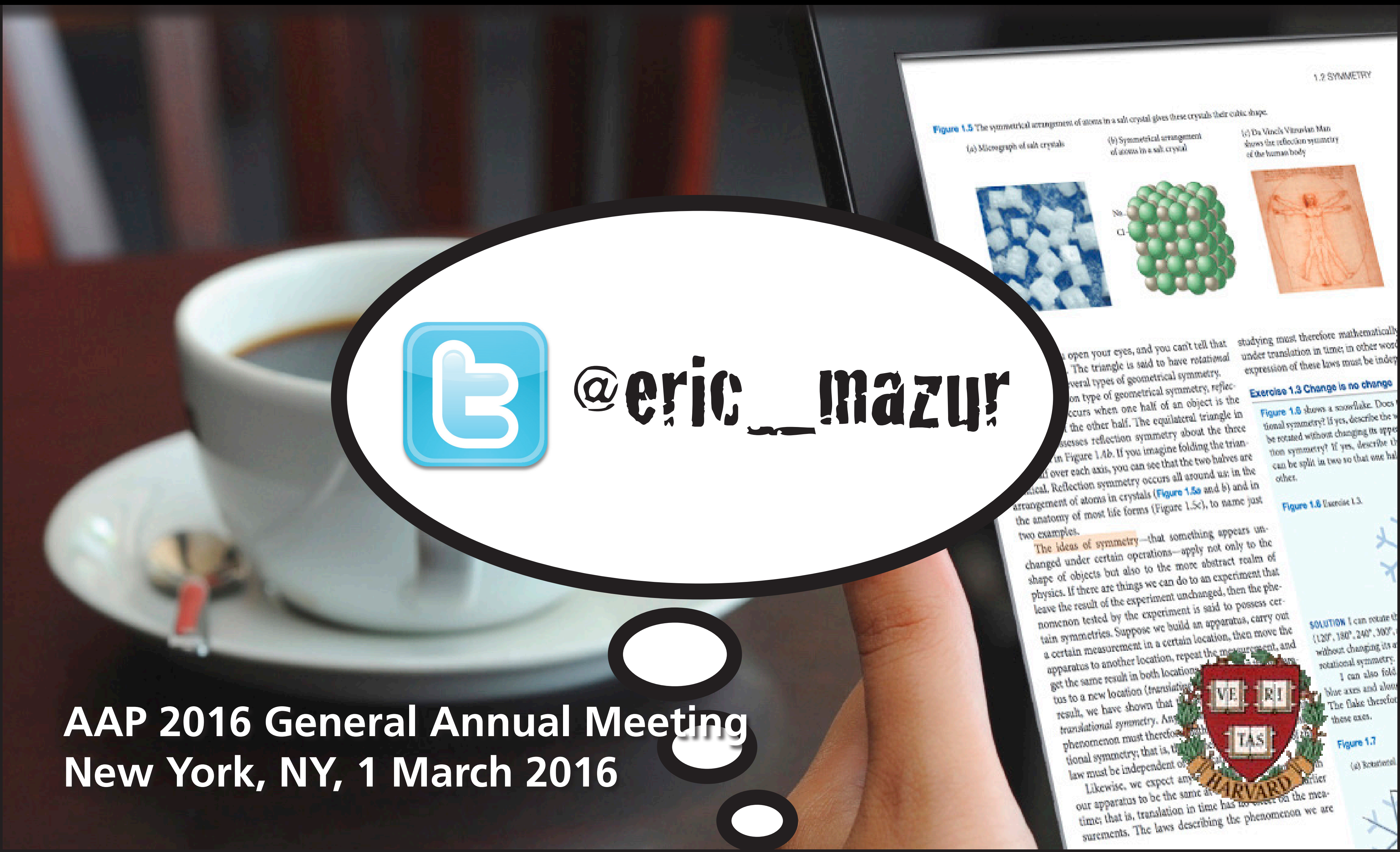
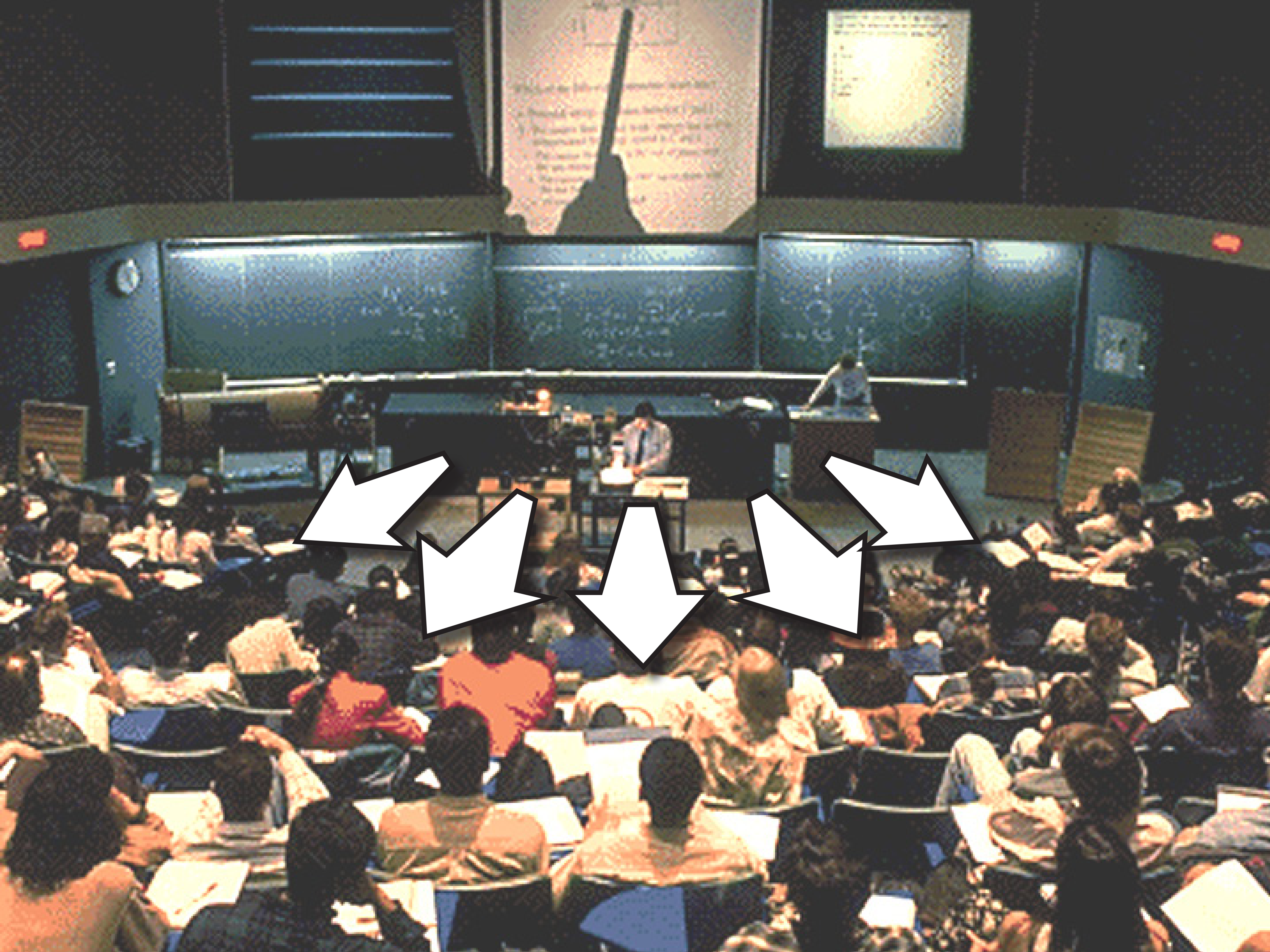
Innovating Education to Educate Innovators



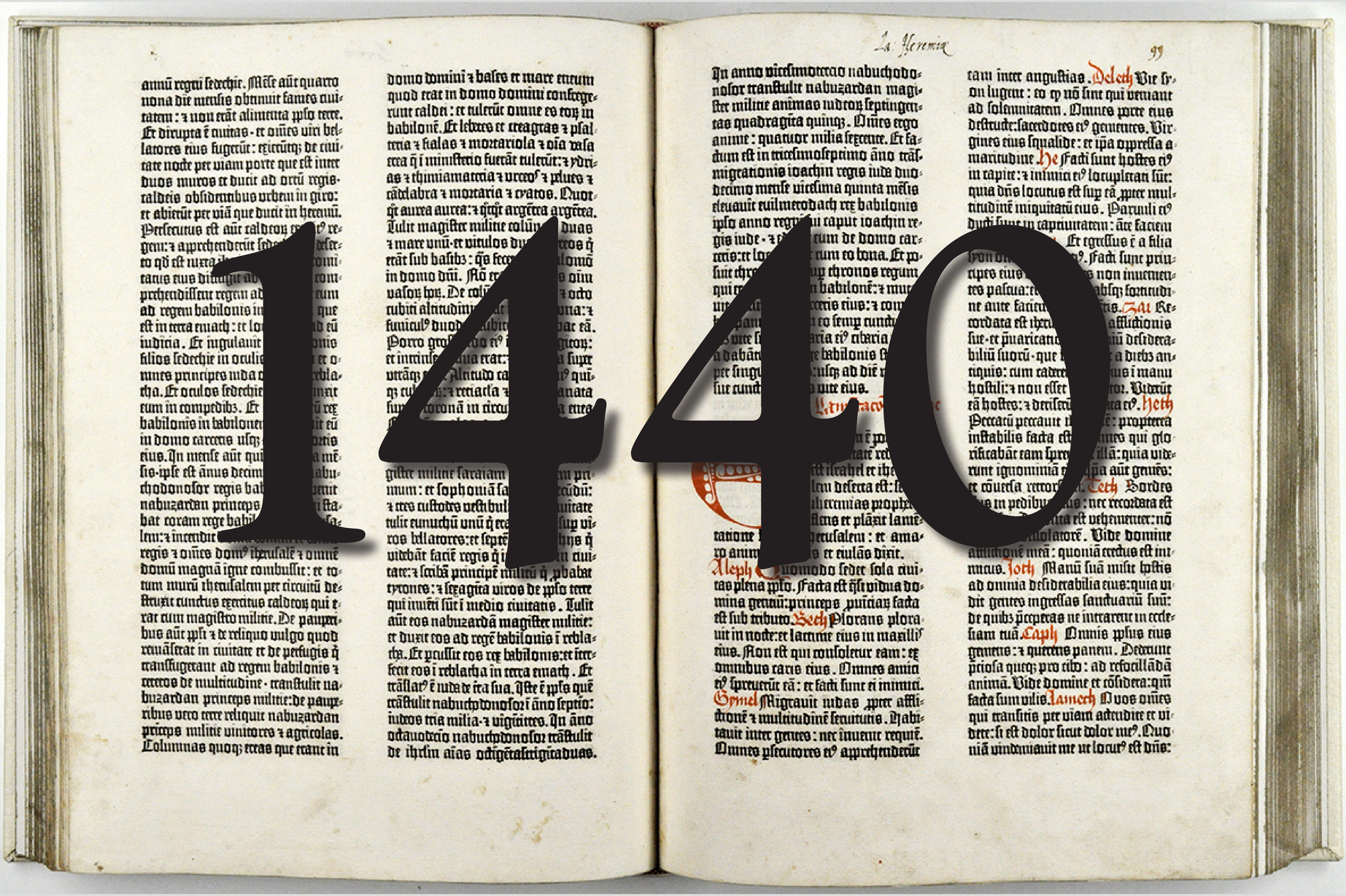
AAP 2016 General Annual Meeting
New York, NY, 1 March 2016



