Confessions of a converted lecturer

Physics Research Conference/TeachWeek
Caltech
Pasadena, CA, 22 October 2015

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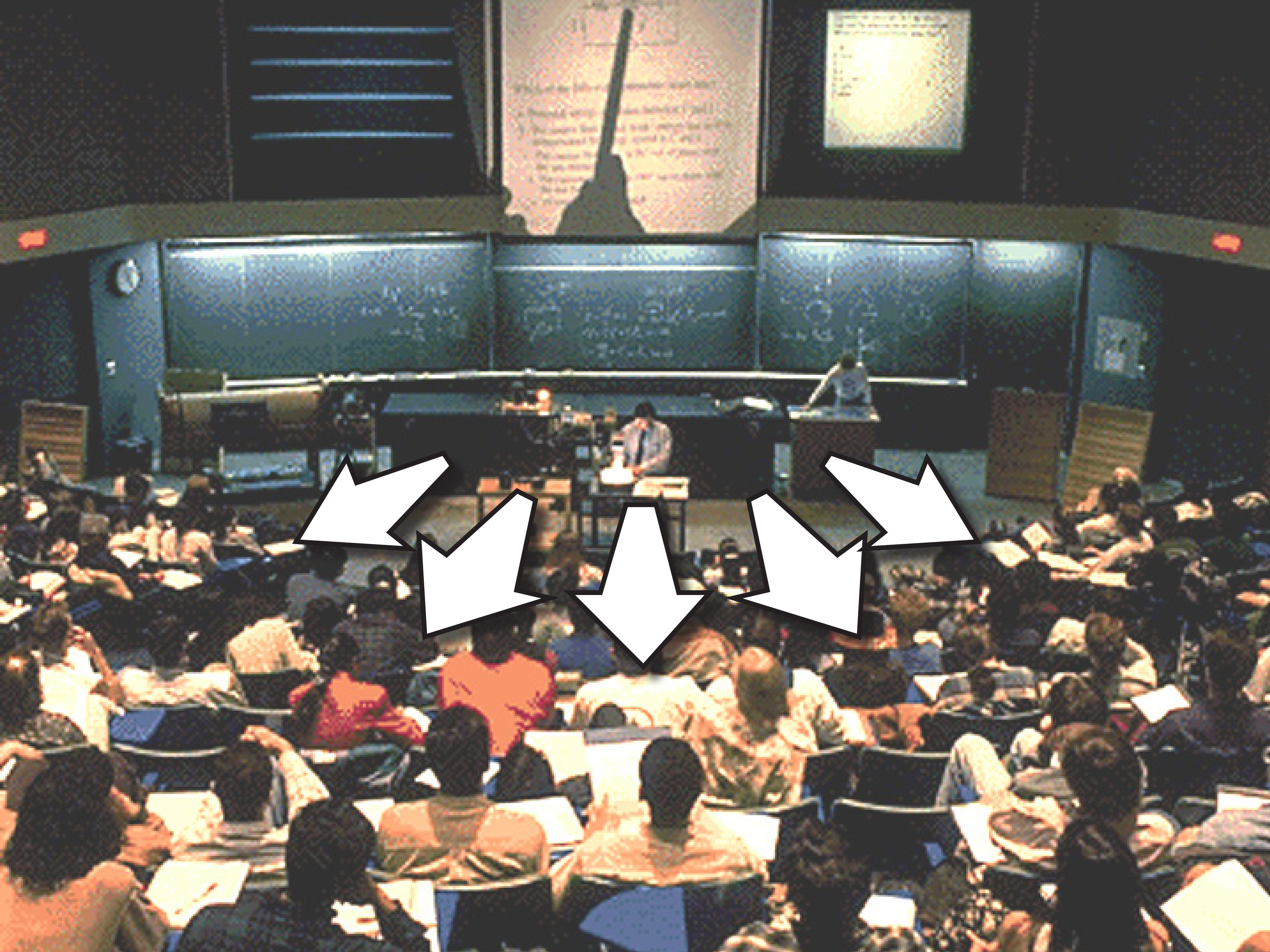


an illusion. . .

1. transfer of information

1. transfer of information

2. assimilation of that information

1. transfer of information (in class)

2. assimilation of that information

1. transfer of information (in class)

2. assimilation of that information (out of class)

Should focus on THIS!

1. transfer of information (i

2. assimilation of that information (out of class)

1. transfer of information (in class)

2. assimilation of that information (out of class)

1. transfer of information (out of class)

2. assimilation of that information (in class)

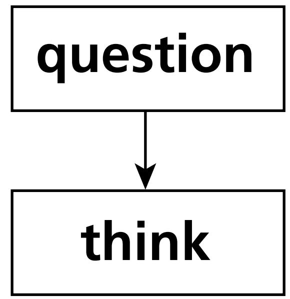
Peer

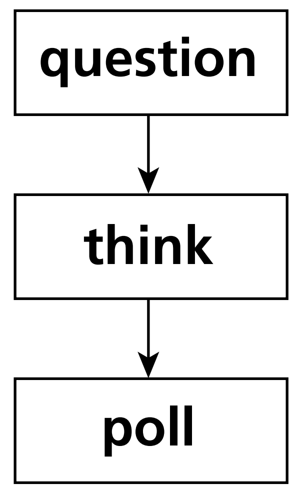
1. transfer of information (out of class)

2. assimilation of that information (in class)

INSTRUCTION

question


question
think


question
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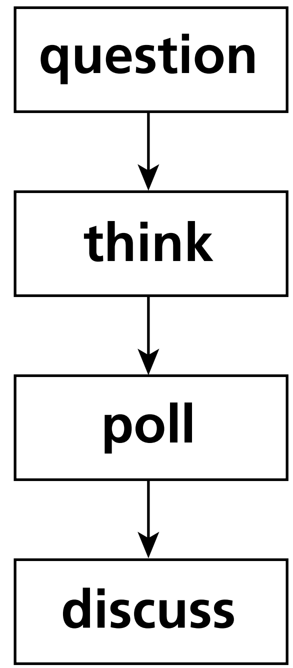
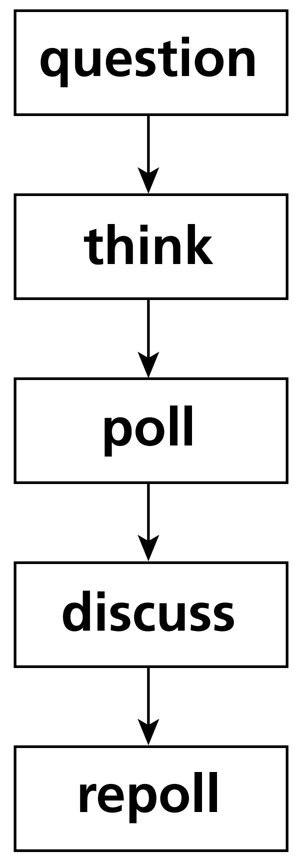

question
think
poll
discuss


question
think
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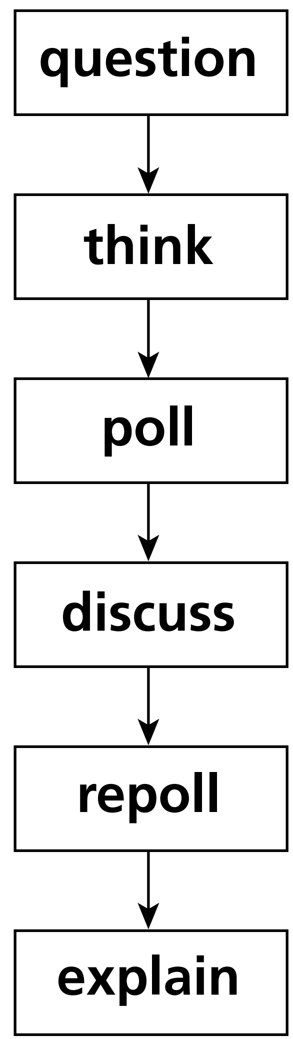
repoll


question
think
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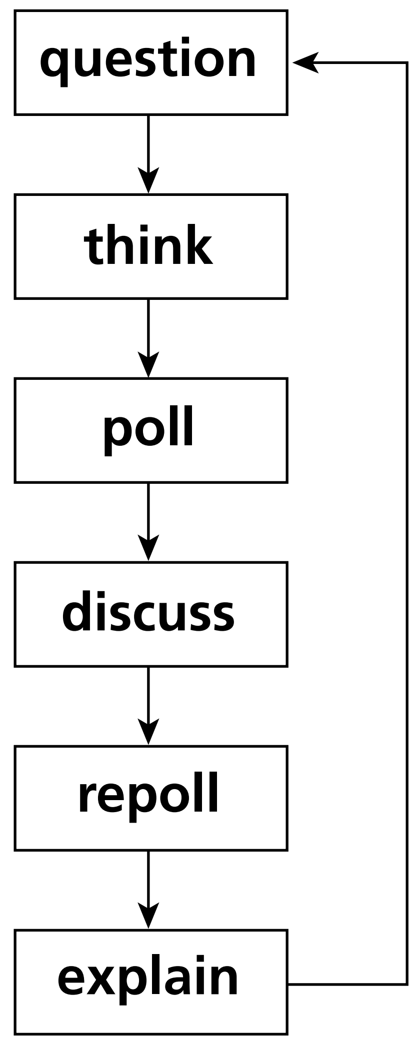
explain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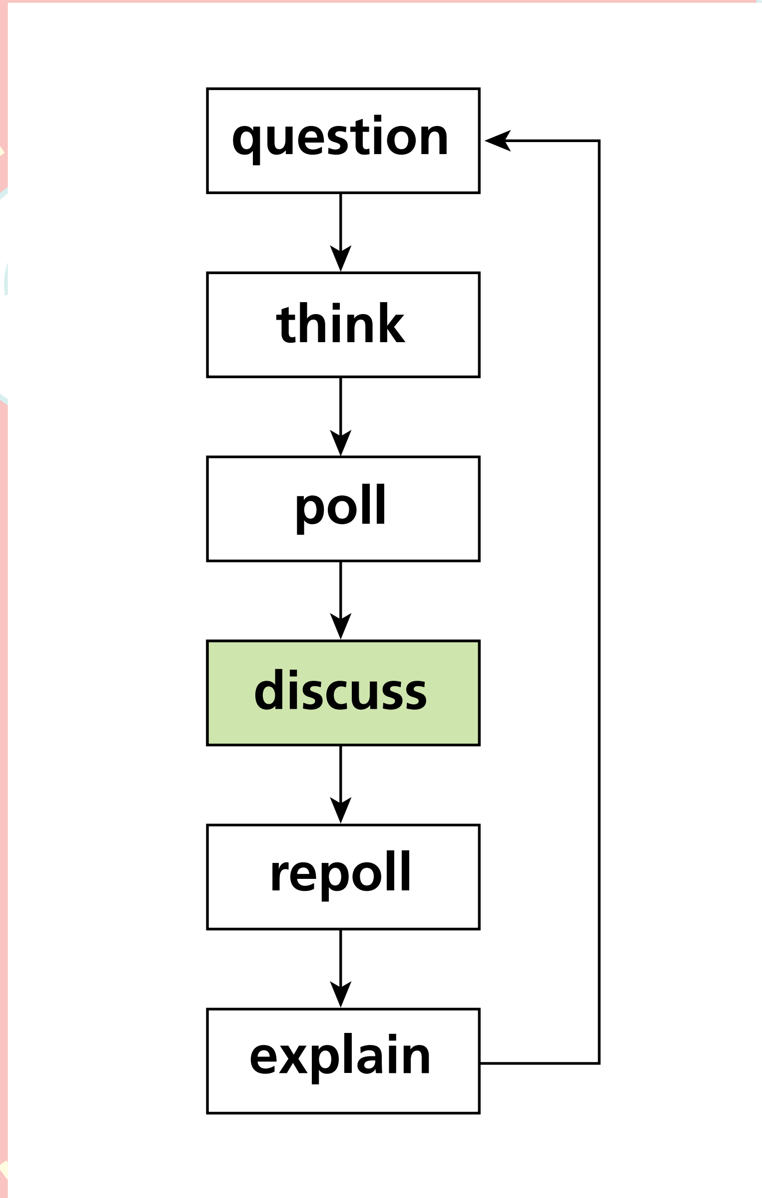
question
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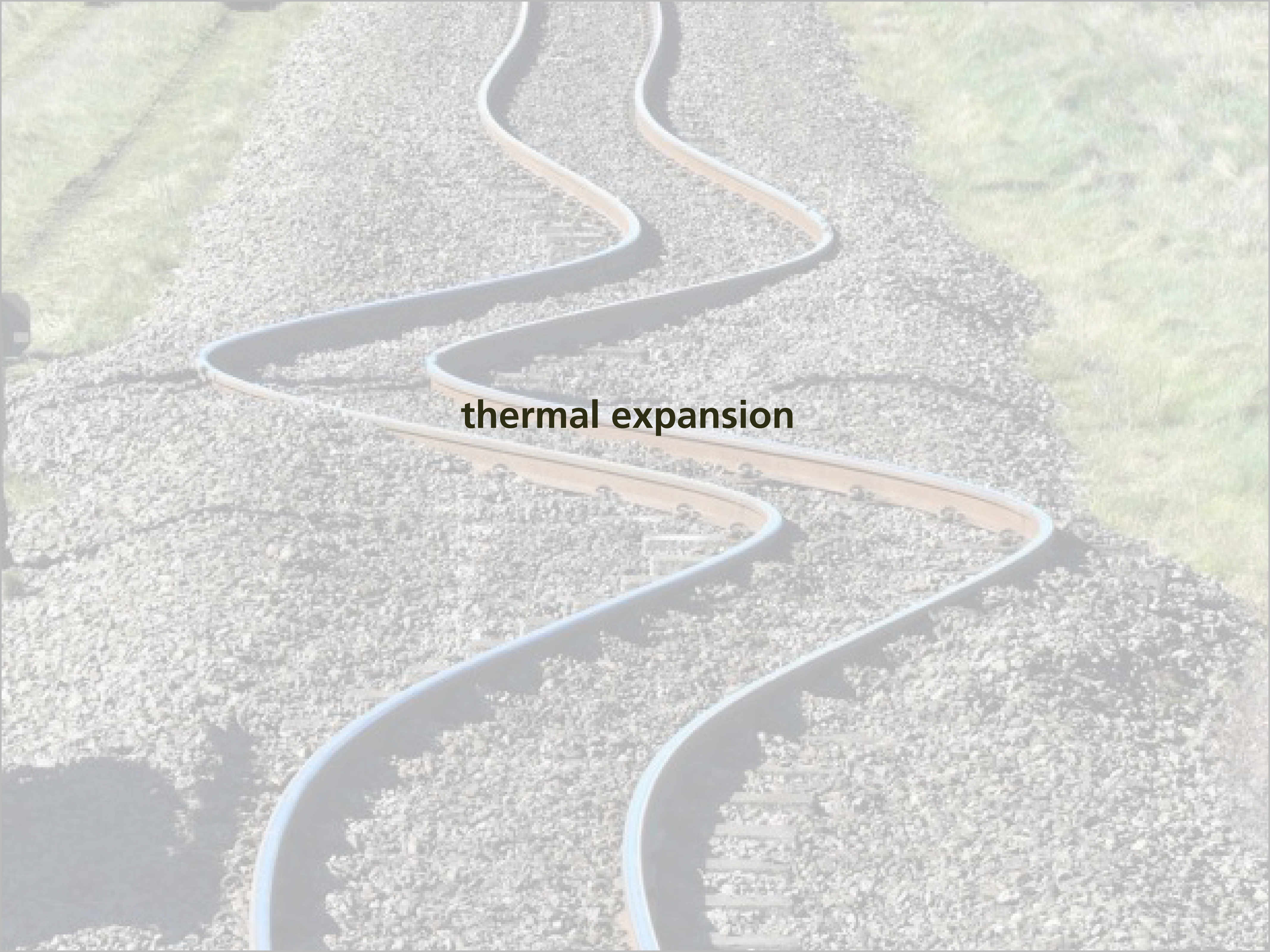
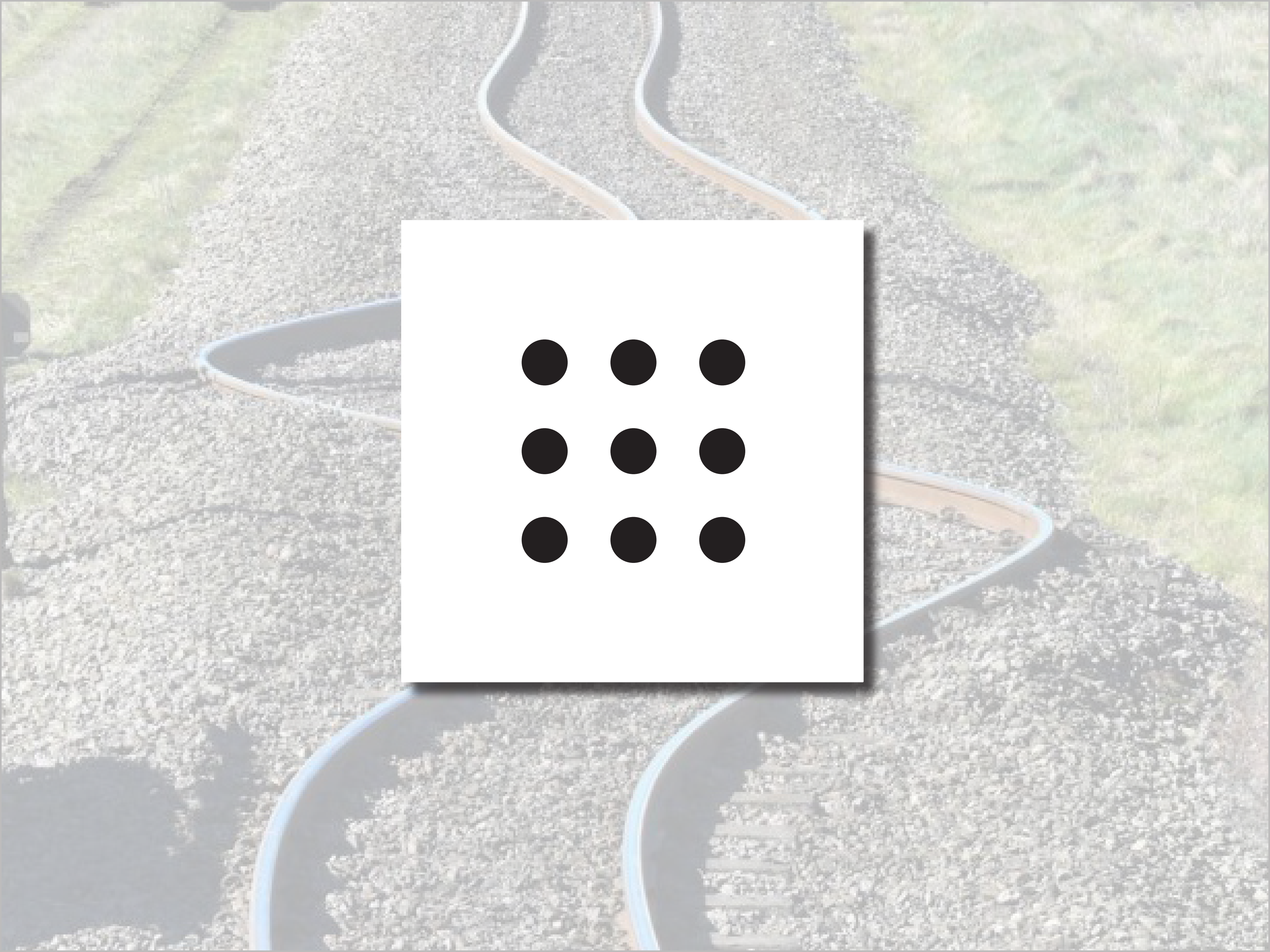
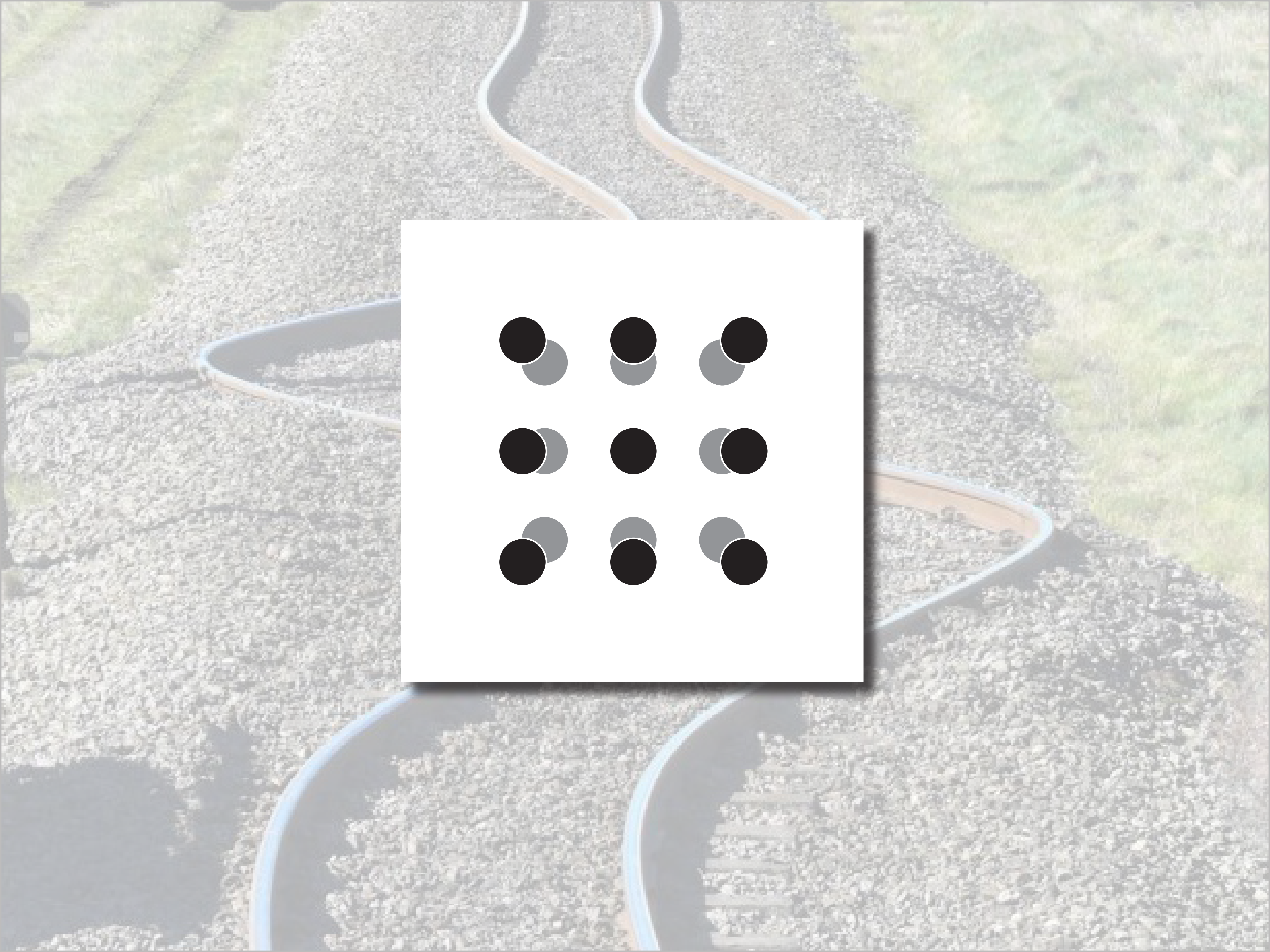
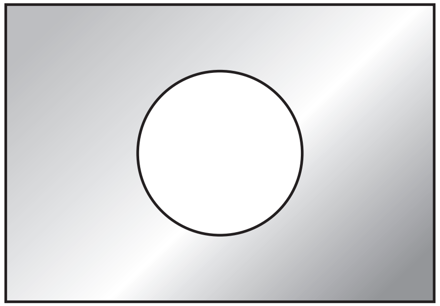

