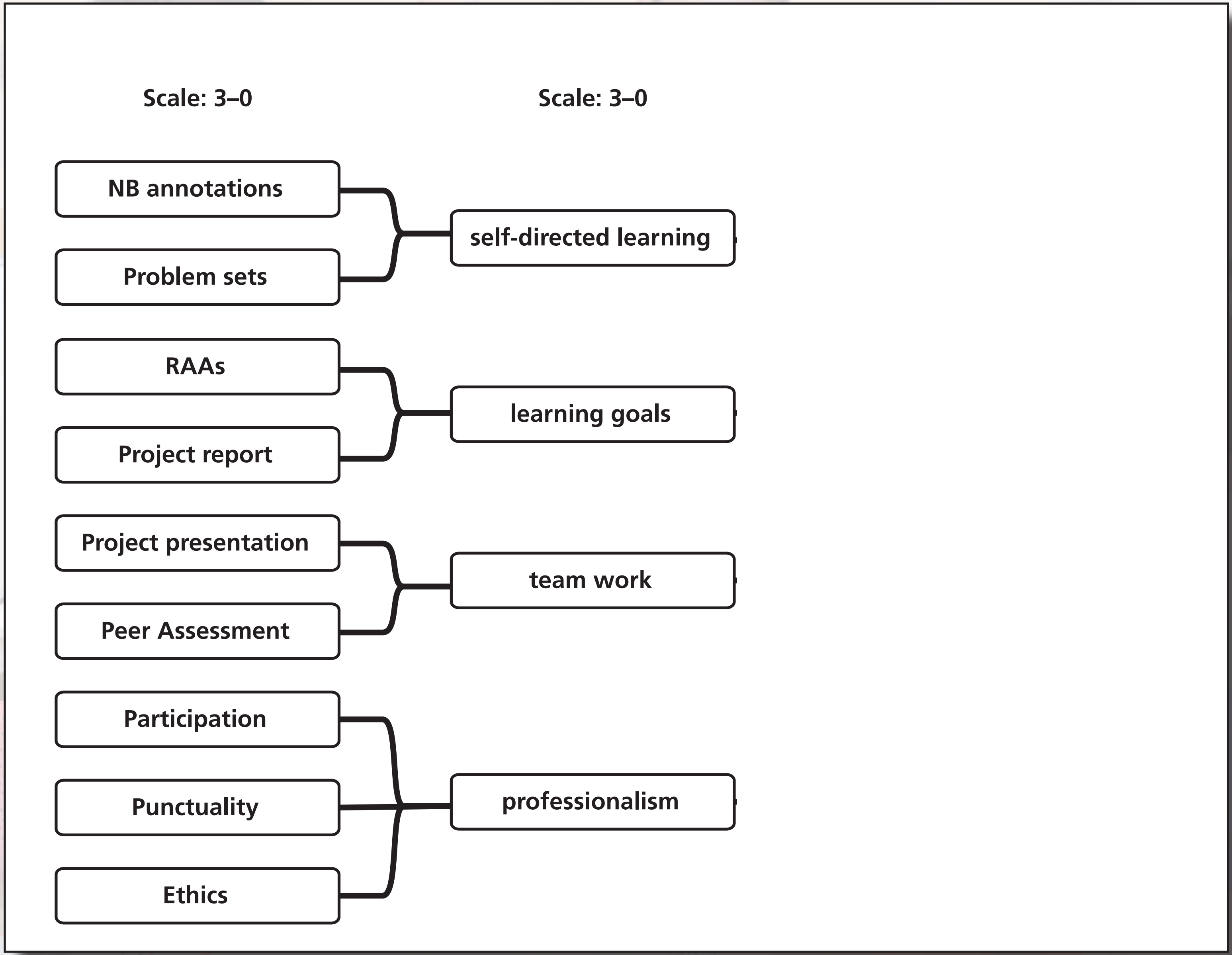
Assessment



1 design

2 approach

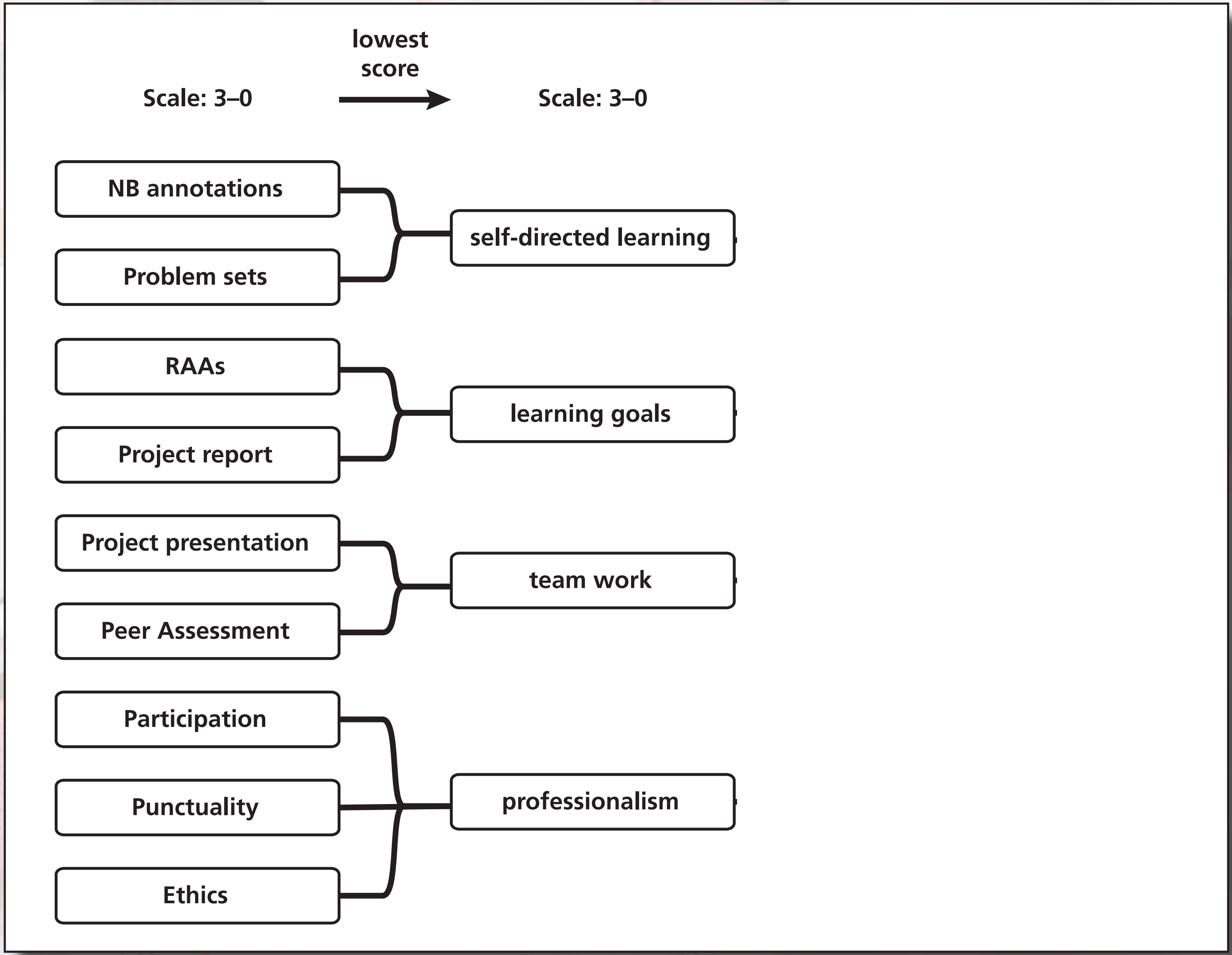
Assessment



1 design

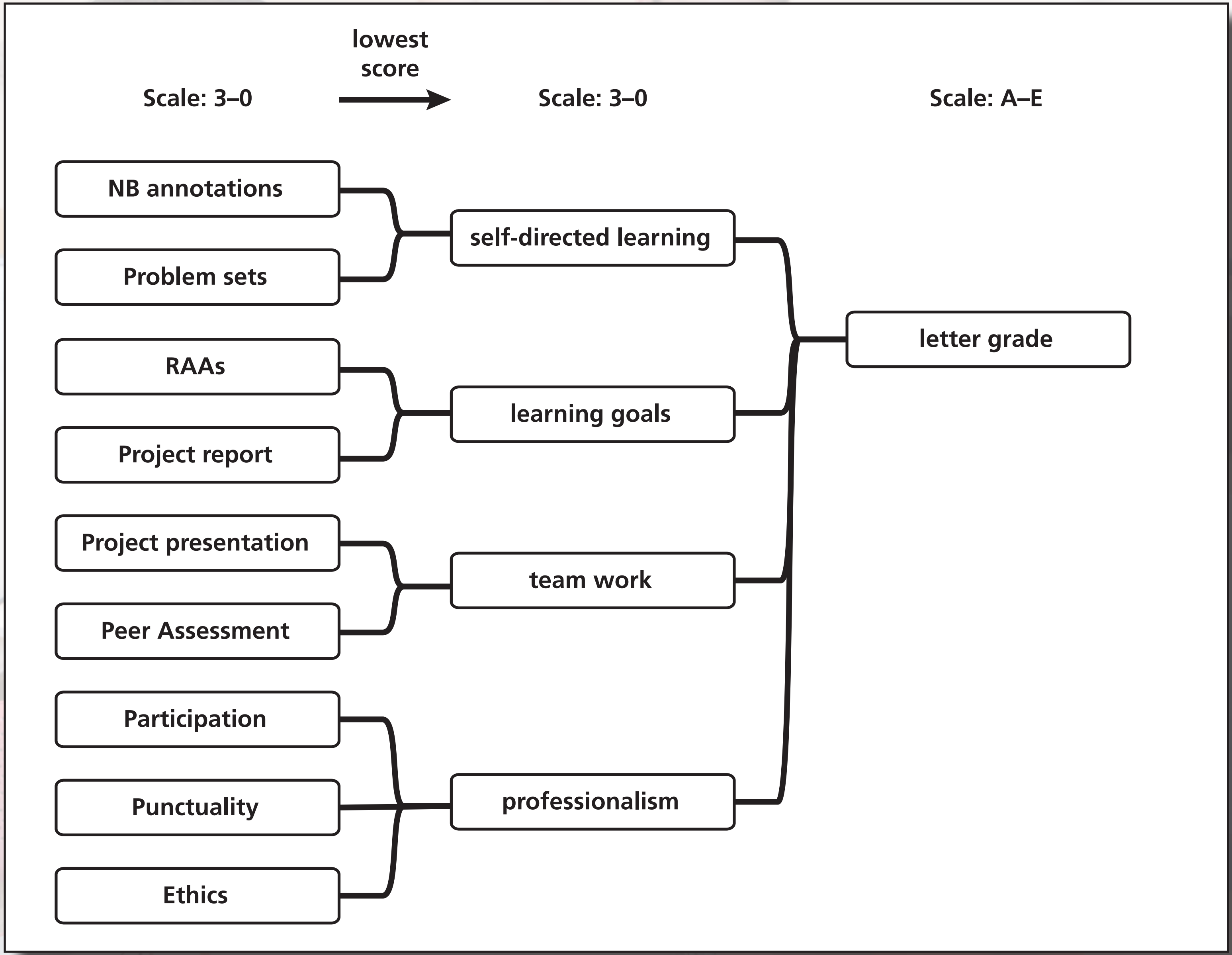
