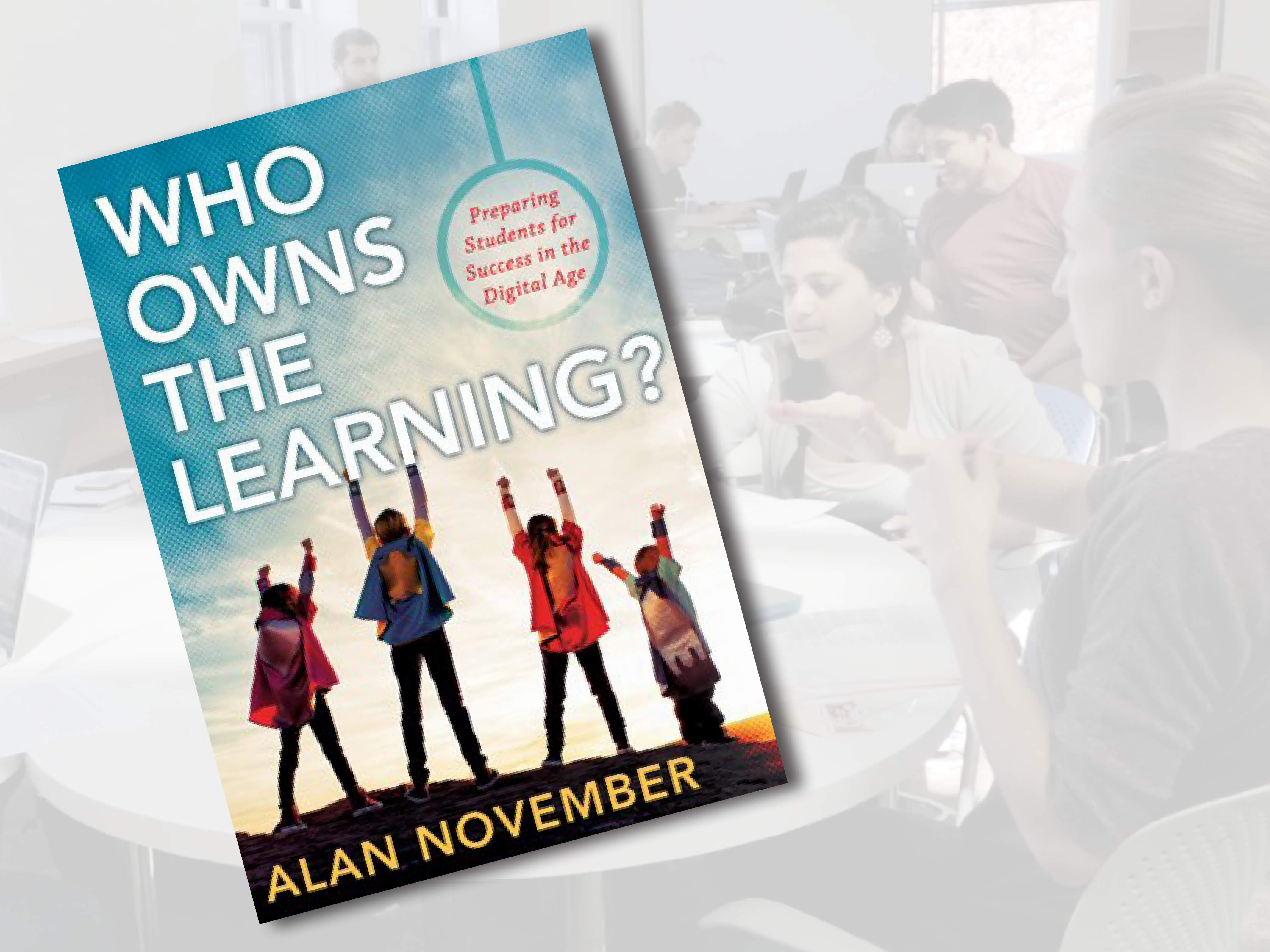
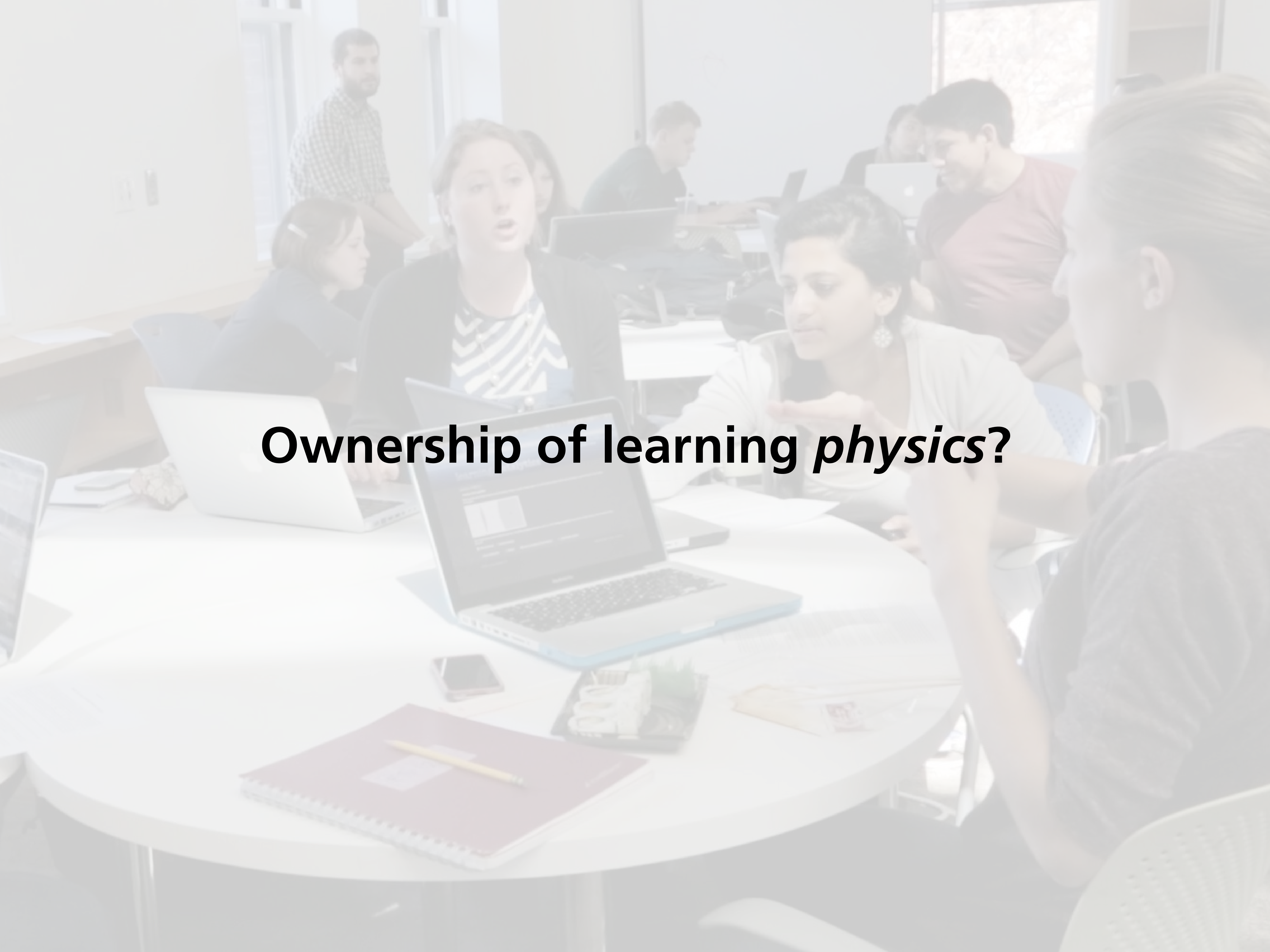
Team Based Learning in Engineering Education

Universiteit Twente
Enschede, Netherlands, 25 November 2015

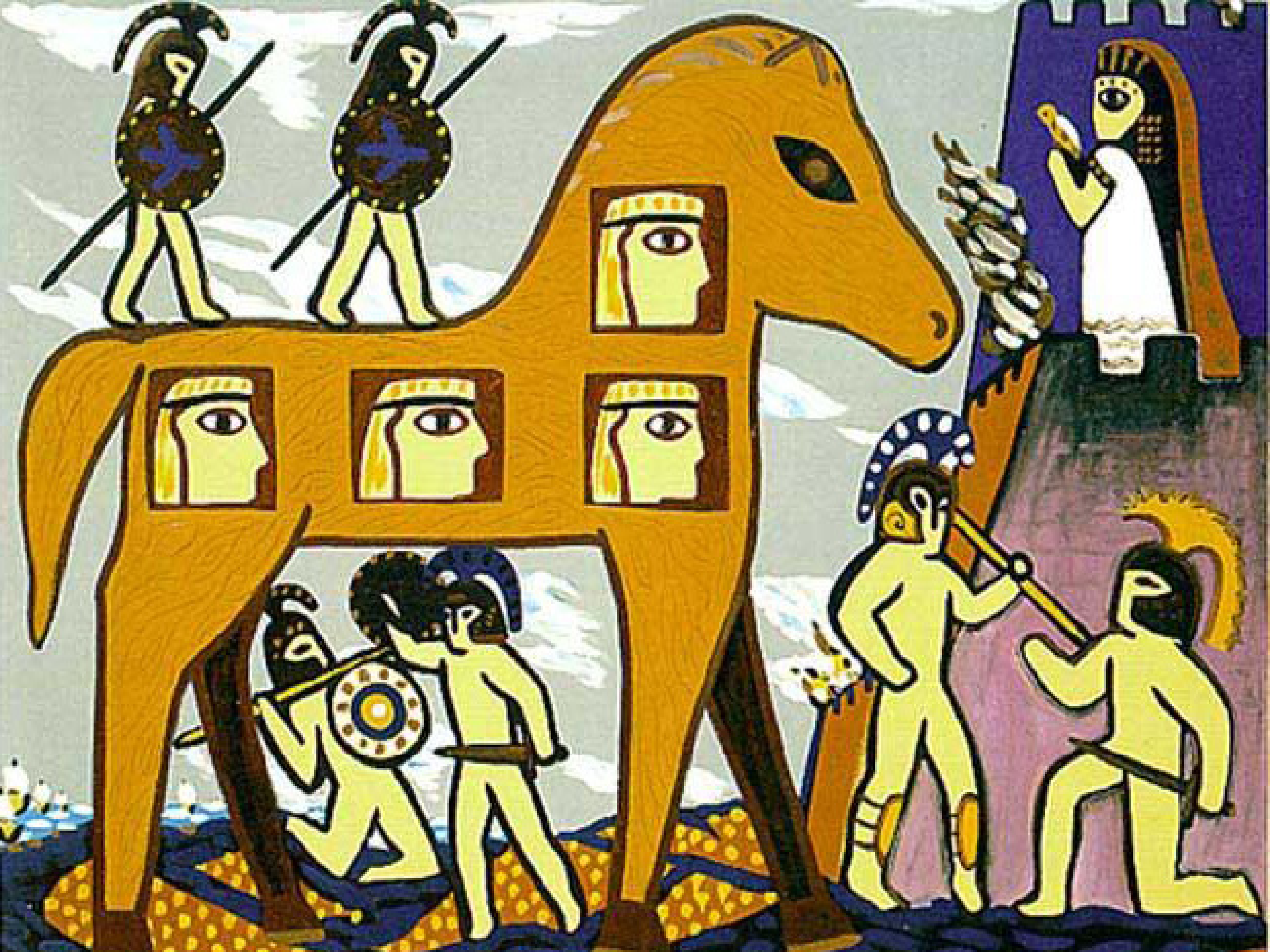
Team Based Learning in Engineering Education

Universiteit Twente
Enschede, Netherlands, 25 November 2015

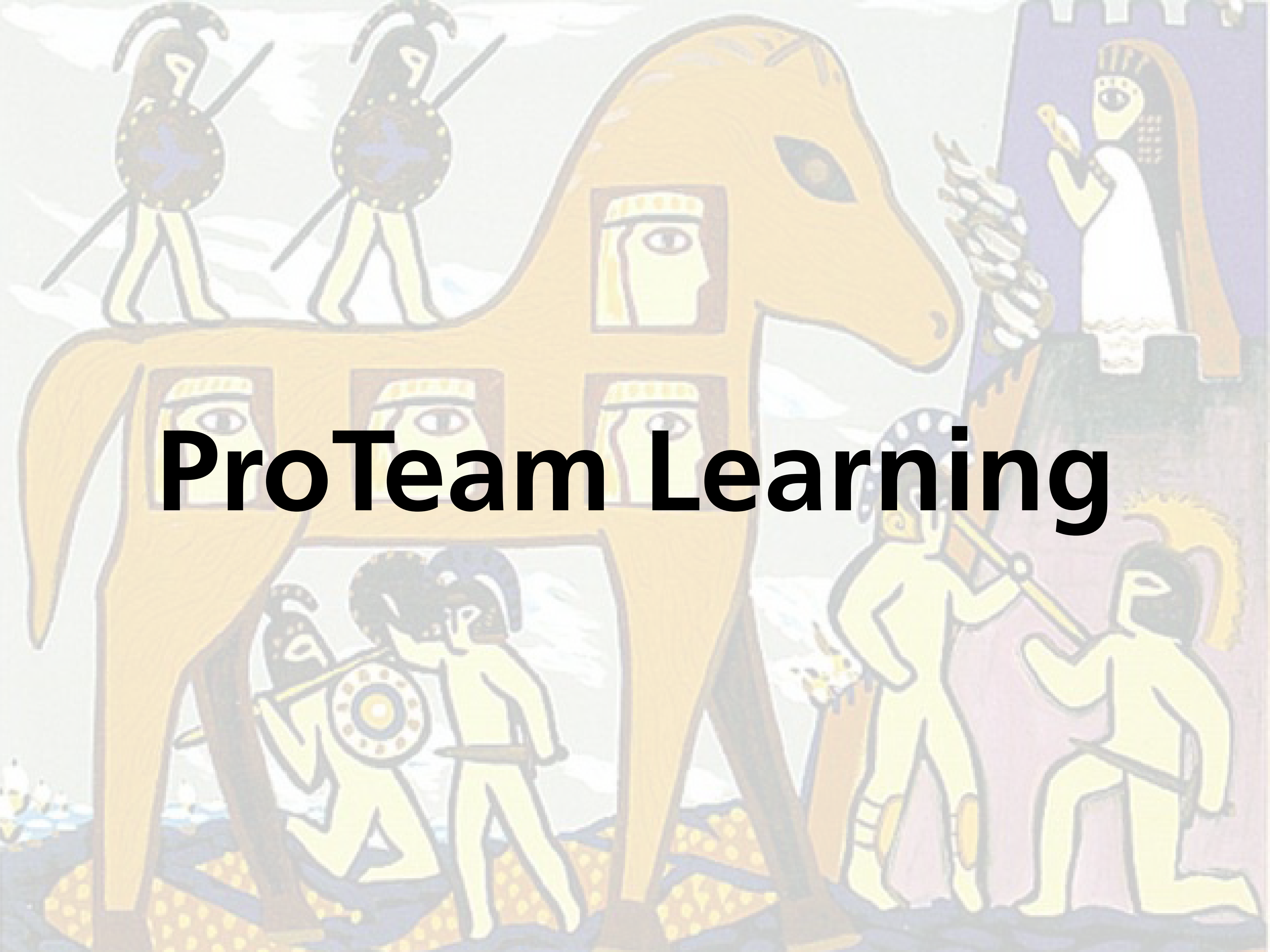

WHO OWNS THE LEARNING?
Preparing Students for Success in the Digital Age
ALAN NOVEMBER



Ownership of learning *physics*?