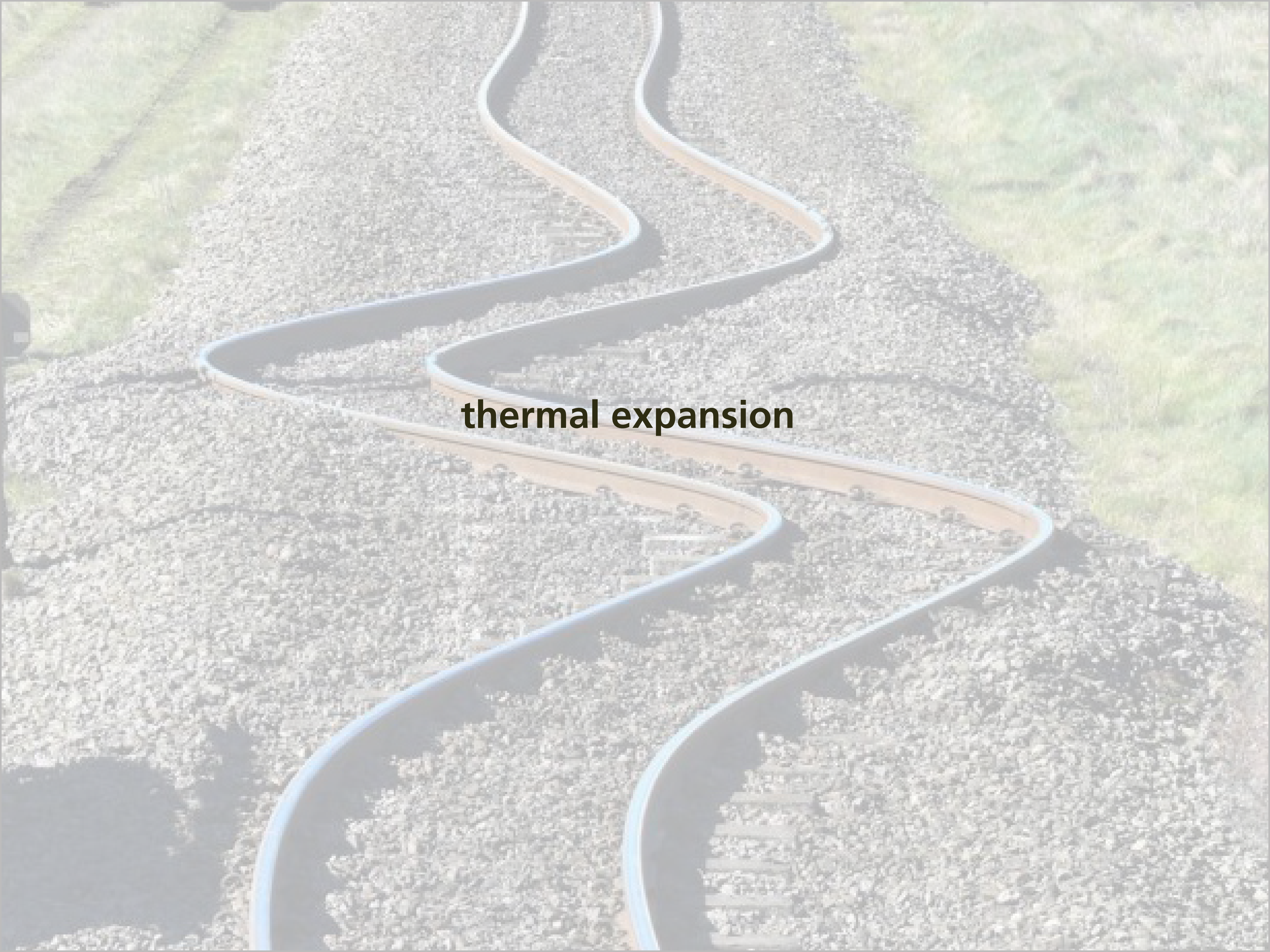
annū regni sedechie. Mēse aūt quarto
nona die mensis obtinuit fames ciui-
tatem: ⁊ non erāt alimenta ꝑplo terre.
Et dirupta ē ciuitas. et om̄es viri bel-
latores eius fugerūt: exierūtq; de ciui-
tate nocte per viam porte que est inter
duos muros et ducit ad ortū regis.
caldeis obsidentibus urbem in giro:
et abierūt per viā que ducit in heremū.
Persecutus est aūt caldeorū exercitꝰ re-
gem: ⁊ apprehenderūt sedechiā in deser-
to qd est iuxta ihericho: ⁊ om̄is comi-
tatus eius diffugit ab eo. Cumq; com-
prehendissent regem adduxerunt eum
ad regem babilonis in reblatha que
est in terra emath: et locutus est ad eū
iudicia. Et iugulauit rex babilonis
filios sedechie in oculis eius: sed et o-
mnes principes iuda occidit in rebla-
tha. Et oculos sedechie eruit: et vinxit
eum in compedibꝫ. Et adduxit eū rex
babilonis in babilonem: et posuit eū
in domo carceris usq; ad diē mortis
eius. In mense aūt quīto. decima mē-
sis. ipse est ānus decimusnonꝰ nabu-
chodonosor regis babilonis: venit
nabuzardan princeps milicie qui sta-
bat coram rege babilonis in iherusa-
lem: ⁊ incendit domū domini et domū
regis ⁊ om̄es domꝰ iherusalē ⁊ omnē
domū magnā igne combussit: et to-
tum murū iherusalem per circuitū de-
struxit cunctus exercitus caldeorū qui e-
rat cum magistro milicie. De paupe-
ribus aūt ꝑpli ⁊ de reliquo vulgo quod
remāserat in ciuitate et de perfugis q̄
transfugerant ad regem babilonis ⁊
ceteros de multitudine. transtulit na-
buzardan princeps milicie: de paupe-
ribus vero terre reliquit nabuzardan
princeps milicie vinitores ⁊ agricolas.
Columnas quoq; ereas que erant in
domo domini ⁊ bases et mare eneum
quod erat in domo domini confrege-
runt caldei: et tulerūt omne es eorū in
babilonē. Et lebetes et creagras ⁊ psal-
teria ⁊ fialas ⁊ mortariola ⁊ oīa vasa
erea q̄ i ministerio fuerāt tulerūt: ⁊ ydri-
as ⁊ thimiamateria ⁊ vrceos ⁊ pelues ⁊
cādelabra ⁊ mortaria ⁊ ciatos. Quot-
quot aurea aurea: ⁊ q̄quot argentea argentea.
Tulit magister milicie colūnas duas
⁊ mare unū. et vitulos duodecī ereos q̄
erāt sub basibꝫ: q̄s fecerat rex salomō
in domo dn̄i. Nō erat pōdꝰ eris oīm
vasorū horū. De colūnis aūt: decē ⁊ octo
cubiti altitudinis erāt ī colūna una: ⁊
funiculꝰ duodecī cubitorū circuibat eā.
Porro grossitudo eiꝰ q̄tuor digitorū:
et intrinsecꝰ caua erat: ⁊ capitella super
utrāq; erea. Altitudo capitelli uniꝰ quī-
q; cubitorū: ⁊ reticula ⁊ malagranata
supra coronā in circuitū: omnia erea.
Et fuerūt malagranata nonagitasex
dependentia: ⁊ omnia malagranata cen-
tum reticulis circūdabant. Et tulit ma-
gister milicie saraiam sacerdotem pri-
mum: et sophoniā sacerdotē secūdū:
⁊ tres custodes vestibuli. Et de ciuitate
tulit eunuchū unū q̄ erat ꝑpositꝰ sup vi-
ros bellatores: et septē viros de hijs q̄
videbāt faciē regis q̄ inuēti sūt in ciui-
tate: ⁊ scribā principē militū q̄ ꝓbabat
tyrones: ⁊ sexagīta viros de ꝑplo terre
qui inuēti sūt ī medio ciuitatis. Tulit
aūt eos nabuzardā magister milicie:
et duxit eos ad regē babilonis ī rebla-
tha. Et percussit eos rex babilonis: et inter-
fecit eos ī reblatha in terra emath. Et
trāslatꝰ ē iuda de tra sua. Iste ē ꝑplꝰ quē
trāstulit nabuchodonosor ī āno septio:
iudeos tria milia. ⁊ vigītitres. In āno
octauodecio nabuchodonosor trāstulit
de ihrlm aīas octīgētastrigītaduas.
In anno vicesimotercio nabuchodo-
nosor transtulit nabuzardan magi-
ster milicie animas iudeorū septingē-
tas quadraginta quinq;. Om̄es ergo
anime: quatuor milia sexcente. Et fa-
ctum est in tricesimoseptimo āno trās-
migrationis ioachin regis iude duo-
decimo mense vicesima quinta mēsis
eleuauit euilmerodach rex babilonis
ipso anno regni sui caput ioachin re-
gis iude. ⁊ eduxit eum de domo car-
ceris: et locutus est cum eo bona. Et po-
suit thronū eius sup thronos regum
qui erant post se in babilonē: ⁊ muta-
uit vestimenta carceris eius: ⁊ comede-
bat panem coram eo semp cunctis di-
ebꝫ vite sue. Et cibaria eiꝰ cibaria ꝑpetu-
a dabātur ei a rege babilonis statuta
per singulos dies: usq; ad diē mortis
sue cunctis diebus vite eius.