thermal expansion






all of them

Consider a rectangular metal plate with a circular hole in it.



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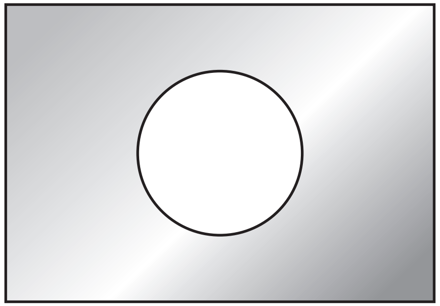

When the plate is uniformly heated, the diameter of the hole

1. increases.
2. stays the same.
3. decreases.

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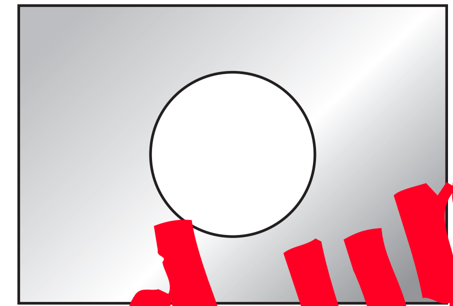
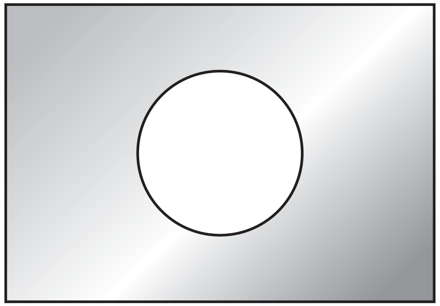


When the plate is uniformly heated, the diameter of the hole

1. increases.
2. stays the same.
3. decreases.

you got all fired up!

Consider a rectangular metal plate with a circular hole in it.



When the plate is uniformly heated, the diameter of the hole

1. increases.
2. stays the same.
3. decreases.

Before I tell you the answer, let’s analyze what happened.

Before I tell you the answer, let's analyze what happened.

You…

Before I tell you the answer, let’s analyze what happened.

You…

1. made a commitment

Before I tell you the answer, let’s analyze what happened.

You…

1. made a commitment
2. externalized your answer

Before I tell you the answer, let's analyze what happened.

You…

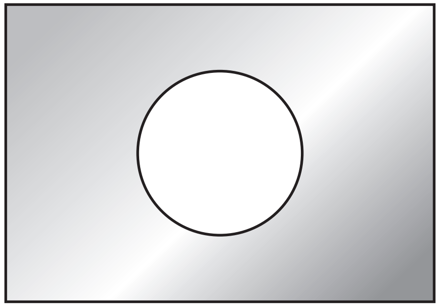
1. made a commitment
2. externalized your answer
3. moved from the answer/fact to reasoning

Before I tell you the answer, let’s analyze what happened.

You…

1. made a commitment
2. externalized your answer
3. moved from the answer/fact to reasoning
4. became emotionally invested in the learning process

Consider a rectangular metal plate with a circular hole in it.



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3. decreases.

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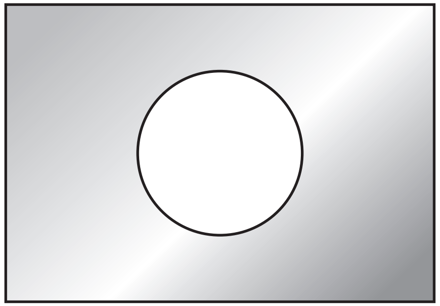
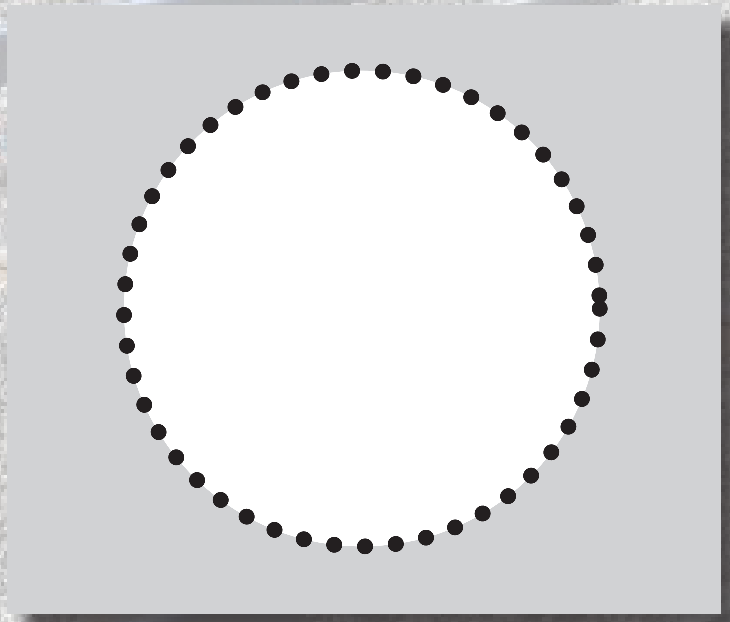


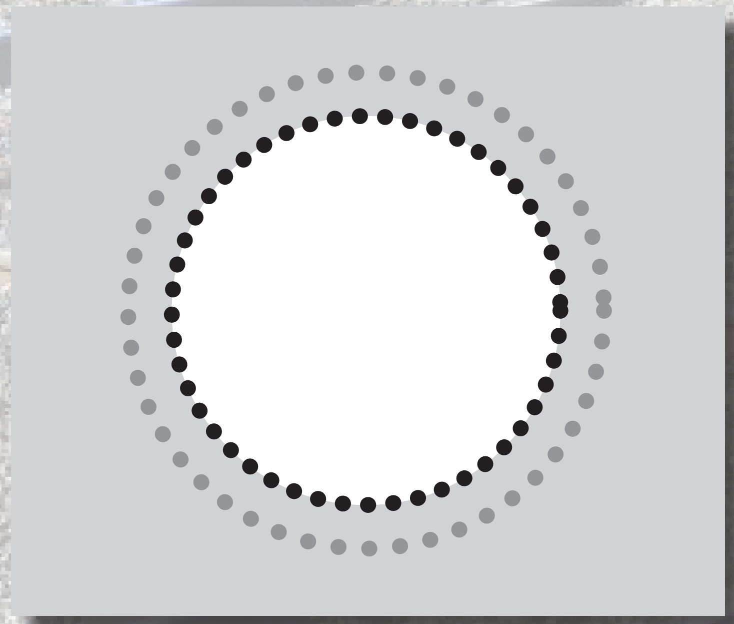
When the plate is uniformly heated, the diameter of the hole

1. increases. ✔
2. stays the same.
3. decreases.