team & project-based approach



ProTeam Learning

1 design

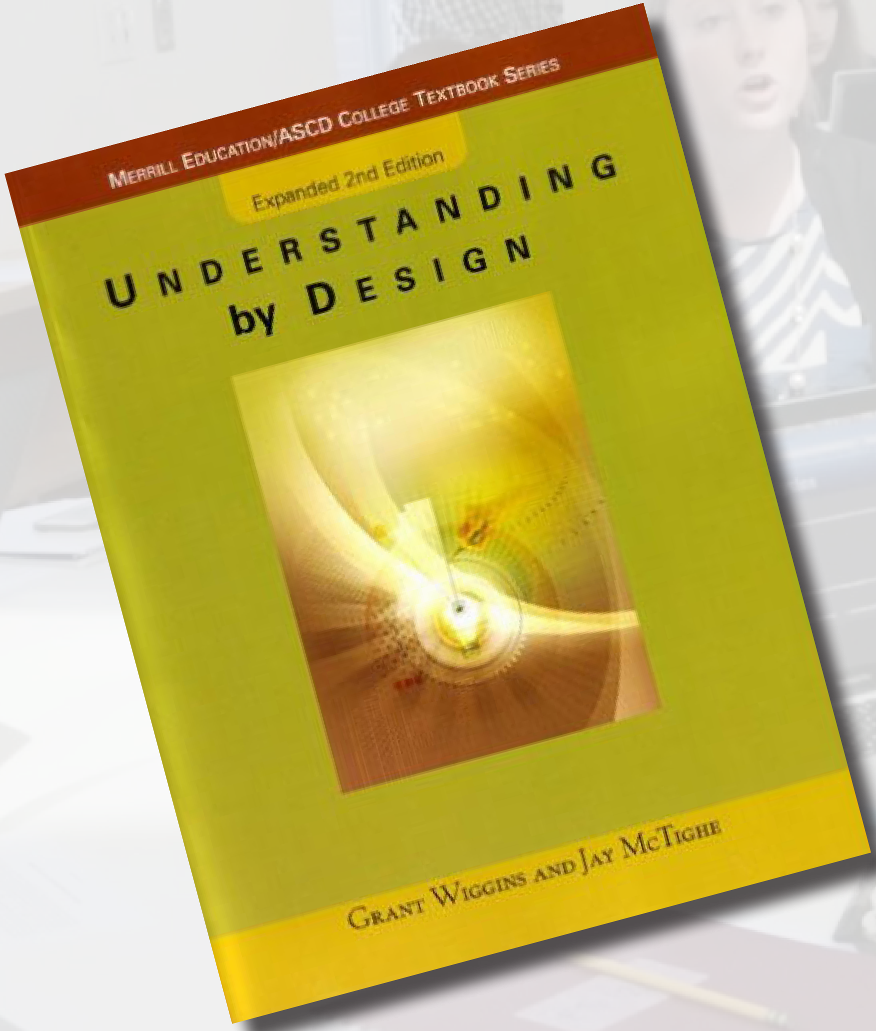
1 **design** 2 **approach**

1 design

2 approach

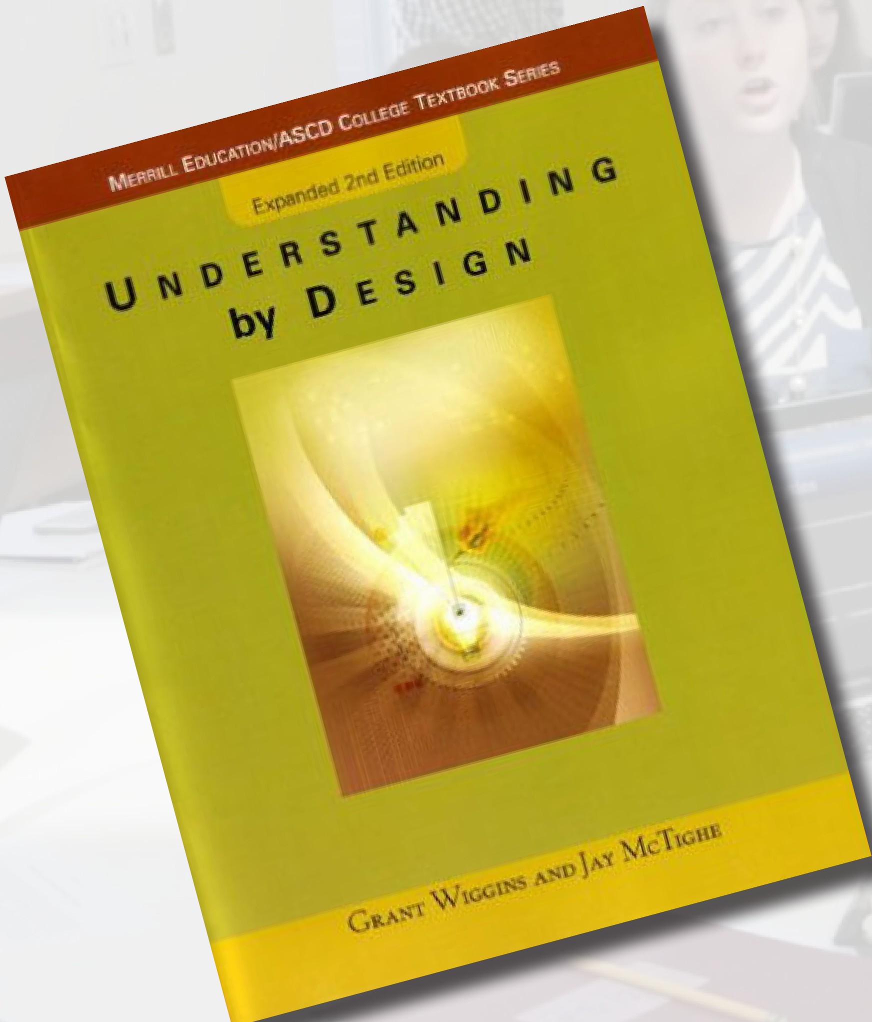
3 results

Setting learning goals



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

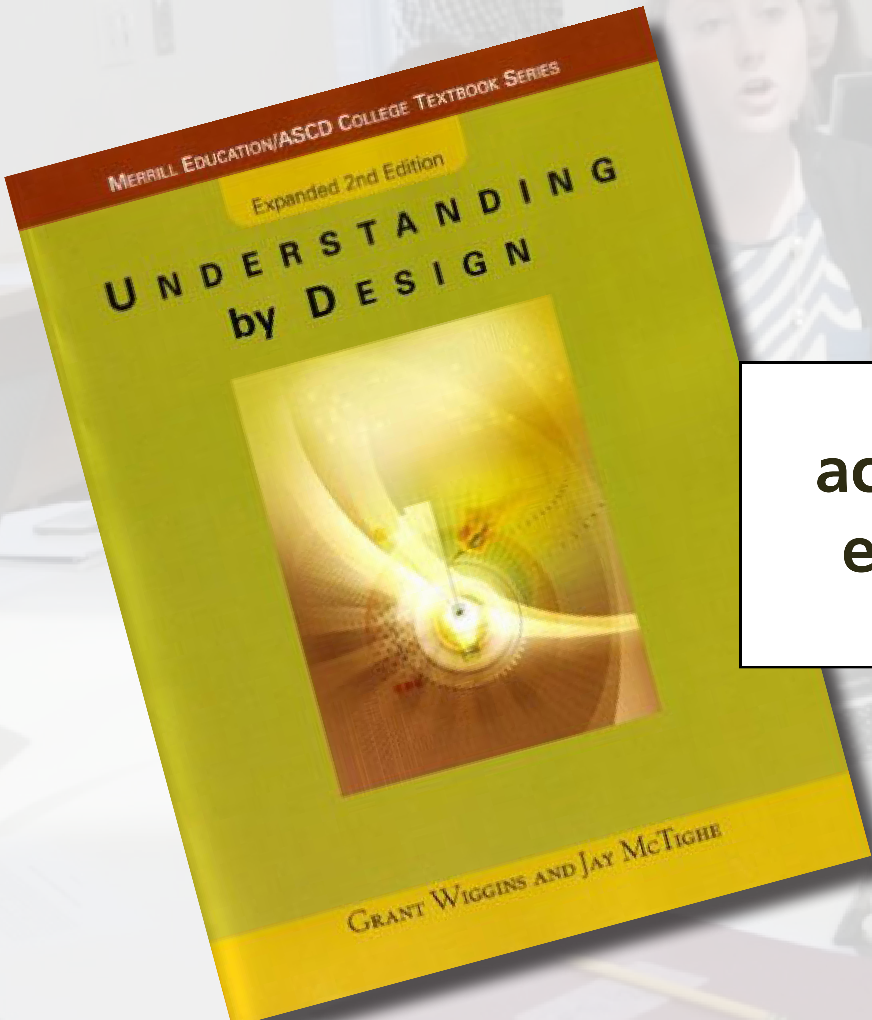
Backward design



desired outcomes

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

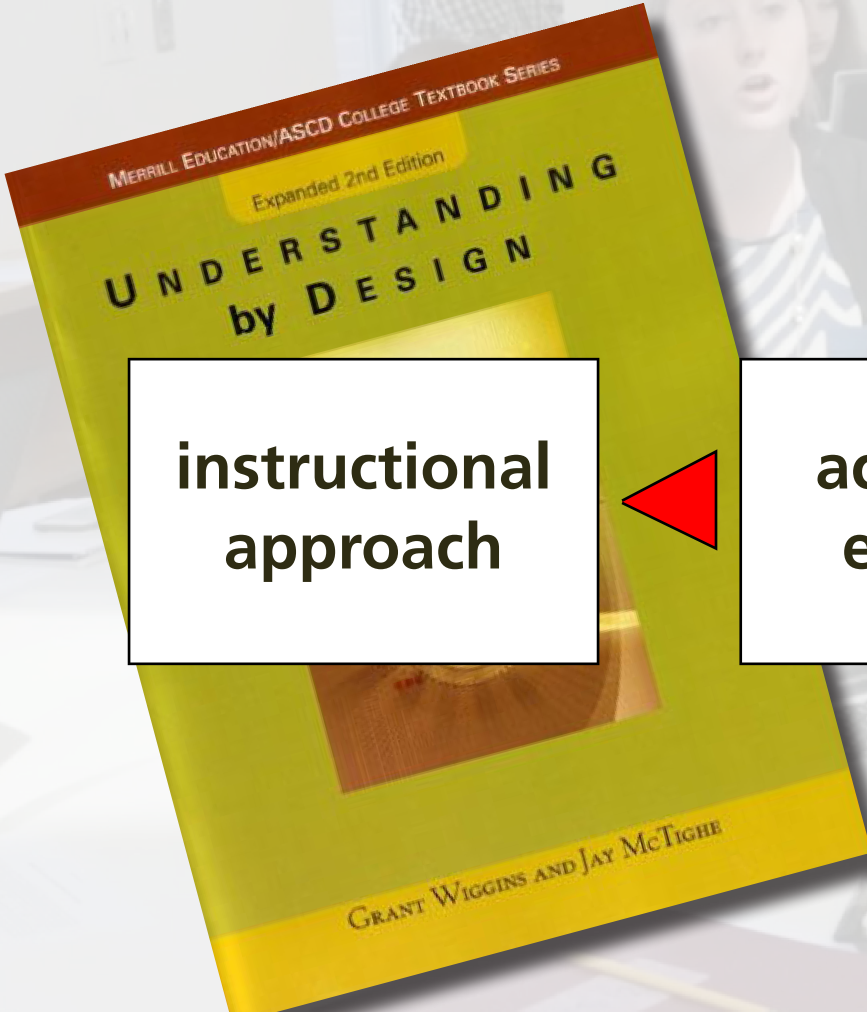
Backward design



acceptable evidence	◀	desired outcomes

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

Backward design



instructional approach ◀ acceptable evidence ◀ desired outcomes

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

competencies

course goals

- **self-directed learning**
- **content mastery**
- **team work**
- **professionalism**

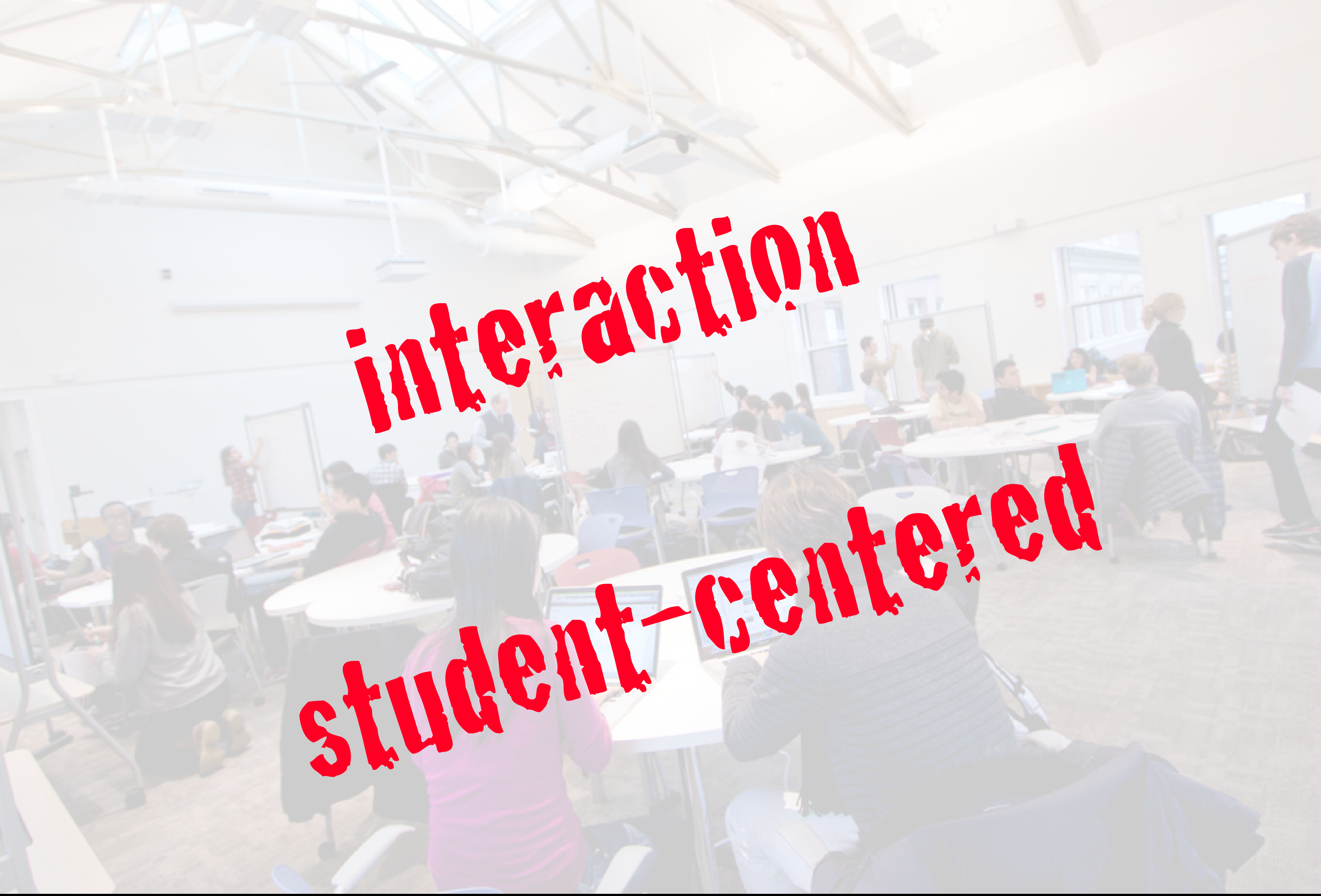
content-specific goals

http://bit.ly/ap50visitor

1 design

1 design

1 design



1 design

1 design 2 approach

1 design

2 approach

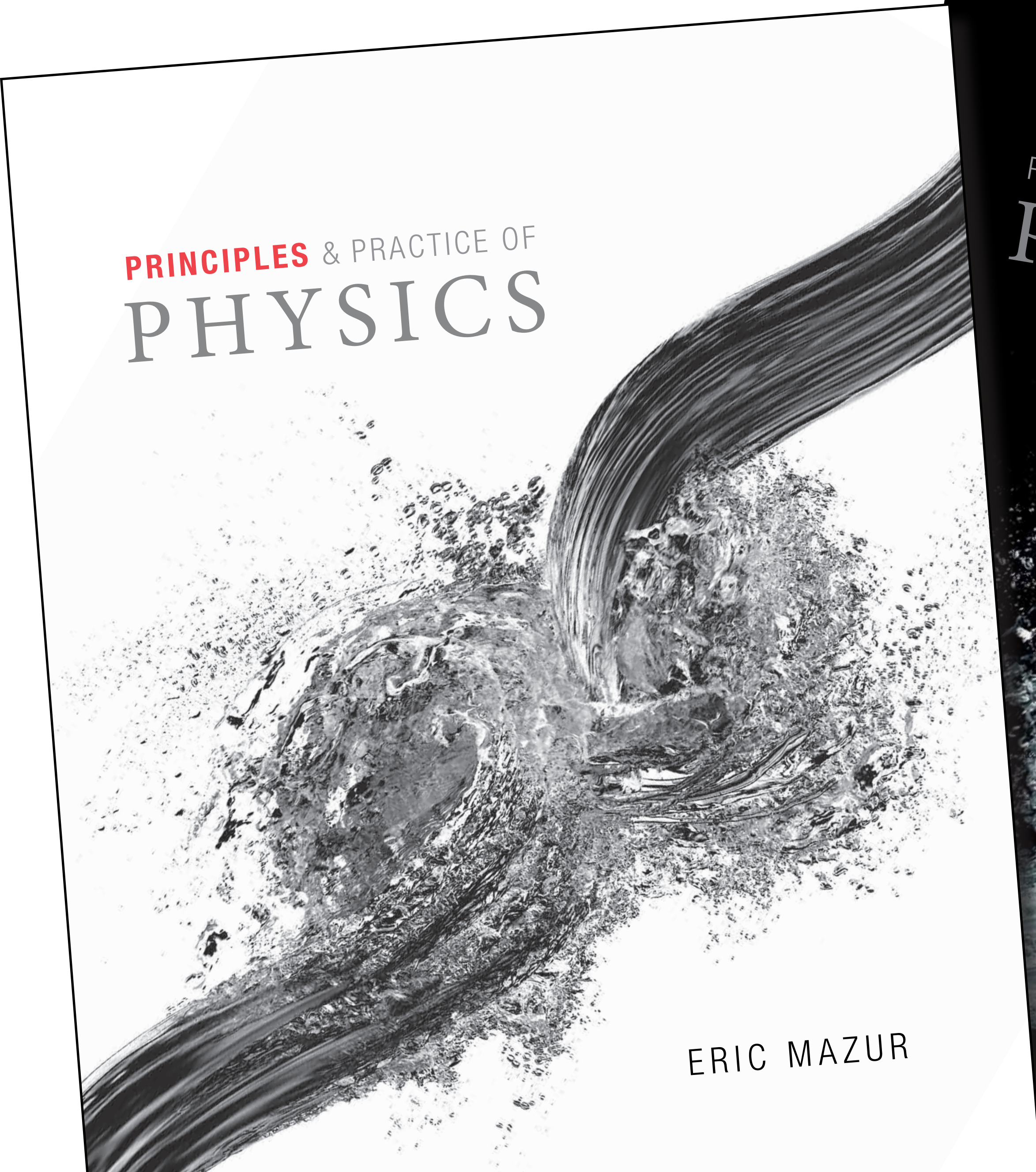
1 design 2 approach

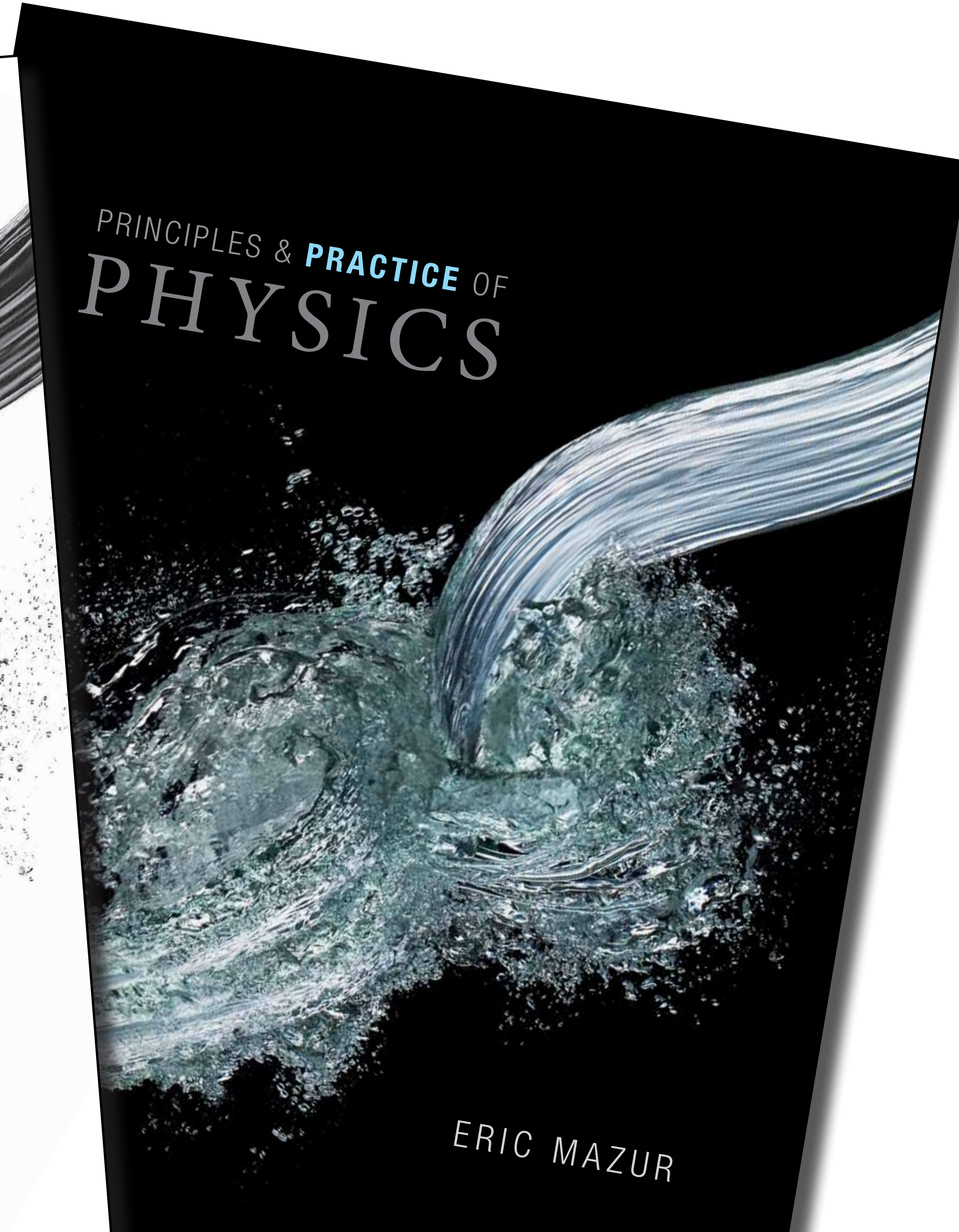
1 design

2 approach

Three major components:

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





1 design

2 approach

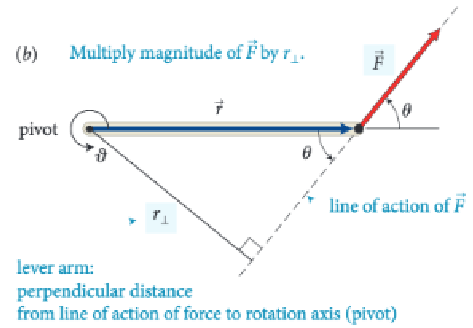
Information transfer

social learning platform

1 design

2 approach

Information transfer



action of the force and the axis of rotation. So, the torque caused by a force exerted on an object is the product of the magnitude of the force and its lever arm distance. It can be written equivalently as $rF_\perp$ and as $r_\perp F$.

Like other rotational quantities, torque carries a sign that depends on the choice of direction for increasing ϑ. In Figure 12.4, for example, the torque caused by $\vec{F}_1$ about the pivot tends to rotate the rod in the direction of increasing ϑ and so is positive; the torque caused by $\vec{F}_2$ is negative. The sum of the two torques about the pivot is then $r_1F_1 + (-r_2F_2)$. As we've seen, the two torques are equal in magnitude when the rod is balanced, and so the sum of the torques is zero. When the sum of the torques is not zero, the rod's rotational acceleration is nonzero, and so its rotational velocity and angular momentum change.

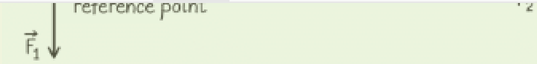
In the situations depicted in Figures 12.4 and 12.5 we used the pivot to calculate the lever arm distances. This is a natural choice because that is the point about which the object under consideration is free to rotate. However, torques also play a role for stationary objects that are suspended or supported at several different points and that are not free to rotate—for example, a plank or bridge supported at either end. To determine what reference point to use in such cases, complete the following exercise.

CONCEPTS

Exercise 12.1 Reference point

Consider again the rod in Figure 12.4. Calculate the sum of the torques about the left end of the rod.

SOLUTION I begin by making a sketch of the rod and the three



The lever arm distances must now be determined relative to the left end of the rod. The lever arm distance of force $\vec{F}_1$ to this point is zero, and so the torque caused by that force about the left end of the rod is zero. If I choose counterclockwise as the positive direction of rotation, $\vec{F}_2$ causes a negative torque about the left end of the rod; the force $\vec{F}^c_{pr}$ exerted by the pivot causes a positive torque about the left end of the rod. The lever arm distance of $\vec{F}_2$ about the left end of the rod is $r_1 + r_2$; that of $\vec{F}^c_{pr}$ is r_1. Because the rod is at rest, the magnitude of the force exerted by the pivot is equal to the sum of the forces $\vec{F}_1$ and $\vec{F}_2$. Taking into account the signs of the torques, we find that the sum of the torques about the left end of the rod is $r_1(F_1 + F_2) - (r_1 + r_2)F_2 = r_1F_1 - r_2F_2$. This is the same result we obtained for the torques about the pivot, and so the sum of the torques about the left end is zero. ✔

Exercise 12.1 shows that the sum of the torques about the left end of the rod is zero, just like the sum of the torques about the pivot. You can repeat the calculation for the torques about the right end of the rod or any other point, and each time you will find that the sum of the torques is zero. The reason is that the rod is not rotating about any point, and so the sum of the torques must be zero about any point. In general we can say:

For a stationary object, the sum of the torques is zero.

For a stationary object we can choose any reference point we like to calculate torques. It pays to choose a reference point that simplifies the calculation. As you have seen, we do not need to consider any force that is exerted at the reference point. So, by putting the reference point at the point of application of a force, we can eliminate that force from the calculation.

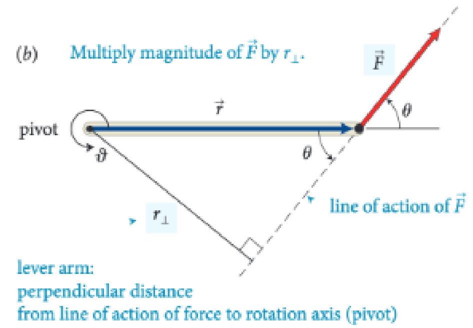
12.2 In the situation depicted in Figure 12.2*a*, you must continue to exert a force on the seesaw to keep the child off the ground. The force you exert causes a torque on the seesaw, and yet the seesaw's rotational acceleration is zero. How can this be if torques cause objects to accelerate rotationally?

Example 12.2 Torques on lever

Three forces are exerted on the lever of Figure 12.7. Forces $\vec{F}_1$ and $\vec{F}_3$ are equal in magnitude, and the magnitude of $\vec{F}_2$ is half as great. Force $\vec{F}_1$ is horizontal, $\vec{F}_2$ and $\vec{F}_3$ are vertical, and the lever

1 design 2 approach

Information transfer



action of the force and the axis of rotation. So, the torque caused by a force exerted on an object is the product of the magnitude of the force and its lever arm distance. It can be

I don't understand how this combination of factors tells you anything about direction? Aren't magnitude and lever arm distance both scalar quantities? It seems like we would need to know some sort of direction to calculate torque. Oct 20 12:09 am

SB I think you may be able to think about the direction separately. So, after multiplying this magnitude and distance, you can attach a sign to the torque based on the defined parameters of the system. In the following paragraph, they start to explain how to choose this direction. Oct 20 12:38 am

This is a great question. To further elaborate on this, we can think of this in terms of the Torque equation. The equation for torque is τ = r X F, with r being the level arm distance and F being force. We know that force is a vector vector from previous chapters, and in regards to "r" it can also be thought of as the radial vector. What this means is that this distance from the pivot points from the axis of rotation to the point where the force acts. In as previously mentioned, there is a general convention (the right-hand rule) that is used to determine the direction which happens to be perpendicular to both the radius from the axis and to the force. Oct 22 8:48 pm

reference point

The lever arm distances must now be determined relative to the left end of the rod. The lever arm distance of force $\vec{F}_1$ to this point is zero, and so the torque caused by that force about the left end of the rod is zero. If I choose counterclockwise as the positive direction of rotation, $\vec{F}_2$ causes a negative torque about the left end of the rod; the force $\vec{F}^c_{pr}$ exerted by the pivot causes a positive torque about the left end of the rod. The lever arm distance of $\vec{F}_2$ about the left end of the rod is $r_1 + r_2$; that of $\vec{F}^c_{pr}$ is r_1. Because the rod is at rest, the magnitude of the force exerted by the pivot is equal to the sum of the forces $\vec{F}_1$ and $\vec{F}_2$. Taking into account the signs of the torques, we find that the sum of the torques about the left end of the rod is $r_1(F_1 + F_2) - (r_1 + r_2)F_2 = r_1F_1 - r_2F_2$. This is the same result we obtained for the torques about the pivot, and so the sum of the torques about the left end is zero. ✔

Exercise 12.1 shows that the sum of the torques about the left end of the rod is zero, just like the sum of the torques about the pivot. You can repeat the calculation for the torques about the right end of the rod or any other point, and each time you will find that the sum of the torques is zero. The reason is that the rod is not rotating about any point, and so the sum of the torques must be zero about any point. In general we can say:

For a stationary object, the sum of the torques is zero.