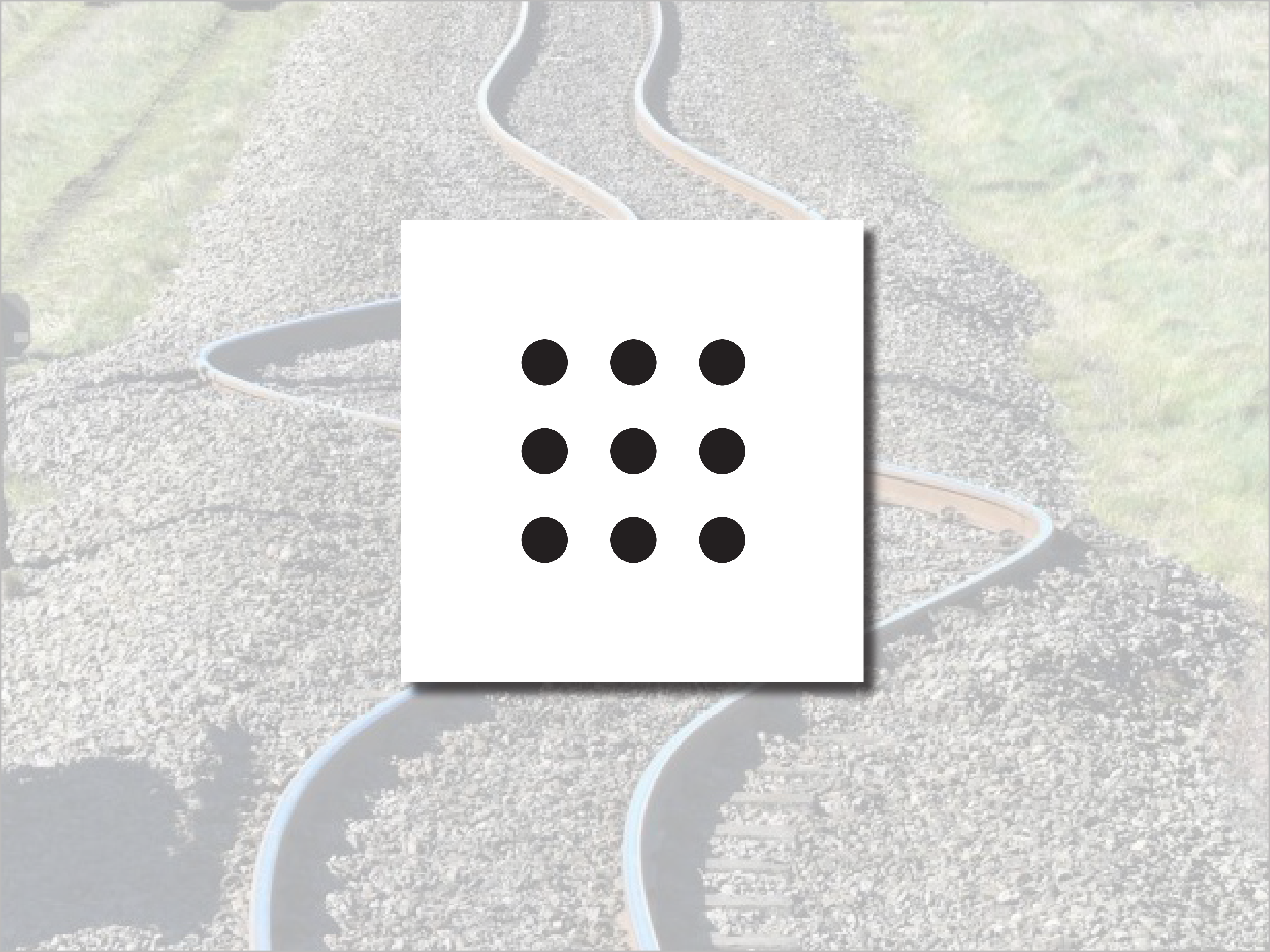
Lamētacões ihēmie

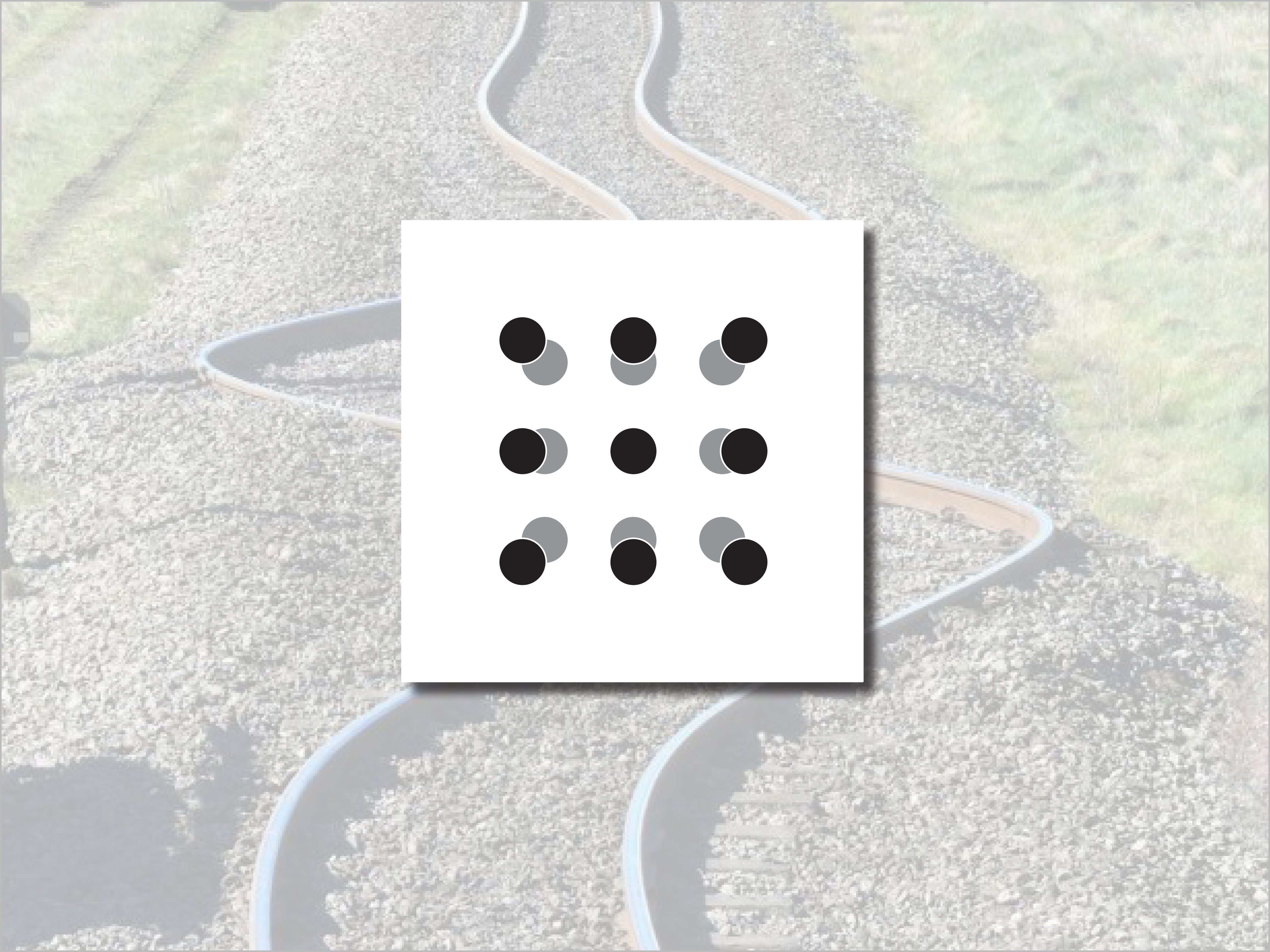
ET factum ē postq̄ in
captiuitatē reductus
est israhel et iherusa-
lem deserta est: sedit
iheremias propheta
flens et plāxit lamē-
tatione hac in iherusalem: et ama-
ro animo suspirās et eiulās dixit.
Aleph Quomodo sedet sola ciui-
tas plena ꝑplo. Facta est q̄si vidua do-
mina gentiū: princeps ꝓuinciarū facta
est sub tributo. Beth Plorans plora-
uit in nocte: et lacrime eius in maxillis
eius. Non est qui consoletur eam: ex
omnibus caris eius. Omnes amici
eiꝰ spreuerūt eā: et facti sunt ei inimici.
Gymel Migrauit iudas ꝓpter affli-
ctionē ⁊ multitudinē seruitutis. Habi-
tauit inter gentes: nec inuenit requiē.
Omnes ꝑsecutores eiꝰ apprehenderūt
eam inter angustias. Deleth Vie sy-
on lugent: eo q̄ nō sint qui veniant
ad solennitatem. Omnes porte eius
destructe: sacerdotes eiꝰ gementes. Vir-
gines eius squalide: et ipa oppressa a-
maritudine. He Facti sunt hostes eiꝰ
in capite: ⁊ inimici eiꝰ locupletati sūt:
quia dn̄s locutus est sup eā ꝓpter mul-
titudinē iniquitatū eius. Paruuli eiꝰ
ducti sunt in captiuitatem: ante faciem
tribulātis. Vau Et egressus ē a filia
syon omnis decor eiꝰ. Facti sunt prin-
cipes eius velut arietes non inuenien-
tes pascua: et abierunt absq; fortitudi-
ne ante faciem subsequētis. Zai Re-
cordata est iherusalē dierū afflictionis
sue. et ꝑuaricationis omniū desidera-
biliū suorū. que habuerat a diebꝫ an-
tiquis: cum caderet ꝑplus eius ī manu
hostili: ⁊ non esset auxiliator. Viderūt
eā hostes: ⁊ deriserūt sabbata eiꝰ. Heth
Peccatū peccauit iherusalē: propterea
instabilis facta est. Omnes qui glo-
rificabāt eam spreuerūt illā: quia vide-
runt ignominiā eiꝰ. Ipa aūt gemēs:
et cōuersa retrorsum. Teth Sordes
eius in pedibus eius: nec recordata est
finis sui. Deposita est vehementer: nō
habens consolatorē. Vide domine
afflictionē meā: quoniā erectus est in-
imicus. Joth Manū suā misit hostis
ad omnia desiderabilia eius: quia vi-
dit gentes ingressas sanctuariū suū:
de quibꝫ ꝑceperas ne intrarent in eccle-
siam tuā. Caph Omnis ꝑplus eius
gemens: ⁊ querens panem. Dederunt
ꝑciosa queq; pro cibo: ad refocillādā
animā. Vide domine et cōsidera: quō
facta sum vilis. Lamech O vos om̄es
qui transitis per viam attendite et vi-
dete: si est dolor sicut dolor meꝰ. Quo-
niā vindemiauit me ut locutꝰ est dn̄s:


1440

thermal expansion

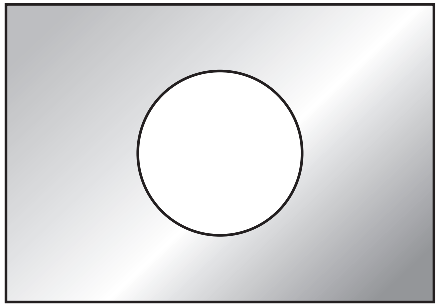




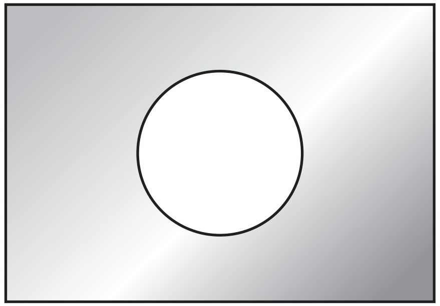



all of them

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



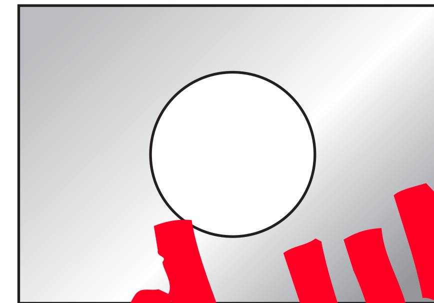
Consider a rectangular metal plate with a circular hole in it.



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

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

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

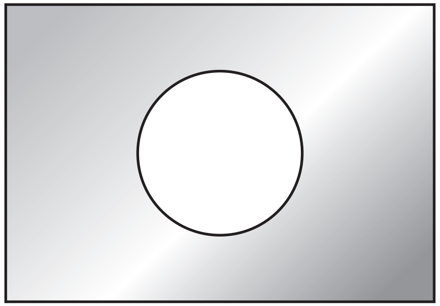


When the plate is uniformly heated, the diameter of the hole

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

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…

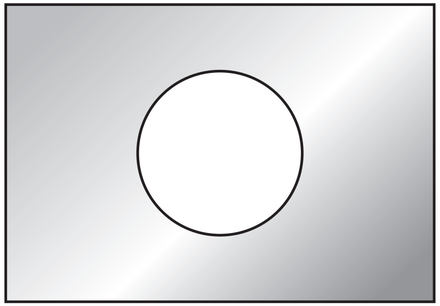
1. **made a commitment**
2. **externalized your answer**
3. **moved from the answer/fact to reasoning**

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

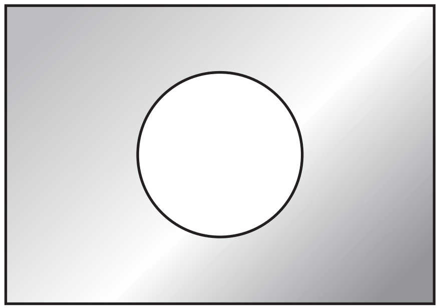
Consider a rectangular metal plate with a circular hole in it.



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

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

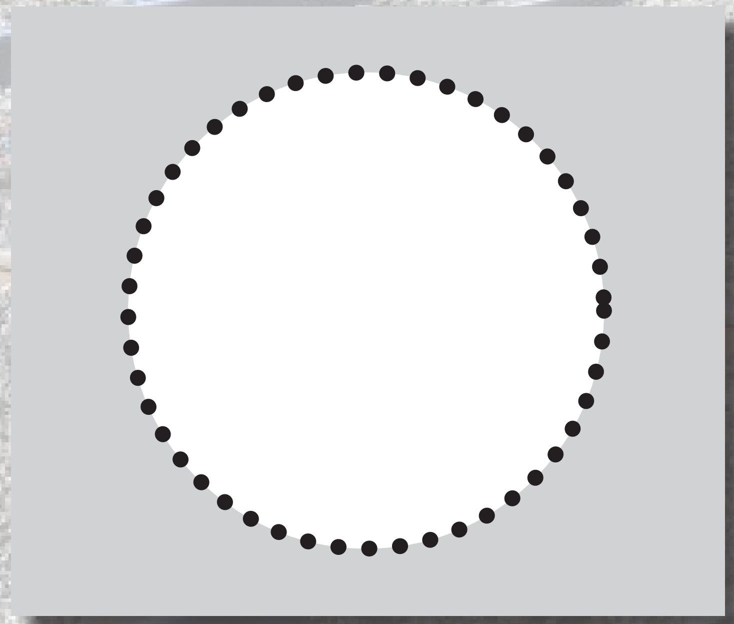
Consider a rectangular metal plate with a circular hole in it.



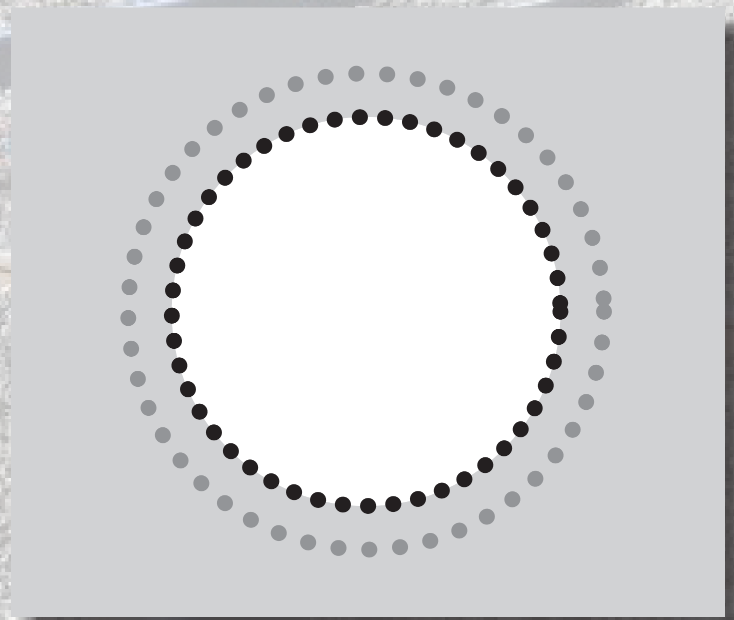
When the plate is uniformly heated, the diameter of the hole