2 approach

Assessment



1 design 2 approach

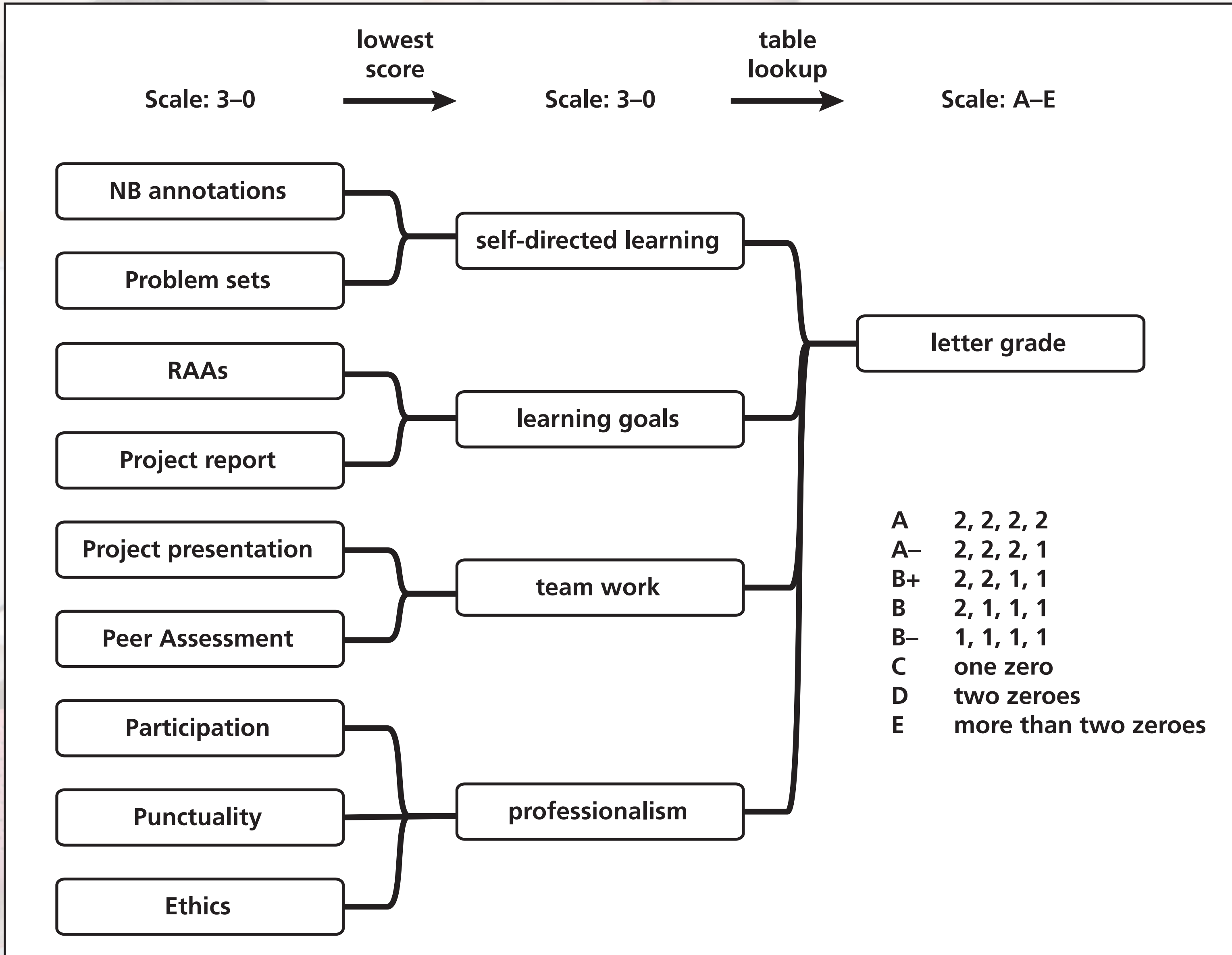
Assessment



1 design

2 approach

Assessment



1 design

2 approach

1 design 2 approach 3 results

Ownership

Ownership

Course evaluation: 4.2/5

Ownership

"The structure of the class made what was my least-favorite subject into one of my favorites.