For a stationary object we can choose any reference point we like to calculate torques. It pays to choose a reference point that simplifies the calculation. As you have seen, we do not need to consider any force that is exerted at the reference point. So, by putting the reference point at the point of application of a force, we can eliminate that force from the calculation.

12.2 In the situation depicted in Figure 12.2*a*, you must continue to exert a force on the seesaw to keep the child off the ground. The force you exert causes a torque on the seesaw, and yet the seesaw's rotational acceleration is zero. How can this be if torques cause objects to accelerate rotationally?

Example 12.2 Torques on lever

Three forces are exerted on the lever of Figure 12.7. Forces $\vec{F}_1$ and $\vec{F}_3$ are equal in magnitude, and the magnitude of $\vec{F}_2$ is half as

1 design

2 approach

Information transfer

I don't understand how this combination of factors tells you anything about direction? Aren't magnitude and lever arm distance both scalar quantities? It seems like we would need to know some sort of direction to calculate torque. Oct 20 12:09 am

SB

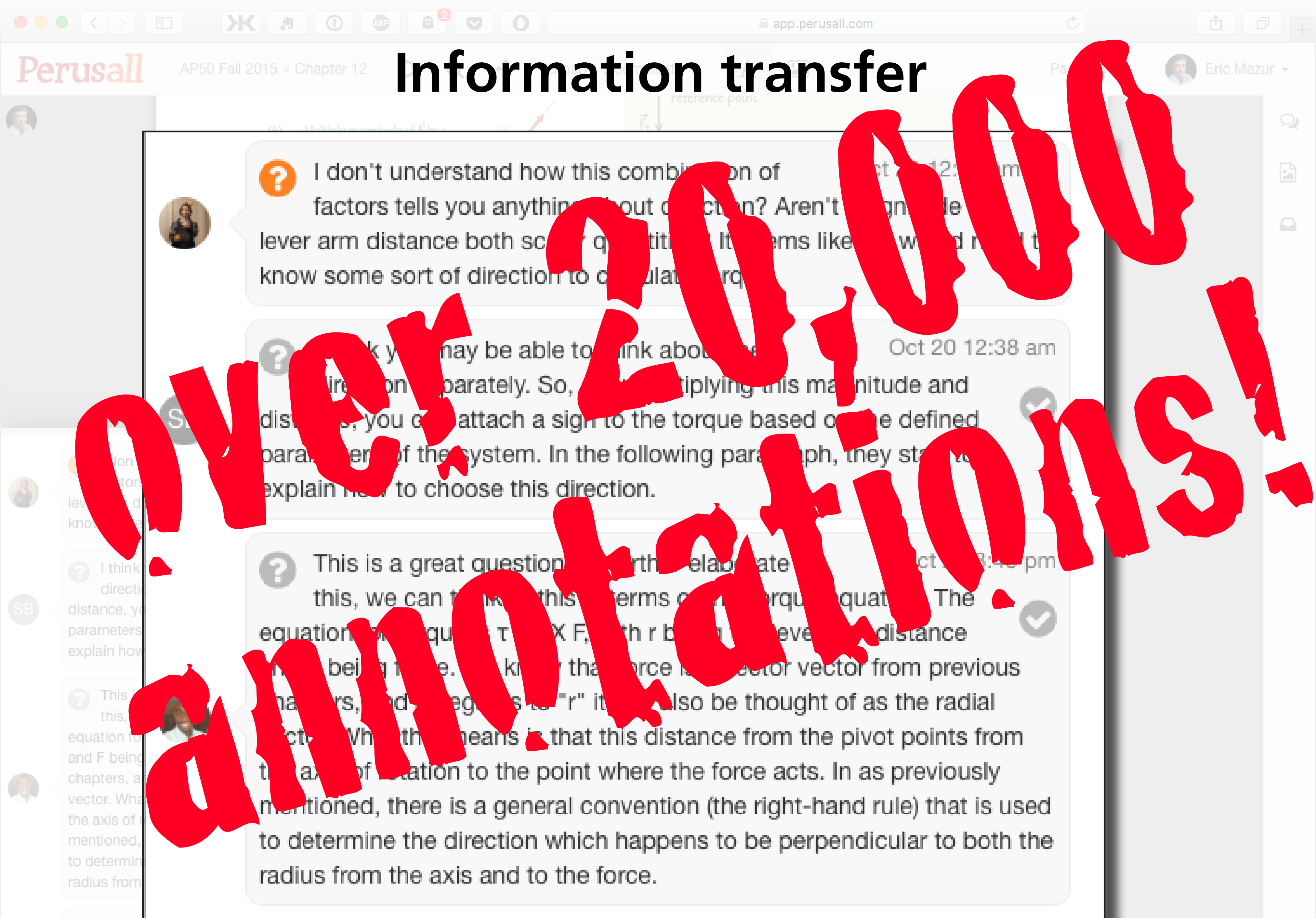
I think you may be able to think about the direction separately. So, after multiplying this magnitude and distance, you can attach a sign to the torque based on the defined parameters of the system. In the following paragraph, they start to explain how to choose this direction. Oct 20 12:38 am

This is a great question. To further elaborate on this, we can think of this in terms of the Torque equation. The equation for torque is τ = r X F, with r being the level arm distance and F being force. We know that force is a vector vector from previous chapters, and in regards to "r" it can also be thought of as the radial vector. What this means is that this distance from the pivot points from the axis of rotation to the point where the force acts. In as previously mentioned, there is a general convention (the right-hand rule) that is used to determine the direction which happens to be perpendicular to both the radius from the axis and to the force. Oct 22 8:48 pm

1 design

2 approach

Information transfer



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 (thoughtful reading & interpretation)
- Quantity (10)
- Timeliness (before class)
- Distributed

Information transfer

READING SCHEDULE

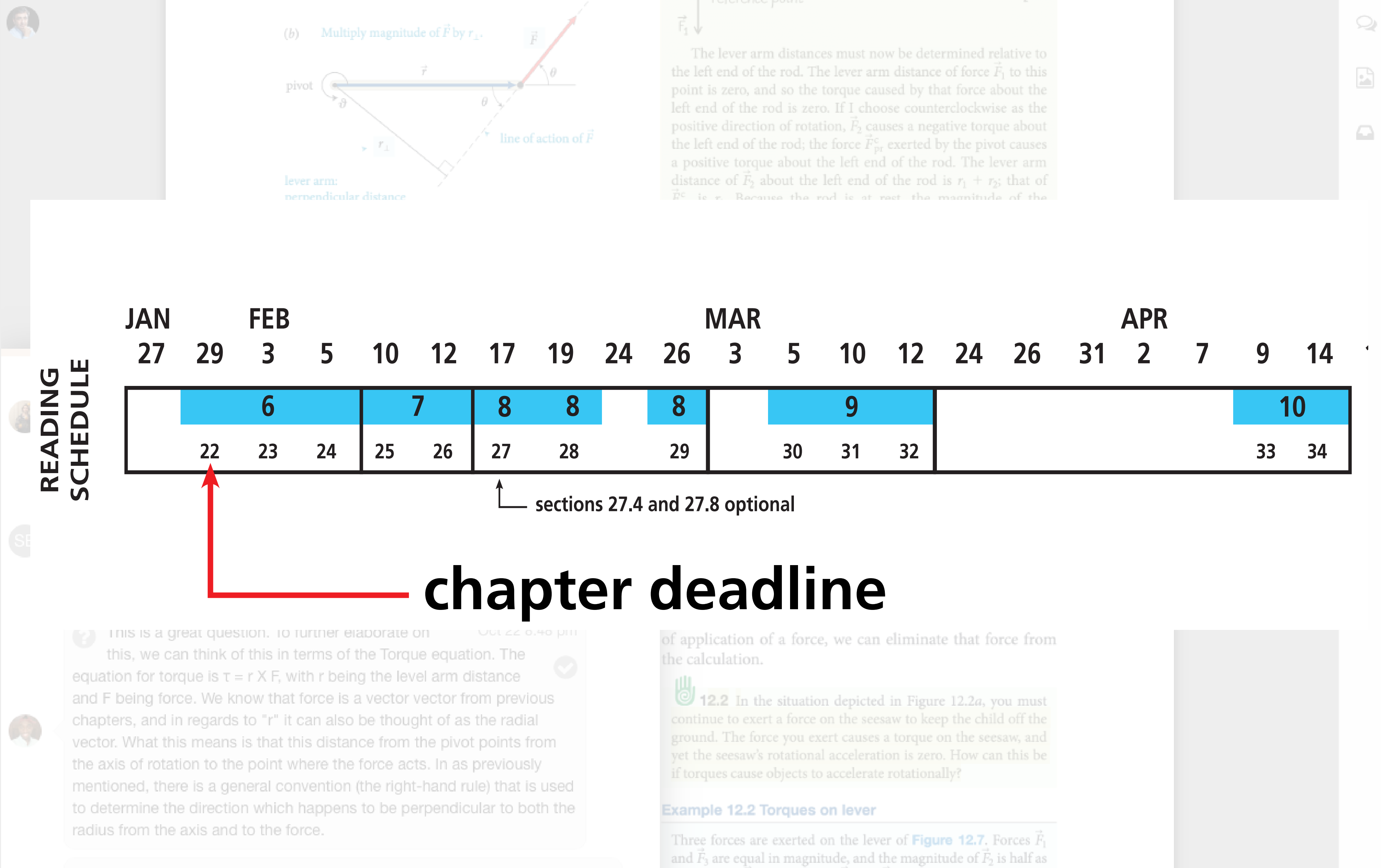
JAN		FEB								MAR							APR			
27	29	3	5	10	12	17	19	24	26	3	5	10	12	24	26	31	2	7	9	14
	6			7		8	8		8		9								10	
	22	23	24	25	26	27	28		29		30	31	32						33	34

sections 27.4 and 27.8 optional

1 design

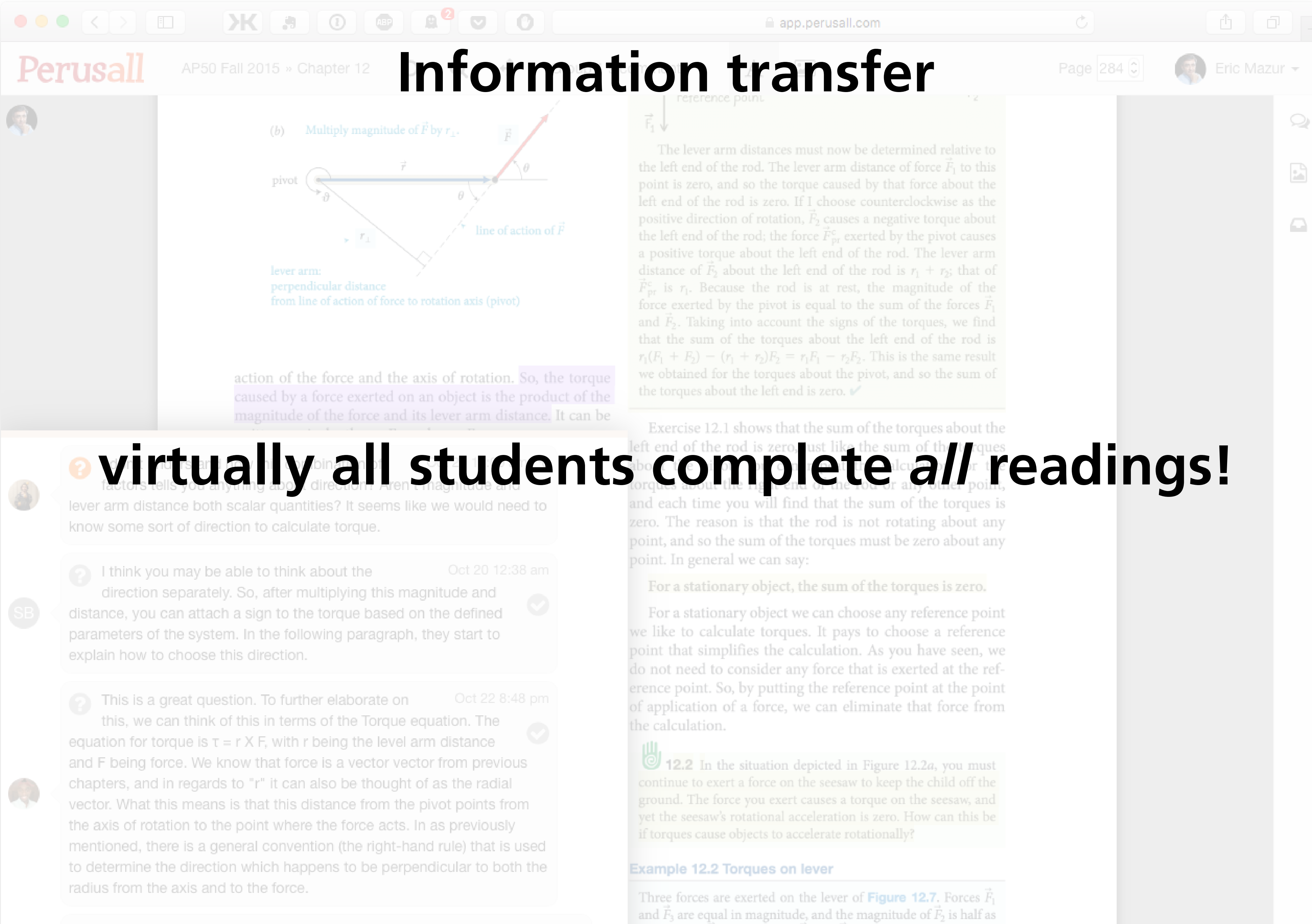
2 approach

Information transfer



1 design **2** approach

Information transfer

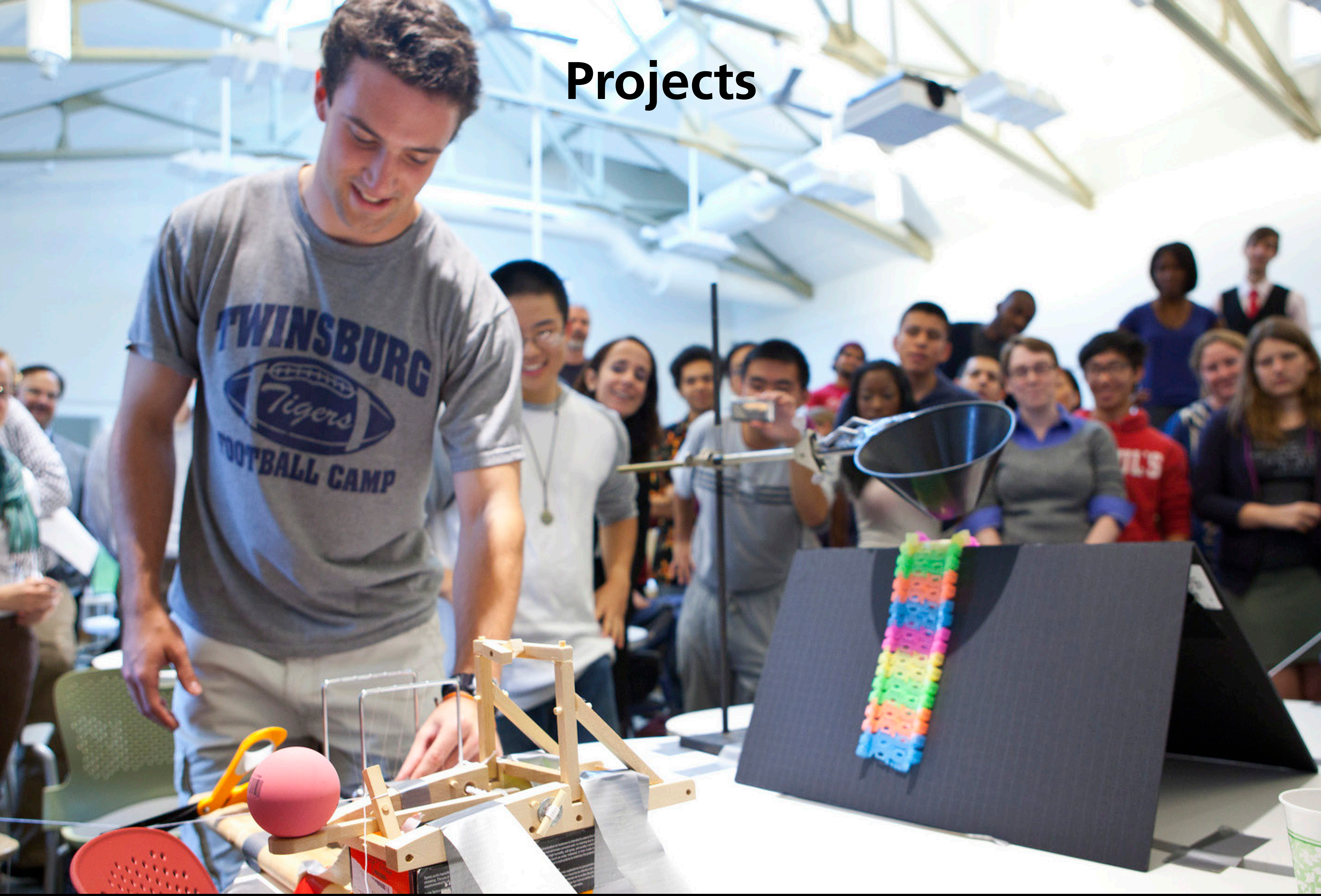


virtually all students complete *all* readings!

❶ design

❷ approach

Projects



1 design

2 approach

Projects

- 1 project/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

Rule-based team formation using GroupEng

www.GroupEng.org

1 design **2** approach

Projects

Rule-based team formation using GroupEng

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

www.GroupEng.org

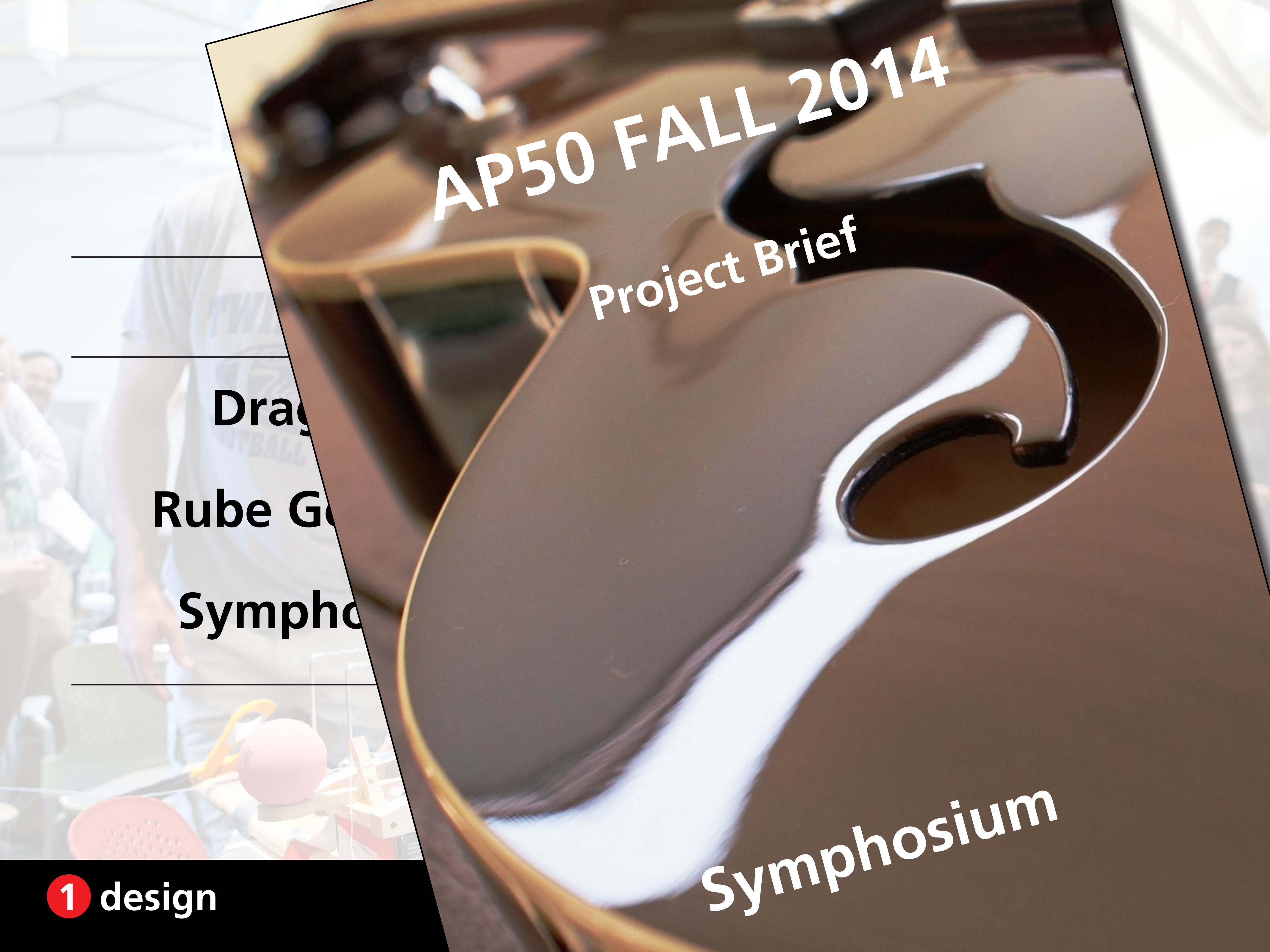
Projects

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
Drag Race	Ecotricity
Rube Goldberg	Crack-a-Thon
Symphosium	inSPECT Fair