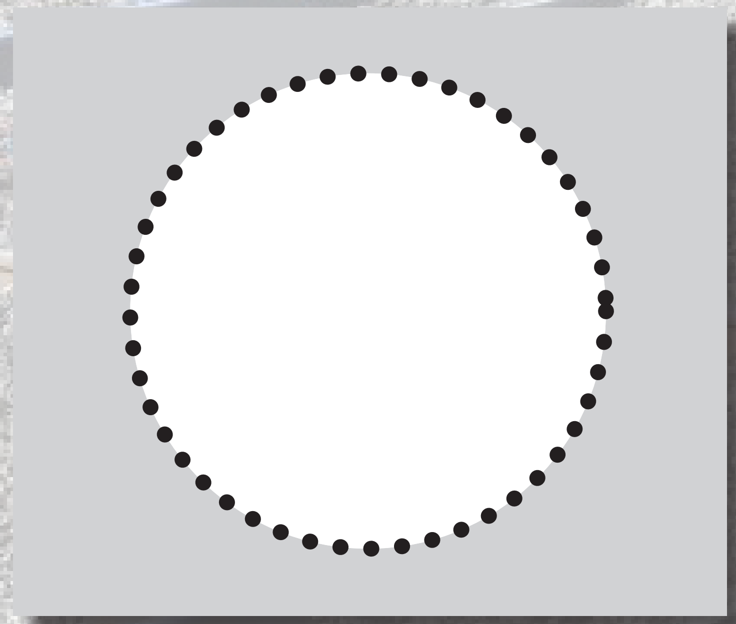
consider atoms at rim of hole



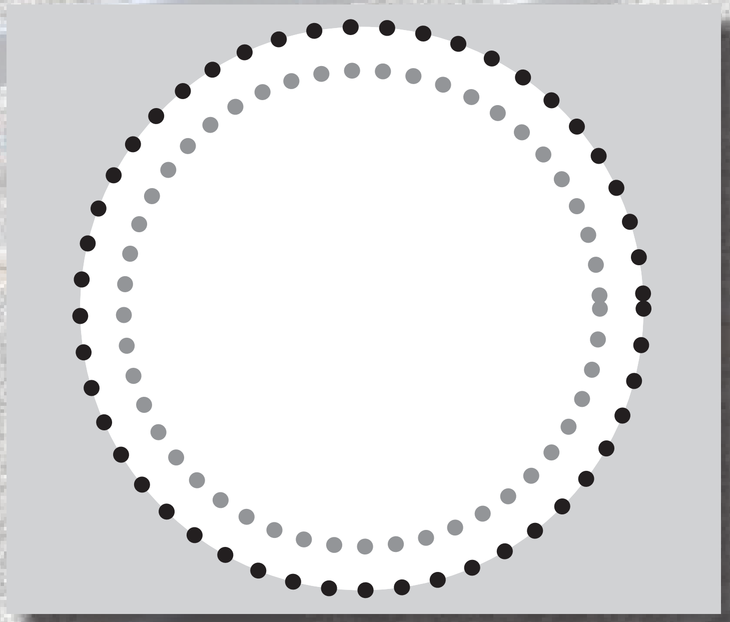
consider atoms at rim of hole



consider atoms at rim of hole



consider atoms at rim of hole



consider atoms at rim of hole

you won't forget this

Peer

back to PI

INSTRUCTION

Peer

INSTRUCTION

Higher learning gains

Peer

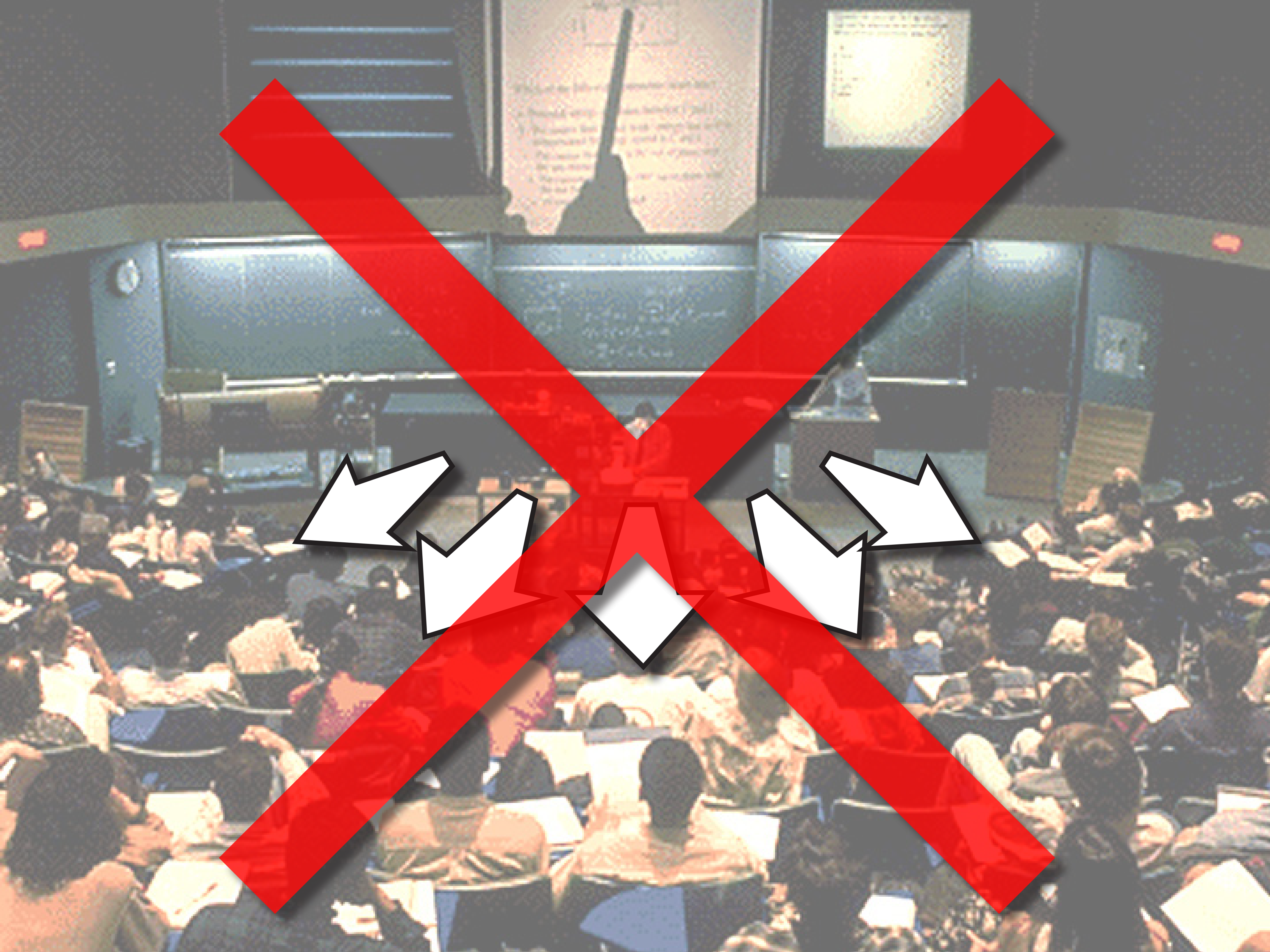
INSTRUCTION

Peer

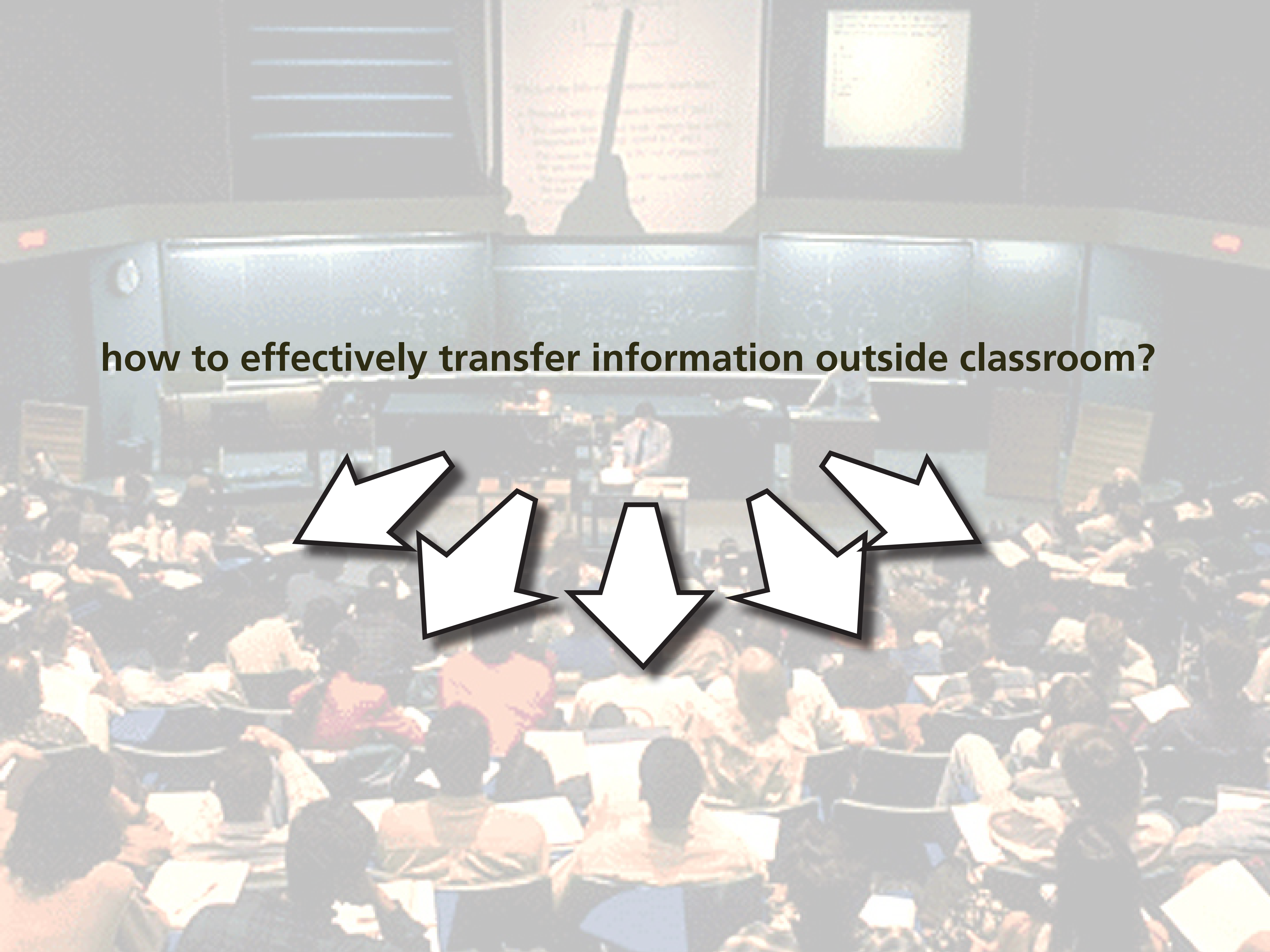
INSTRUCTION

Higher learning gains

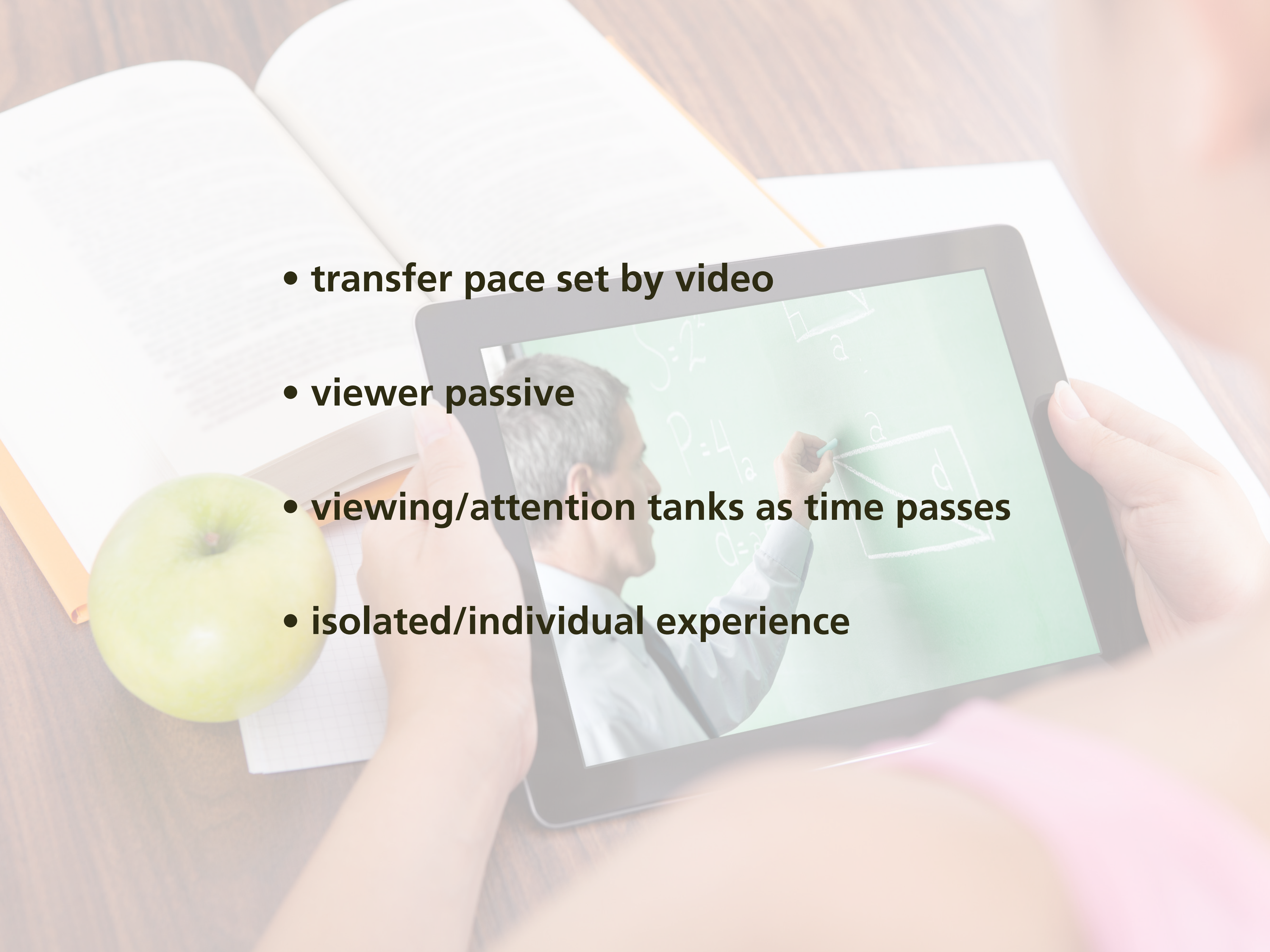
Better retention



how to effectively transfer information outside classroom?

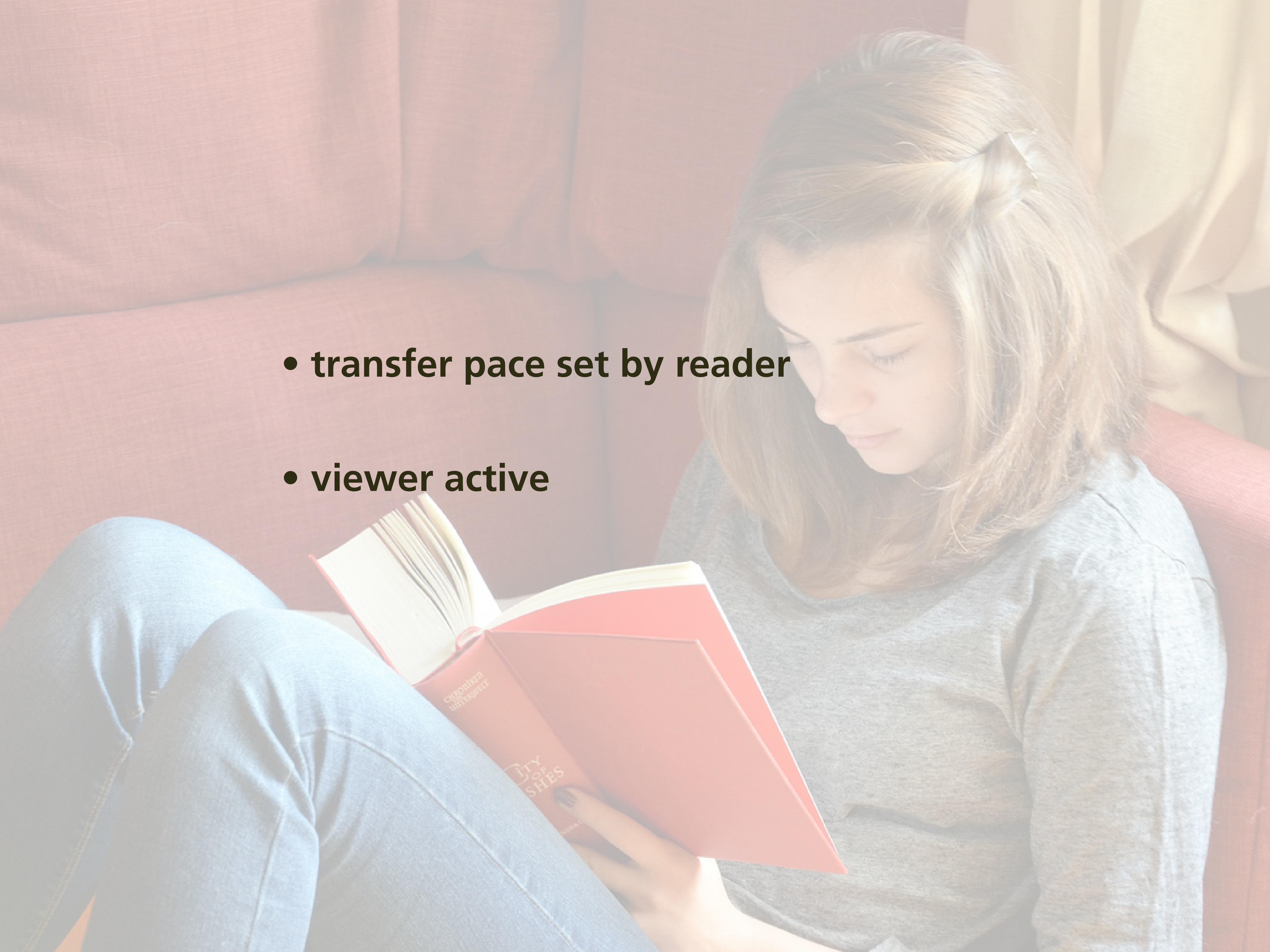


but…



- transfer pace set by video
- viewer passive
- viewing/attention tanks as time passes
- isolated/individual experience

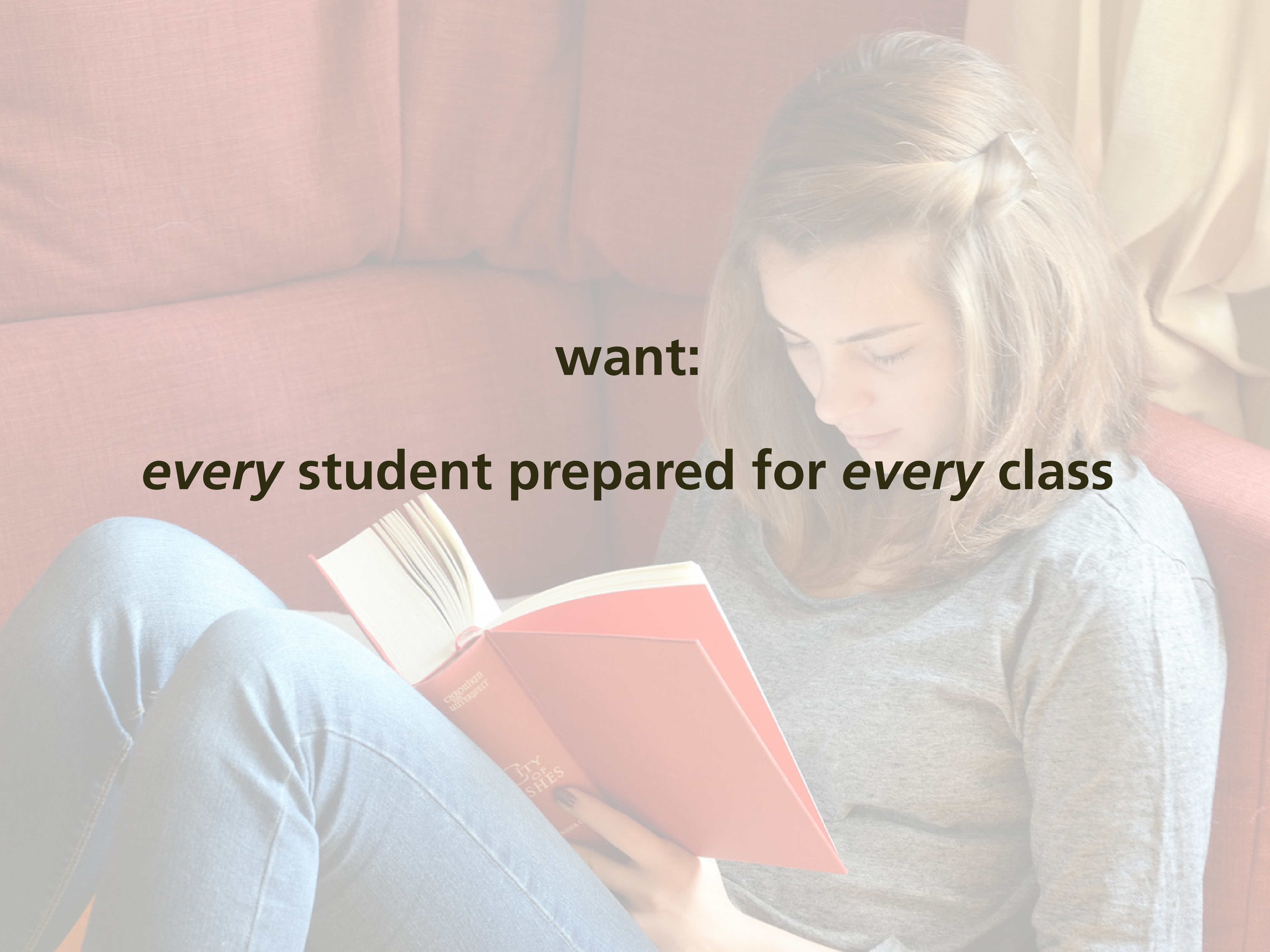

we’re simply moving this outside classroom!

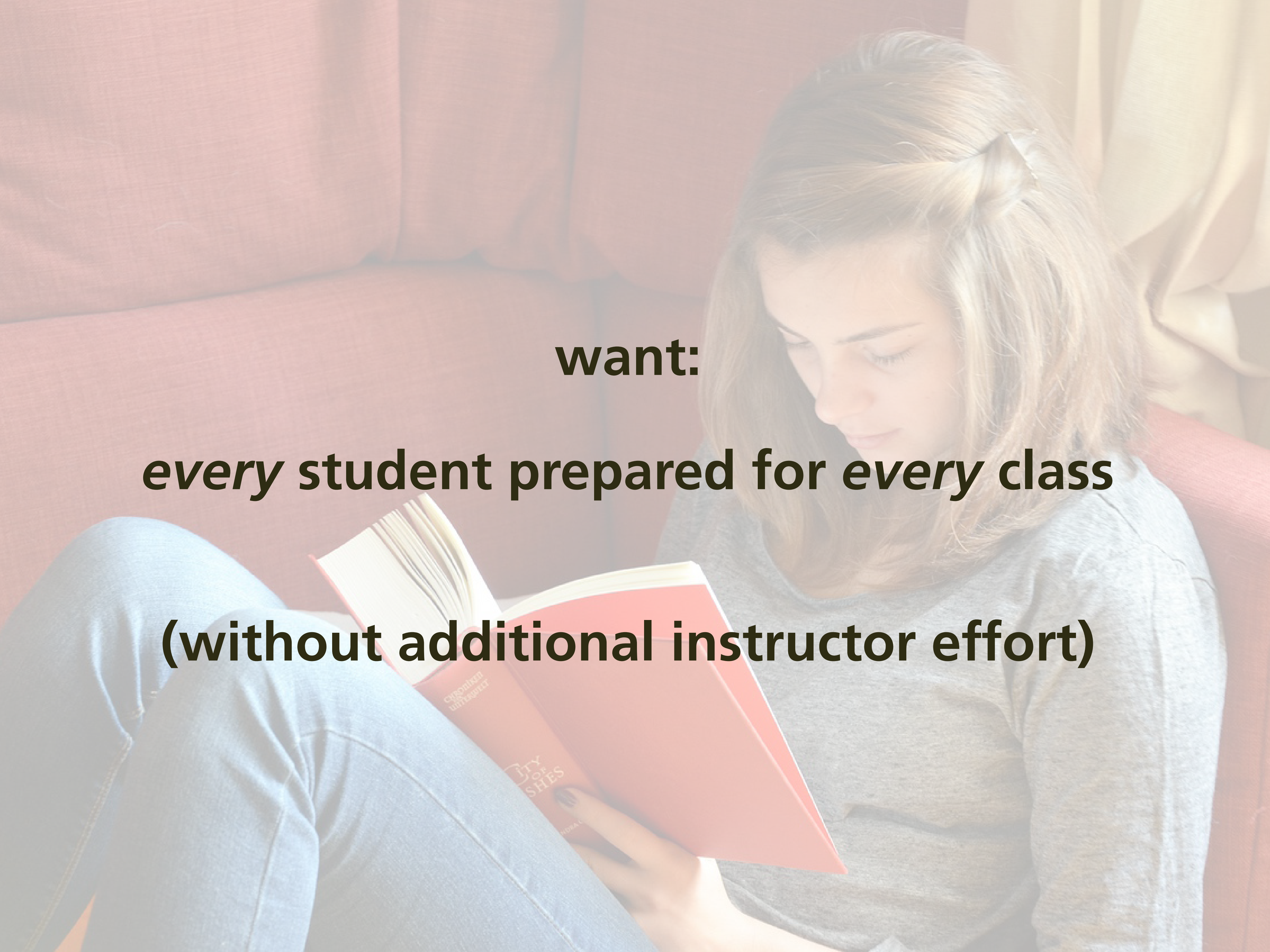


- transfer pace set by reader
- viewer active

but…


isolated/individual experience &
no real accountability


want:
every student prepared for *every* class



want:

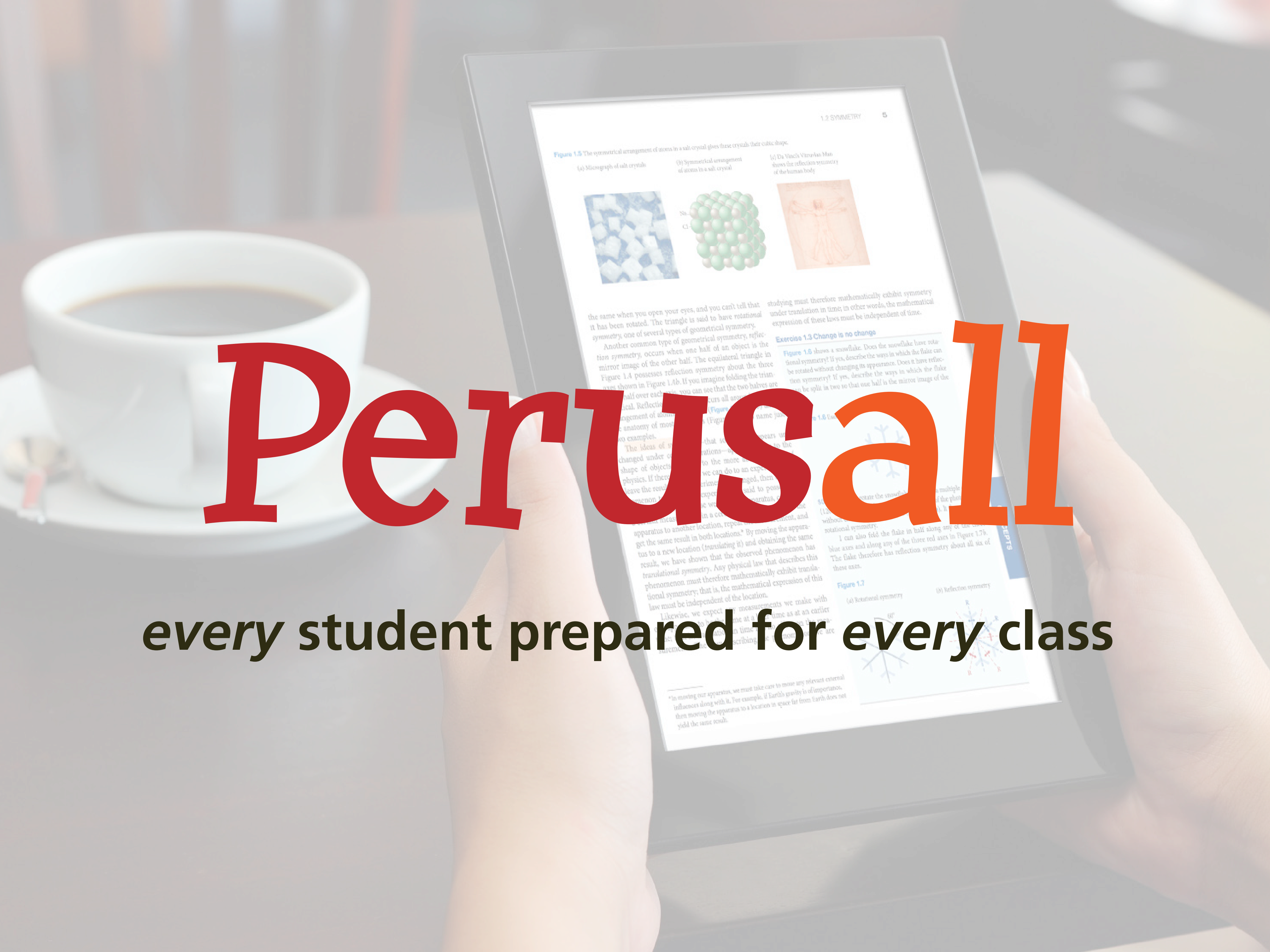
every student prepared for *every* class

(without additional instructor effort)

Solution

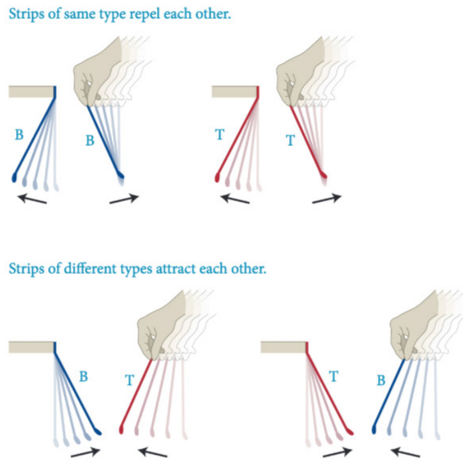
turn out-of-class component

also into a social interaction!