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

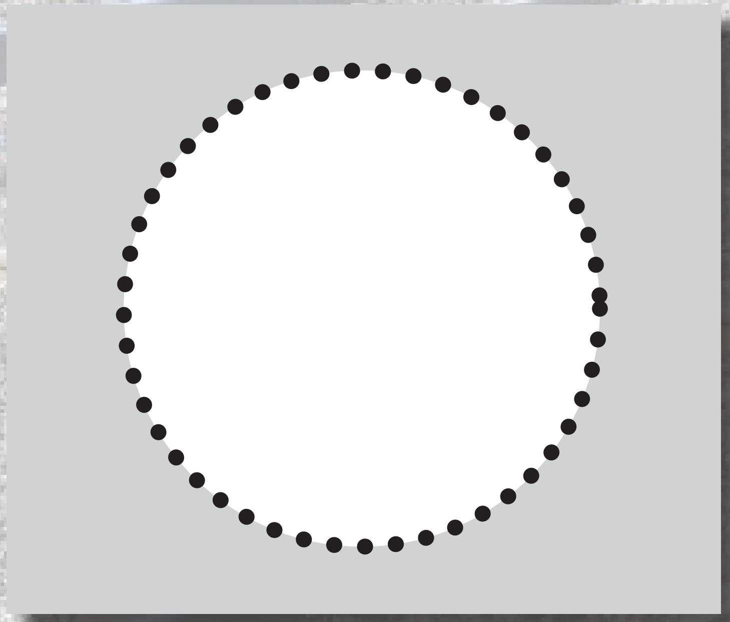
consider atoms at rim of hole



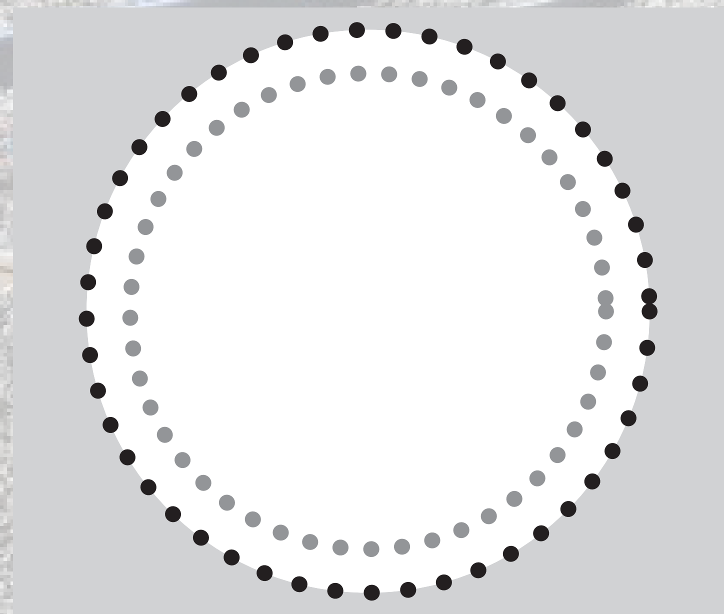
consider atoms at rim of hole



consider atoms at rim of hole



consider atoms at rim of hole




consider atoms at rim of hole
you won't forget this

Peer

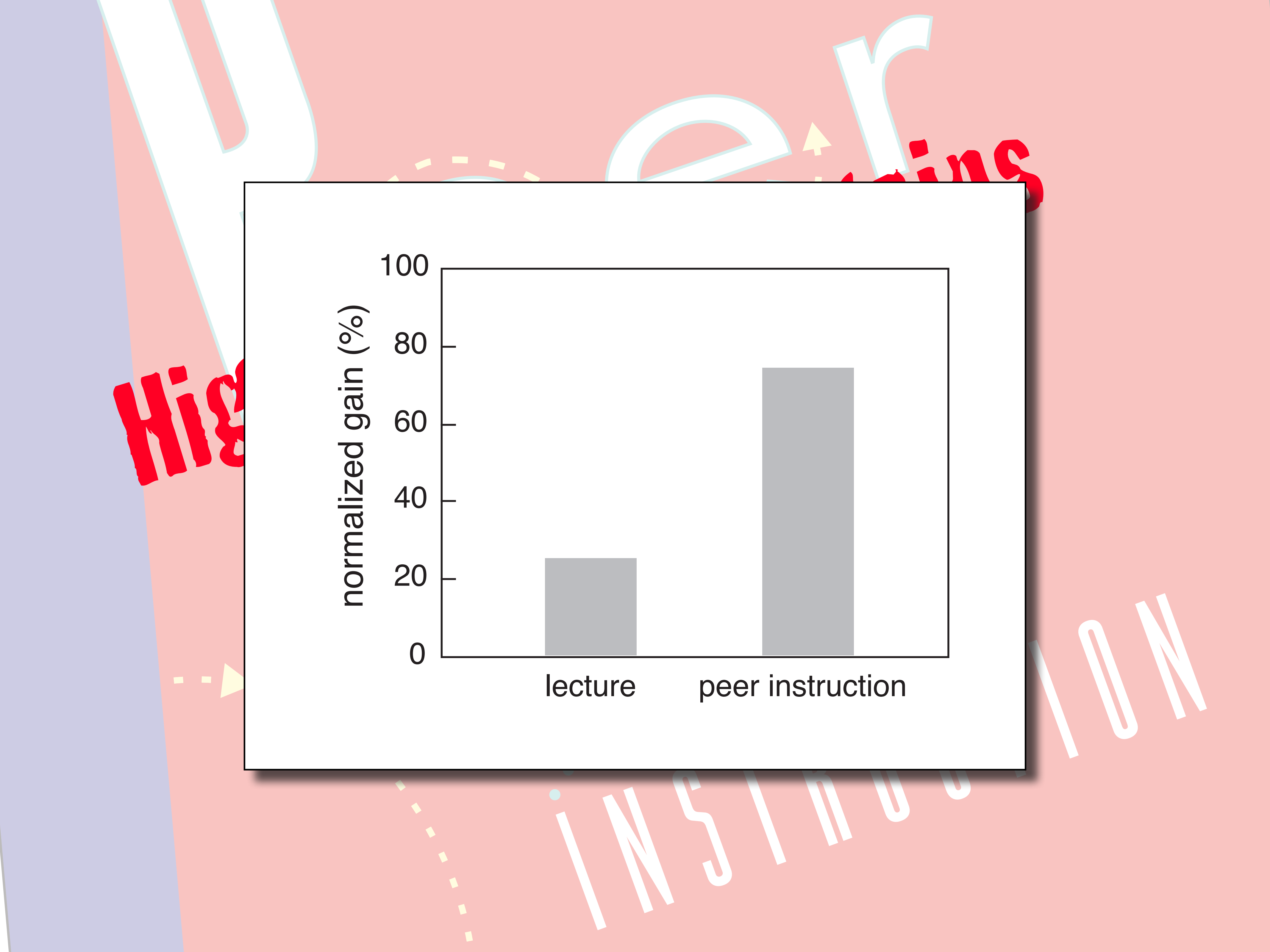
back to PI

INSTRUCTION

Peer

INSTRUCTION


Peer
Higher learning gains
INSTRUCTION


normalized gain (%)
100
80
60
40
20
0
lecture
peer instruction

Peer

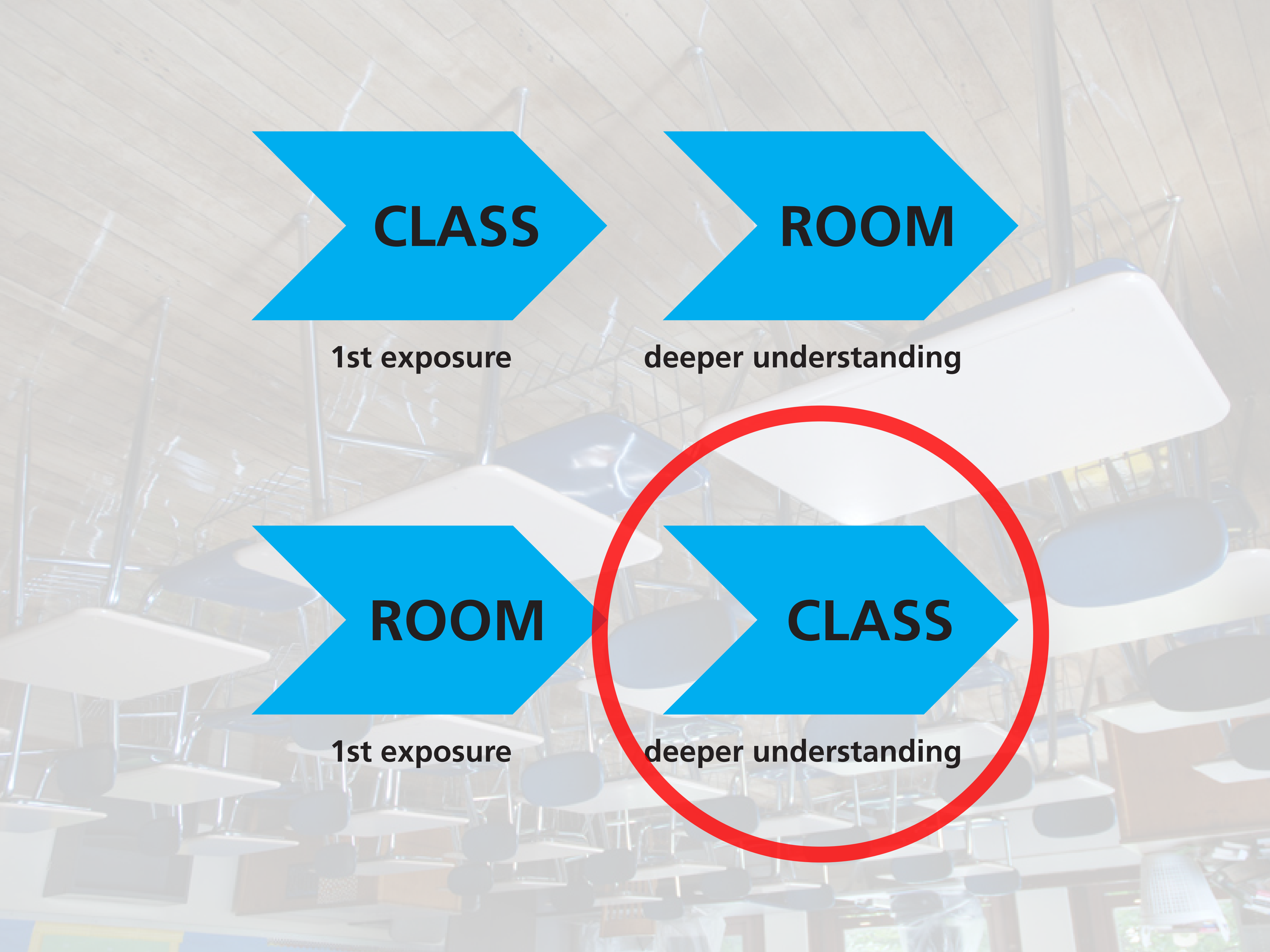