Drag
Rube Go
Sympho
1 design
AP50 FALL 2014
Project Brief
Symphosium

❶ design ❷ approach

Projects

❶ design ❷ 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

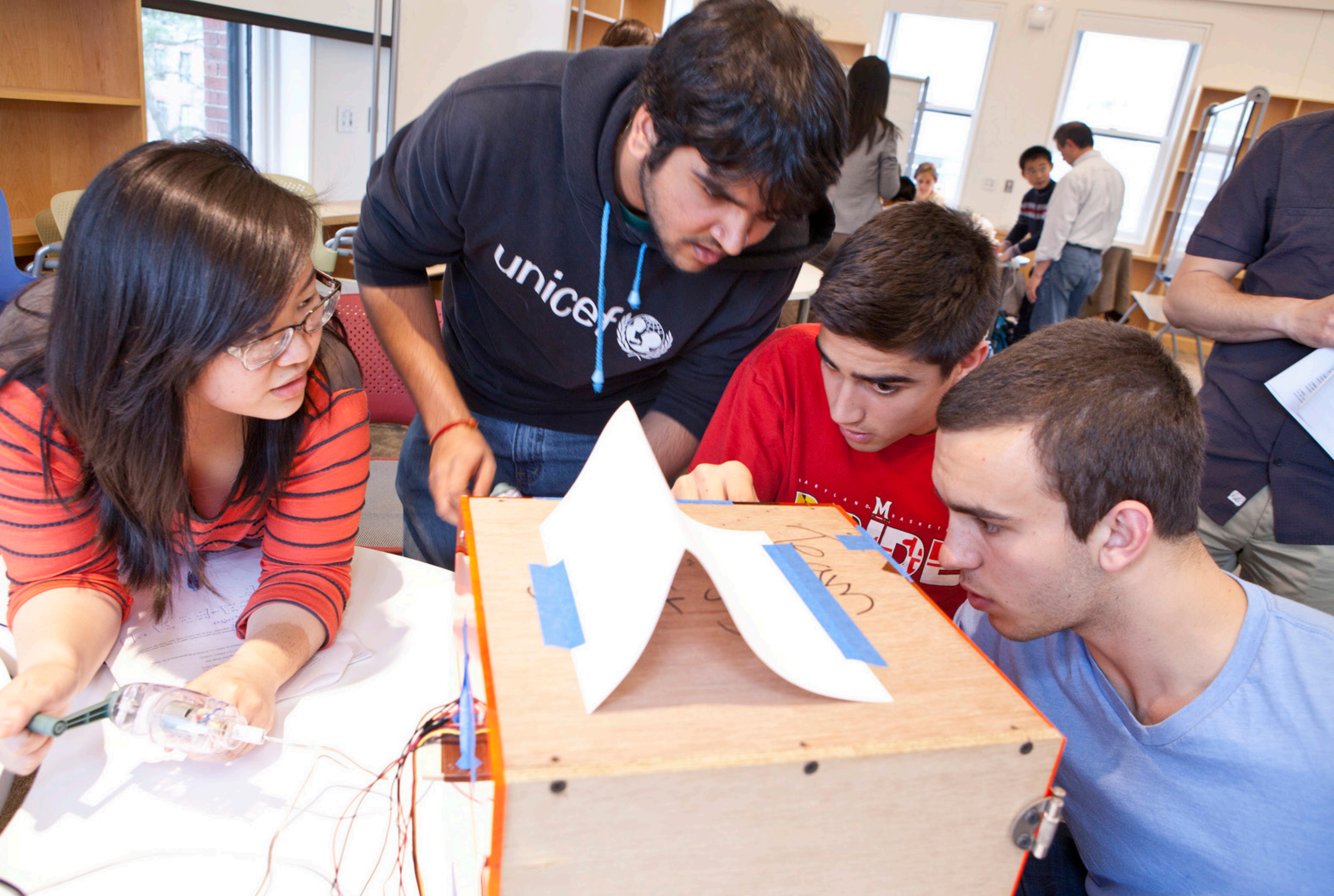
Projects

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

❶ design ❷ approach

In-class activities

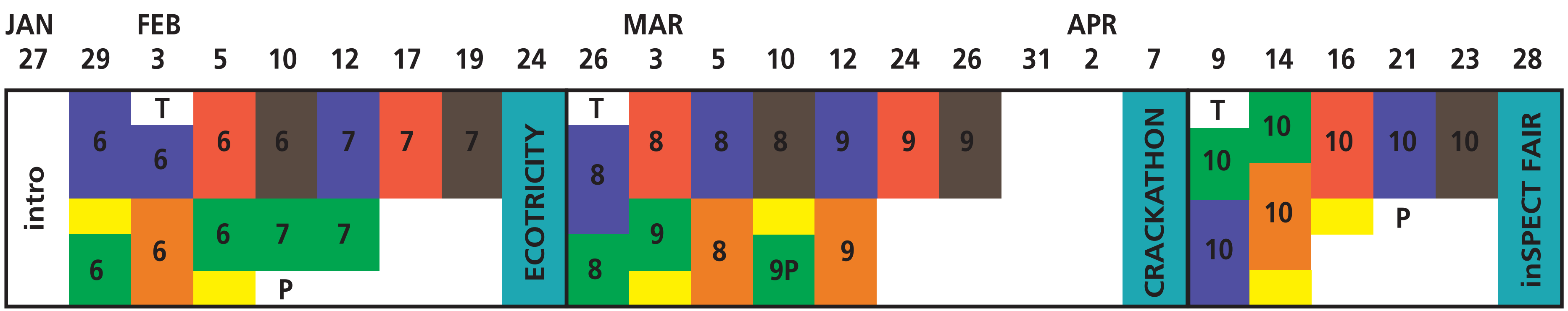
2 weekly 3-hour class periods

In-class activities

blend of 6 “best practices”

1 design 2 approach

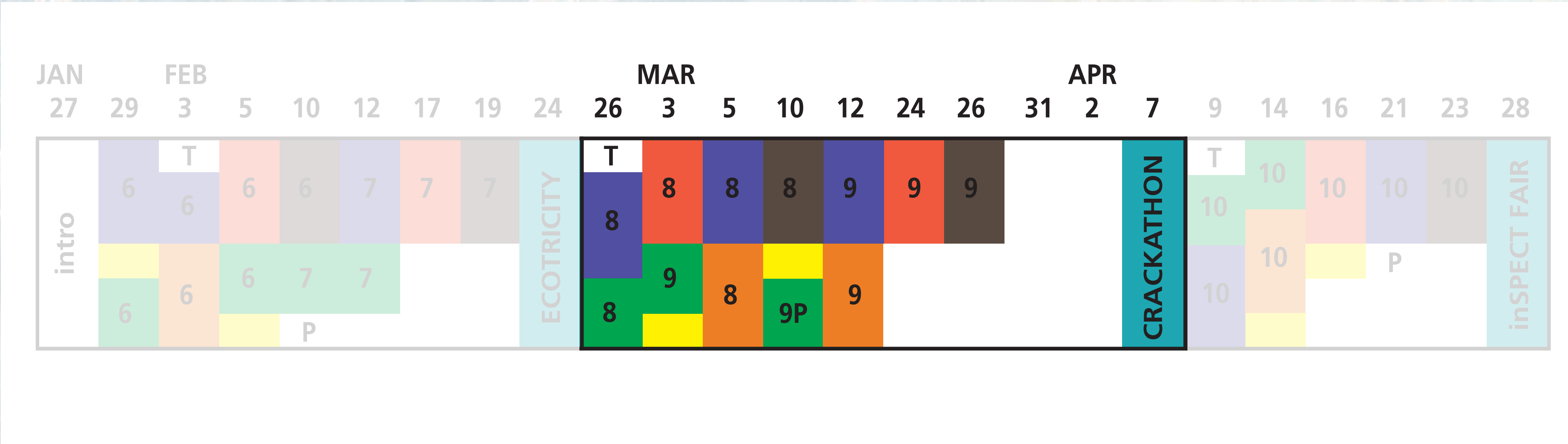
In-class activities



1 design
2 approach

In-class activities

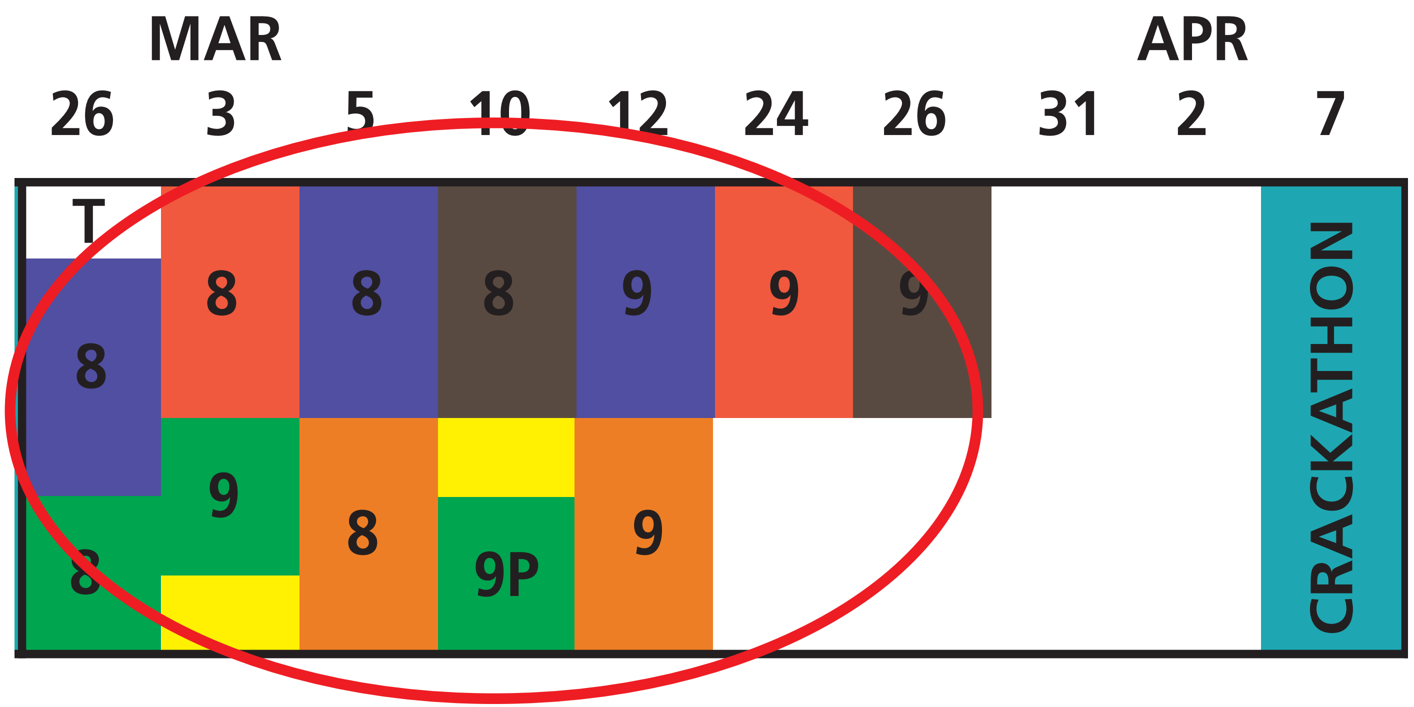
one project



1 design
2 approach

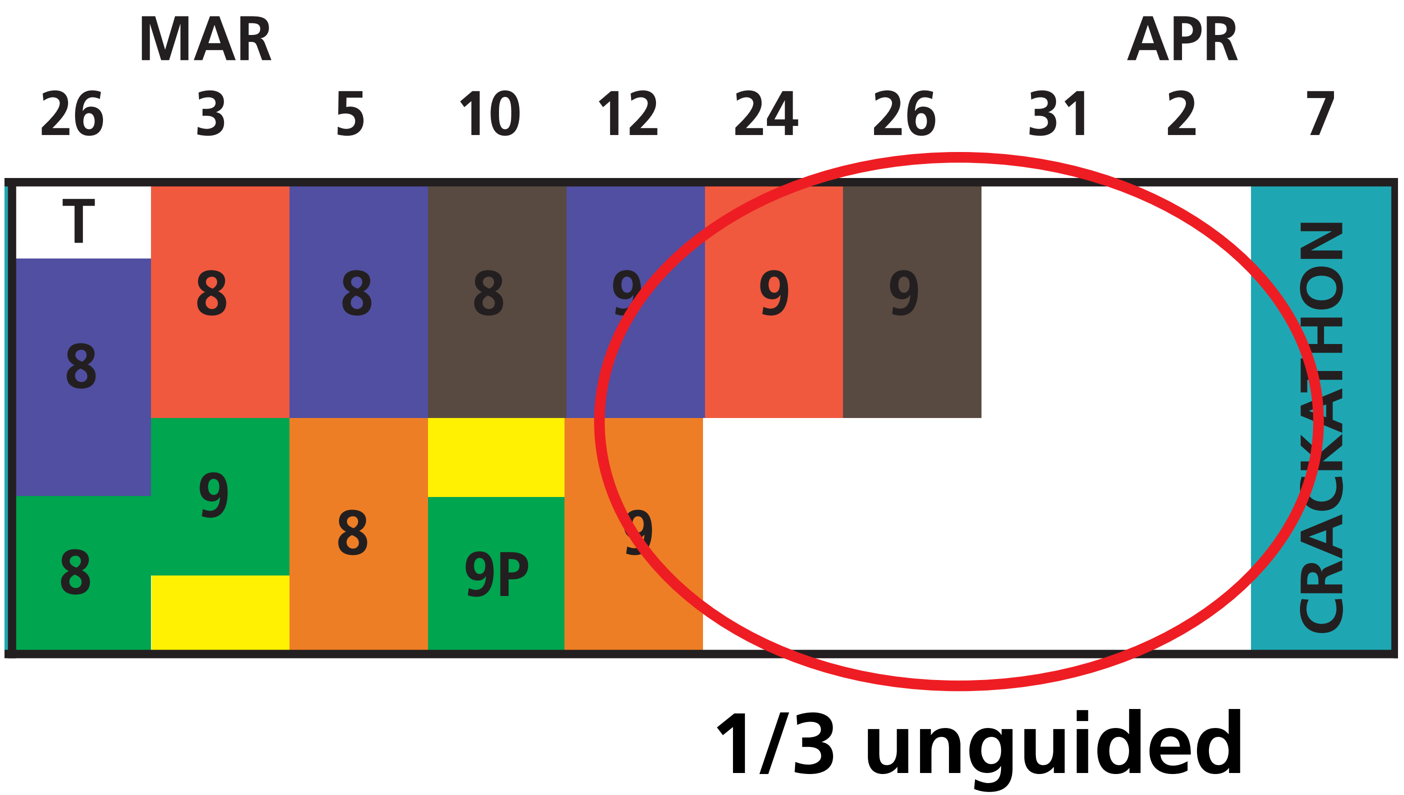
In-class activities

2/3 scaffolded, guided



1 design
2 approach

In-class activities



1 design
2 approach

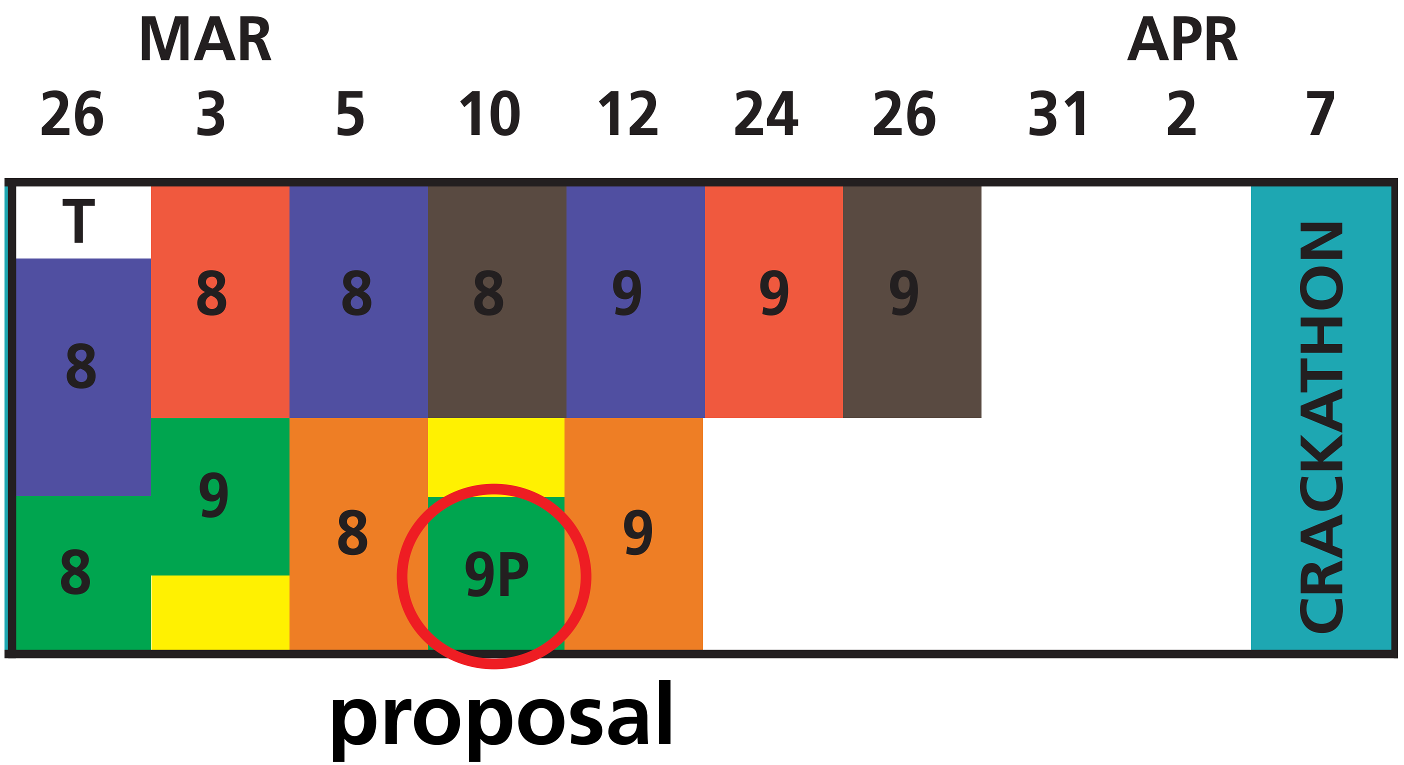
In-class activities

team intro

1 design

2 approach

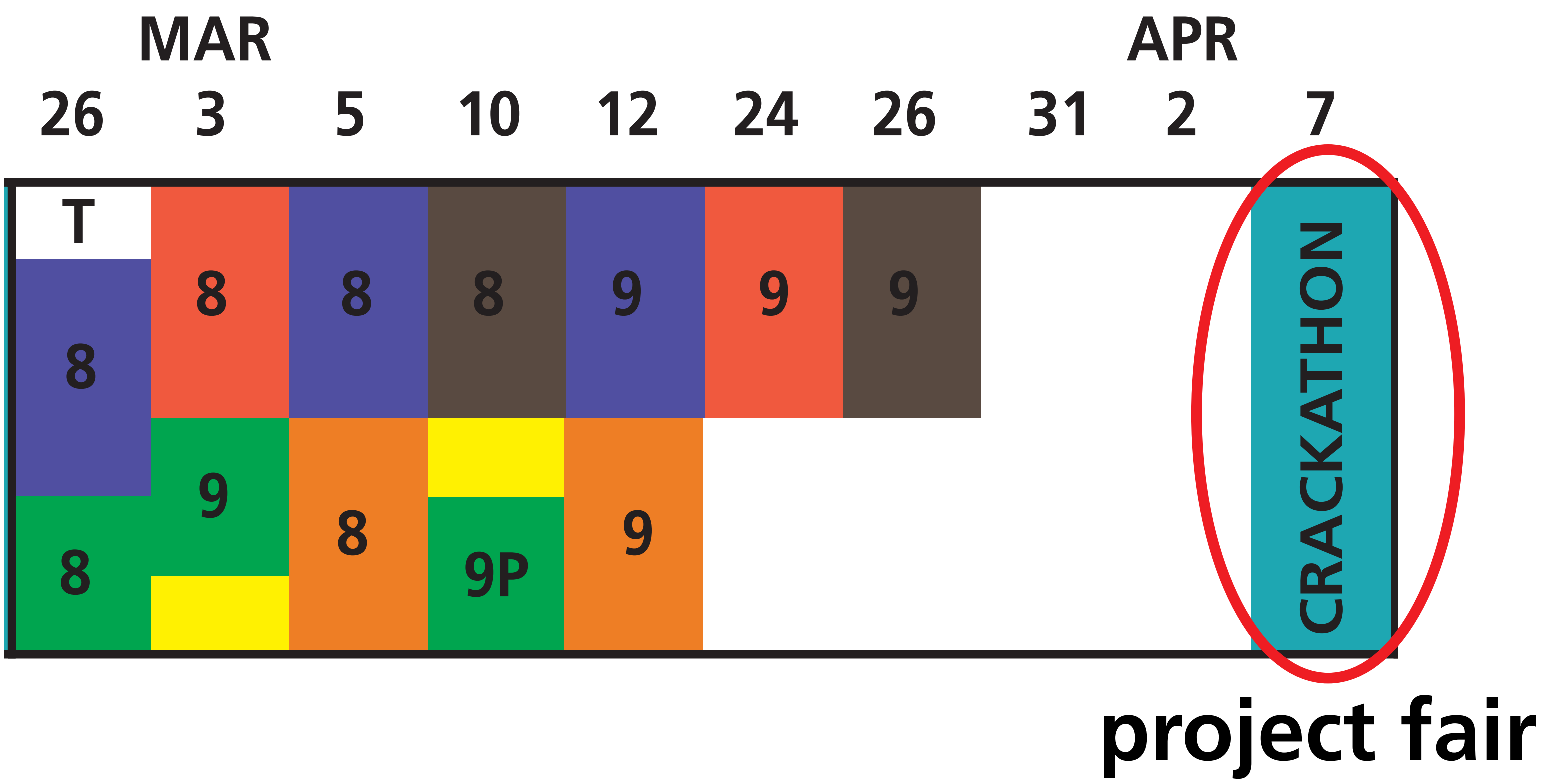
In-class activities



1 design

2 approach

In-class activities



1 design
2 approach

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

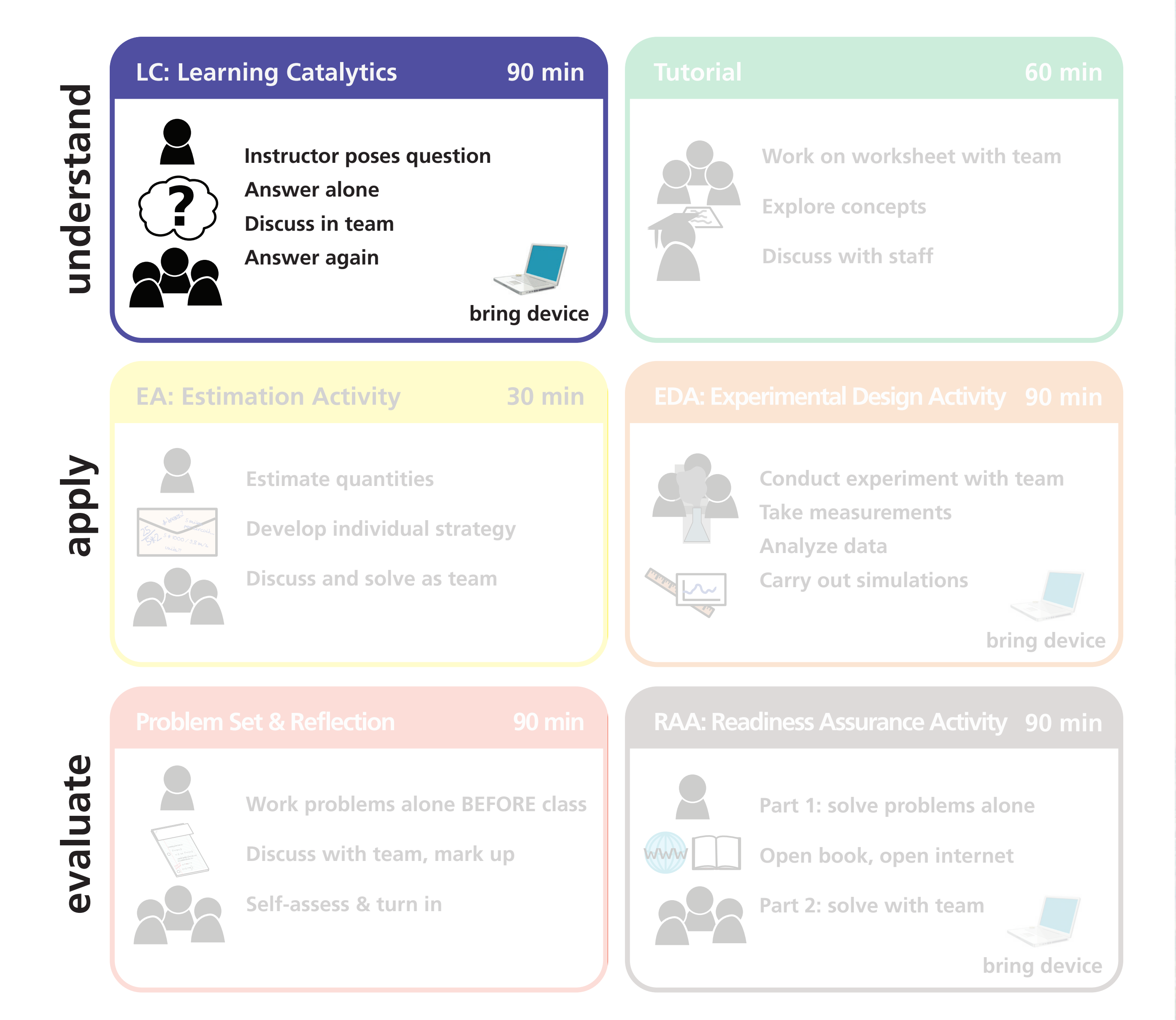
RAA: Readiness Assurance Activity — 90 min