Perusall
every student prepared for *every* class

social interaction

Figure 22.6 Interactions of B and T charged strips.



Experiments show that *any* charged object—obtained by rubbing objects together or otherwise—always attracts either a B strip or a T strip and repels the other. No one has ever found a charged object that repels or attracts *both* types of strips. In other words:

There are two and only two types of charge. Objects that carry like charges repel each other; objects that carry opposite charges attract each other.

The two types of charge never appear independently of each other: Whenever two neutral objects are either rubbed together and then separated or, if an adhesive surface is involved, stuck together and then separated and one of them acquires a charge of one type, the other object always acquires a charge of the other type. The generation of opposite charges is obvious when you separate a neutral pair of tape strips. When you pass a comb through your hair, the comb acquires a charge of one type and your hair acquires a charge of the other type. On a dry day, you may have noticed that some hair strands stand up away from your head. Each charged strand is being repelled by the other charged strands, and so they are all getting as far away from one another as possible.

It can be shown that when two tape strips are separated, the forces exerted by the B strip and the T strip on a third charged strip are equal in magnitude, although one is attractive and the other repulsive. Furthermore, when the B and T strips are recombined, the combination is neutral again. These observations suggest that after you rub and then separate a pair of objects, the objects carry equal amounts of opposite charge. Combining these equal amounts of opposite charge produces zero charge. These observations indicate that all neutral matter contains equal amounts of positive and negative charge. The two types of charge are called **positive** and **negative charges.** The definition of negative charge is as follows:*

Negative charge is the type of charge acquired by a plastic comb that has been passed through hair a few times.

22.9 Does the B strip you created in Checkpoint 22.8 carry a positive charge or a negative charge?

When two neutral objects touch, some charge can be transferred from one object to the other, with the result that one object ends up with a surplus of one type of charge and the other object ends up with an equal surplus of the other type of charge. For example, when a neutral piece of styrofoam is rubbed with a neutral piece of plastic wrap, the styrofoam acquires a positive charge (meaning it contains more positive than negative charge) and the plastic wrap acquires a negative charge (it has a surplus of negative charge). Without further information, however, we cannot tell whether positive charge has been transferred from the wrap to the styrofoam, or negative charge has been transferred from the styrofoam to the plastic wrap, or a combination of these two. (See Figure 22.7 on the next page.) Summarizing:

All neutral matter contains equal amounts of positive and negative charge; charged objects contain unequal amounts of positive and negative charge.

In illustrations, surplus charge is represented by plus or minus signs. Keep in mind, however, that these signs never represent the only type of charge in an object. The plus signs on the positively charged styrofoam in Figure 22.7, for example, mean only that the styrofoam contains more positive than negative charge, either because some of its negative charge has been removed or because some positive charge has been added. In addition to the 12 positive charge carriers shown in Figure 22.7, the styrofoam contains millions and millions of positive charge carriers paired with millions and millions of negative charge carriers. A drawing such as Figure 22.7, shows only *unpaired* charge carriers (usually referred to as *surplus charge*).

As our observations in Figure 22.6 show, oppositely charged B and T strips attract each other. The interaction between positive and negative charge tends to bring positive and negative charge carriers as close together as possible. Because combining equal amounts of positive and negative charge results in zero charge, we can say that charge carriers always tend to arrange themselves in such a way as to produce uncharged objects—indeed, all matter around us tends to be neutral.

CONCEPTS

*Historically, negative charge was (arbitrarily) defined by Benjamin Franklin (1706–1790) as the charge acquired by a rubber rod rubbed with cat fur. Because plastic combs and hair are more easily accessible than rubber rods and cat fur, the definition of negative charge given here is more convenient.

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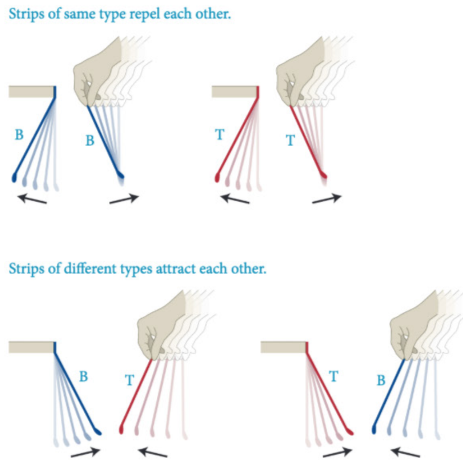
social interaction

Figure 22.6 Interactions of B and T charged strips.



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highlighting text…

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CONCEPTS

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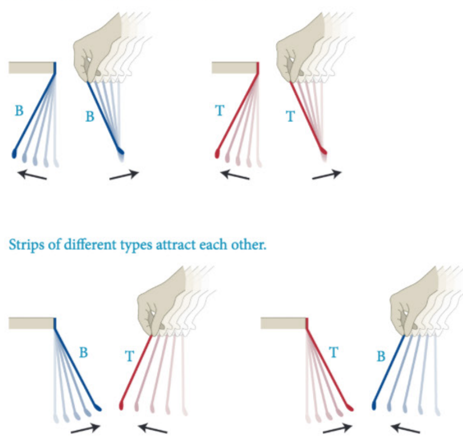
social interaction

Figure 22.6 Interactions of B and T charged strips.

Strips of same type repel each other.



Strips of different types attract each other.

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…opens chat window

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CONCEPTS

Enter your comment or question and press Enter

social interaction

Electricity is a familiar term—outlets, batteries, light bulbs, computers all involve electricity. It is no understatement to say that modern life depends on electricity, but what exactly *is* electricity? We all know what electricity does, but it's not that easy to explain what electricity *is*.

Electricity manifests itself in many ways: from the sparks that fly when you scuff your feet across a carpet on a dry winter day to the electricity we use in our homes to the transmission of radio and television programs. Even the attraction between magnets has to do with electricity. In this chapter, we begin our treatment of electricity with a discussion of static electricity.

22.1 Static electricity

When you tear off some plastic wrap from its roll, the wrap is attracted to anything that gets close: your hand, the countertop, a dish. This interaction between the plastic wrap and other objects doesn't have to involve any physical contact. For example, you can feel the presence of a piece of freshly torn-off plastic wrap with your cheek or the back of your hand even when your face or hand is held some distance away from the piece. You may have experienced many similar interactions: Styrofoam peanuts are attracted to your arms when you unpack a box full of them (Figure 22.1). Running a comb through your hair on a dry day causes the comb to attract your hair. After rubbing a balloon against a woolen sweater, you can hold the balloon close to a wall and *see* the attraction as the balloon moves toward the wall. In all these instances, the mass of the objects is too small for the interactions to be gravitational. What, then, is this interaction?

You may never have thought of these interactions as being particularly strong, but consider this: If you rub a comb through your hair and then pass the comb over some small bits of paper, the bits of paper jump up to your comb and stick to it. In other words, the bits of paper accelerate upward, which means the force exerted by your comb on them must be *greater* than the gravitational force exerted on them by Earth!

Now try this: Quickly pull a 20-cm strip of transparent tape* out of a dispenser and suspend it from the edge of a table (just be sure the table is not metal). Notice how the tape is attracted to anything brought nearby. It might even take some practice to prevent the tape from curling up and sticking to the underside of the table or to your hand. Bring a few objects near the suspended tape and notice the attractive interaction between them.† Go ahead—experiment!

CONCEPTS

Figure 22.1 Styrofoam peanuts cling to the cat's fur because of static electricity.

22.1 Suspend a freshly pulled piece of transparent tape from the edge of your desk. (*a*) What happens when you hold a battery near the tape? Does it matter whether you point the + side or the − side of the battery toward the tape? Does a spent battery yield a different result? Does a wooden object yield a different result? (*b*) What happens when you hold a strip of freshly pulled tape near the power cord of a lamp? Does it make any difference if the lamp is on or off?

All these interactions involving static electricity are examples of **electric interactions.** The experiment you just did tells you there is no obvious connection between electric interactions and the electricity we think of as "flowing" in electric circuits and batteries. In Chapter 31 we shall see, however, that the two are connected.

Objects that participate in electric interactions exert an **electric force** on each other. The electric force is a field force (see Section 8.3): Objects exerting electric forces on each other need not be physically touching. As you may have noticed from the interaction between the strips of tape and various nearby objects, the magnitude of the electric force depends on distance: It decreases as you increase the separation.

22.2 Suspend a freshly pulled strip of transparent tape from the edge of your desk. (*a*) Pull a second strip of tape out of the dispenser and hold it near the first strip. What do you notice? (*b*) Does it matter which sides of the strips you orient toward each other?

As Checkpoint 22.2 makes clear, not all electric interactions are attractive. Even if you increase the mass of the strips by suspending paper clips from them, the repulsion between the strips is great enough to keep the paper clips apart (Figure 22.2). Now place your hand between two repelling strips and notice how both strips fly toward your hand! Then run each strip of tape several times between your fingers and notice how the electric interaction diminishes or even disappears.

22.3 Suspend two freshly pulled 20-cm strips of transparent tape from the edge of your desk. Cut two 20-cm strips of paper, making each strip the same width as the tape, and investigate the interactions between the paper strips and the tape by bringing them near each other. Which of the following combinations display an electric interaction: paper-paper, tape-paper, tape-tape?

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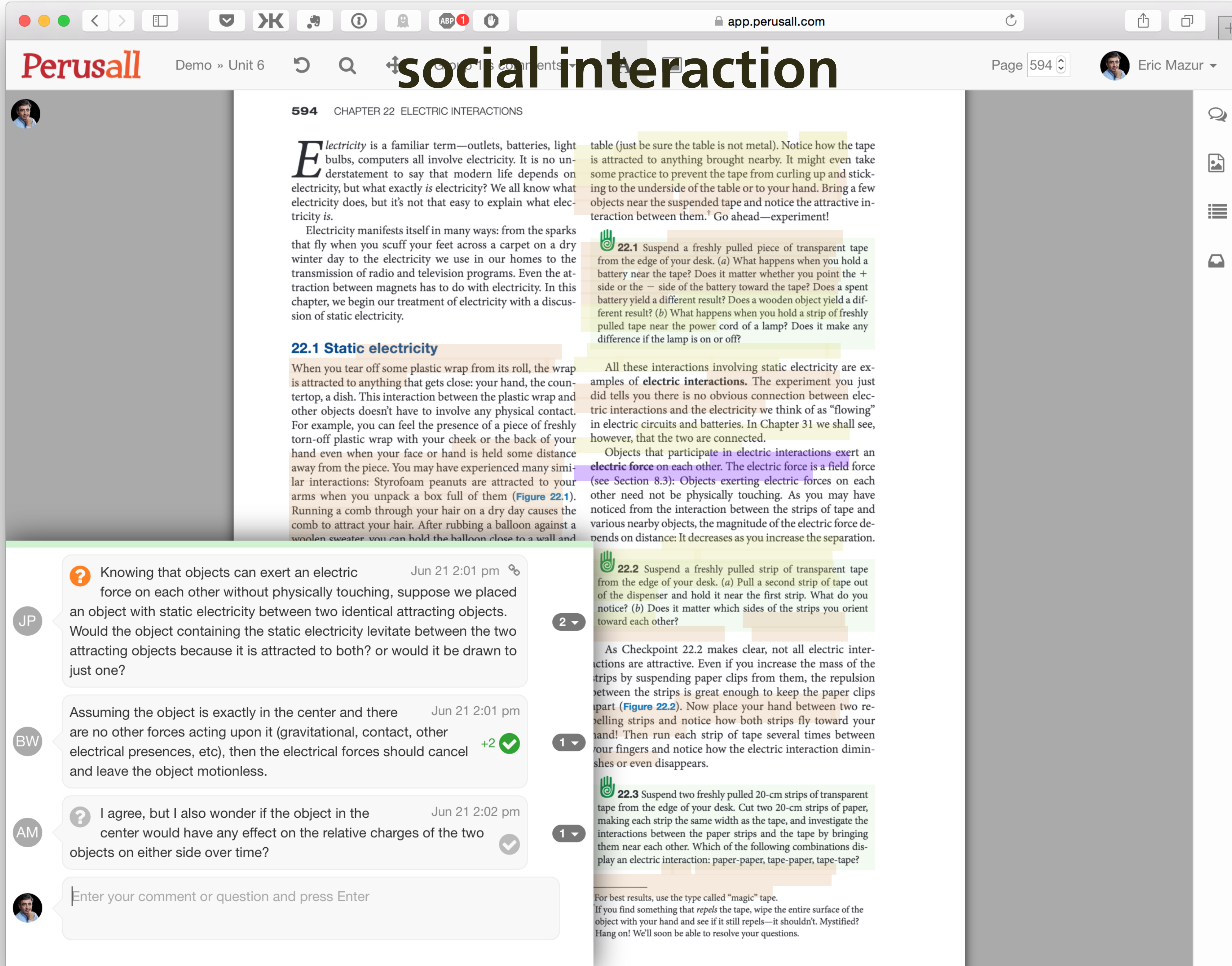
social interaction



594 CHAPTER 22 ELECTRIC INTERACTIONS

Electricity is a familiar term—outlets, batteries, light bulbs, computers all involve electricity. It is no understatement to say that modern life depends on electricity, but what exactly *is* electricity? We all know what electricity does, but it's not that easy to explain what electricity *is*.

Electricity manifests itself in many ways: from the sparks that fly when you scuff your feet across a carpet on a dry winter day to the electricity we use in our homes to the transmission of radio and television programs. Even the attraction between magnets has to do with electricity. In this chapter, we begin our treatment of electricity with a discussion of static electricity.

22.1 Static electricity

When you tear off some plastic wrap from its roll, the wrap is attracted to anything that gets close: your hand, the countertop, a dish. This interaction between the plastic wrap and other objects doesn't have to involve any physical contact. For example, you can feel the presence of a piece of freshly torn-off plastic wrap with your cheek or the back of your hand even when your face or hand is held some distance away from the piece. You may have experienced many similar interactions: Styrofoam peanuts are attracted to your arms when you unpack a box full of them (Figure 22.1). Running a comb through your hair on a dry day causes the comb to attract your hair. After rubbing a balloon against a woolen sweater, you can hold the balloon close to a wall and

table (just be sure the table is not metal). Notice how the tape is attracted to anything brought nearby. It might even take some practice to prevent the tape from curling up and sticking to the underside of the table or to your hand. Bring a few objects near the suspended tape and notice the attractive interaction between them.† Go ahead—experiment!

22.1 Suspend a freshly pulled piece of transparent tape from the edge of your desk. (*a*) What happens when you hold a battery near the tape? Does it matter whether you point the + side or the − side of the battery toward the tape? Does a spent battery yield a different result? Does a wooden object yield a different result? (*b*) What happens when you hold a strip of freshly pulled tape near the power cord of a lamp? Does it make any difference if the lamp is on or off?

All these interactions involving static electricity are examples of **electric interactions.** The experiment you just did tells you there is no obvious connection between electric interactions and the electricity we think of as "flowing" in electric circuits and batteries. In Chapter 31 we shall see, however, that the two are connected.

Objects that participate in electric interactions exert an **electric force** on each other. The electric force is a field force (see Section 8.3): Objects exerting electric forces on each other need not be physically touching. As you may have noticed from the interaction between the strips of tape and various nearby objects, the magnitude of the electric force depends on distance: It decreases as you increase the separation.