Ownership

"The structure of the class made what was my least-favorite subject into one of my favorites. I was worried that people, including myself, would just slack off and do the bare minimum, but you really need to be on top of your readings and concepts in order to contribute to your team. GREAT CLASS!!!!!!"

Ownership

"Dear Harvard students, this class will be unlike any class you've taken at Harvard, and it will, hopefully, shift the entire foundation upon which you've based your education. I truly believe everyone should take this course; prepare to take full ownership of your learning."

Ownership

Attendance: 94% (AP50a), 97% (AP50b)

Ownership

Attendance: 94% (AP50a), 97% (AP50b)

3 hours and they don't *leave*!

Ownership

"I don't think I am well enough to make it through class. I feel terrible because I don't want to let my team down by not being there, but I don't think I'd be very helpful in my current state."

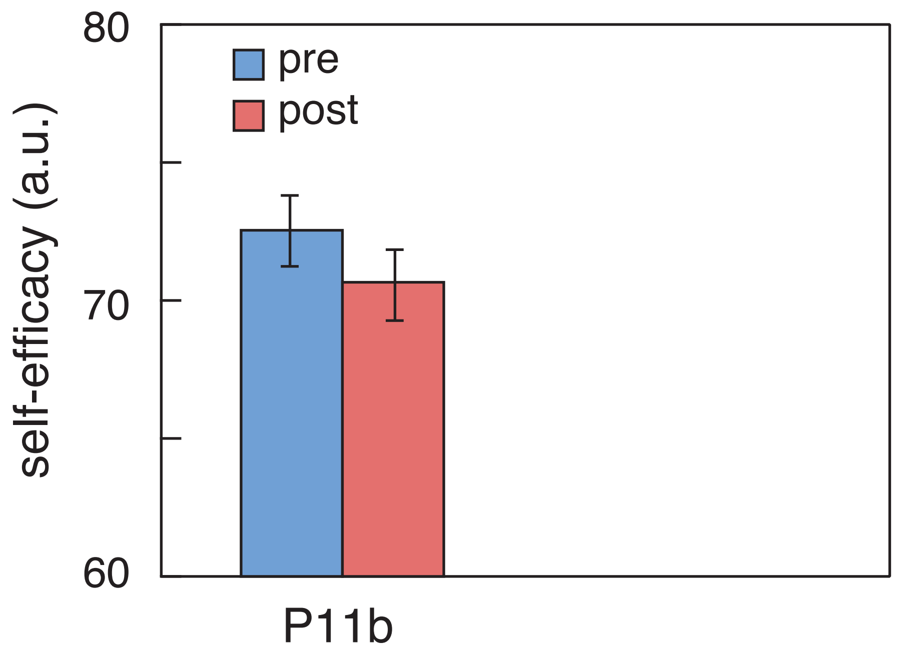
(via email)

Self-efficacy

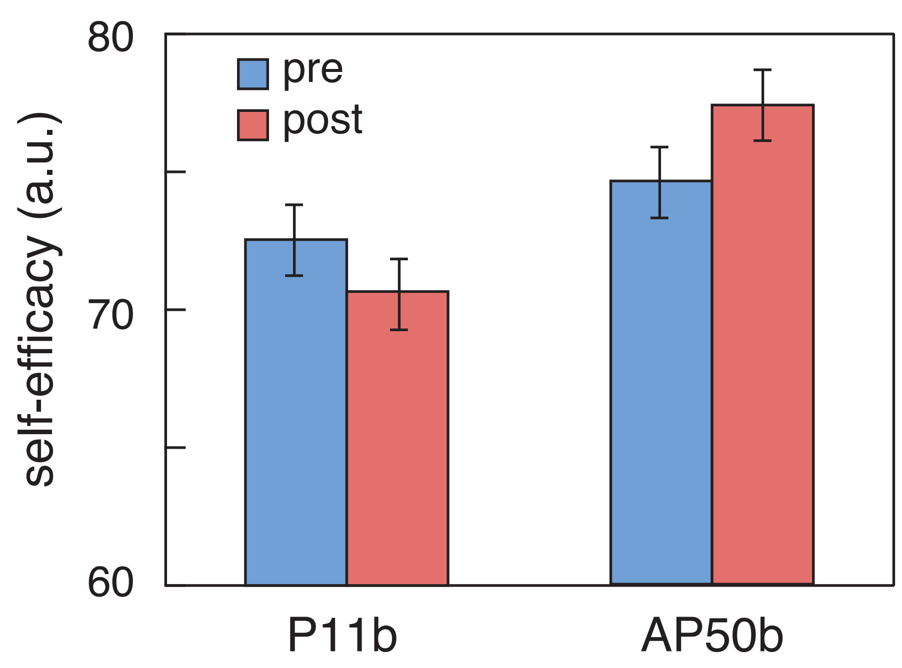
Self-efficacy

(students' belief in their ability to succeed)