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

bring device

1 design   2 approach

In-class activities



1 design 2 approach

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

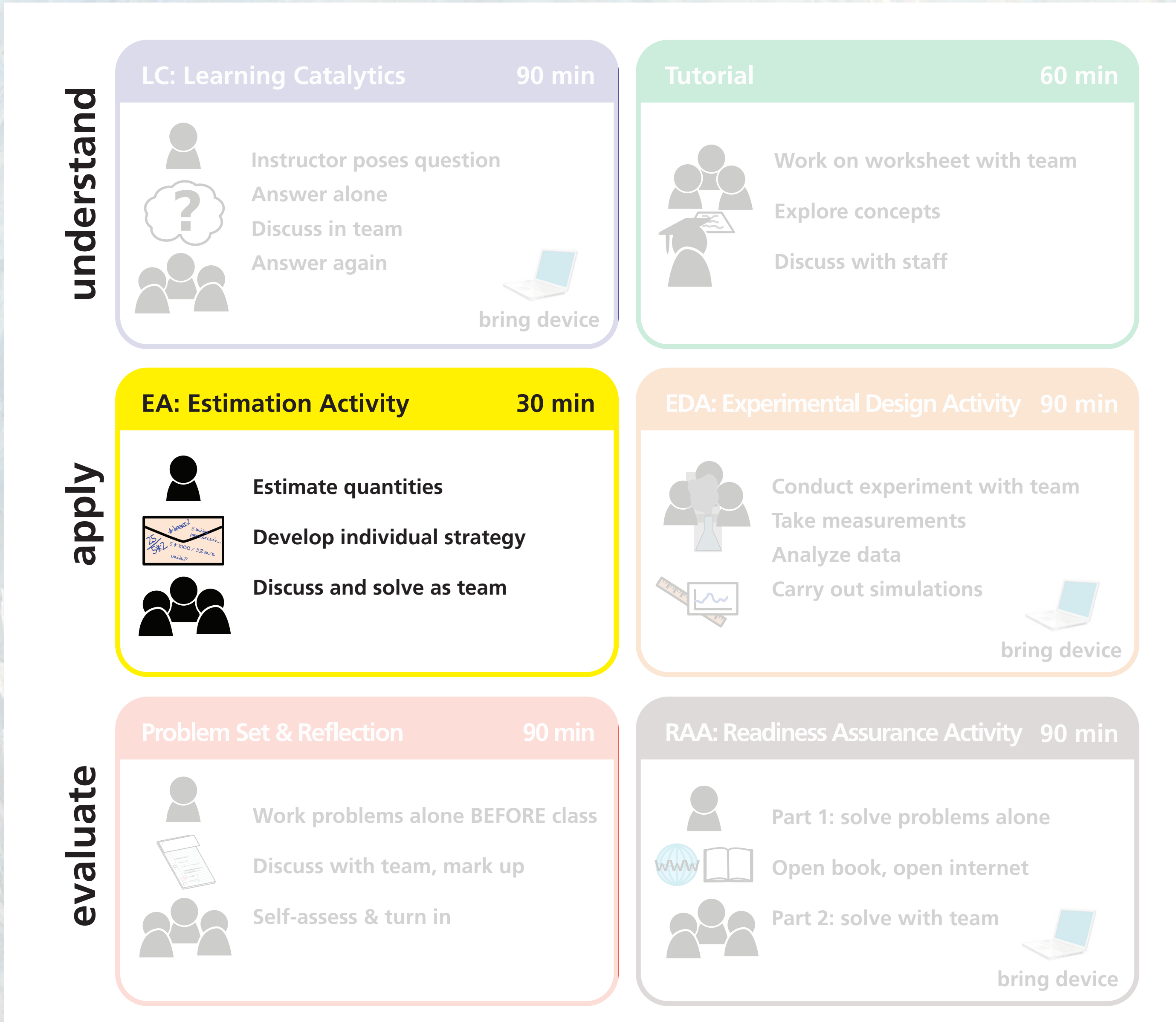
Problem Set & Reflection — 90 min
- Work problems alone BEFORE class
- Discuss with team, mark up
- Self-assess & turn in

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

In-class activities



1 design 2 approach

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

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

AP50b Fall 2013

Problem Set 1

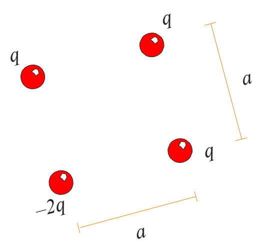
due W Feb 6 in class

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.

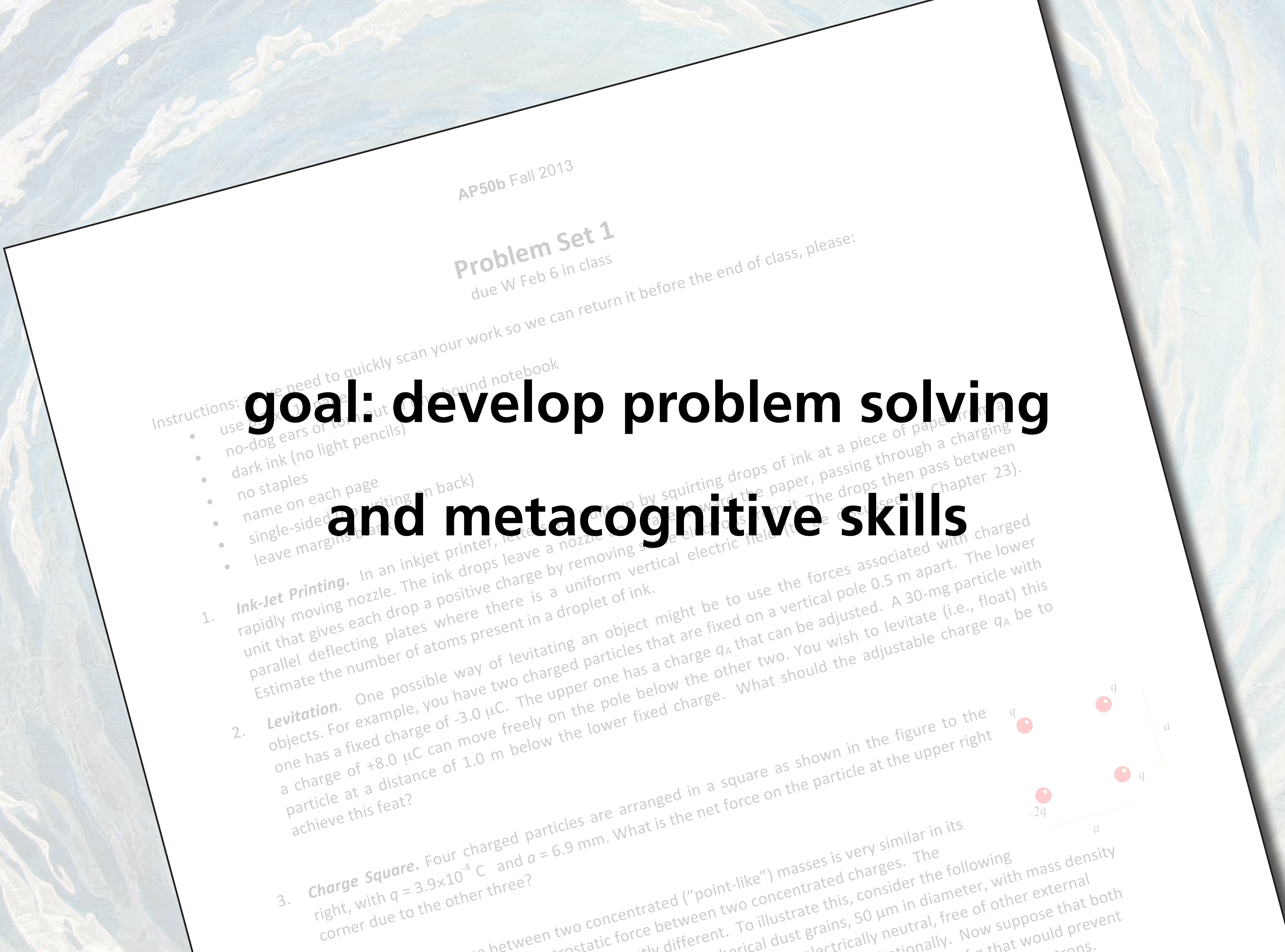
2. ***Levitation***. One possible way of levitating an object might be to use the forces associated with charged objects. For example, you have two charged particles that are fixed on a vertical pole 0.5 m apart. The lower one has a fixed charge of -3.0 μC. The upper one has a charge q_A that can be 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 … electrostatic force between two concentrated charges. The … vastly different. To illustrate this, consider the following … spherical dust grains, 50 μm in diameter, with mass density … are electrically neutral, free of other external … gravitationally. 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. During this stage, you may only use **red ink** to write on your problem sets (pens will be provided in class) ... 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 problem ... 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

Individual phase (at home): From the time you receive a problem set to the time it is due to work on the problem set **alone**. The work you complete during this phase will be correctness. You may only use **blue or black ink** and you must attempt to solve each pr 4-step procedure (see Section 1.8 in the textbook for additional details)

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

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

1 design

2 approach

Individual phase (at home): From the time you receive a problem set to the time it is due to work on the problem set **alone**. The work you complete during this phase will be correctness. You may only use **blue or black ink** and you must attempt to solve each pr 4-step procedure (see Section 1.8 in the textbook for additional details)

Getting Started — State the important information and summarize the problem. If po Note any assumptions you're making.

Devise Plan — Devise a plan of attack before diving into the solution. Break down ma [illegible] u can a

Execute Plan — Carry out your plan, explaining each step. The argument should be your thought process at each step (including roadblocks). Any va defined, and your diagrams should be labeled.

Evaluate Answer — Check each solution for reasonableness. There are many ways to jus the symmetry of the solution, evaluate limiting or special cases situations with known solutions, check units, use dimensional analysi of magnitude of an answer.

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

at home:

implement 4-step procedure

(evaluated on effort)

1 design 2 approach

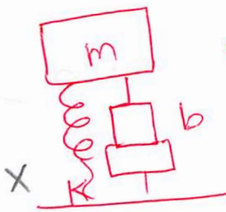
Applied Physics 50a

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

Getting started.

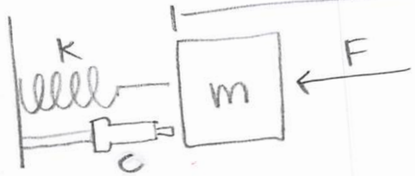
car moving forward

$F = m \circ a$



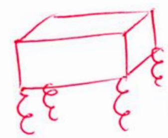
$$m\frac{d^2x}{dt^2} + b\frac{dx}{dt} + kx = 0$$

Damping coeff (c)



$F_s = -kx$

$F_d = -cv$



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

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

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

Translational eq = $\Sigma F_x = 0$

Execute plan.

$F = m \circ a$

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

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

1 design **2** approach

Applied Physics 50a

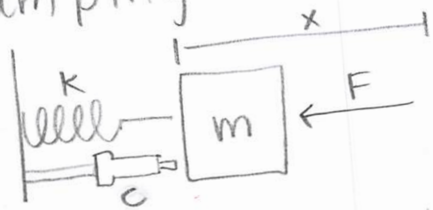
(1) Estimate damping coeff. for a shock absorber on a midsize car.

Getting started.

car moving forward

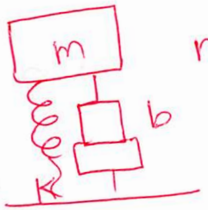
$F = m \cdot a$

Damping coeff (c)

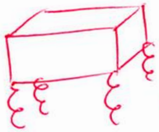


$F_s = -kx$

$F_d = -cv$



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



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

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

Execute plan.

$\Sigma F_x = F_{EC}^{G} - F_{SC}^{C} = 4mg - k(x_{eq} - x_0)$

Translational eq $= \Sigma F_x = 0$

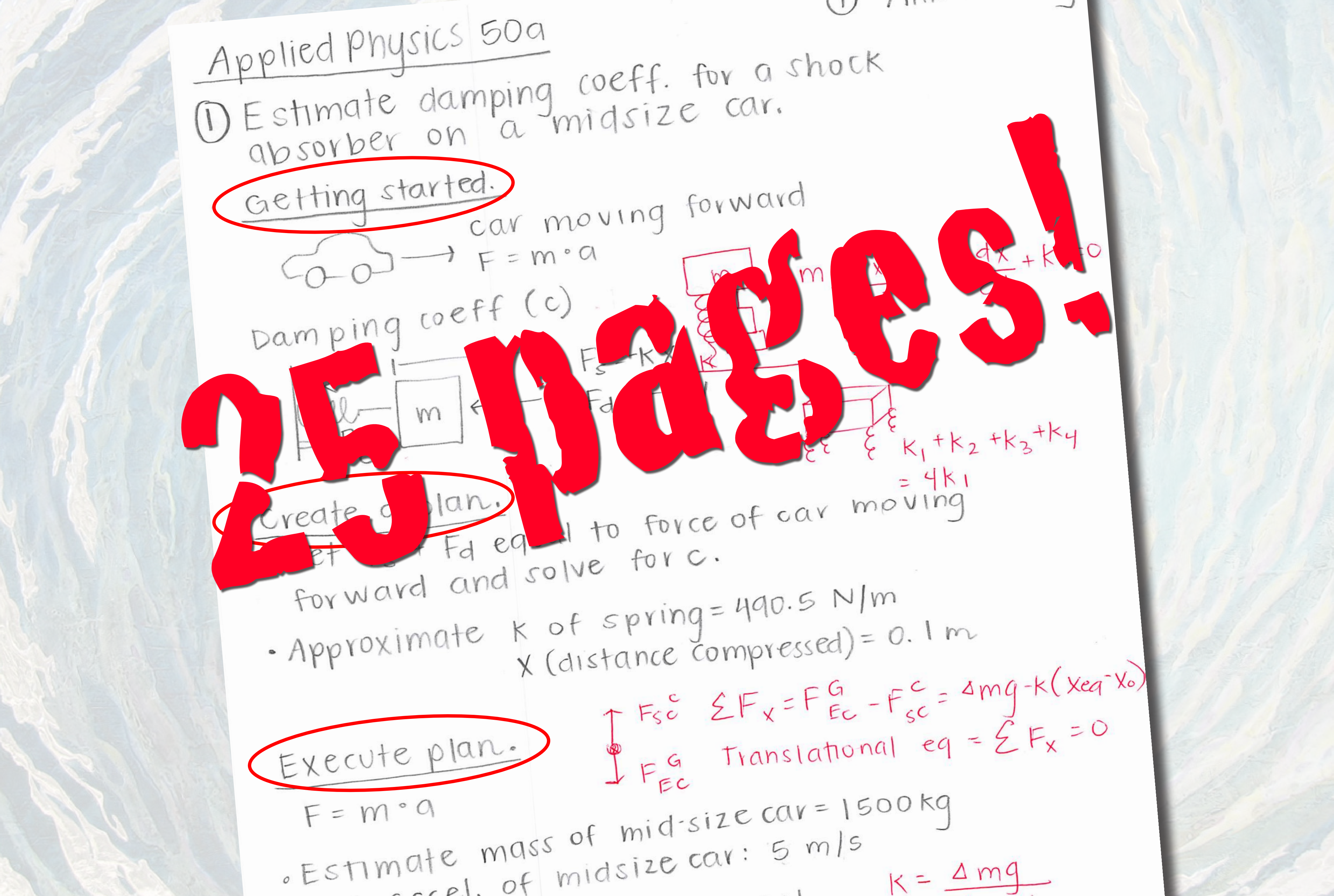
$F = m \cdot a$

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

$k = \frac{4mg}{\ldots}$

1 design

2 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

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

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

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

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

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.

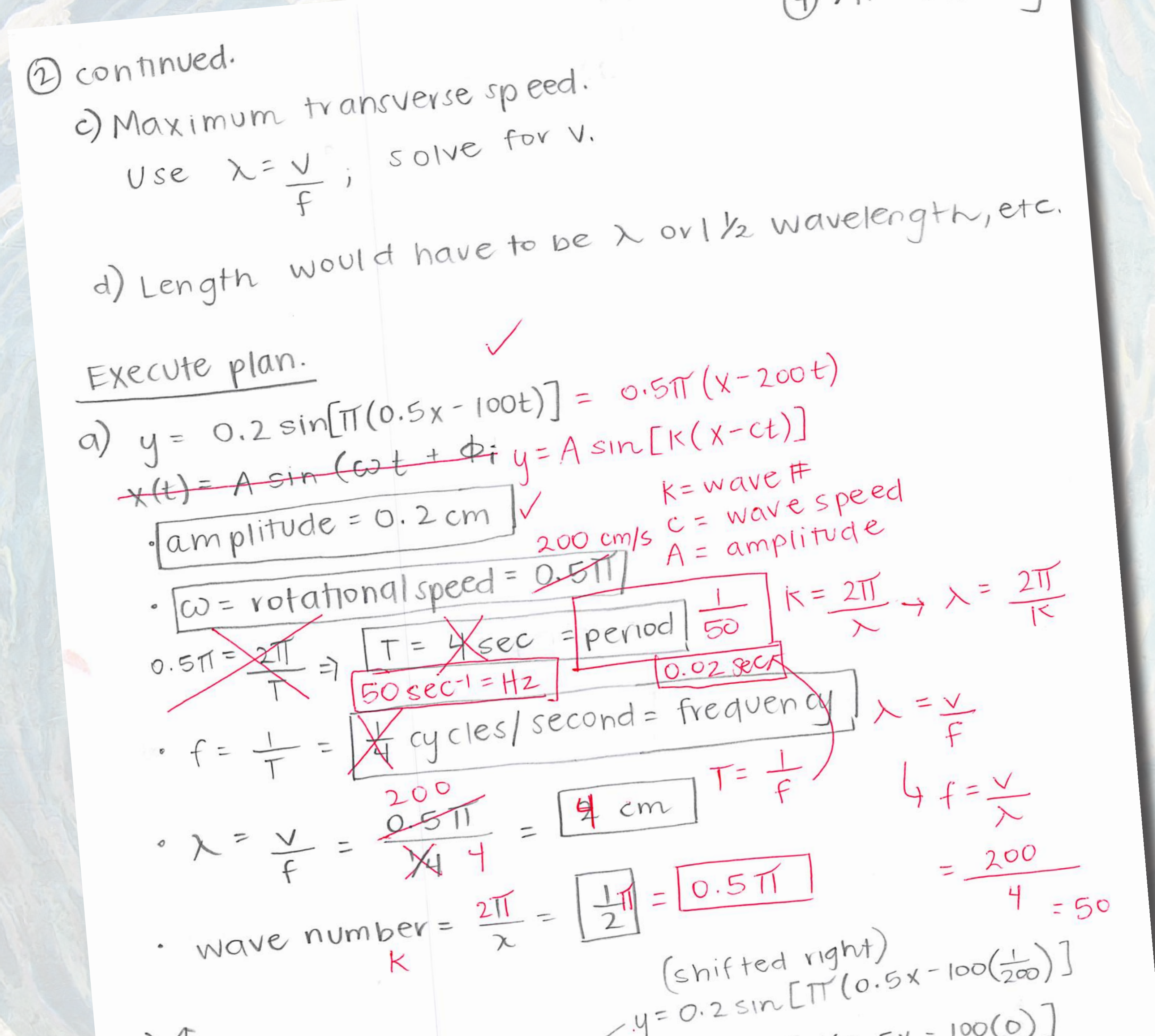
Important: Writing on the problem set in class in any other color but red will be considere

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 $1\frac{1}{2}$ 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

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

50 sec⁻¹ = Hz

• $f = \frac{1}{T}$ = ~~$\frac{1}{4}$~~ cycles/second = frequency

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

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

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

• $\lambda = \frac{v}{f} = \frac{\overset{200}{\cancel{0.5\pi}}}{\cancel{1/4}\ 4}$ = 4 cm