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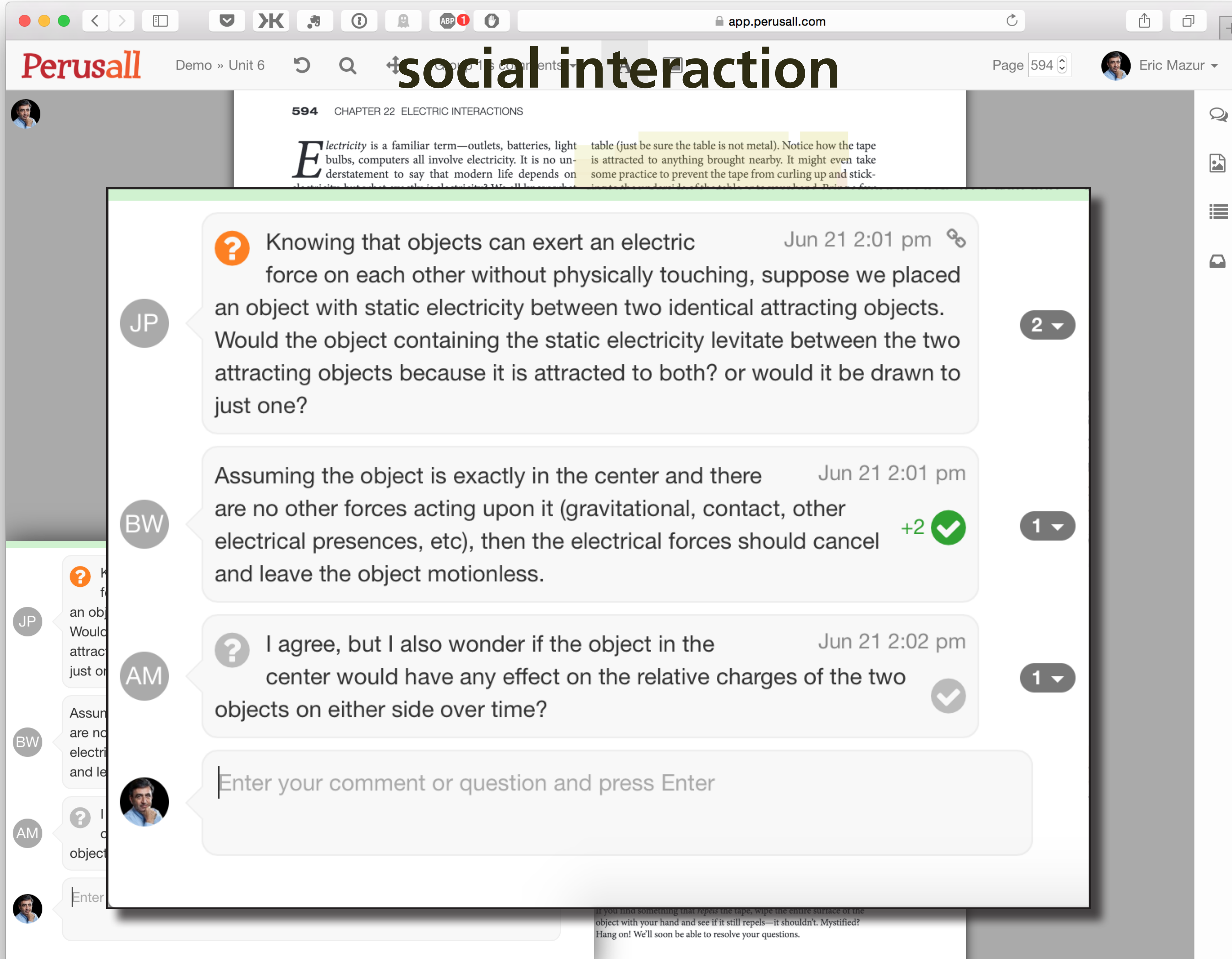
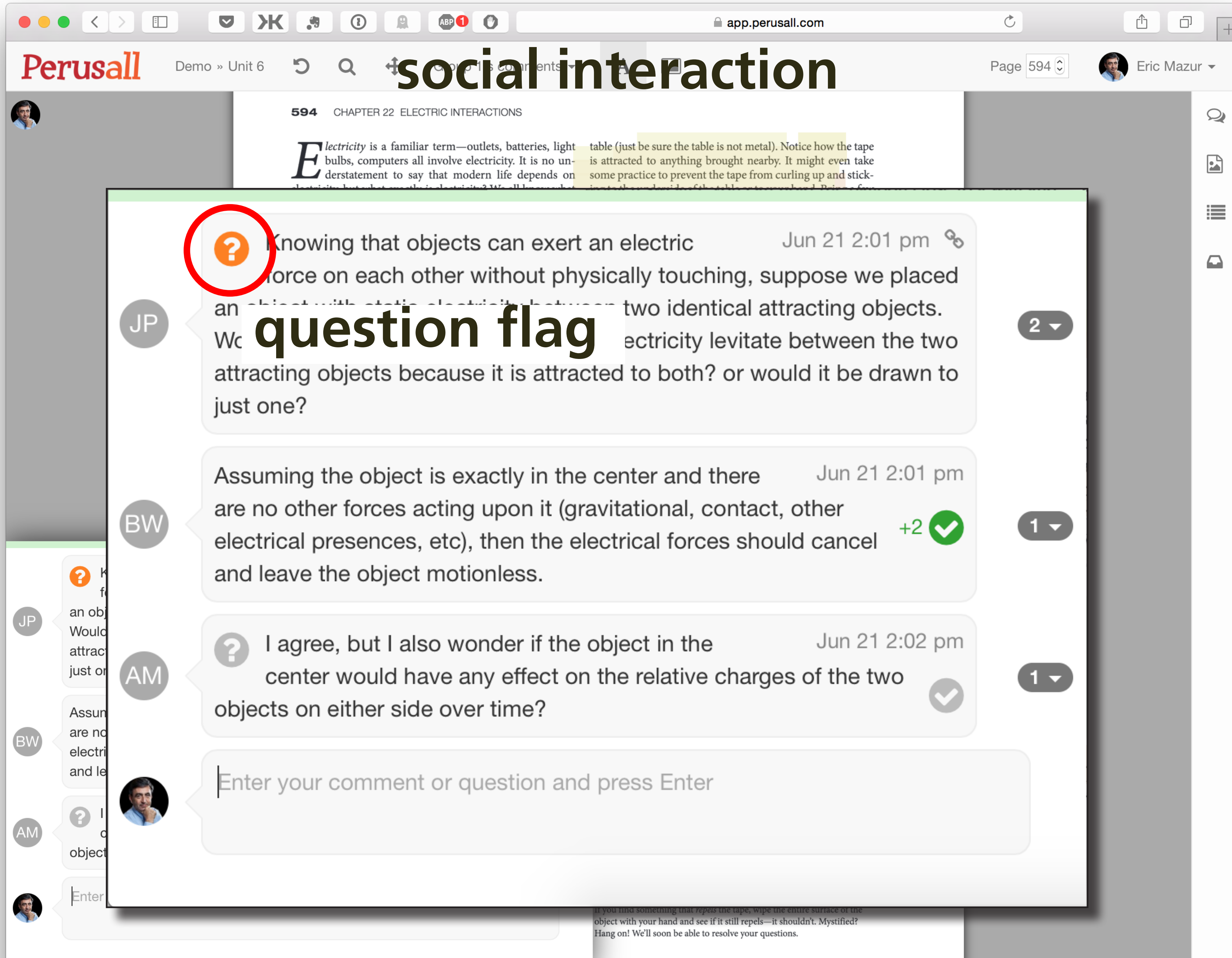
social interaction





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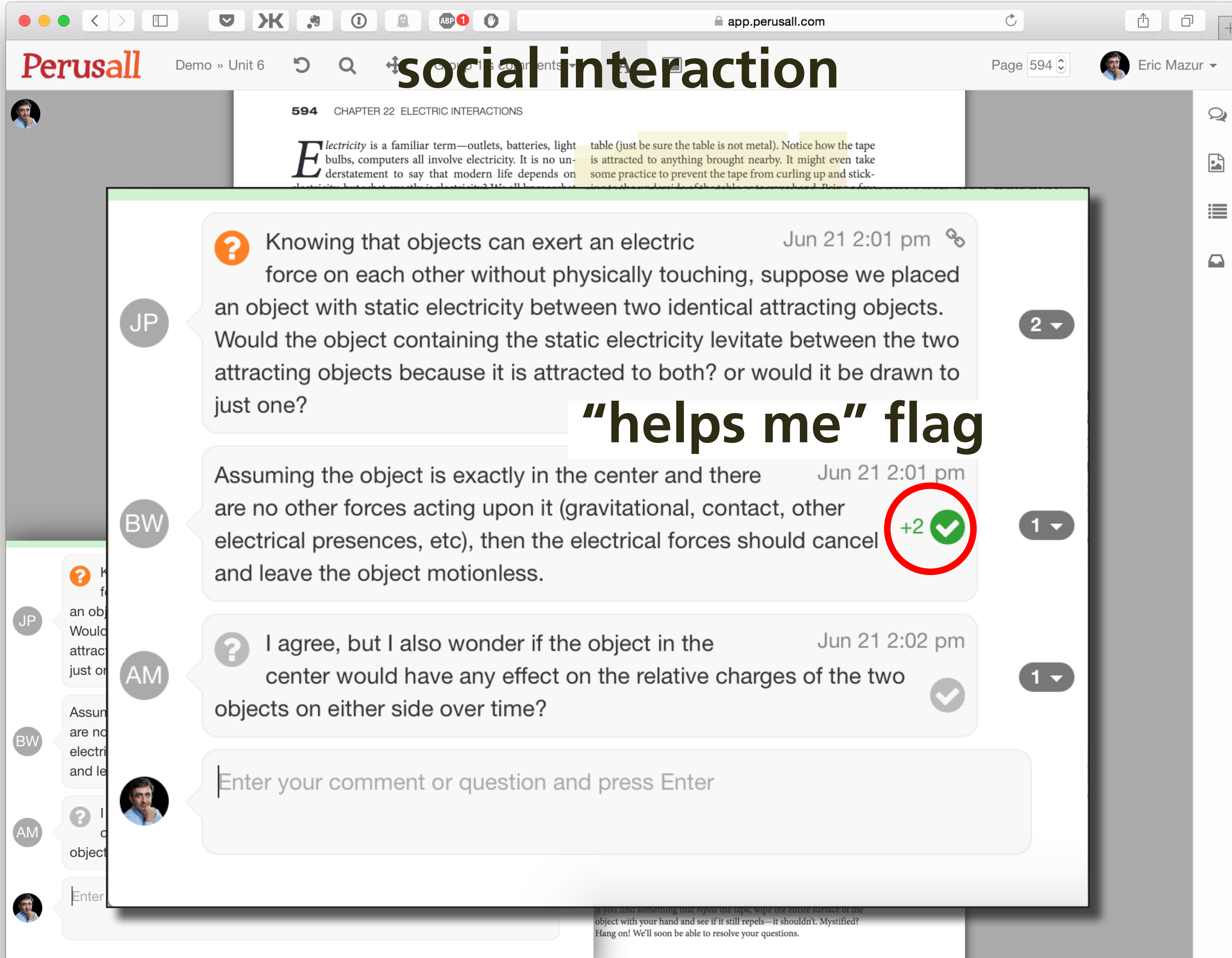
Eric Mazur
594 CHAPTER 22 ELECTRIC INTERACTIONS
Knowing that objects can exert an electric force on each other without physically touching, suppose we placed an object with static electricity between two identical attracting objects. Would the object with static electricity levitate between the two attracting objects because it is attracted to both? or would it be drawn to just one?
Jun 21 2:01 pm
JP
2
Assuming the object is exactly in the center and there are no other forces acting upon it (gravitational, contact, other electrical presences, etc), then the electrical forces should cancel and leave the object motionless.
Jun 21 2:01 pm
+2
BW
1
I agree, but I also wonder if the object in the center would have any effect on the relative charges of the two objects on either side over time?
Jun 21 2:02 pm
AM
1
Enter your comment or question and press Enter



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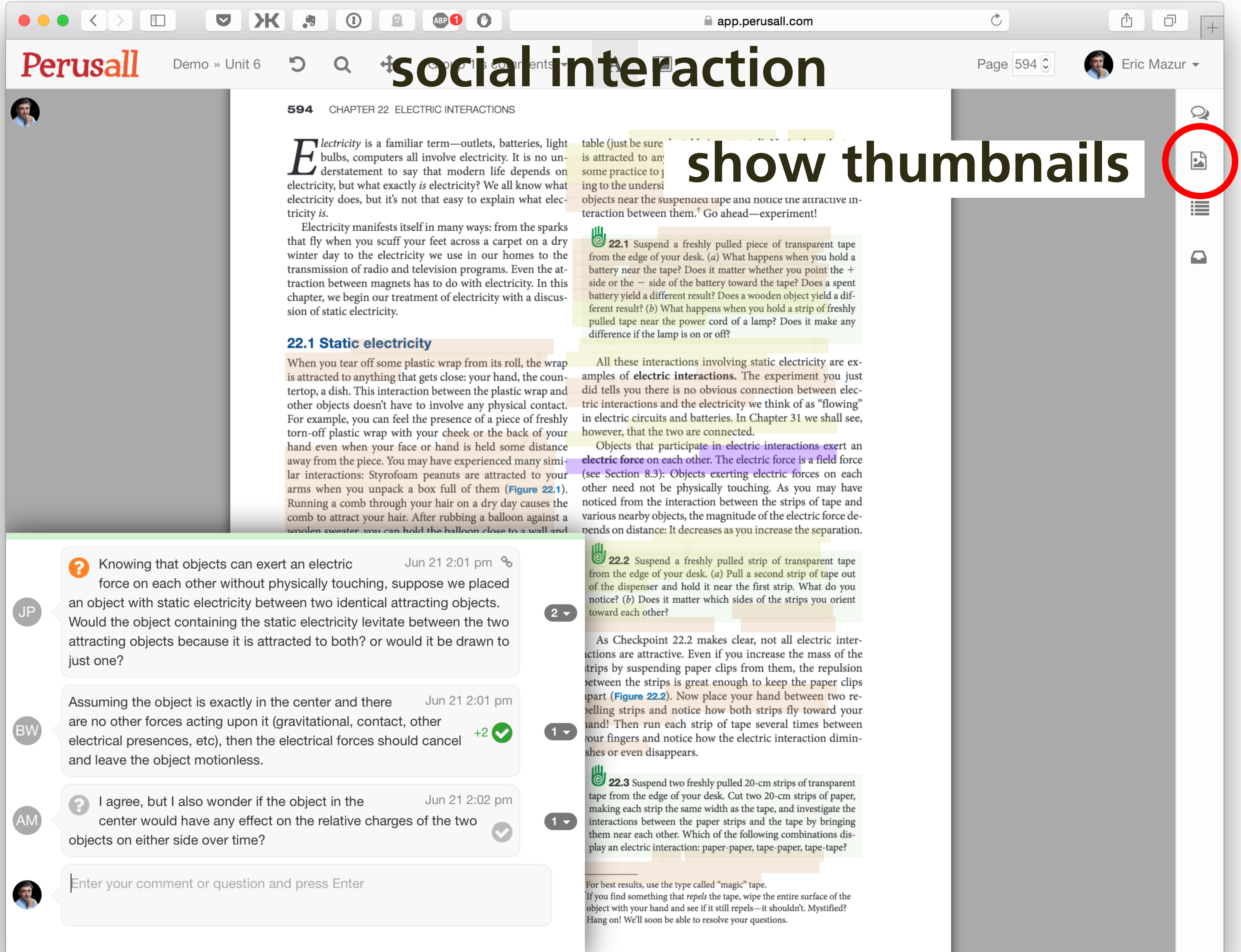

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Eric Mazur
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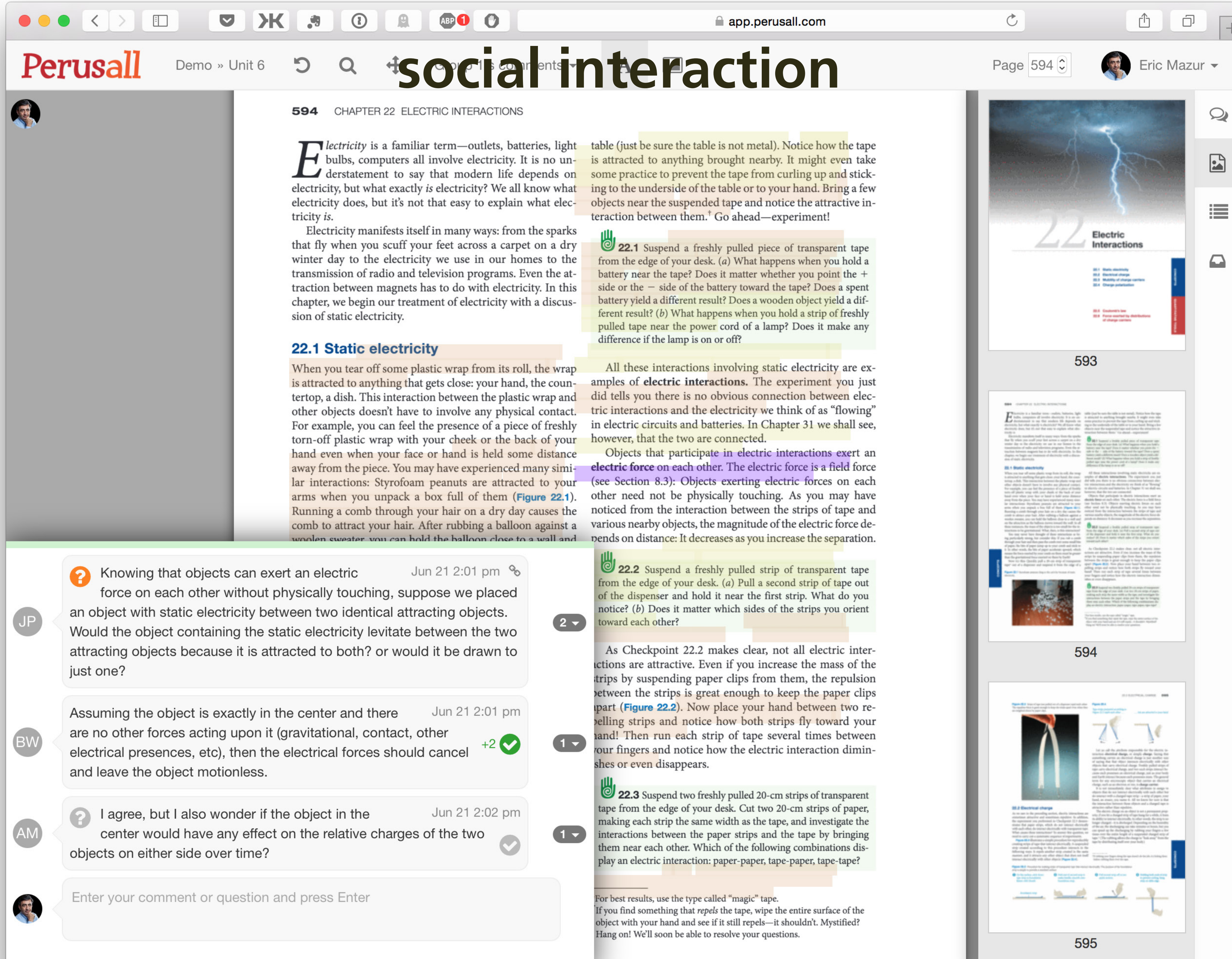
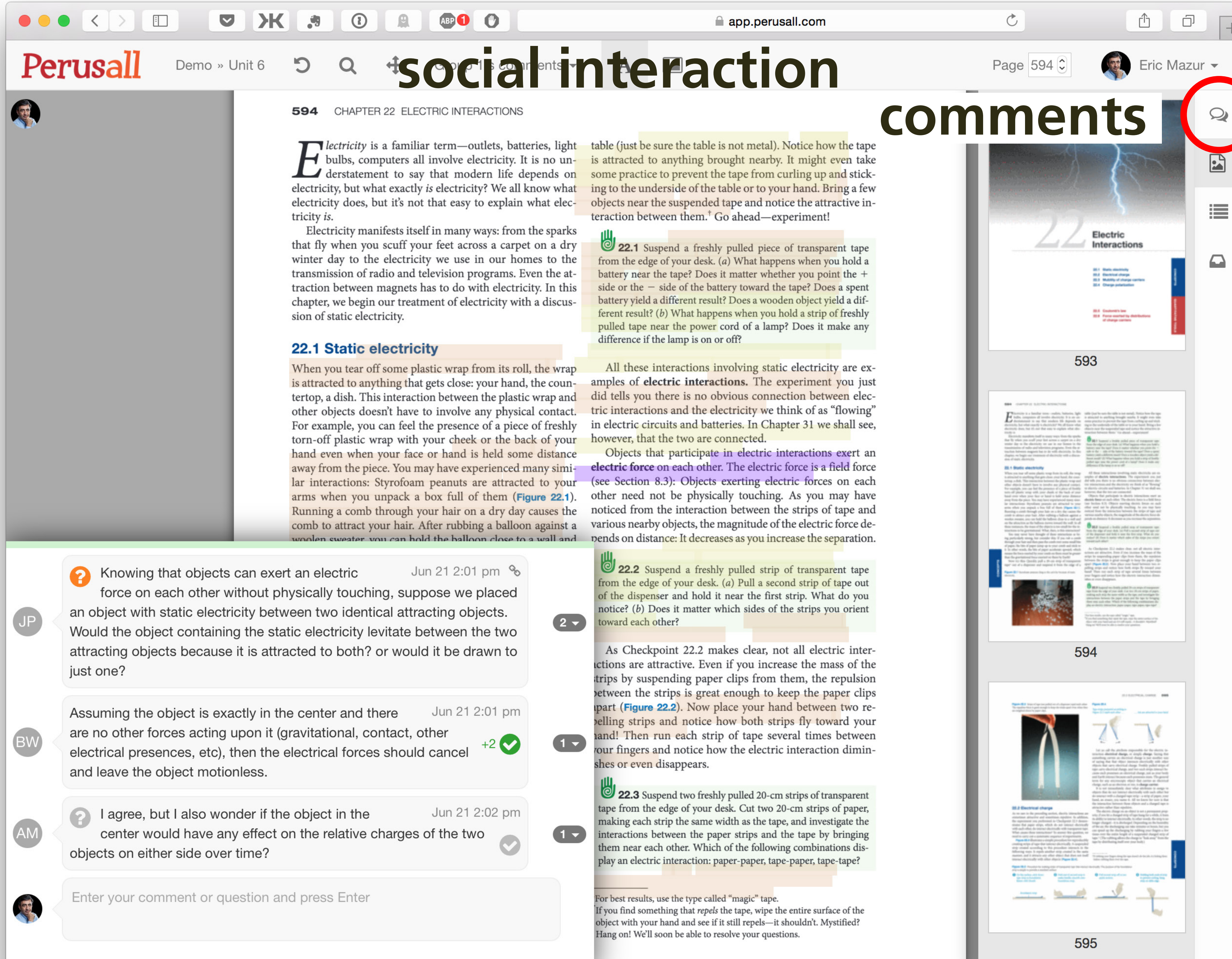
Jun 21 2:02 pm
1
Enter your comment or question and press Enter