Self-efficacy



Self-efficacy



1 design 2 approach 3 results

Self-directed learning

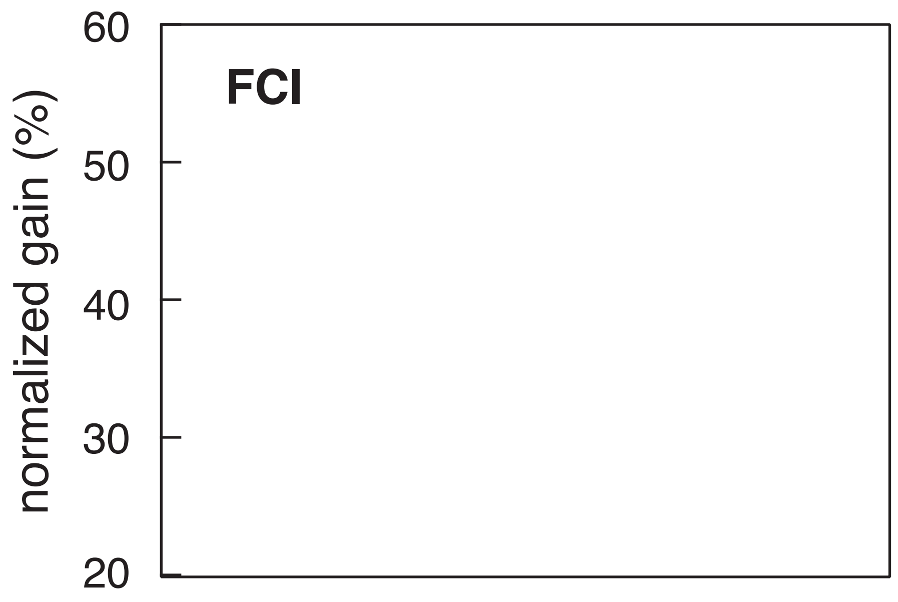
1 design 2 approach 3 results

Self-directed learning

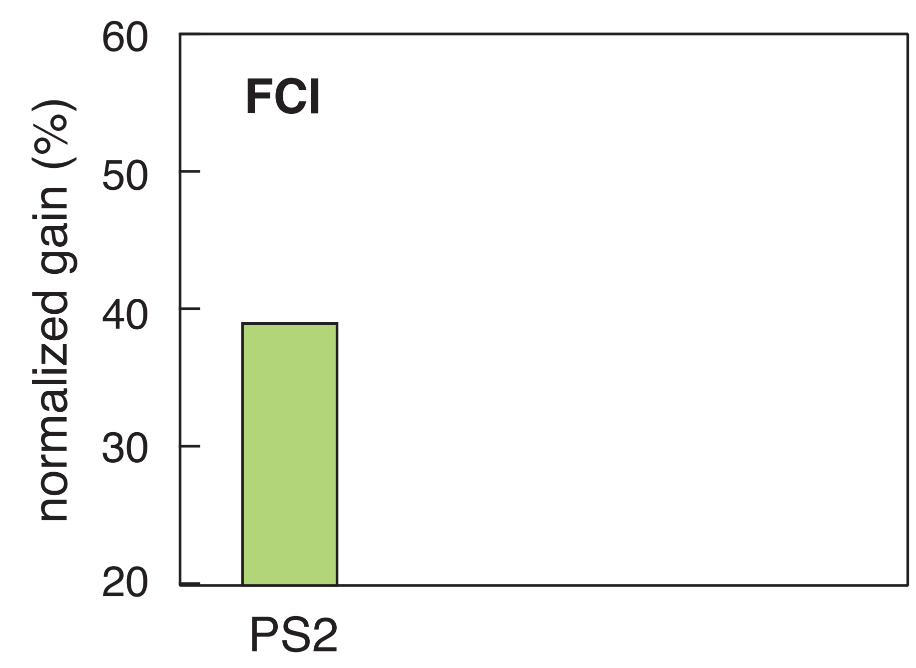
NB data shows:

- student spend on average 2.3 hrs/chapter
- 600–700 annotations/chapter (8–10/stu)