• wave number k $= \frac{2\pi}{\lambda} = \frac{1}{2}\pi = 0.5\pi$

(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 understand 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

phase	credit
solve (at home/individual)	50%
reflect (in class/team)	50%

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

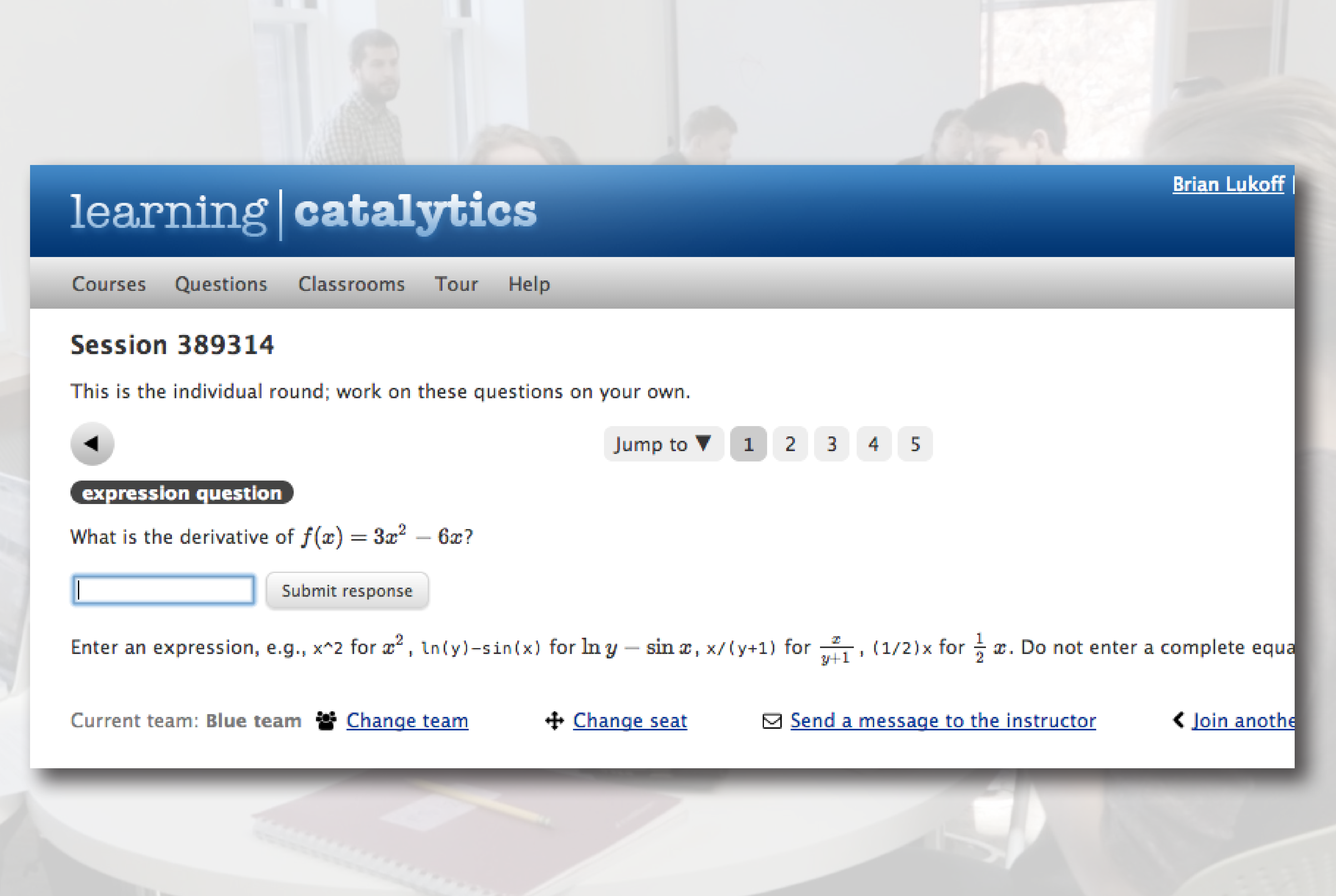
bring device

1 design **2 approach**

goal: formative assessment

collaborative learning

❶ design ❷ approach



1 design   2 approach

This is the individual round;

expression question

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

[ ] Submit response

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

❶ design ❷ approach

This is the individual round;

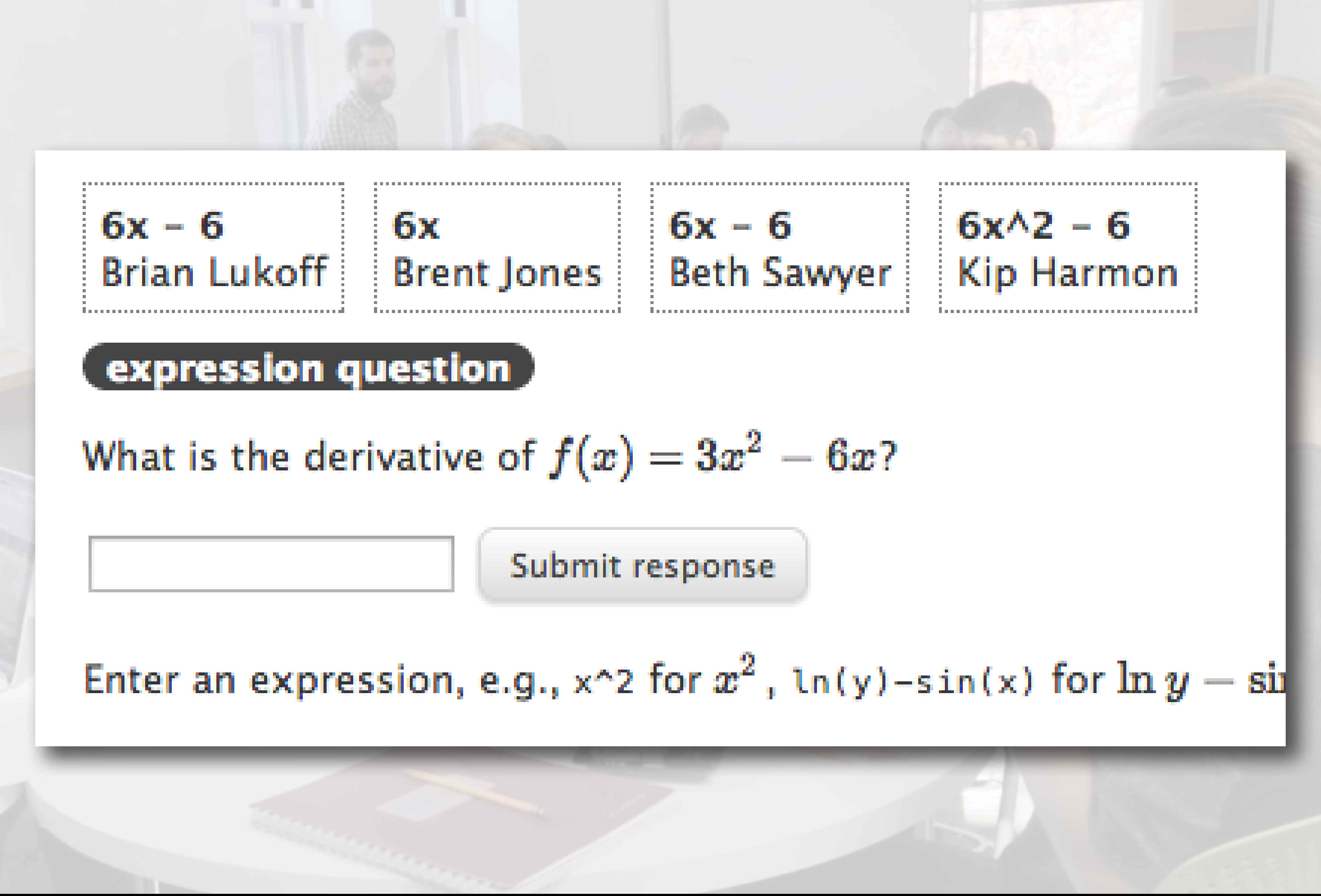
expression question

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 $\ln y - \mathrm{si}$

1 design **2** approach

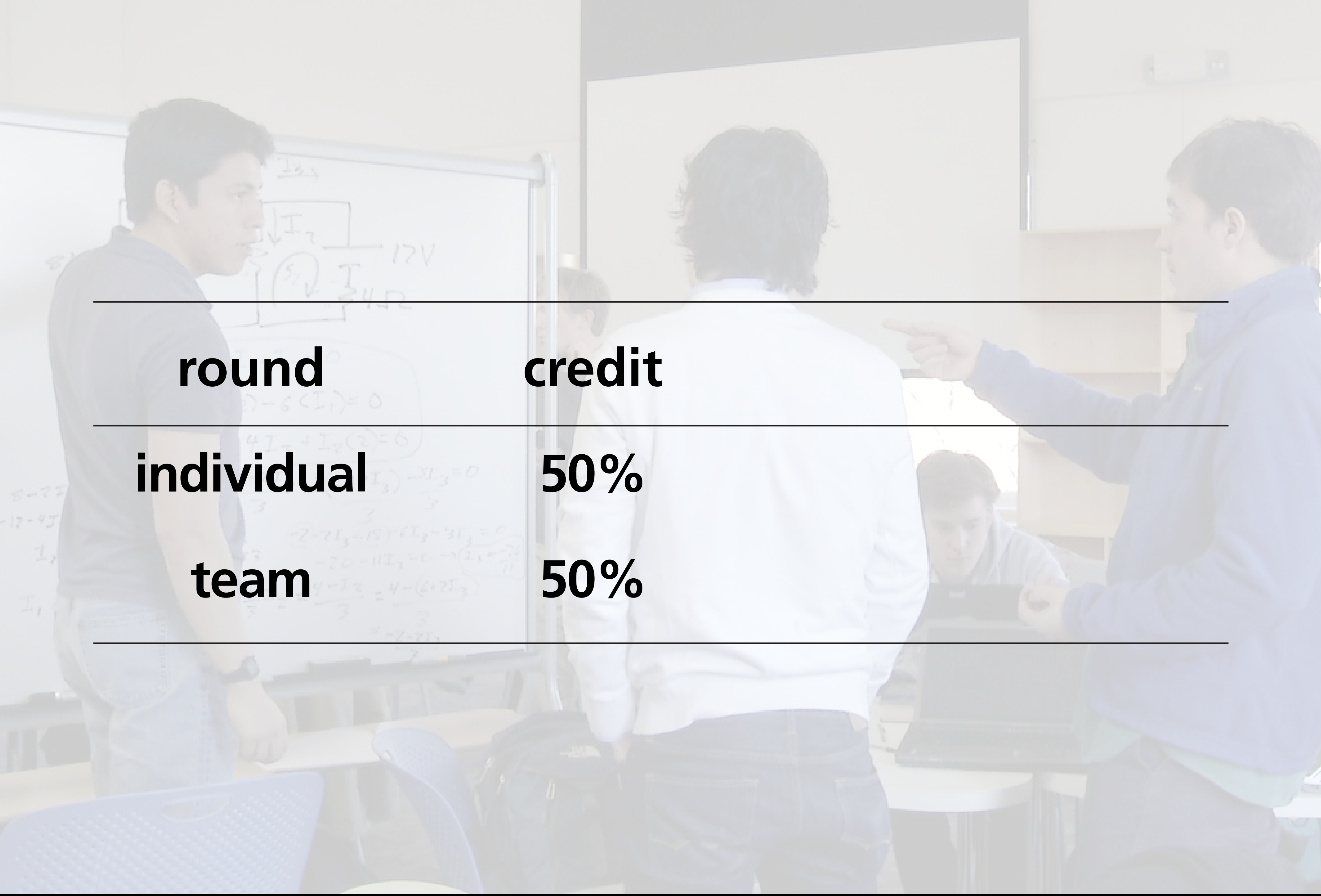


1 design

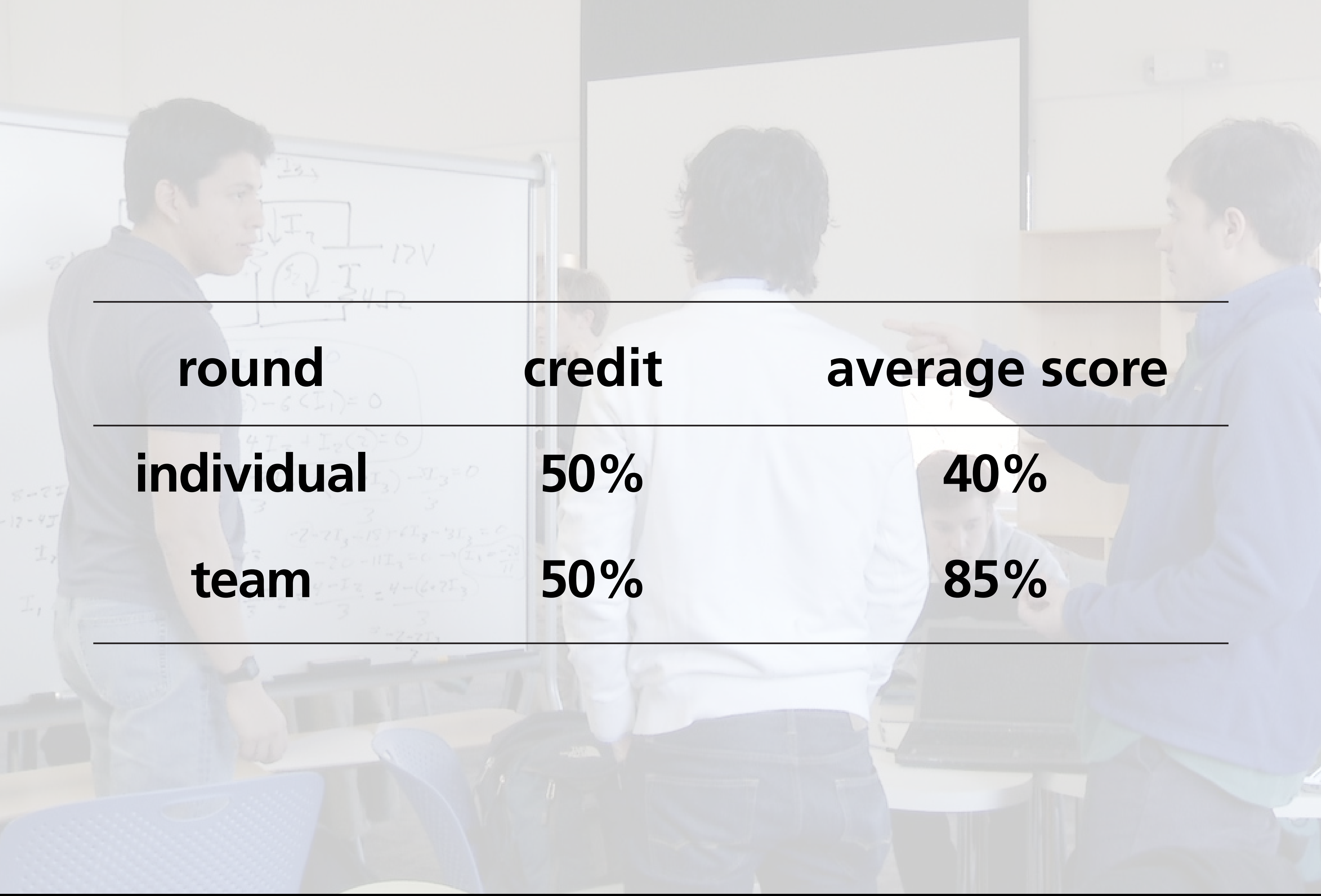
2 approach

1 design

2 approach

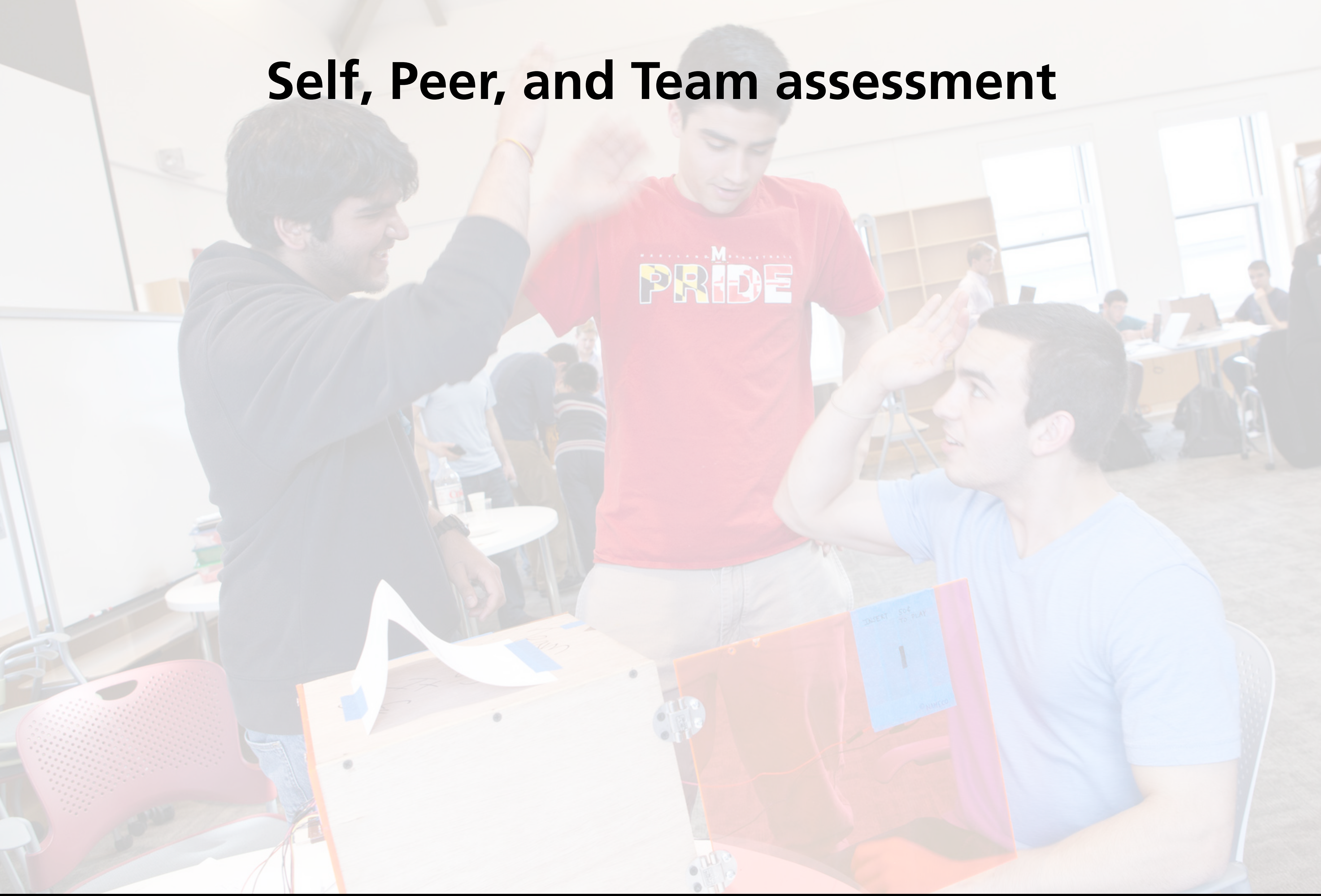


round	credit
individual	50%
team	50%



round	credit	average score
individual	50%	40%
team	50%	85%

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

❶ design ❷ approach

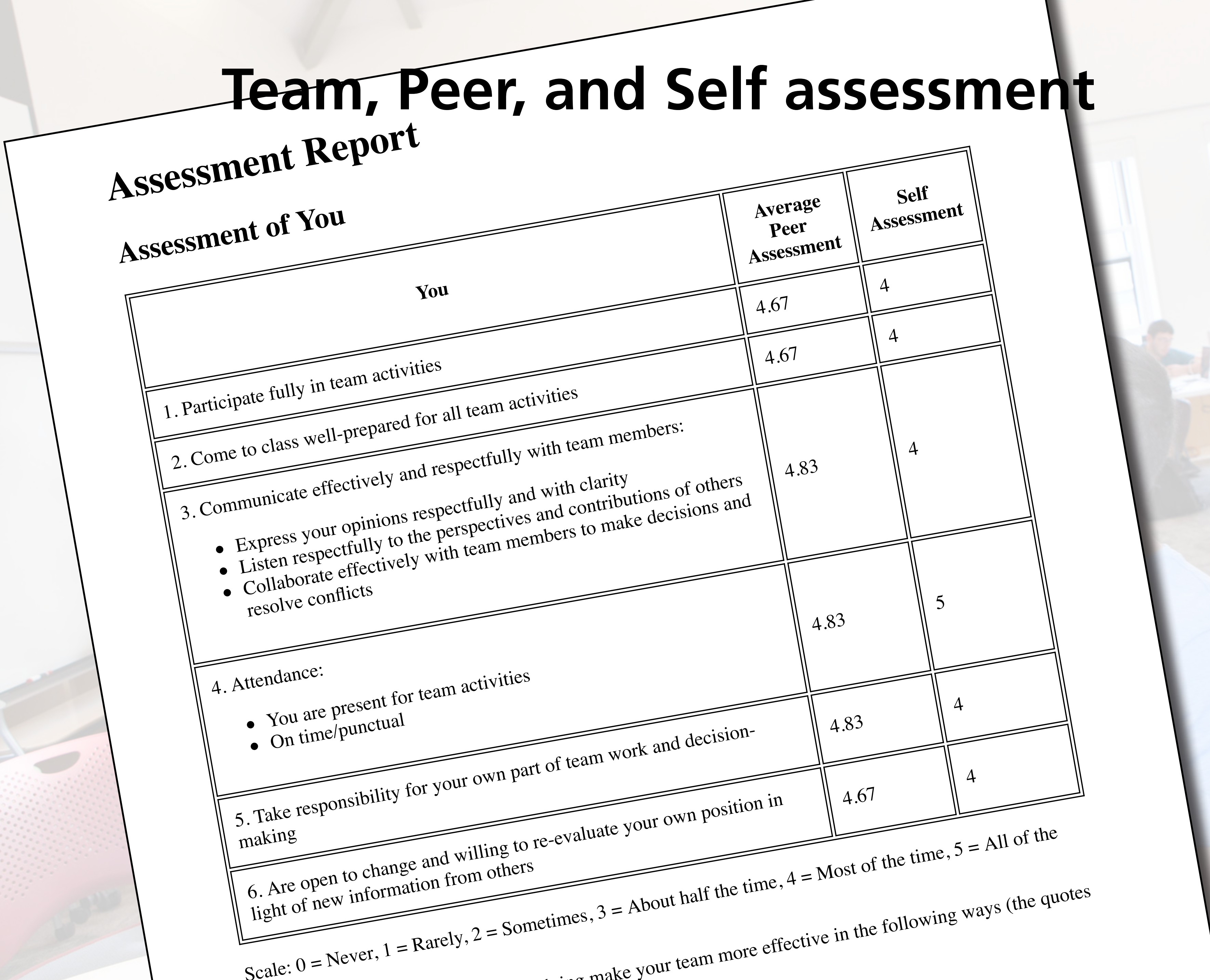
Team, Peer, and Self assessment

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							

Team, Peer, and Self assessment



Assessment Report

Assessment of You

You	Average Peer Assessment	Self Assessment
1. Participate fully in team activities	4.67	4
2. Come to class well-prepared for all team activities	4.67	4
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	4.83	4
4. Attendance: • You are present for team activities • On time/punctual	4.83	5
5. Take responsibility for your own part of team work and decision-making	4.83	4
6. Are open to change and willing to re-evaluate your own position in light of new information from others	4.67	4

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

helping make your team more effective in the following ways (the quotes

1 design

2 approach

Team, Peer, and Self assessment

- You were great to work with and a true team player!
- Your ideas were a great contribution to our team
- You come up with good ideas
- You were really easy to work with and had a contagious enthusiasm

Team, Peer, and Self assessment

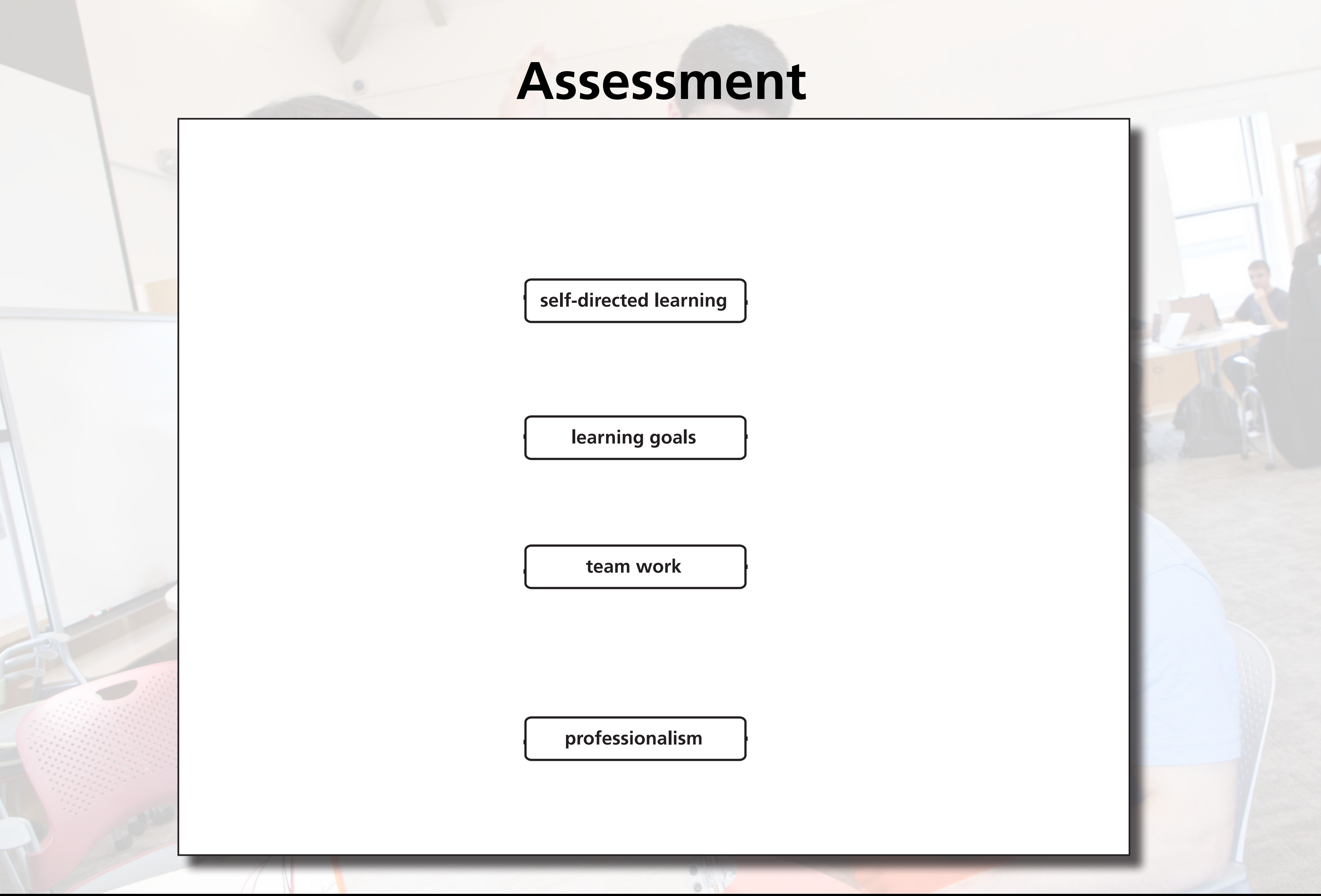
- You were great to work with and a true team player!
- Your ideas were a great contribution to our team
- You come up with good ideas
- You were really easy to work with and had a contagious enthusiasm

"I felt as if I was able to effectively communicate my ideas, even though they may have been wrong… (still good for discussion, right?)"