social interaction



social interaction



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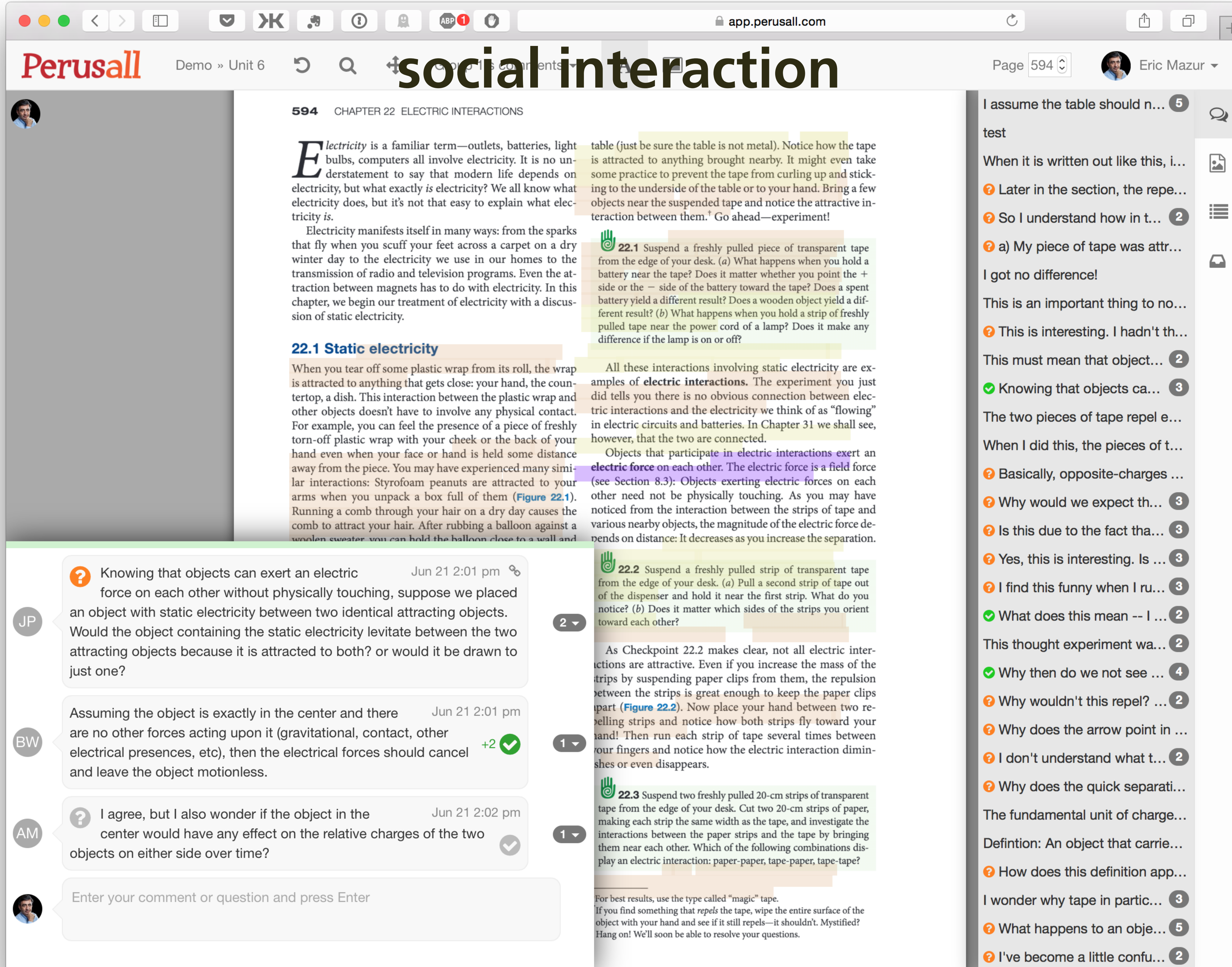

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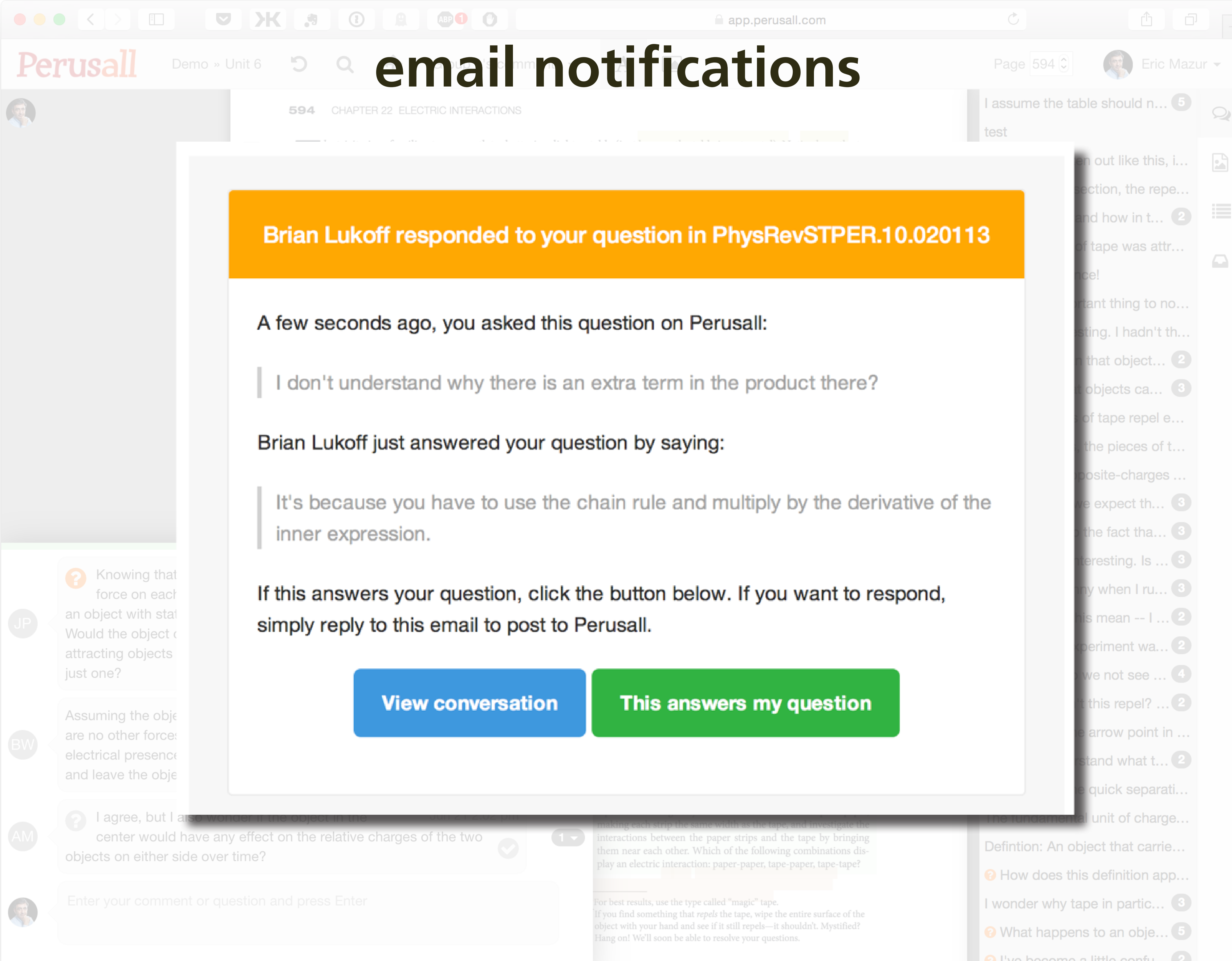

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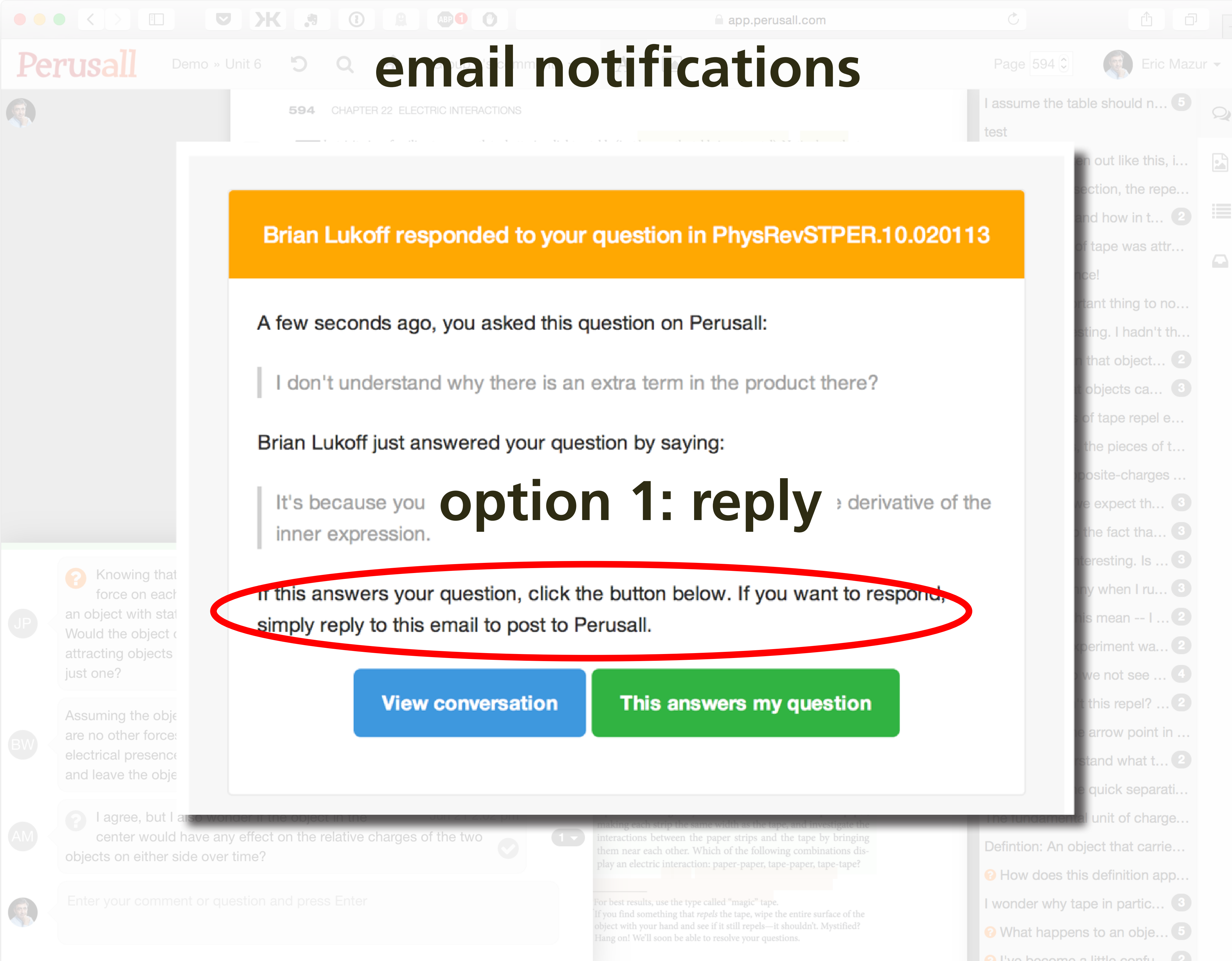
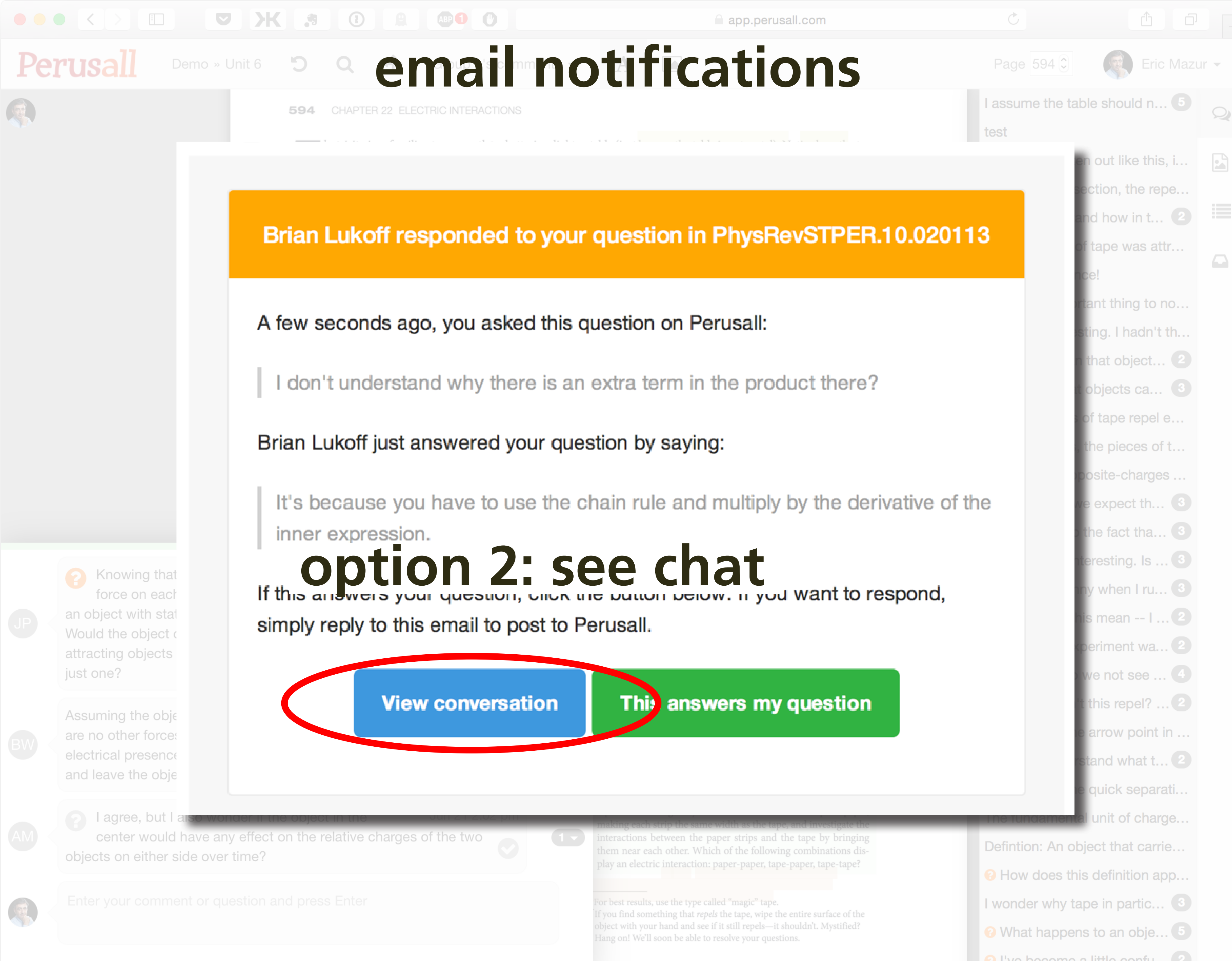


option 1: reply



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Brian Lukoff responded to your question in PhysRevSTPER.10.020113
A few seconds ago, you asked this question on Perusall:
I don't understand why there is an extra term in the product there?
Brian Lukoff just answered your question by saying:
It's because you have to use the chain rule and multiply by the derivative of the inner expression.
option 2: see chat
If this answers your question, click the button below. If you want to respond, simply reply to this email to post to Perusall.
View conversation
This answers my question
Enter your comment or question and press Enter
I assume the table should n…
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Defintion: An object that carrie…
How does this definition app…
I wonder why tape in partic…
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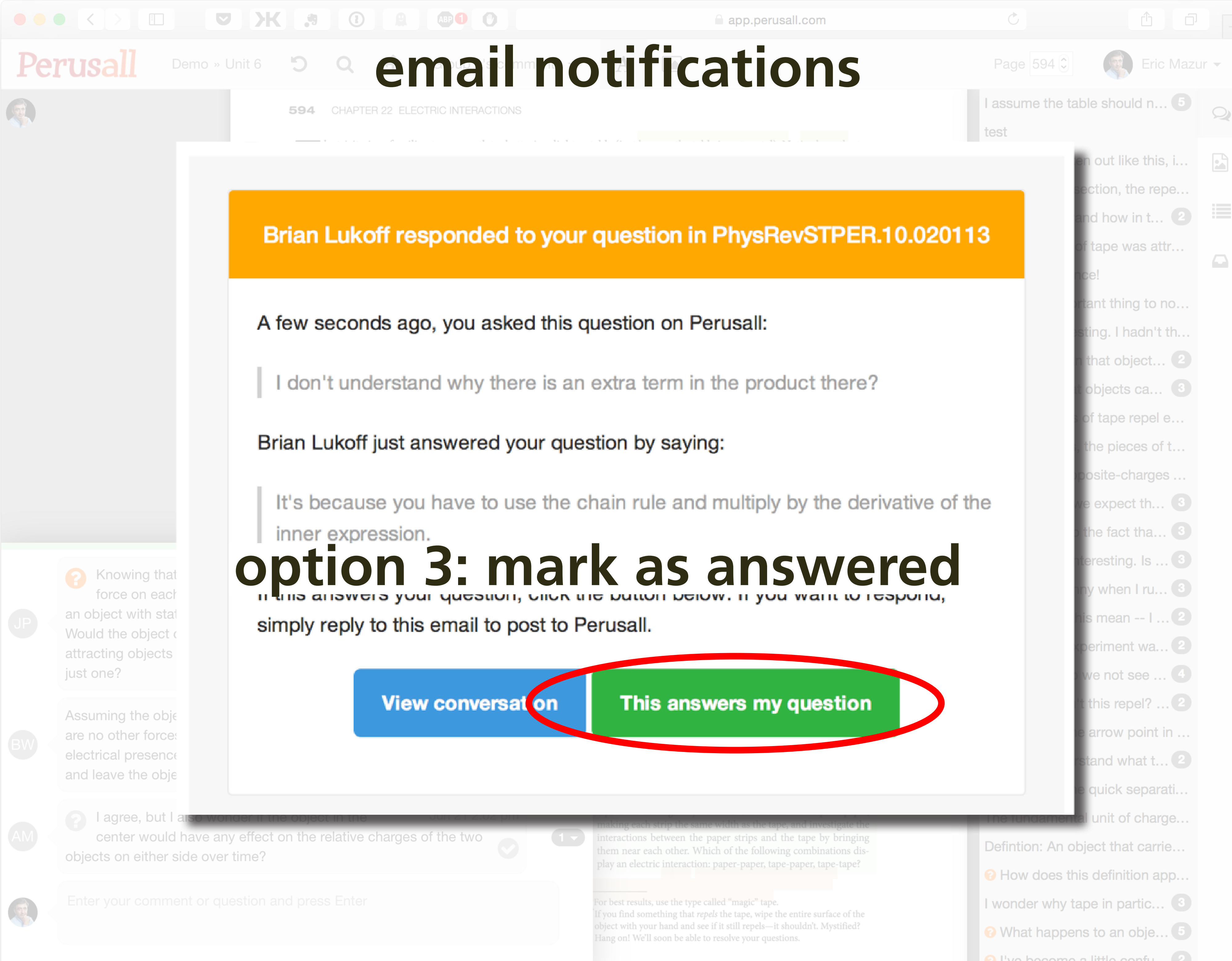
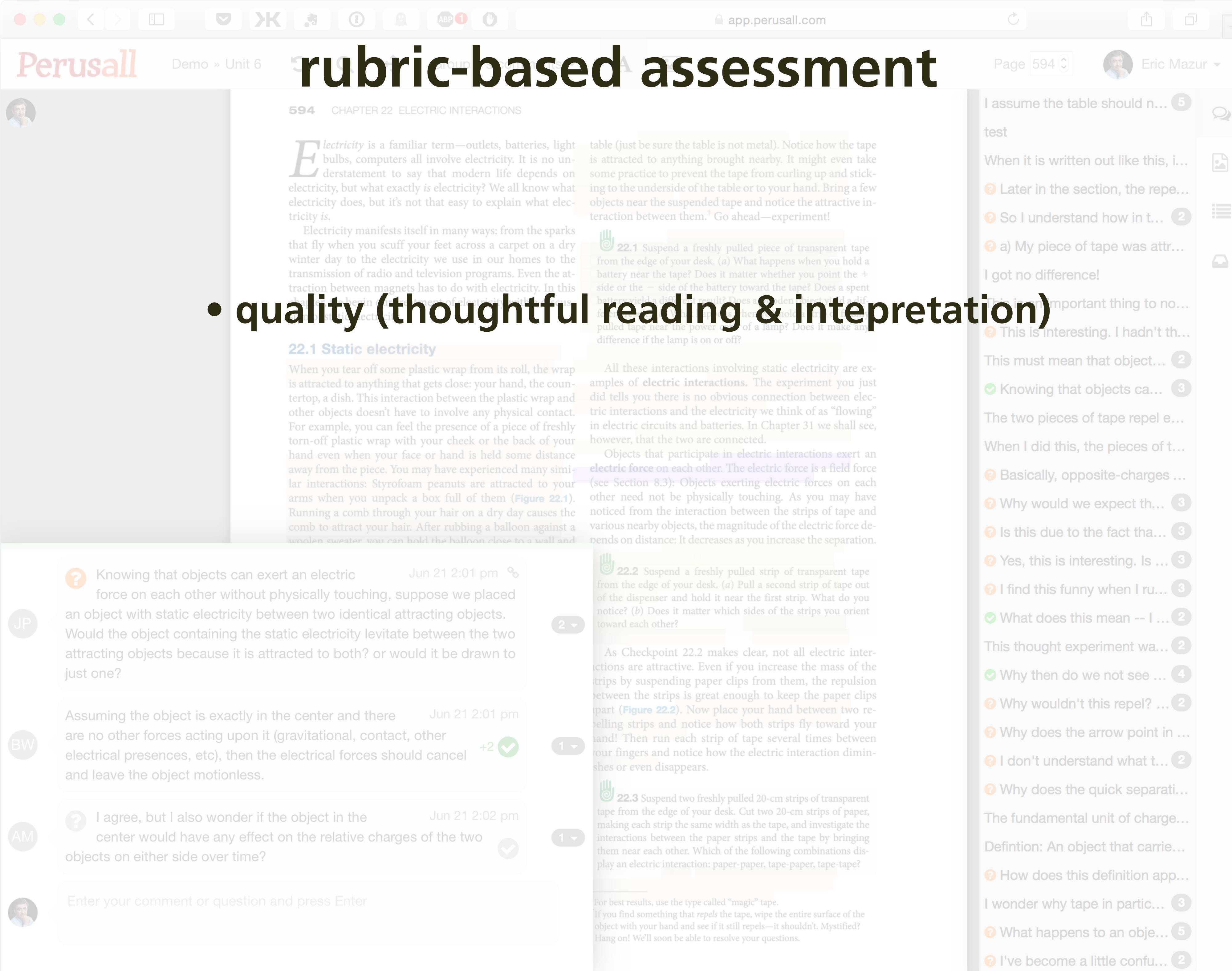