Conceptual Mastery

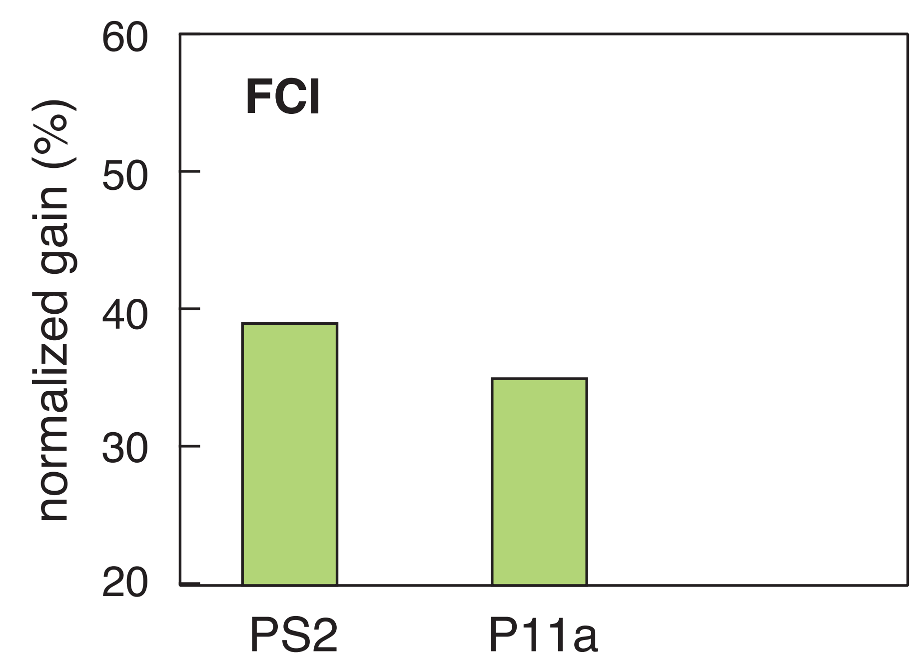


Conceptual Mastery



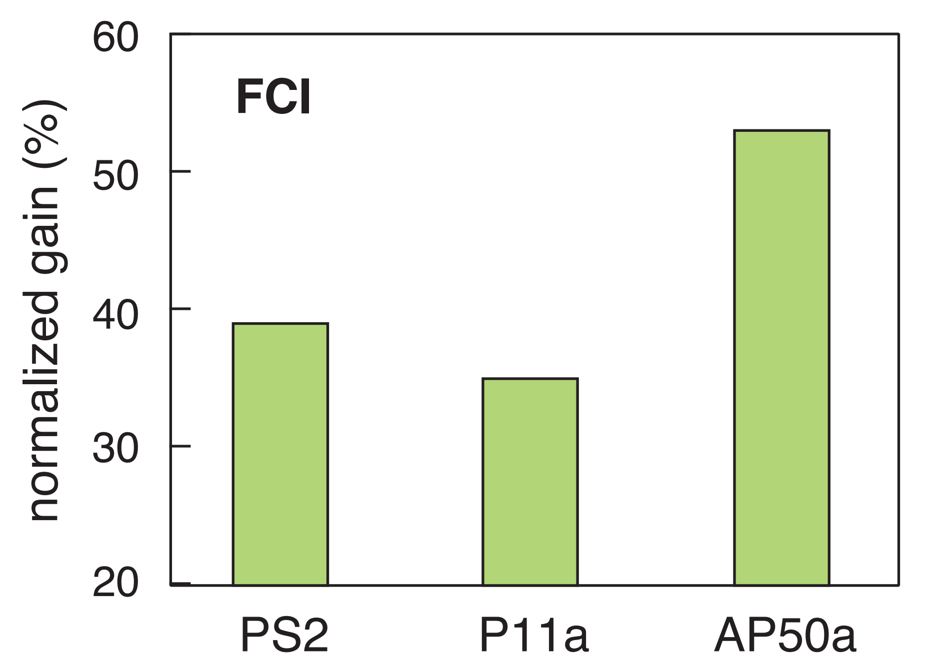
1 design
2 approach
3 results

Conceptual Mastery



1 design   2 approach   3 results

Conceptual Mastery