Team, Peer, and Self assessment

- I would suggest being more responsive throughout the project process.
- Sometimes you're not engaged in activities
- It was hard to understand what you actually thought about an idea or project
- You could be more reasonable about what is actually feasible and what isn't

Assessment



1 design
2 approach

Assessment

Scale: 3–0

self-directed learning

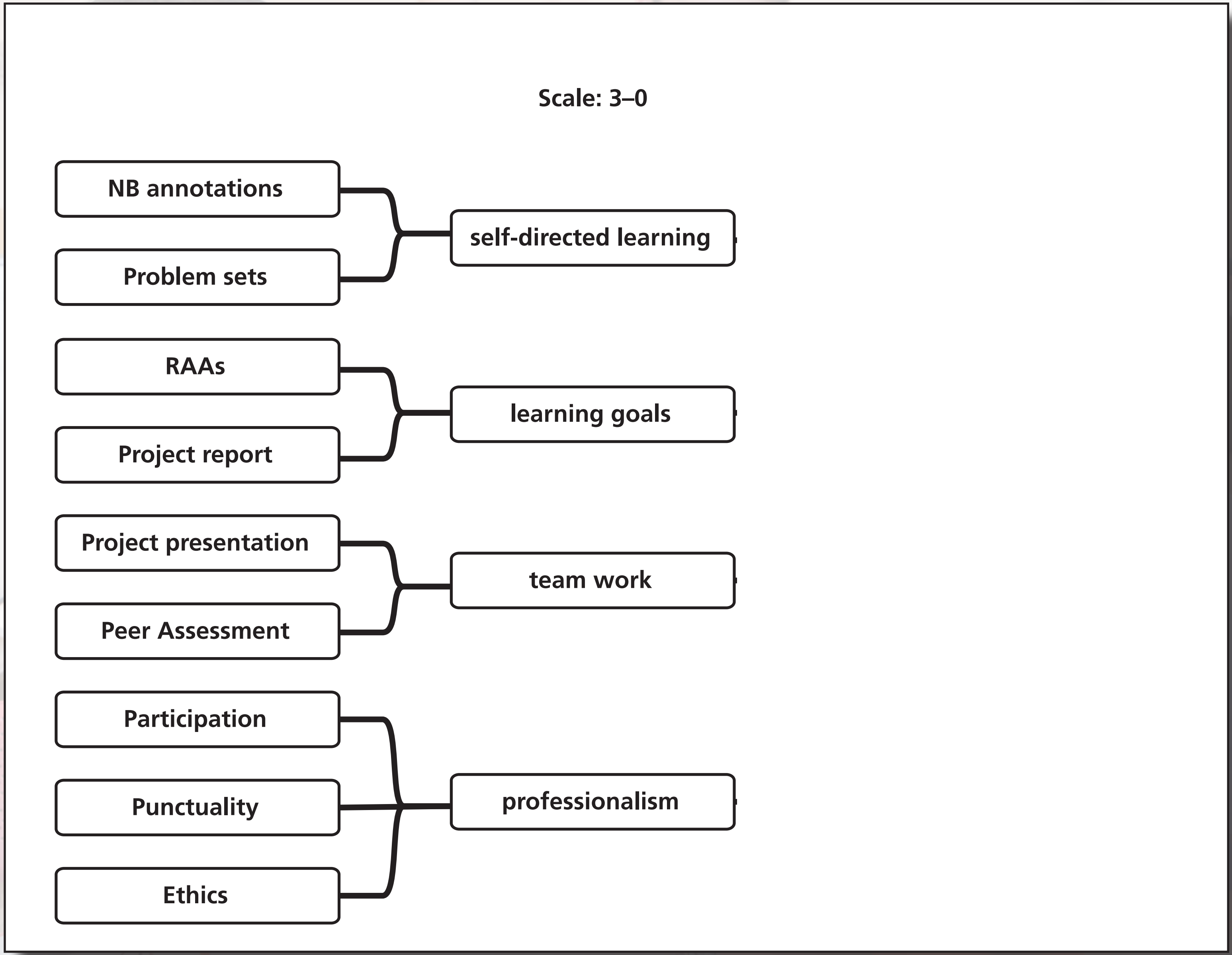
learning goals

team work

professionalism

1 design   2 approach

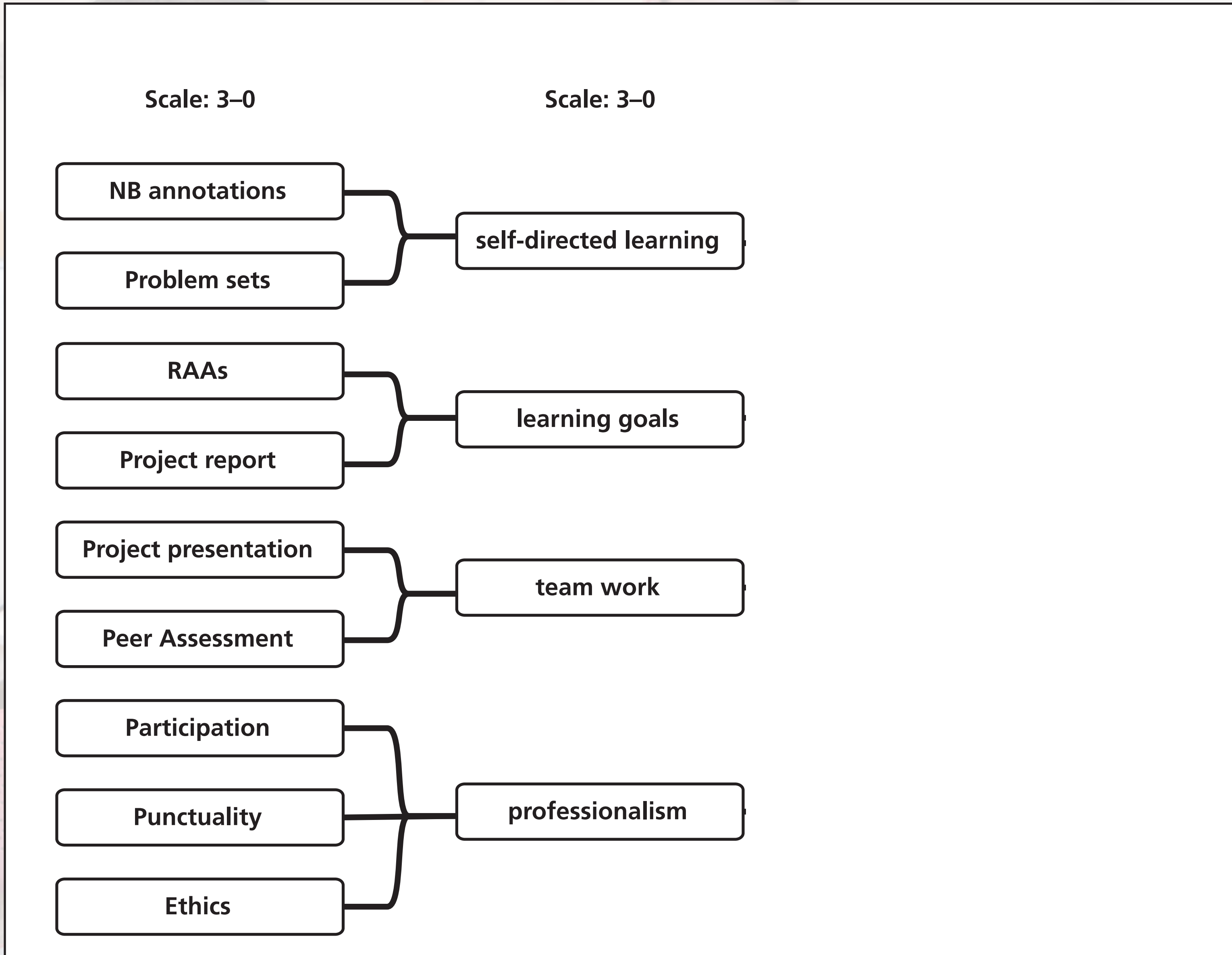
Assessment



1 design

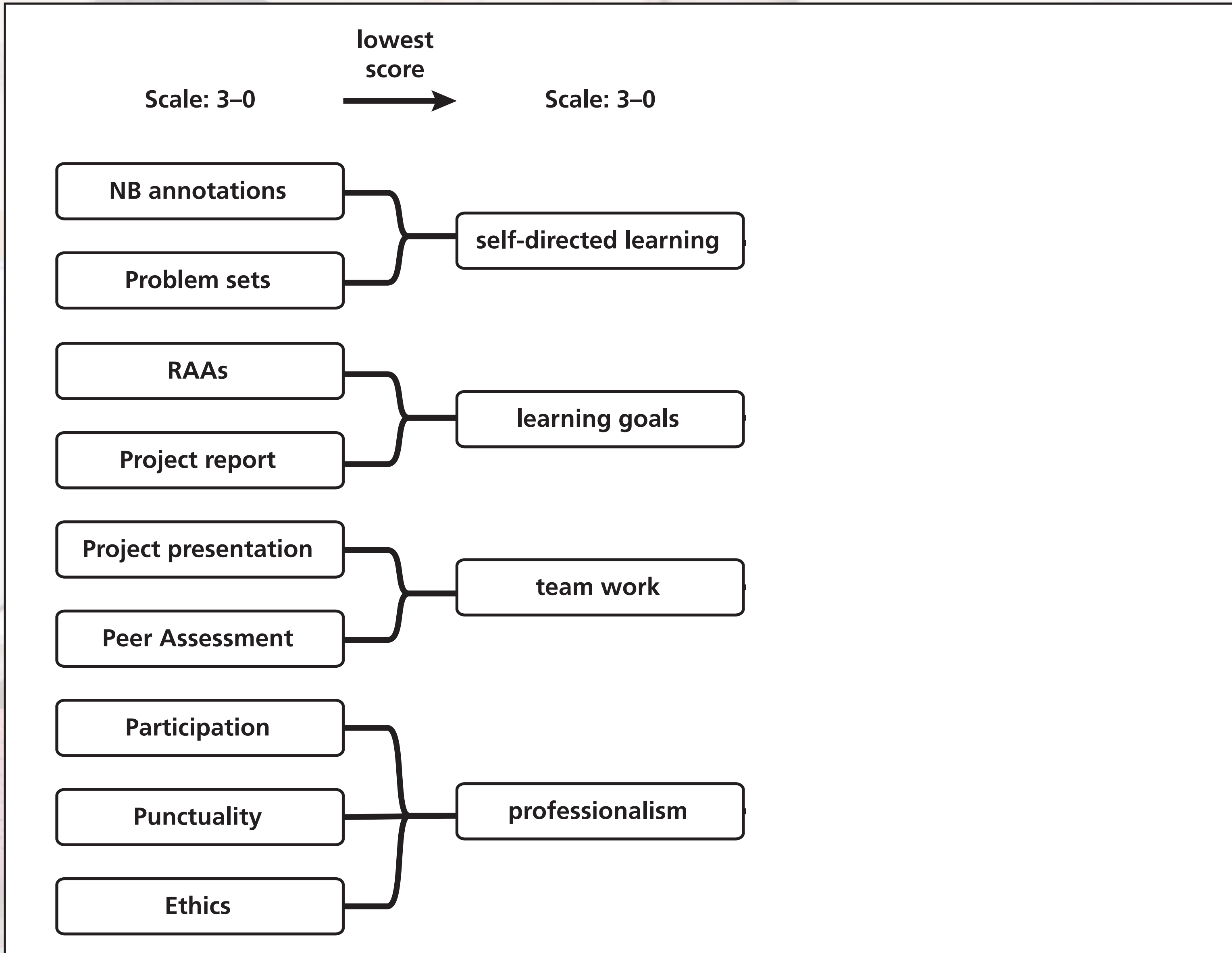
2 approach

Assessment



1 design 2 approach

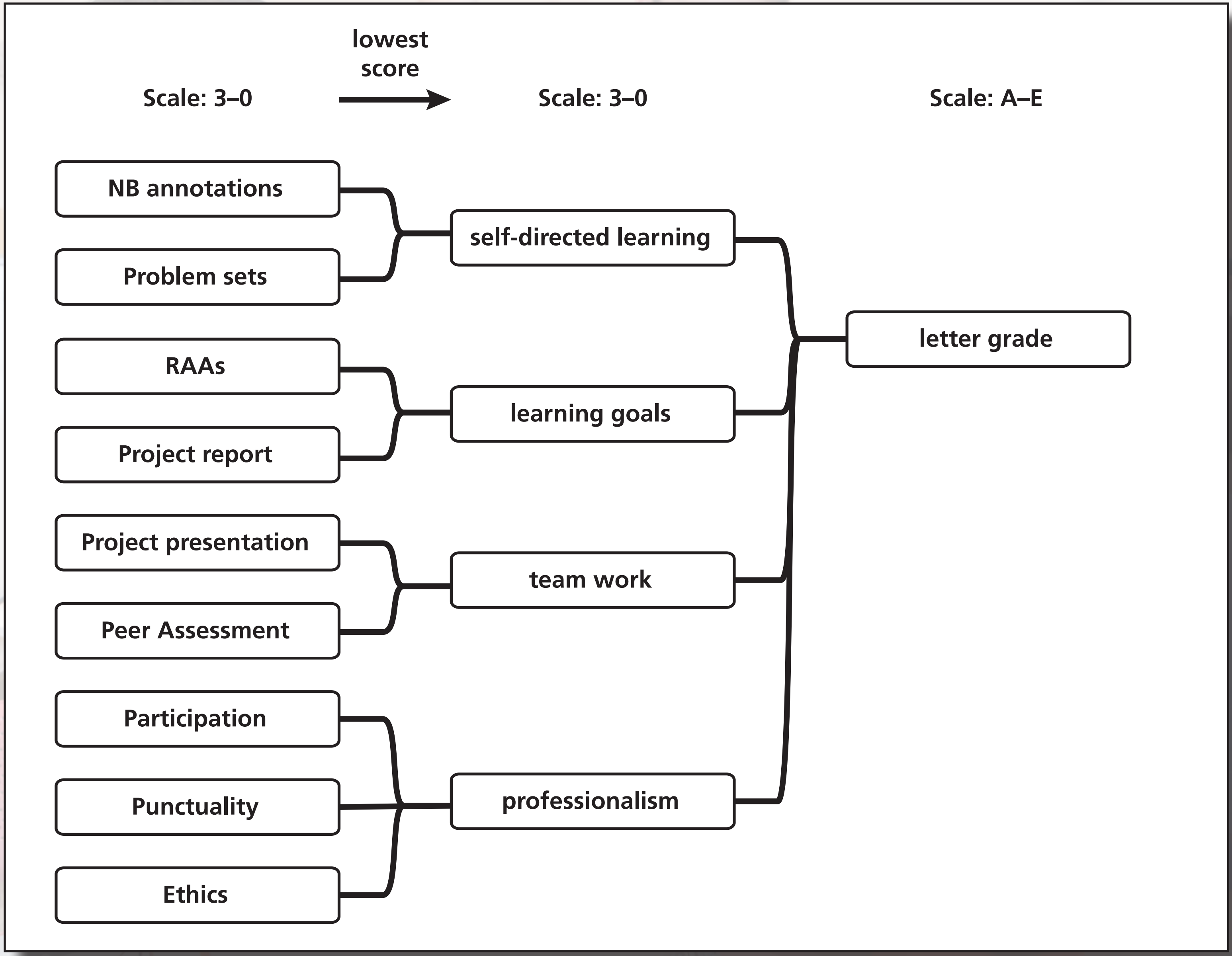
Assessment



1 design

2 approach

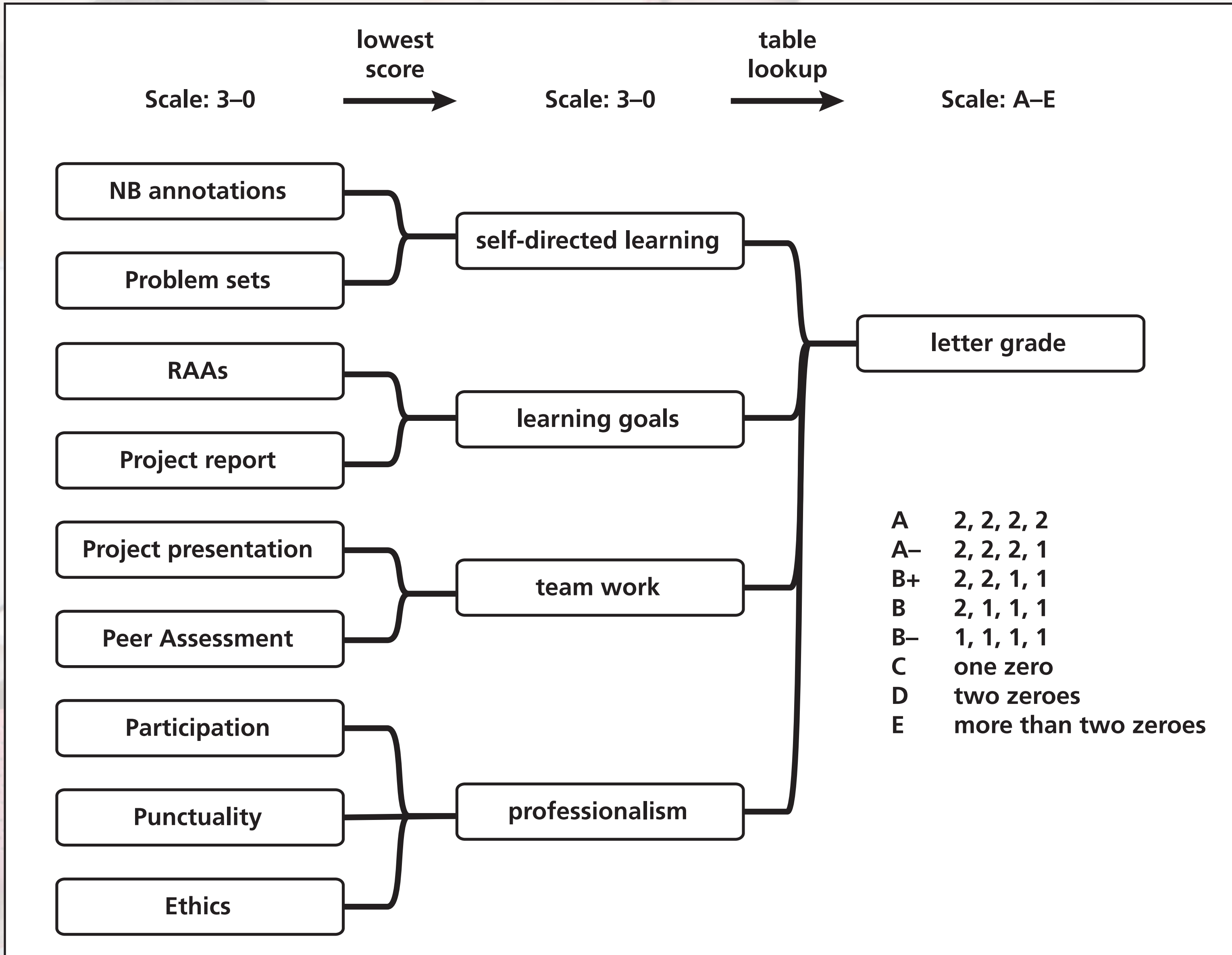
Assessment



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."