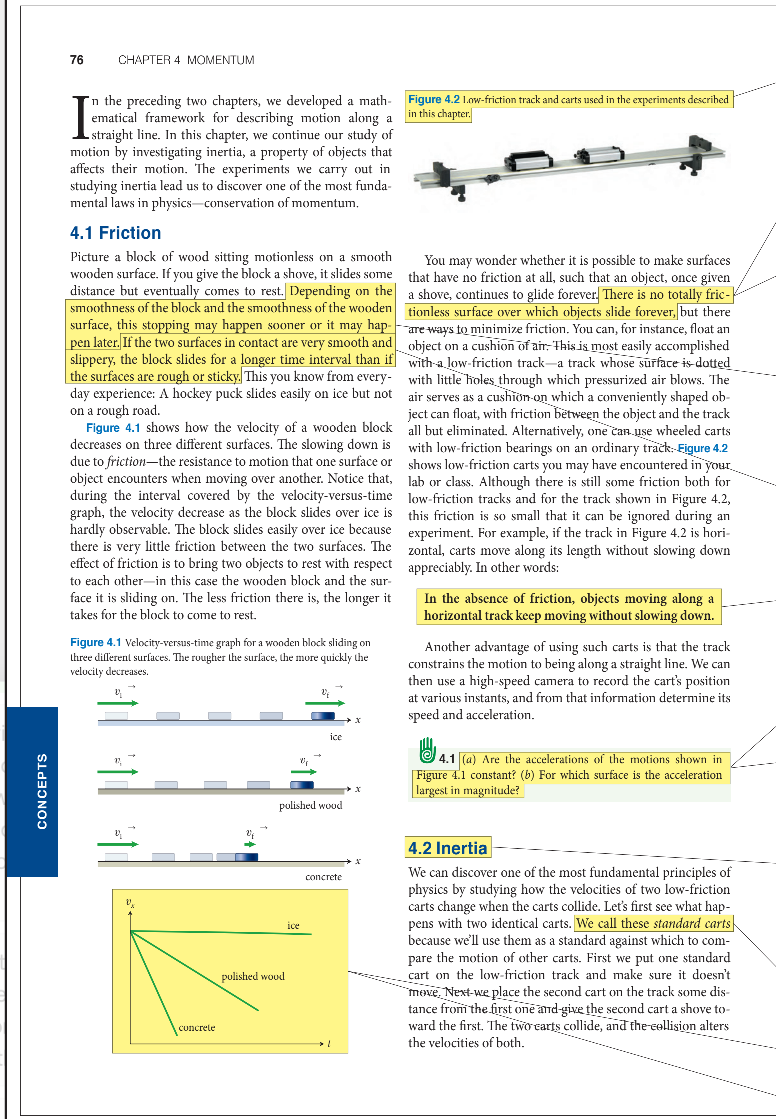
option 3: mark as answered

rubric-based assessment

- quality (thoughtful reading & intepretation)



rubric-based assessment



In the preceding two chapters, we developed a mathematical framework for describing motion along a straight line. In this chapter, we continue our study of motion by investigating inertia, a property of objects that affects their motion. The experiments we carry out in studying inertia lead us to discover one of the most fundamental laws in physics—conservation of momentum.

4.1 Friction

Picture a block of wood sitting motionless on a smooth wooden surface. If you give the block a shove, it slides some distance but eventually comes to rest. Depending on the smoothness of the block and the smoothness of the wooden surface, this stopping may happen sooner or it may happen later. If the two surfaces in contact are very smooth and slippery, the block slides for a longer time interval than if the surfaces are rough or sticky. This you know from everyday experience: A hockey puck slides easily on ice but not on a rough road.

Figure 4.1 shows how the velocity of a wooden block decreases on three different surfaces. The slowing down is due to *friction*—the resistance to motion that one surface or object encounters when moving over another. Notice that, during the interval covered by the velocity-versus-time graph, the velocity decrease as the block slides over ice is hardly observable. The block slides easily over ice because there is very little friction between the two surfaces. The effect of friction is to bring two objects to rest with respect to each other—in this case the wooden block and the surface it is sliding on. The less friction there is, the longer it takes for the block to come to rest.

Figure 4.1 Velocity-versus-time graph for a wooden block sliding on three different surfaces. The rougher the surface, the more quickly the velocity decreases.

Figure 4.2 Low-friction track and carts used in the experiments described in this chapter.

You may wonder whether it is possible to make surfaces that have no friction at all, such that an object, once given a shove, continues to glide forever. There is no totally frictionless surface over which objects slide forever, but there are ways to minimize friction. You can, for instance, float an object on a cushion of air. This is most easily accomplished with a low-friction track—a track whose surface is dotted with little holes through which pressurized air blows. The air serves as a cushion on which a conveniently shaped object can float, with friction between the object and the track all but eliminated. Alternatively, one can use wheeled carts with low-friction bearings on an ordinary track. Figure 4.2 shows low-friction carts you may have encountered in your lab or class. Although there is still some friction both for low-friction tracks and for the track shown in Figure 4.2, this friction is so small that it can be ignored during an experiment. For example, if the track in Figure 4.2 is horizontal, carts move along its length without slowing down appreciably. In other words:

In the absence of friction, objects moving along a horizontal track keep moving without slowing down.

Another advantage of using such carts is that the track constrains the motion to being along a straight line. We can then use a high-speed camera to record the cart's position at various instants, and from that information determine its speed and acceleration.

4.1 (*a*) Are the accelerations of the motions shown in Figure 4.1 constant? (*b*) For which surface is the acceleration largest in magnitude?

4.2 Inertia

We can discover one of the most fundamental principles of physics by studying how the velocities of two low-friction carts change when the carts collide. Let's first see what happens with two identical carts. We call these *standard carts* because we'll use them as a standard against which to compare the motion of other carts. First we put one standard cart on the low-friction track and make sure it doesn't move. Next we place the second cart on the track some distance from the first one and give the second cart a shove toward the first. The two carts collide, and the collision alters the velocities of both.

ANNOTATION	EVALUATION	
Alan: I remember, in high school, being amazed at how quickly carts could travel on these tracks - air would blow up through these tiny holes evenly distributed along the length of the track and the cart would essentially float on the air and consequently - the cart would move very quickly with the slightest push.	No substance. Does not demonstrate any thoughtful interpretation of the text.	0
Bob: Although there is no way to create frictionless surfaces, I find it interesting that we consider experiments "in the absence of friction." In a way, this relates back to Chapter 1.5 where we talked about the importance of having too little or too much information in our representations. In some cases, the friction is so insignificant that we ignore it (simplifying our representation).	Annotation interprets the text and demonstrates understanding of concepts through analogy and synthesis of multiple concepts.	2
Claire: Does this only apply to solid surfaces? I feel as if a substance that floats on water either has negligible or very little friction.	Possibly insightful question but does not elaborate on thought process, nor demonstrate thoughtful reading of the text.	1
Alan: Why is this? I don't get it.	Question does not explicitly identify point of confusion nor demonstrates thoughtful reading or interpretation of the text.	0
David: believe this applies to almost every surface, although I'm not sure if water would count more as resistance than friction. Anyways, the best example I could think of would be a surf board. If people who were paddling in the same direction as the waves experienced no resistance, they would continually speed up, and eventually reach very high speeds. However, in reality if they were two stop paddling they'd slow down and only the waves would slowly push them to shore.	Response demonstrates a thoughtful explanation with a claim substantiated with a concrete example	2
Alan: Is it possible to have a surface, in real life, that inflicts NO friction at all?	Question exhibits superficial reading, but does not exhibit any interpretation of the textbook.	1
Erica: Doesn't air resistance factor into this at all? It seems that it is not enough for there to be only an absense of friction for something to keep moving without slowing down. What about some other opposing force - like air resistance? Or is air resistance just another example of friction?	Demonstrates thoughtful interpretation of the text by refuting a statement through a counter example.	2
Bob: The key word is "appreciably". In the absense of friction, the cart does not slow down appreciably but still would a little due to air resistance	Responds to the question by thoughtfully interpreting the text	2
Alan: a) yes b) concrete has the acceleration of greatest magnitude	Annotation not backed up by any reasoning or theoretical assumptions. No evidence of thoughtful reading of text.	0
Erica: I would think that they are not constant because if we think of the formula F=ma, the force of friction is different in every case so that would change the acceleration value (where mass would stay the same since it's assumed that th object is the same in each situation).	Response backed up with reasoning that demonstrates an interpretation of the text and applies understanding of concepts	2
Claire: As a theoretical question about inertia, if an object in motion will stay in motion, but is being affected by friction, will it slow down perpetually but remain in motion, or will it eventually stop completely due to the friction? Just curious.	Profound question that goes beyond the material covered in the textbook.	2
Alan: With friction everything slows down to a half at one point or another. It is only if an outside force acts on the object if that object will maintain motion after the effects of inertia.	Demonstrates some thought but does not really address Claire's question	1
Claire: Standard carts: identical carts in mass, shape, etc. I like this notion of standard carts, it provides a good baseline to compare other motion and to understand the concepts before building on it.	No substance. Does not demonstrate any thoughtful reading.	0
Alan: Great visual representation of friction! It is interesting how this compares the velocity of things on different surfaces	No substance. Does not demonstrate any thoughtful reading.	0
Bob: The rougher the surface, the more friction between the surface and the wooden block, and thus acceleration will be greater.	Interprets the graph and applies understanding of both the concept of friction, how a v-t graph corresponds to acceleration and the relationship between the force of friction and acceleration	2

rubric-based assessment

ANNOTATION	EVALUATION	
Alan: I remember, in high school, being amazed at how quickly carts could travel on these tracks - air would blow up through these tiny holes evenly distributed along the length of the track and the cart would essentially float on the air and consequently - the cart would move very quickly with the slightest push.	No substance. Does not demonstrate any thoughtful interpretation of the text.	0
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Claire: Does this only apply to solid surfaces? I feel as if a substance that floats on water either has negligible or very little friction.	Possibly insightful question but does not elaborate on thought process, nor demonstrate thoughtful reading of the text.	1
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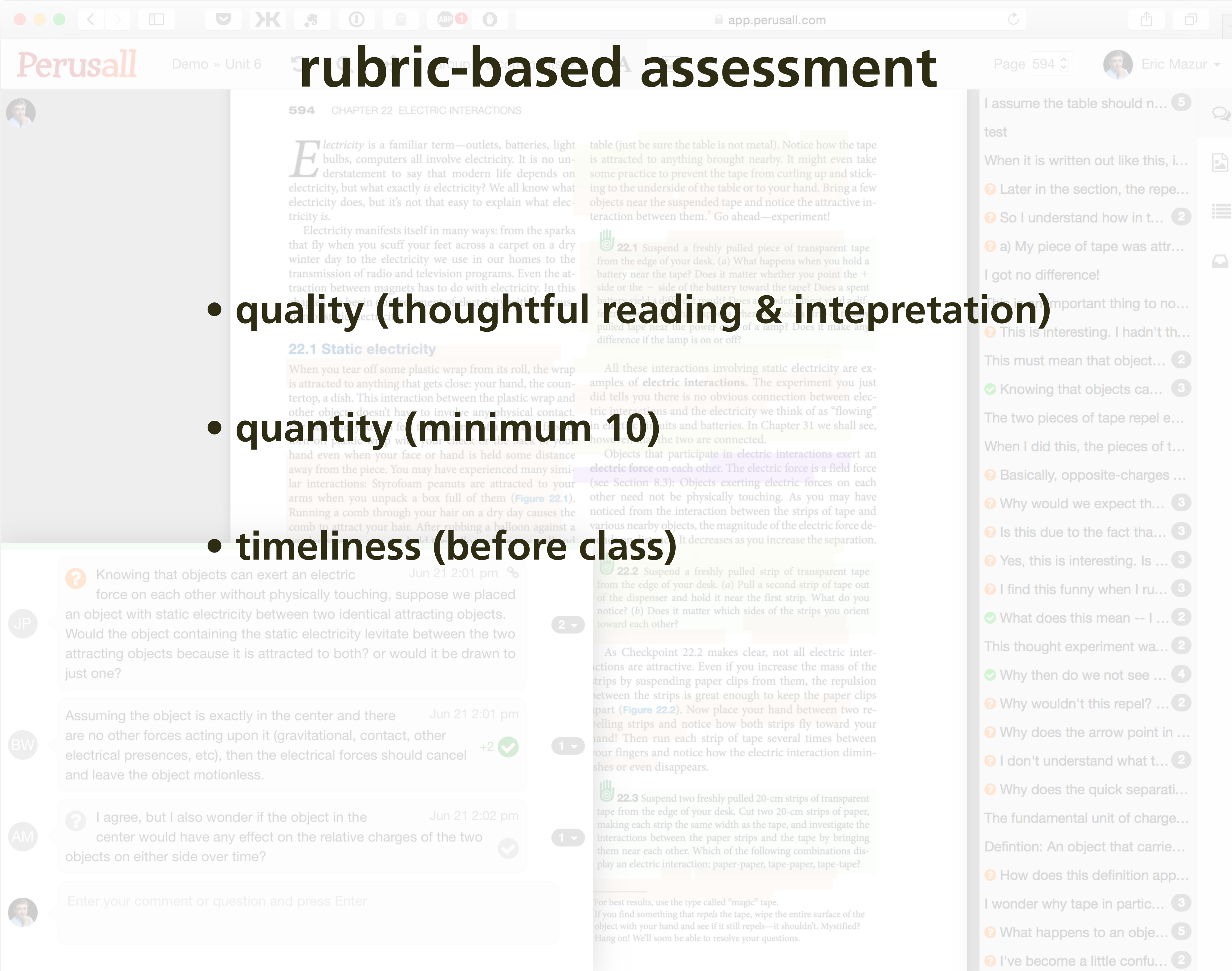
rubric-based assessment

- quality (thoughtful reading & intepretation)
- quantity (minimum 10)

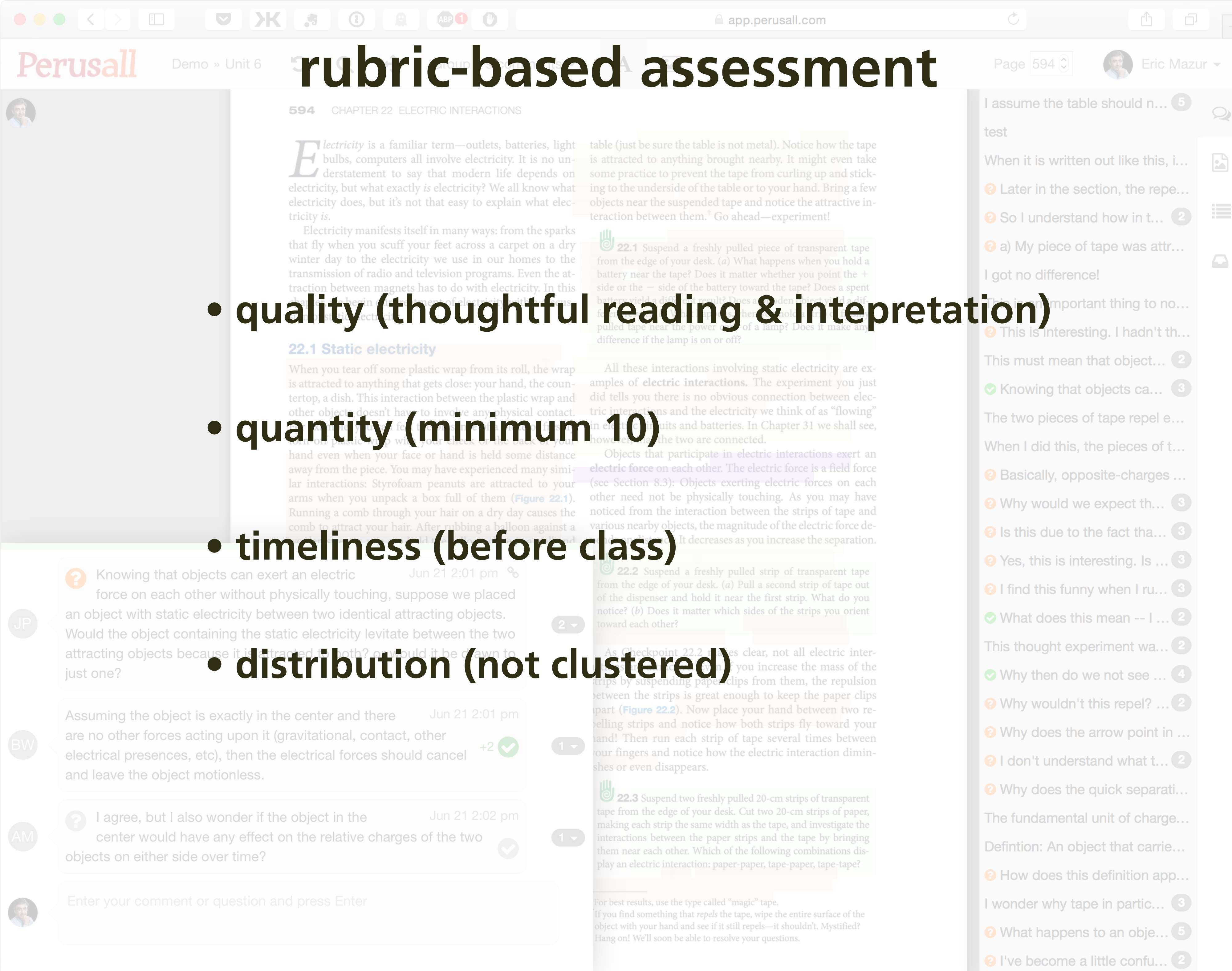
rubric-based assessment

- quality (thoughtful reading & intepretation)
- quantity (minimum 10)
- timeliness (before class)



rubric-based assessment

- quality (thoughtful reading & intepretation)
- quantity (minimum 10)
- timeliness (before class)
- distribution (not clustered)