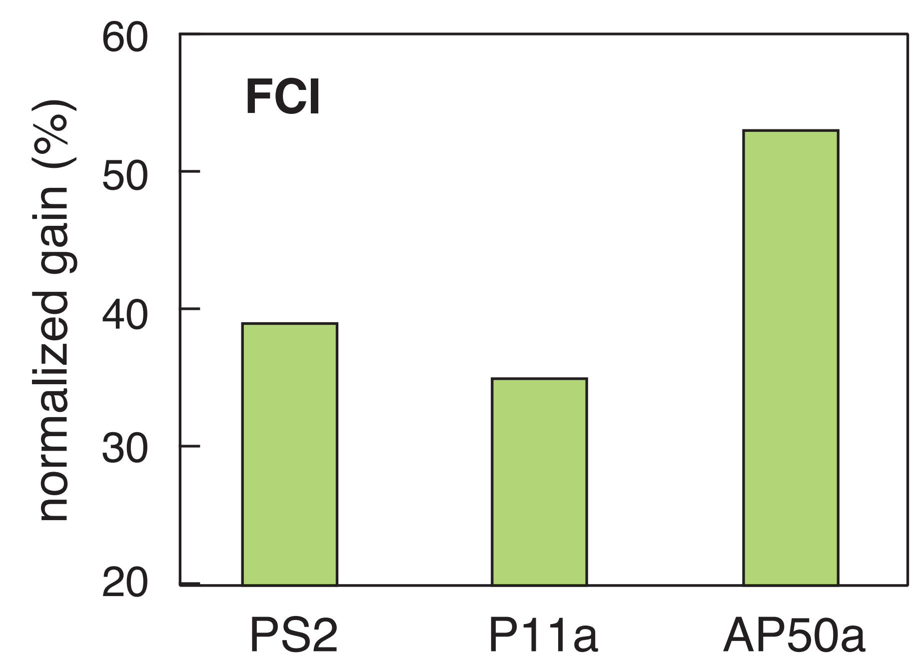


1 design

2 approach

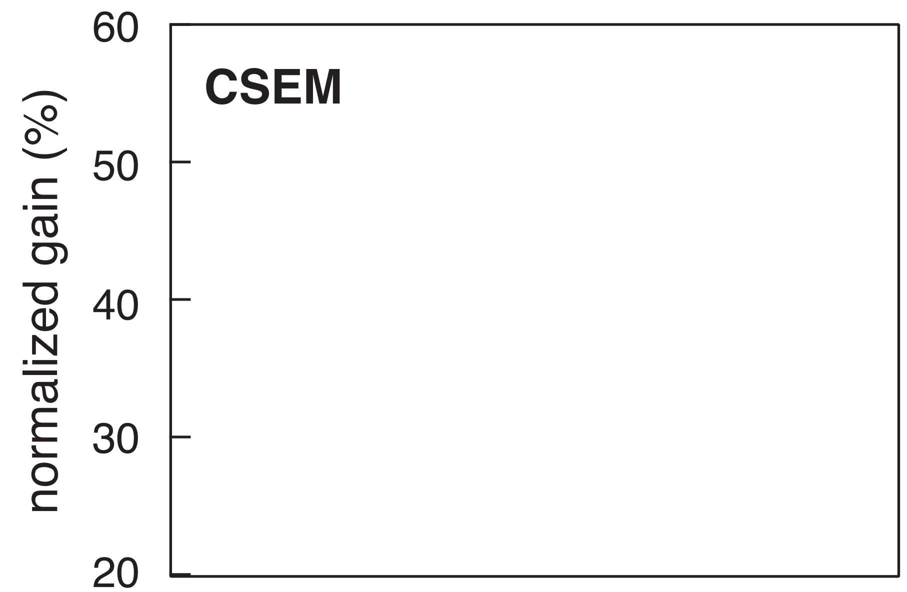
3 results

Conceptual Mastery

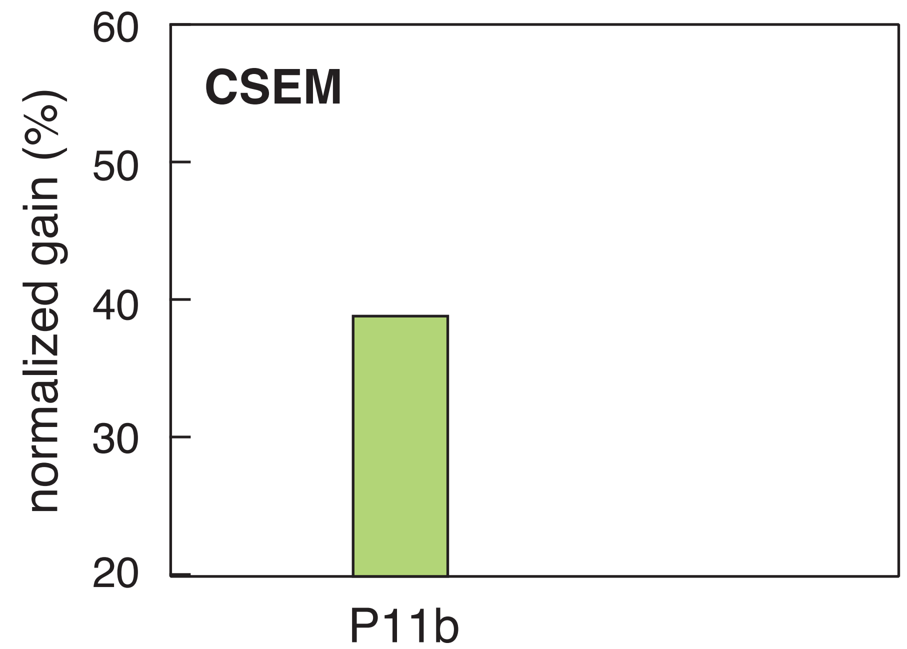


largest conceptual gain in *any* course past 6 yrs!