INSTRUCTION

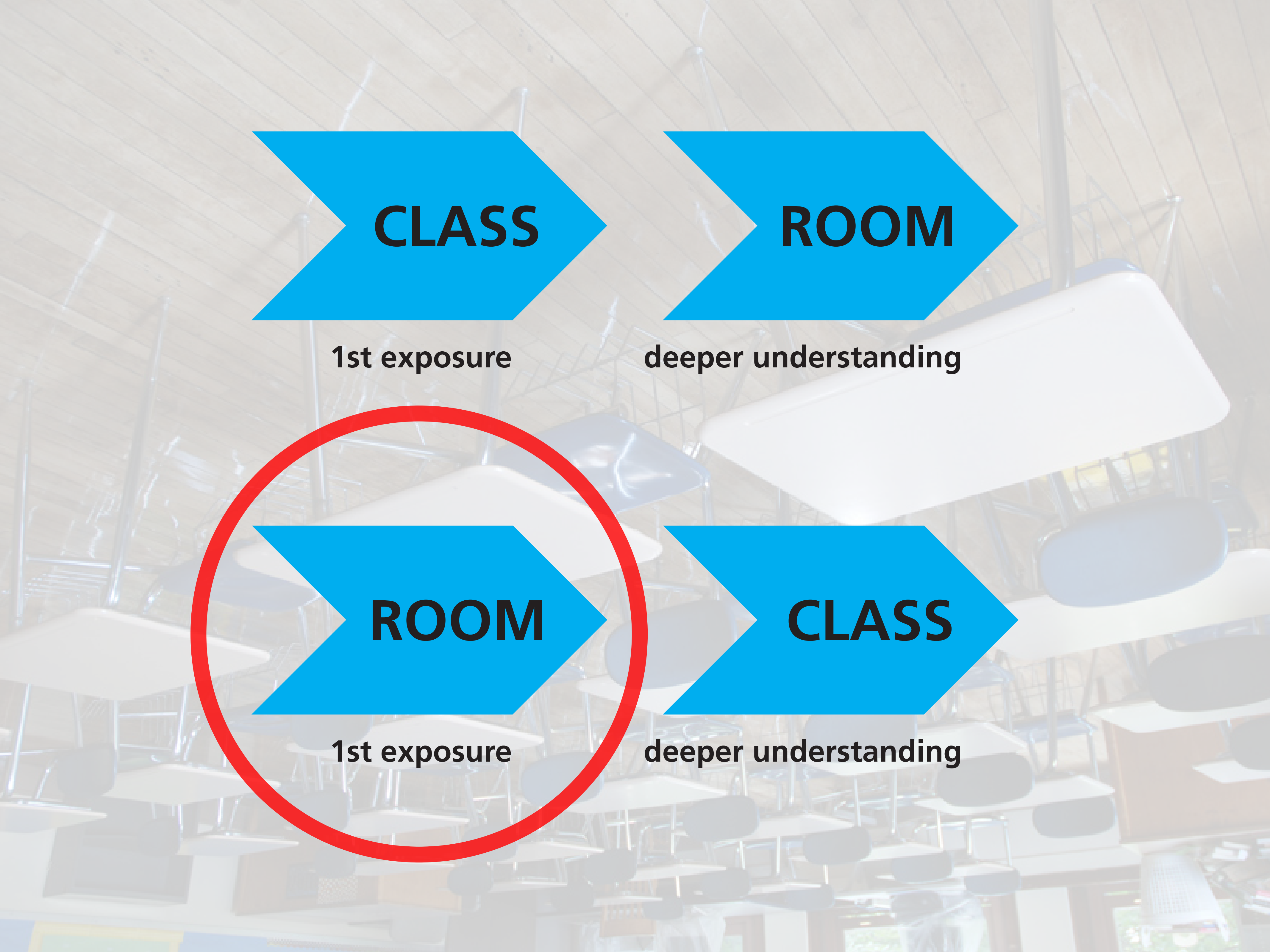
Higher learning gains

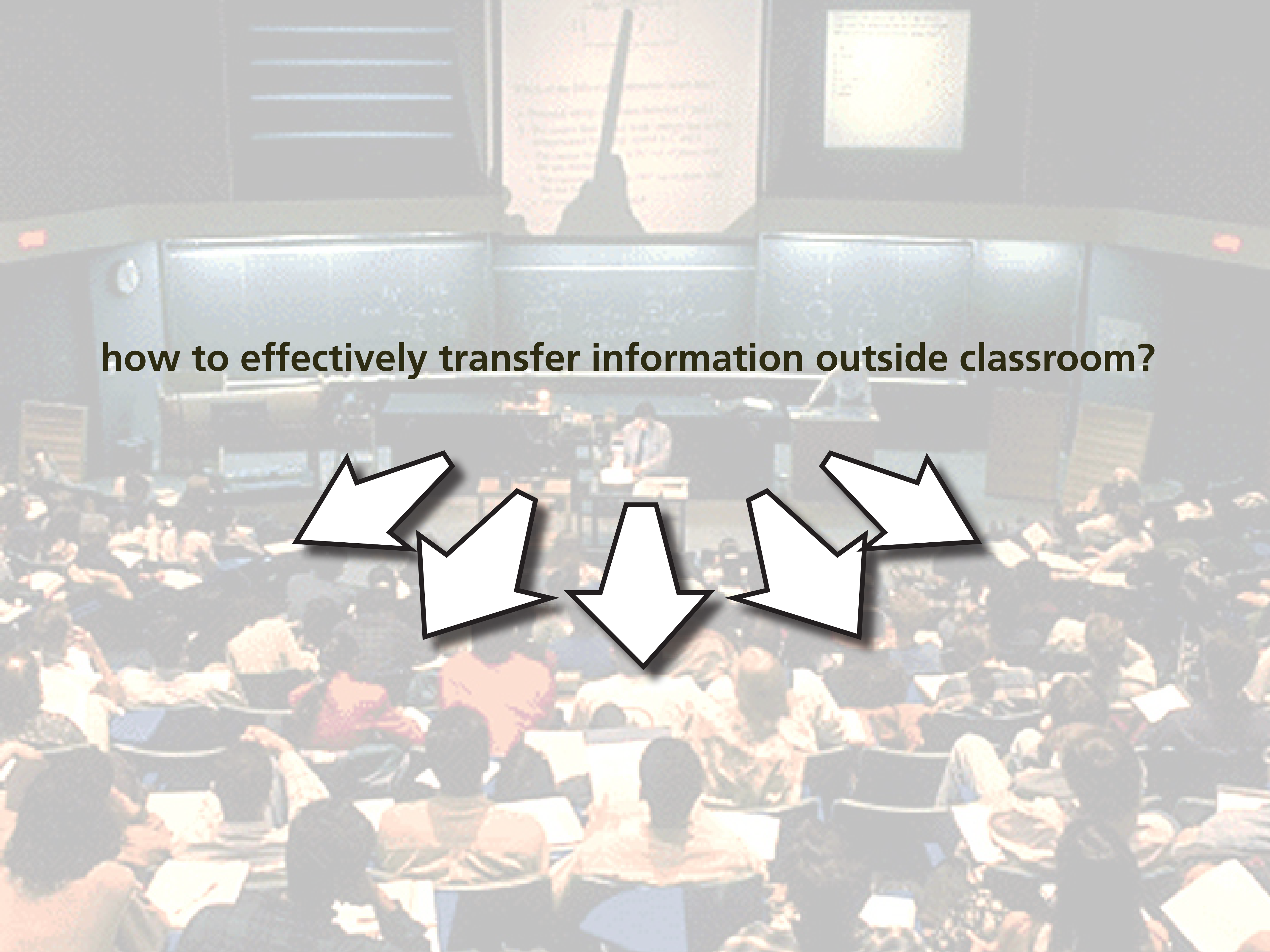
Better retention


CLASS
ROOM
1st exposure
deeper understanding


CLASS
ROOM
1st exposure
deeper understanding
ROOM
CLASS
1st exposure
deeper understanding

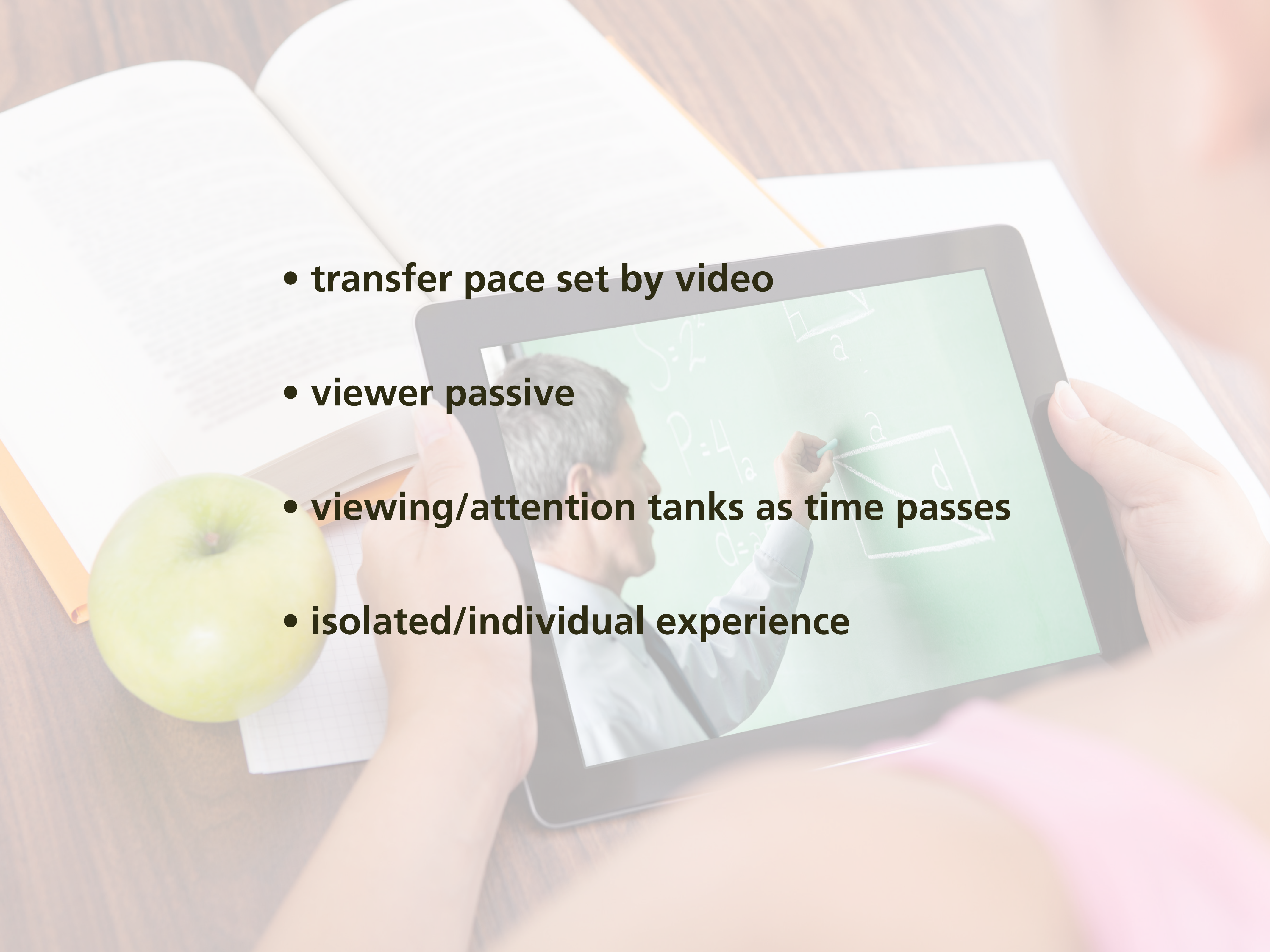

CLASS
ROOM
1st exposure
deeper understanding
ROOM
CLASS
1st exposure
deeper understanding


CLASS
ROOM
1st exposure
deeper understanding
ROOM
CLASS
1st exposure
deeper understanding


how to effectively transfer information outside classroom?