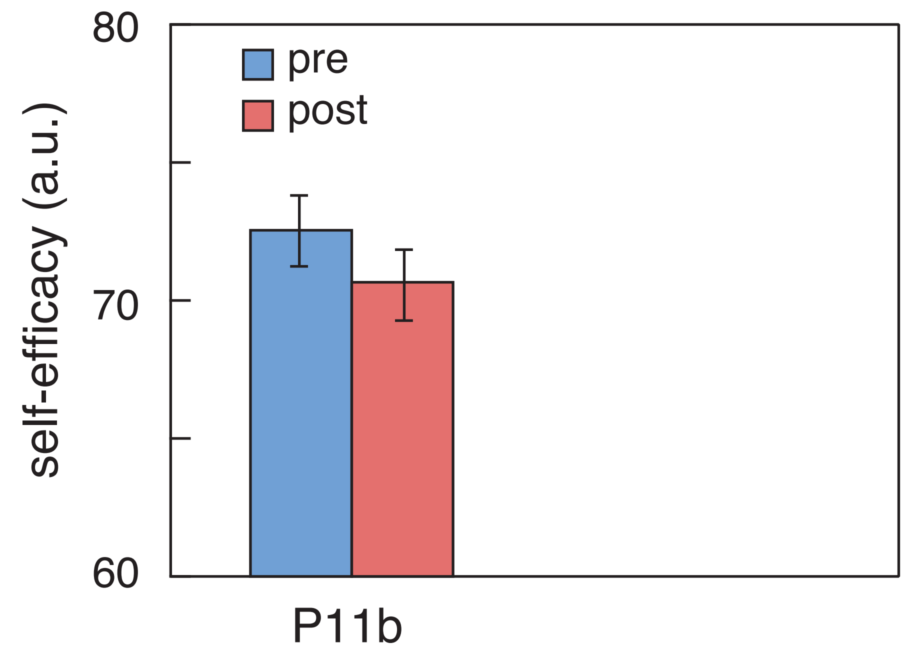
(via email)

Self-efficacy

Self-efficacy

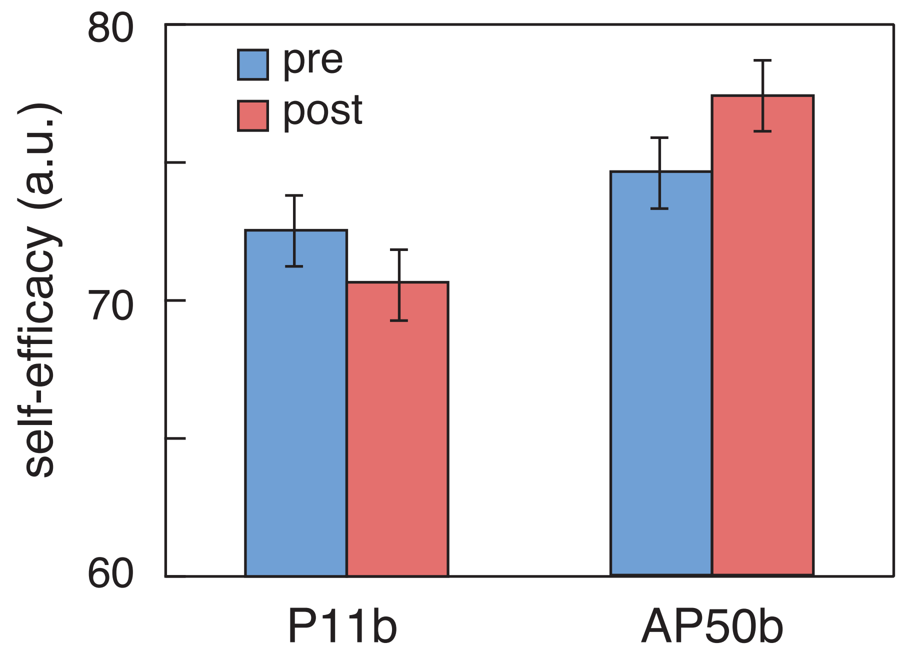
(students' belief in their ability to succeed)

Self-efficacy



1 design 2 approach 3 results

Self-efficacy



1 design 2 approach 3 results

Self-directed learning

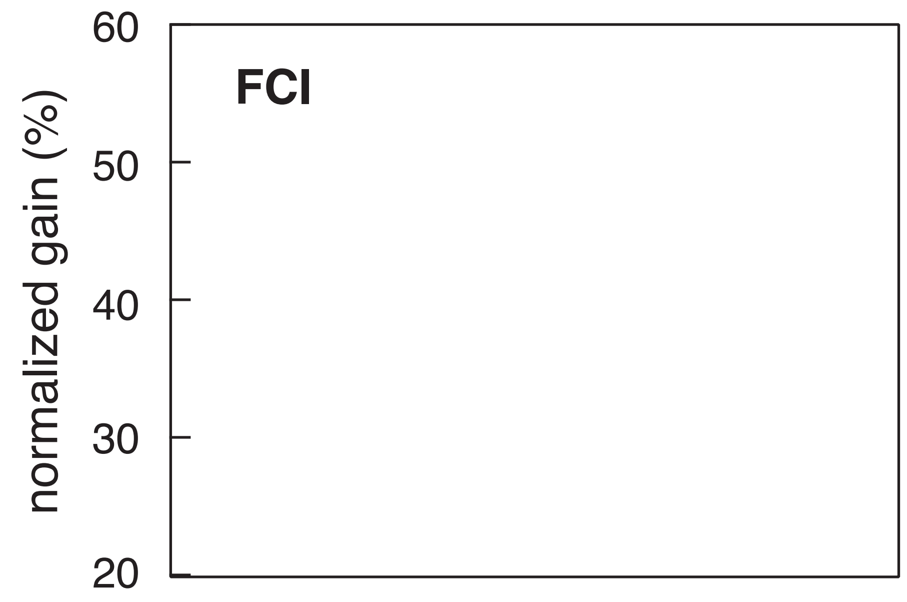
1 design 2 approach 3 results

Self-directed learning

NB data shows:

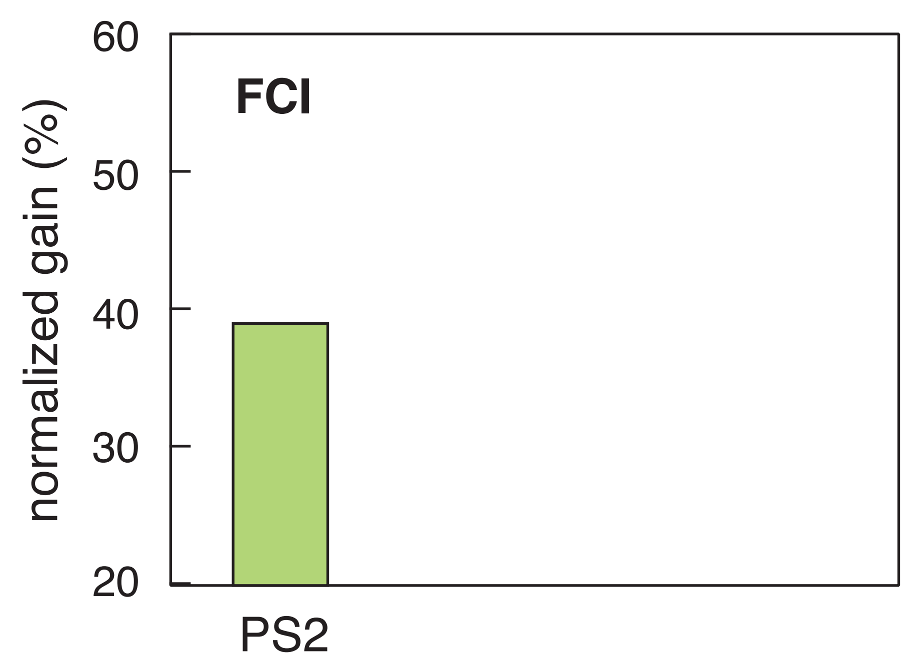
- student spend on average 2.3 hrs/chapter
- 600–700 annotations/chapter (8–10/stu)

Conceptual Mastery

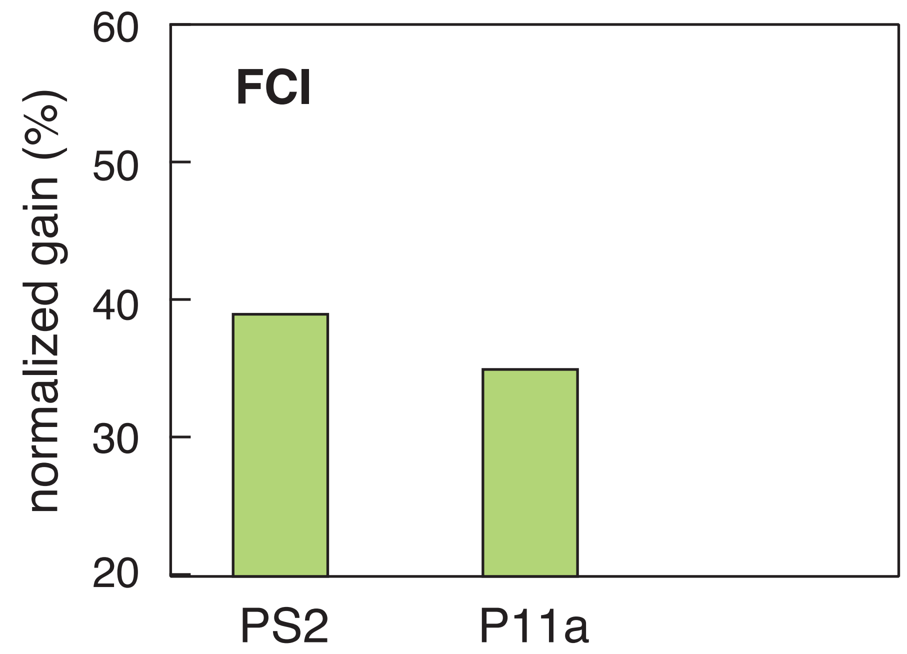


1 design
2 approach
3 results

Conceptual Mastery

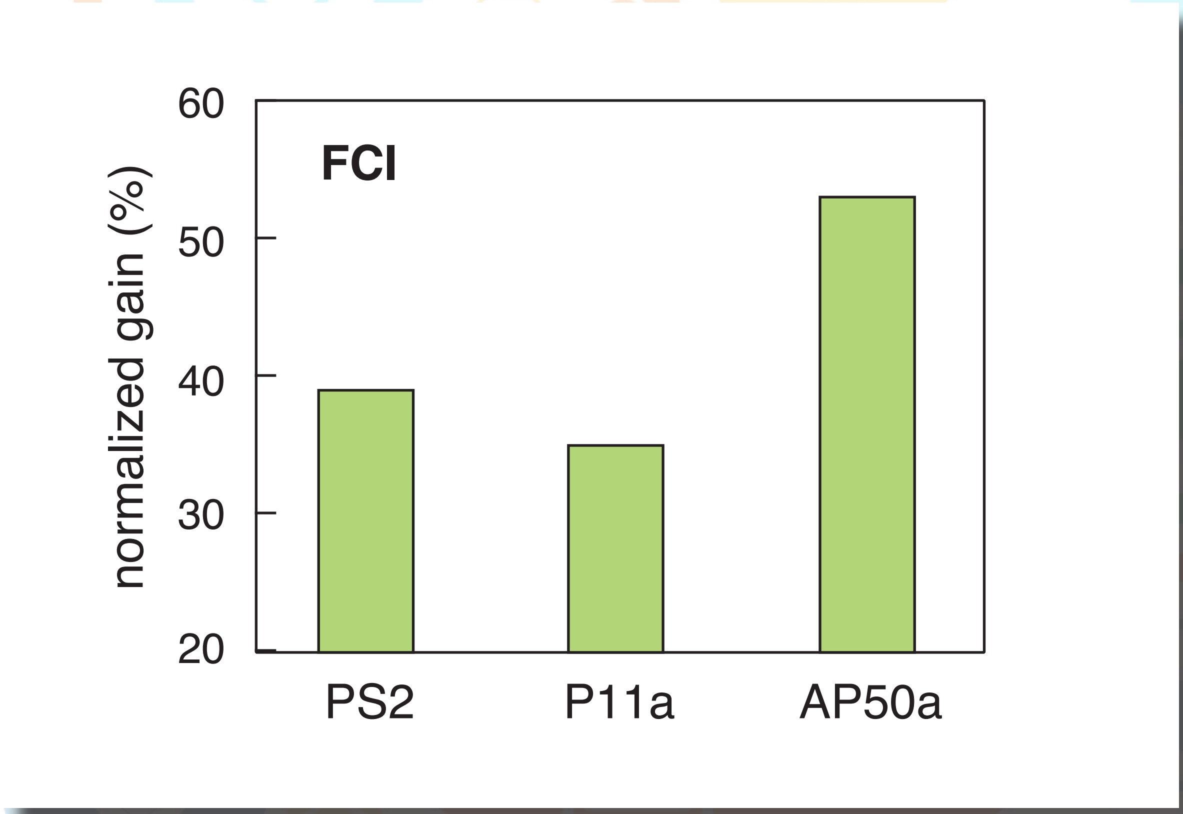


Conceptual Mastery

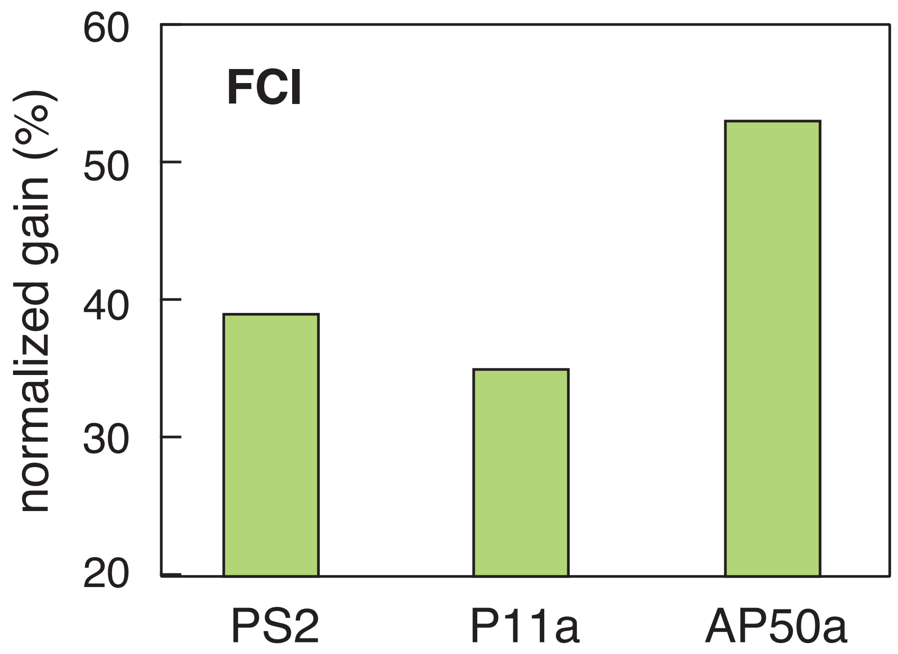


1 design 2 approach 3 results

Conceptual Mastery

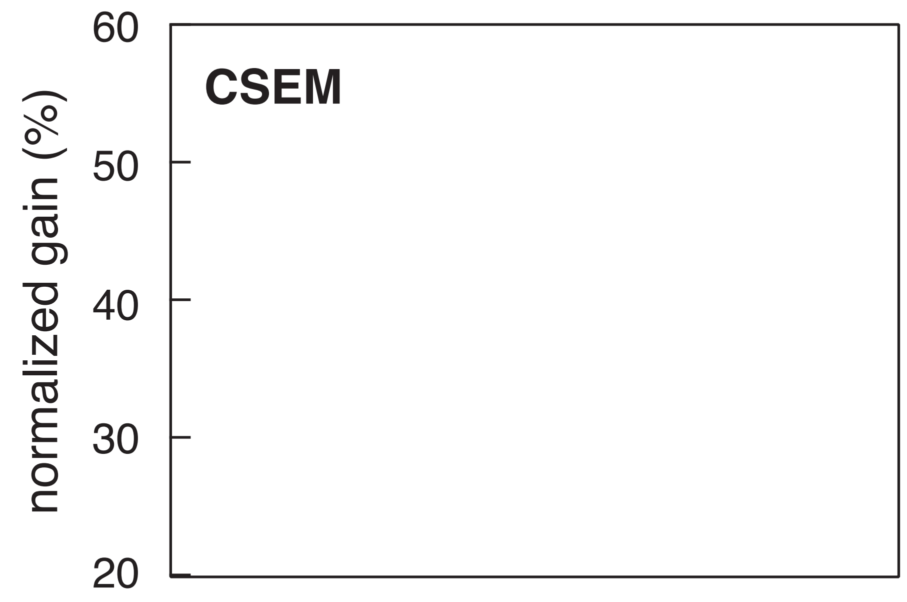


Conceptual Mastery



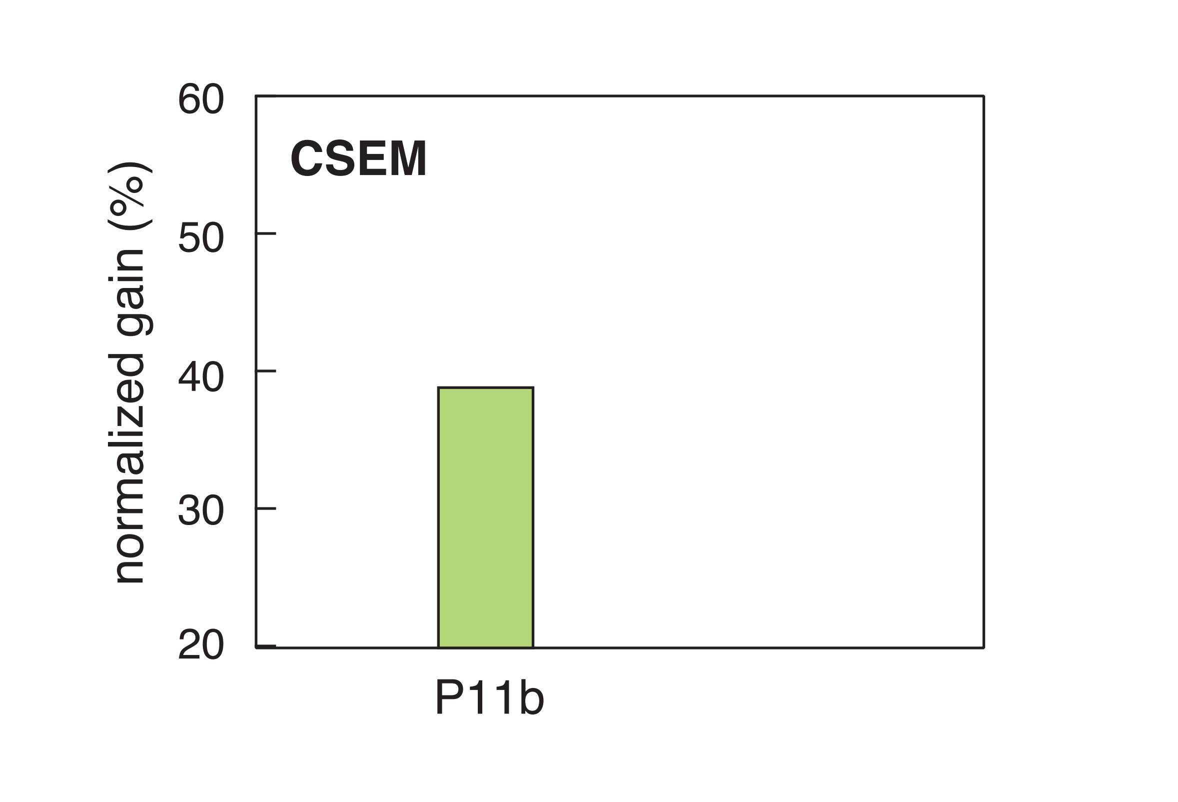
largest conceptual gain in *any* course past 6 yrs!

Conceptual Mastery



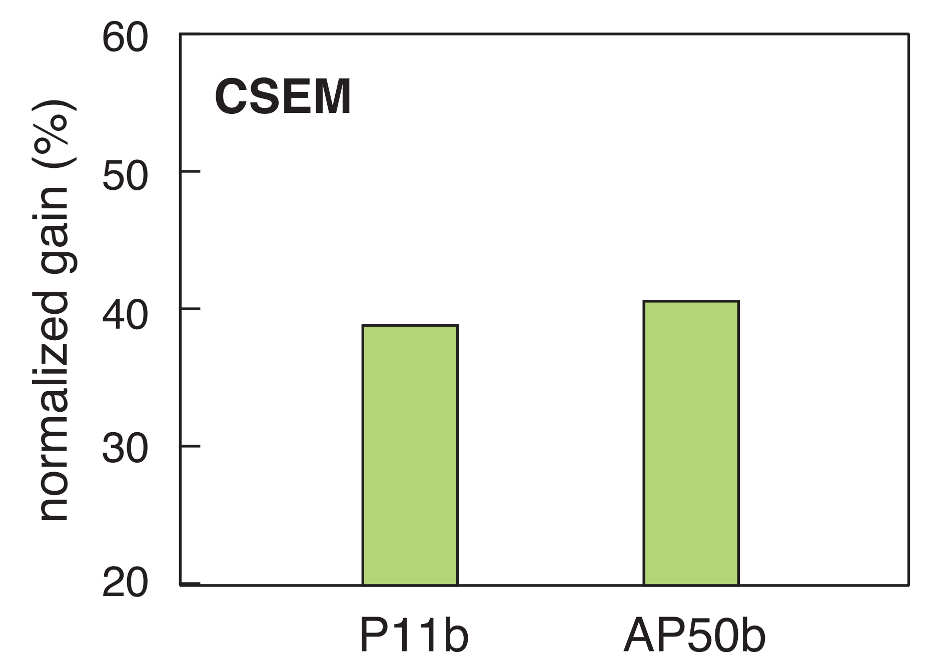
1 design
2 approach
3 results

Conceptual Mastery

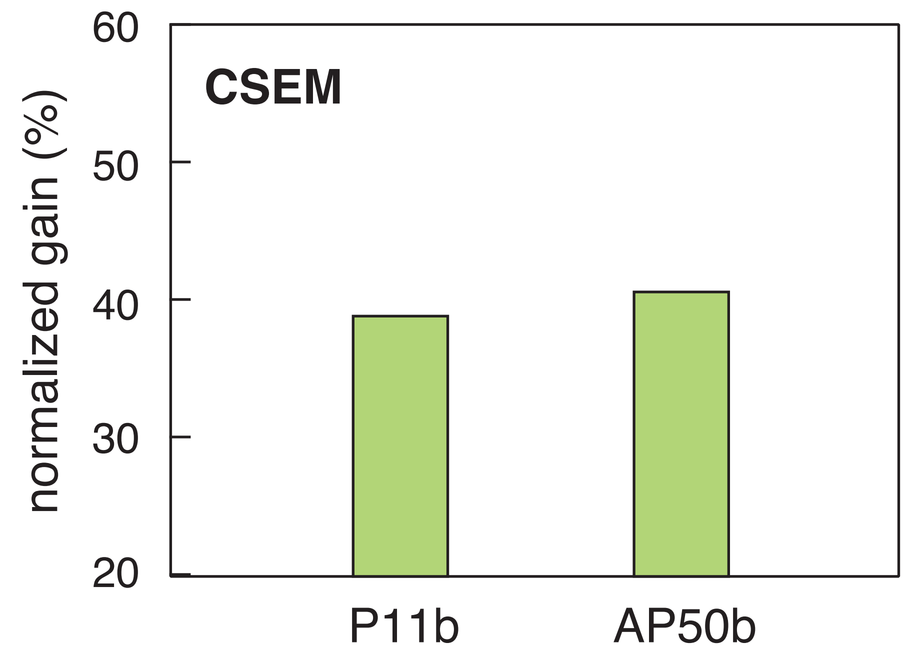


1 design 2 approach 3 results

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!**

fun!

Can create ownership of learning physics!

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

1 design 2 approach 3 results