Conceptual Mastery

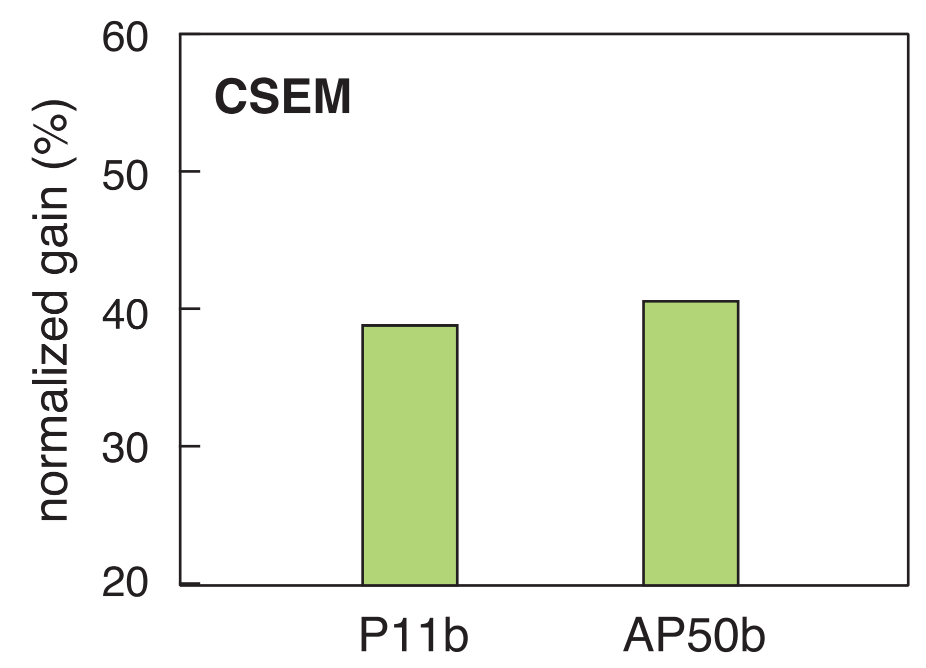


Conceptual Mastery

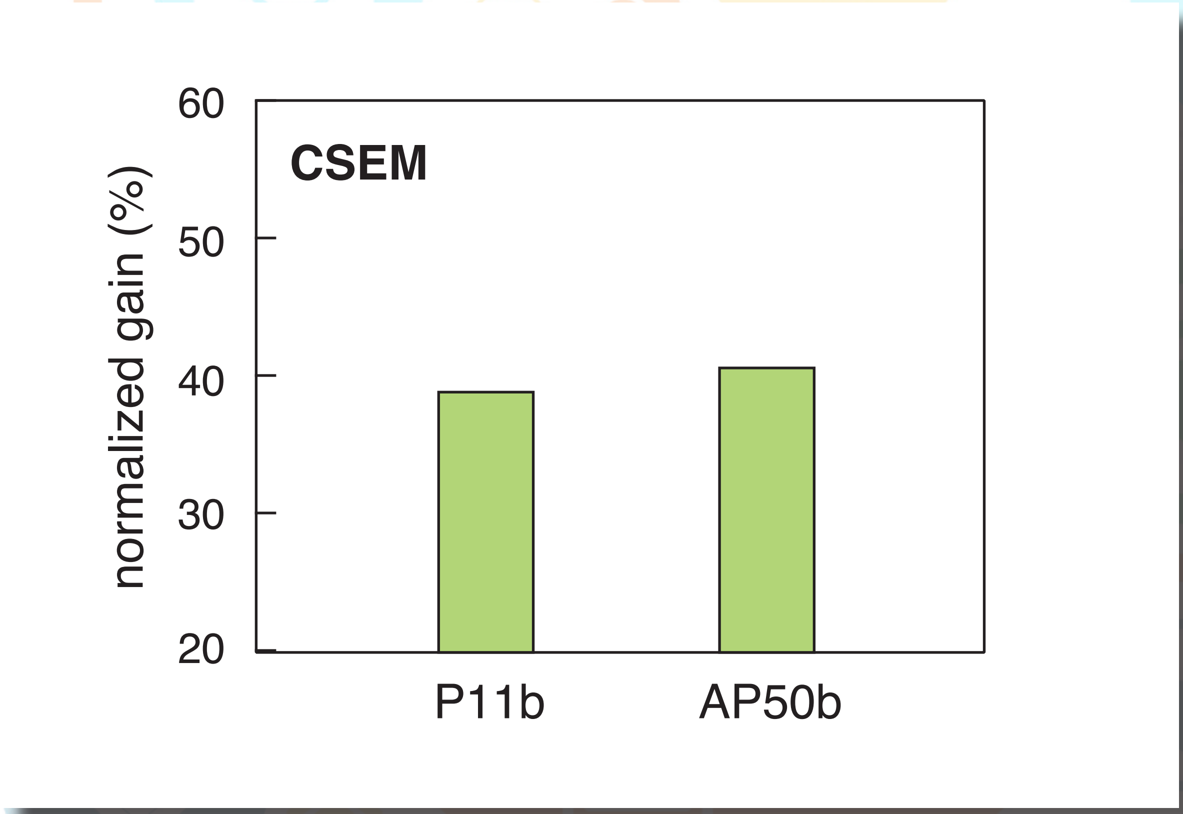


1 design 2 approach 3 results

Conceptual Mastery



Conceptual Mastery



as good as when I do my best teaching!

1 design

2 approach

3 results

Can **create ownership of learning physics!**

Can create ownership of learning physics!

1 design 2 approach 3 results

"you come out with so much know-ledge and experience and fun"

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