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over 20,000 annotations!

rubric-based assessment

- quality (thoughtful reading and intepretation)
- quantity (minimum 10)
- timeliness (before class)
- distribution (not clustered)

fully automated assessment

rubric-based assessment

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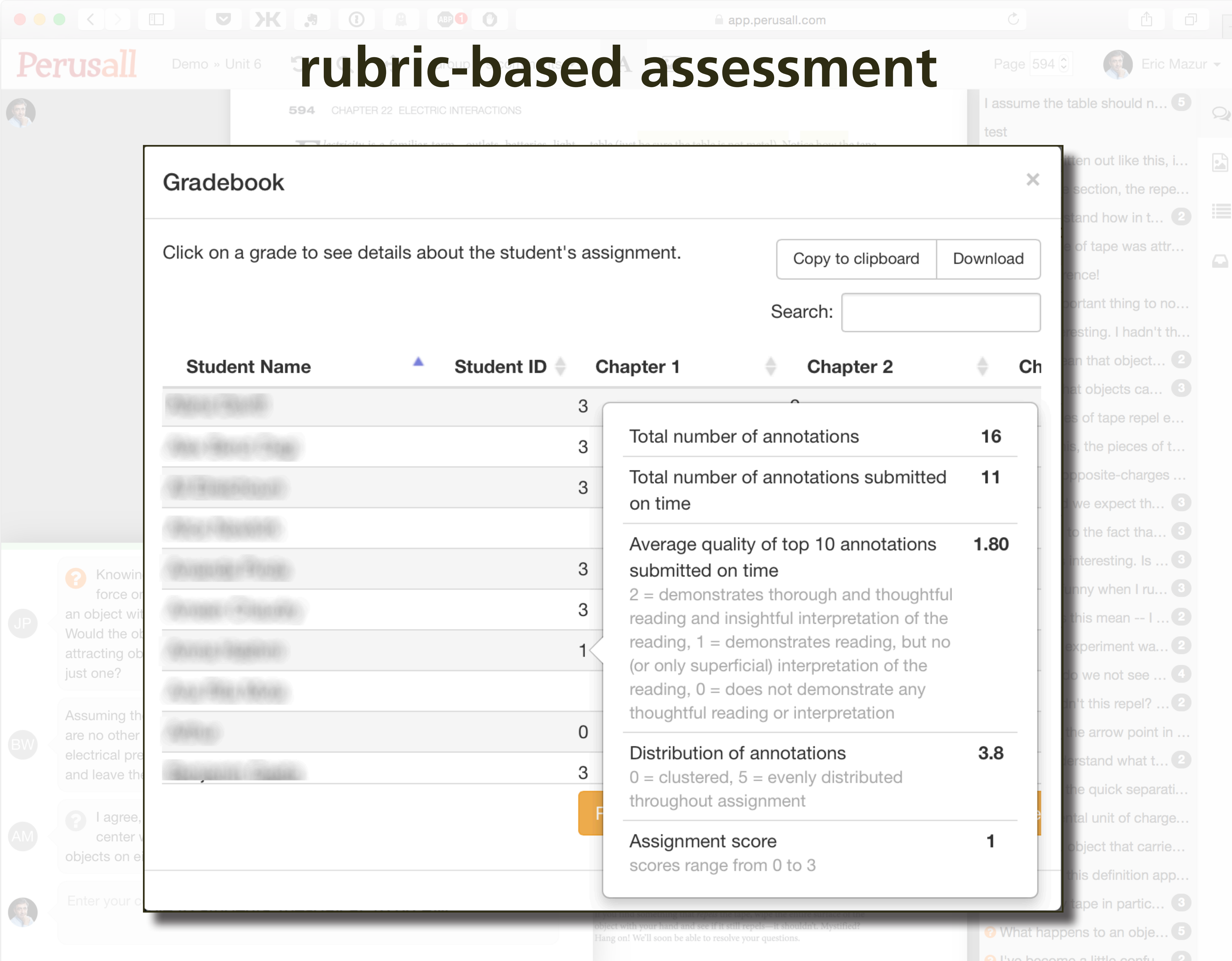
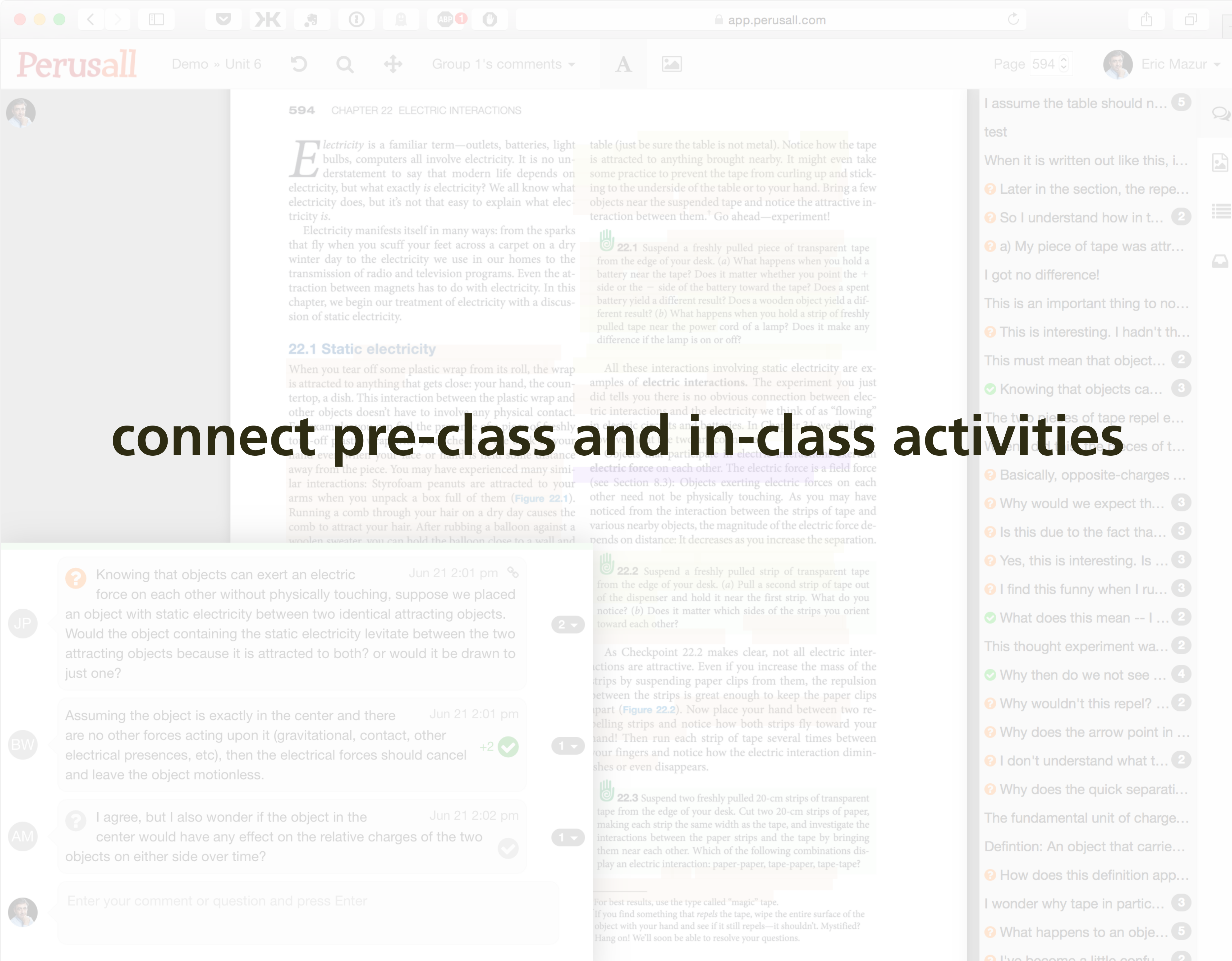


connect pre-class and in-class activities



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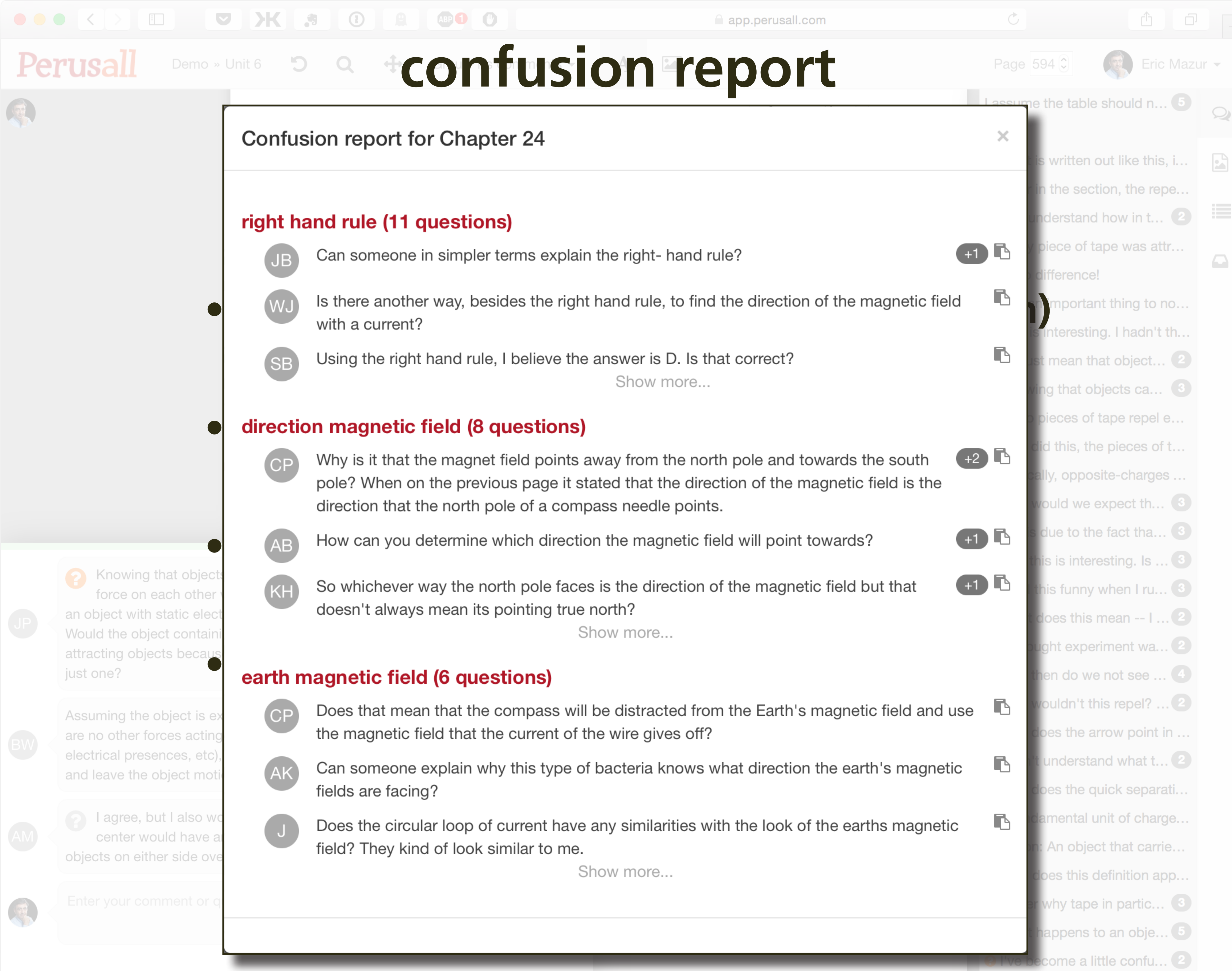
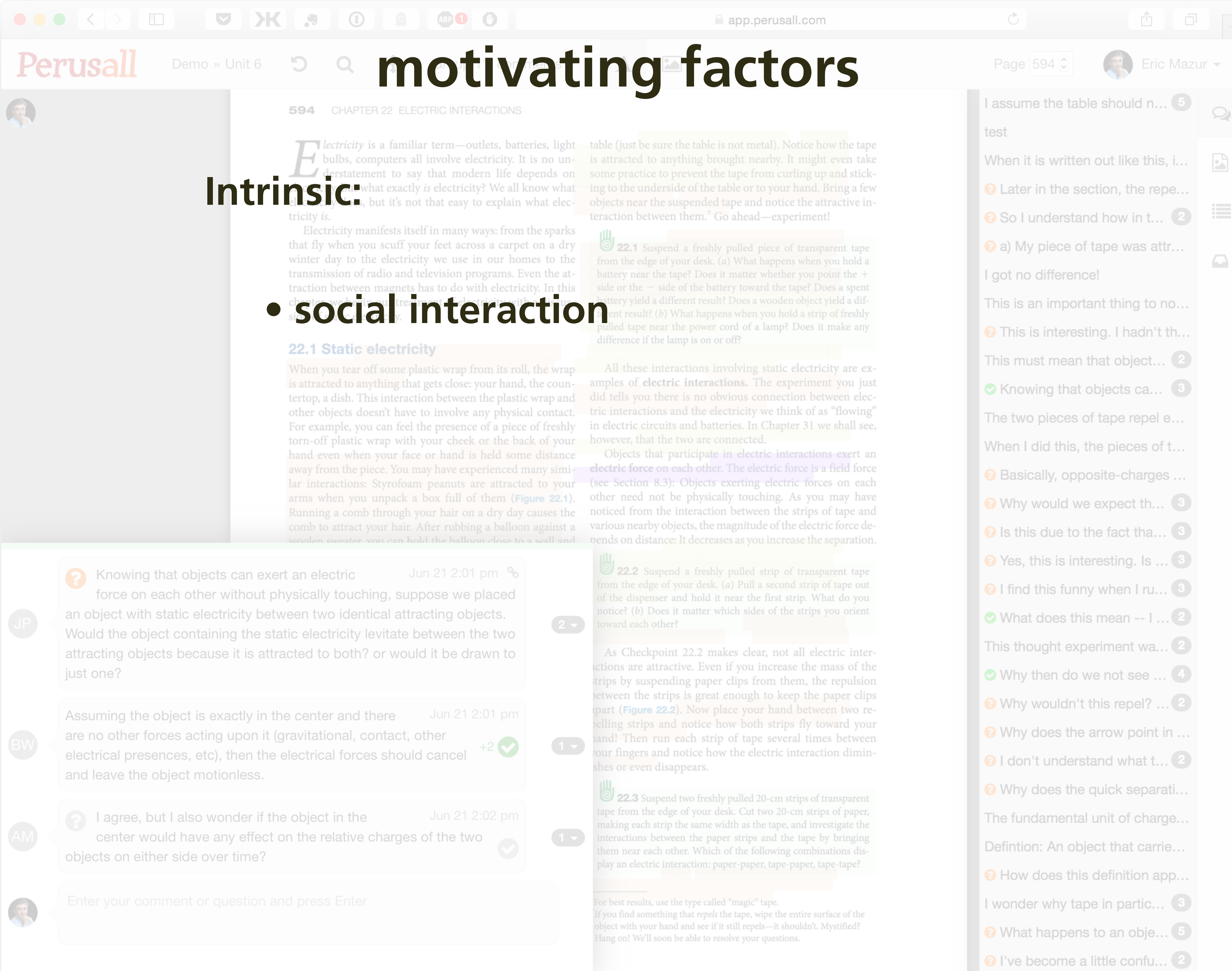


motivating factors

Intrinsic:

- social interaction



motivating factors

Intrinsic:

- social interaction
- tie-in to in-class activity

motivating factors

Intrinsic:

- social interaction
- tie-in to in-class activity

Extrinsic:

- assessment (fully automated)

motivating factors

"I think the Perusall app and annotation system is way better than just reading a text-book normally… I've been reading for almost four hours now and haven't gotten bored"

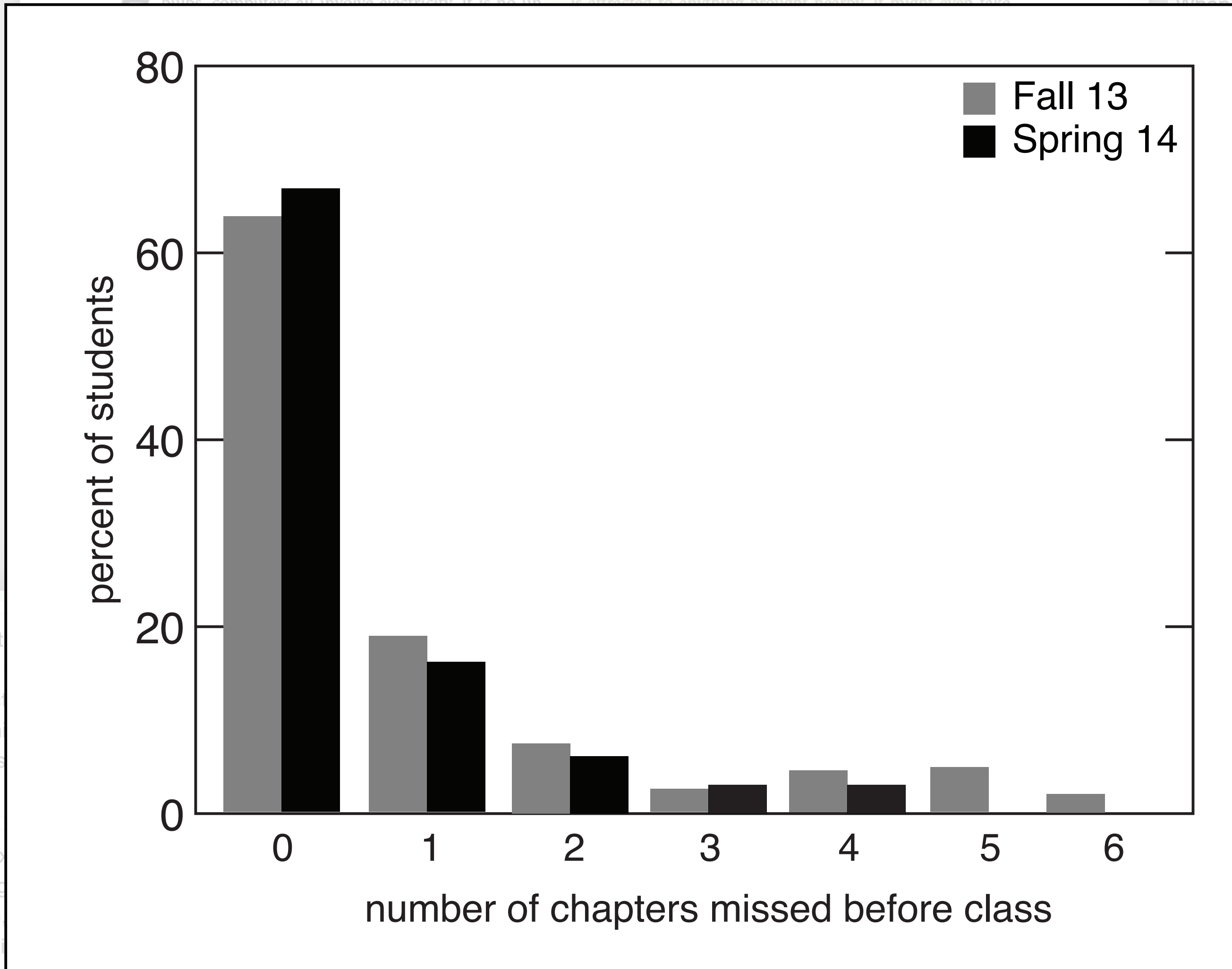
Harvard student

motivating factors

"It makes the book fun to read... All the other students on my floor are disappointed their Prof isn't using Perusall because they don't read the book."

Ohio State student

preliminary results



implementing Perusall

- sign up at http://perusall.com
- provide access code to your students
- students obtain textbook through Perusall

http://perusall.com

Benefits

- virtually 100% completion of assignments
- improved use of class time
- cheaper texts for students

all without any additional instructor effort!

http://perusall.com

Education is not just about:

- transferring information
- getting students to do what we do

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active engagement/social interaction a must!

ericmazur.com

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