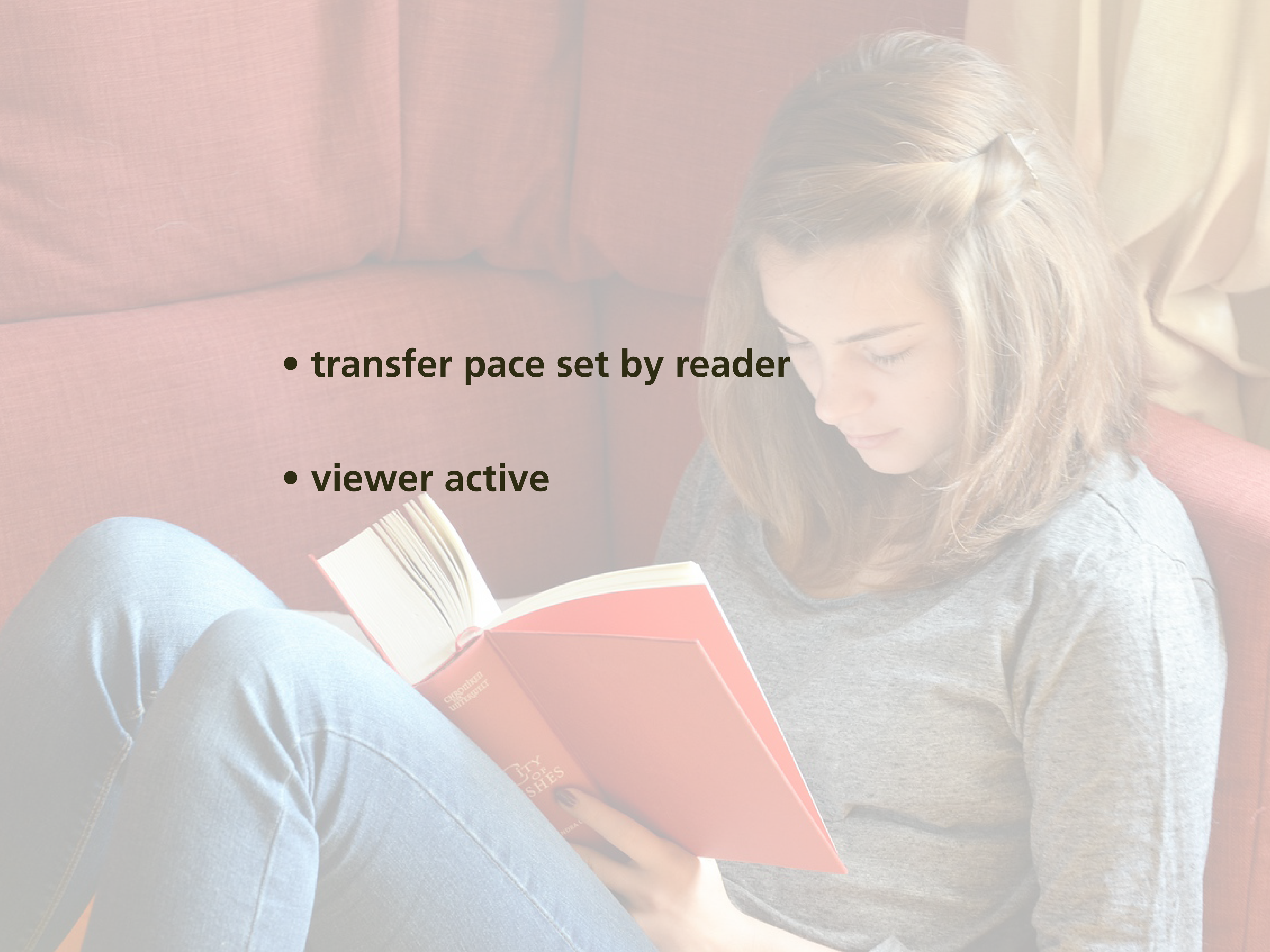

P=4a
a
d


but…



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

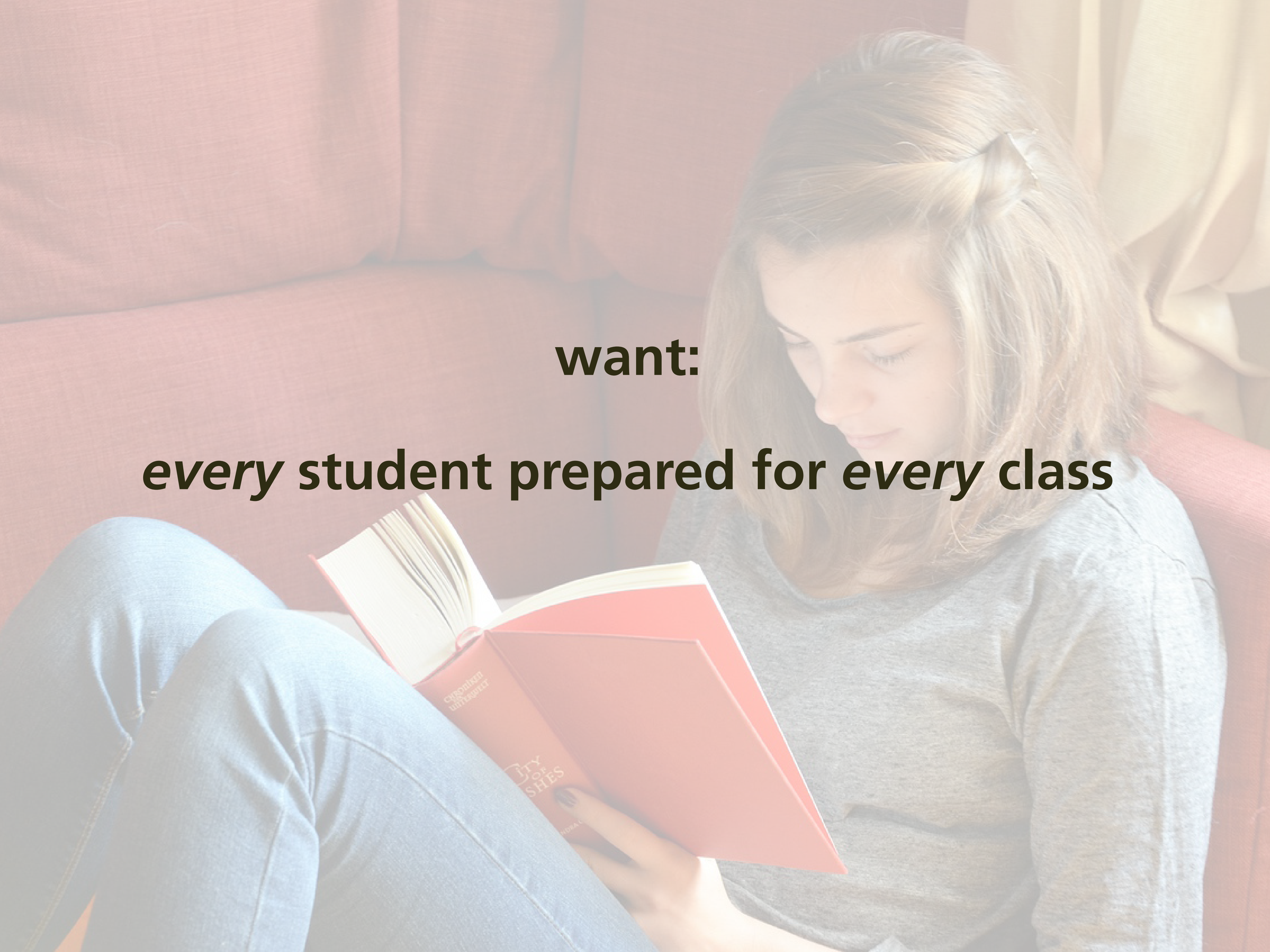

we're simply moving this outside classroom!



- transfer pace set by reader
- viewer active

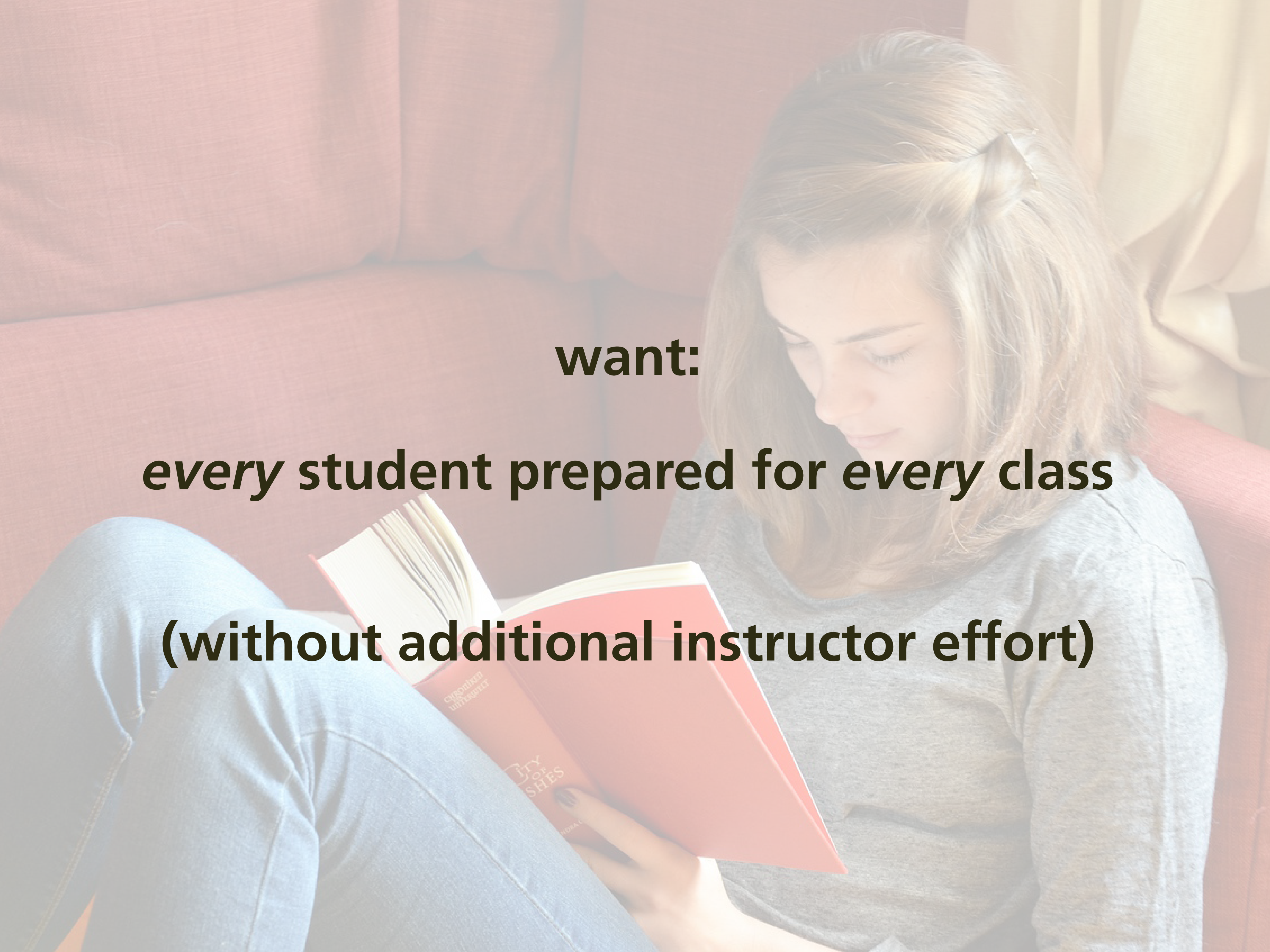

but…


isolated/individual experience &
no real accountability



want:

***every* student prepared for *every* class**



want:

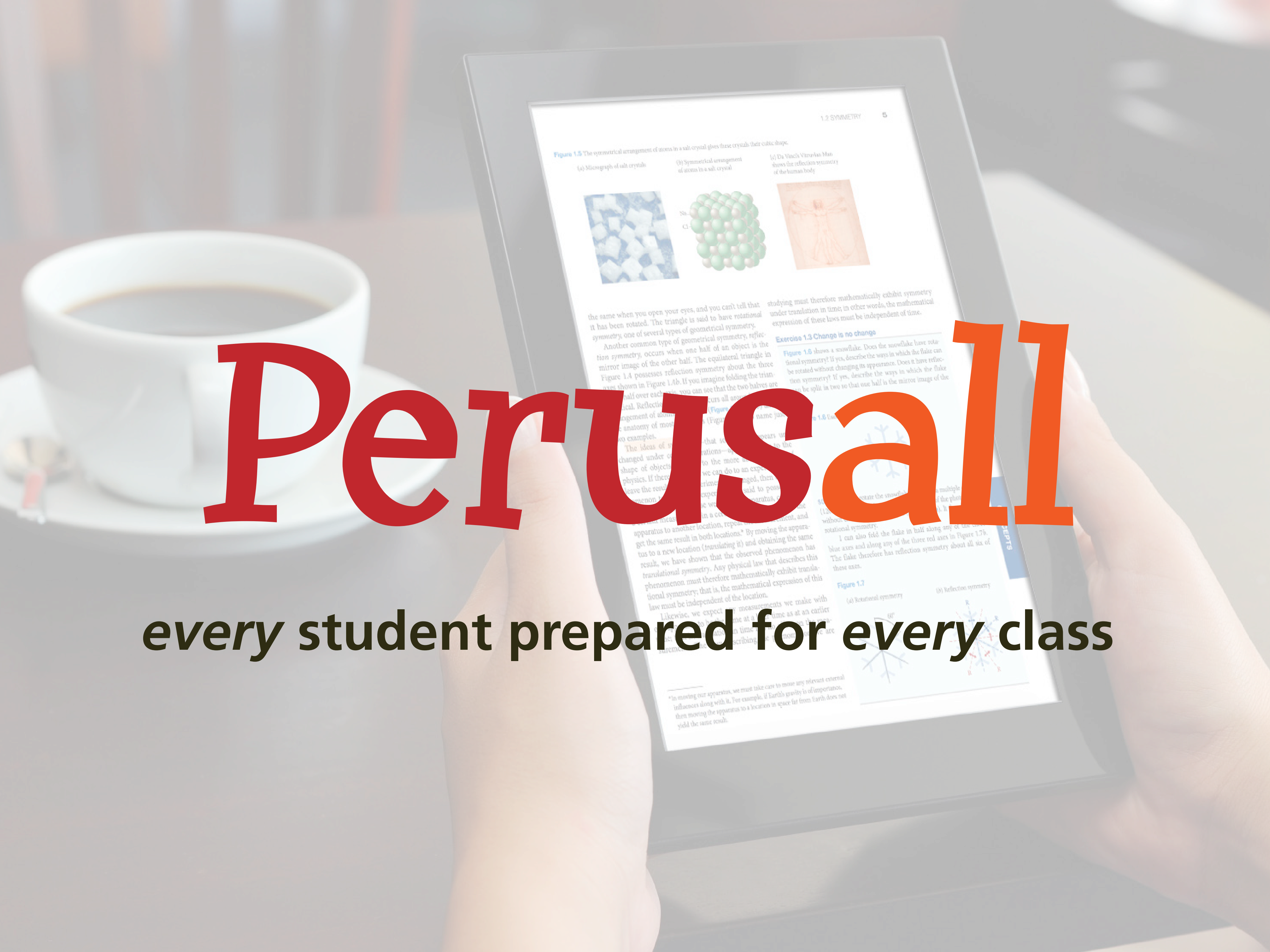
every **student prepared for** ***every*** **class**

(without additional instructor effort)

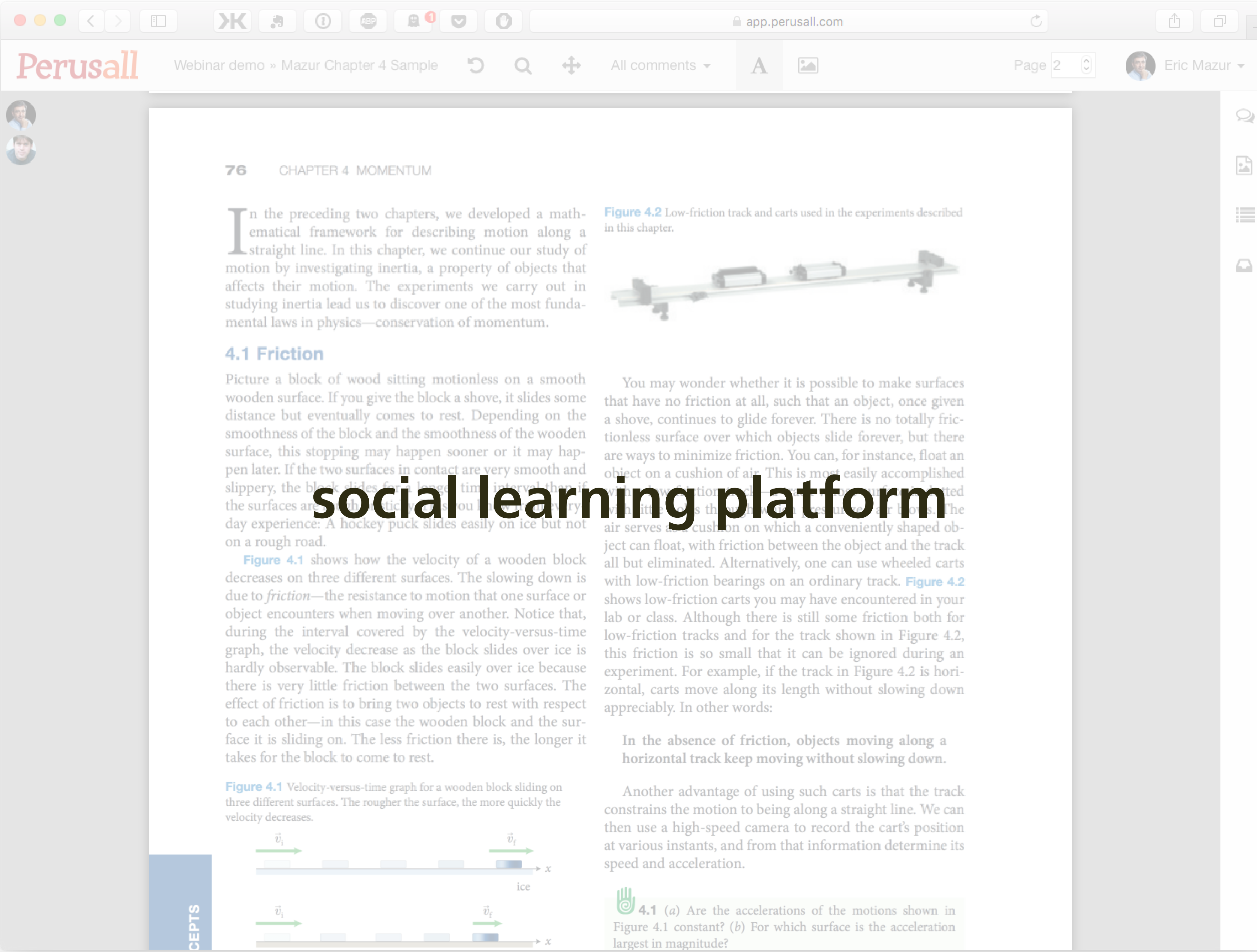
Solution

turn out-of-class component

also into a social interaction!


Perusall
every student prepared for *every* class

social learning platform



76 CHAPTER 4 MOMENTUM

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 bl[illegible] the surfaces ar[illegible] day 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.

$\vec{v}_i$ $\vec{v}_f$ x ice

$\vec{v}_i$ $\vec{v}_f$ x

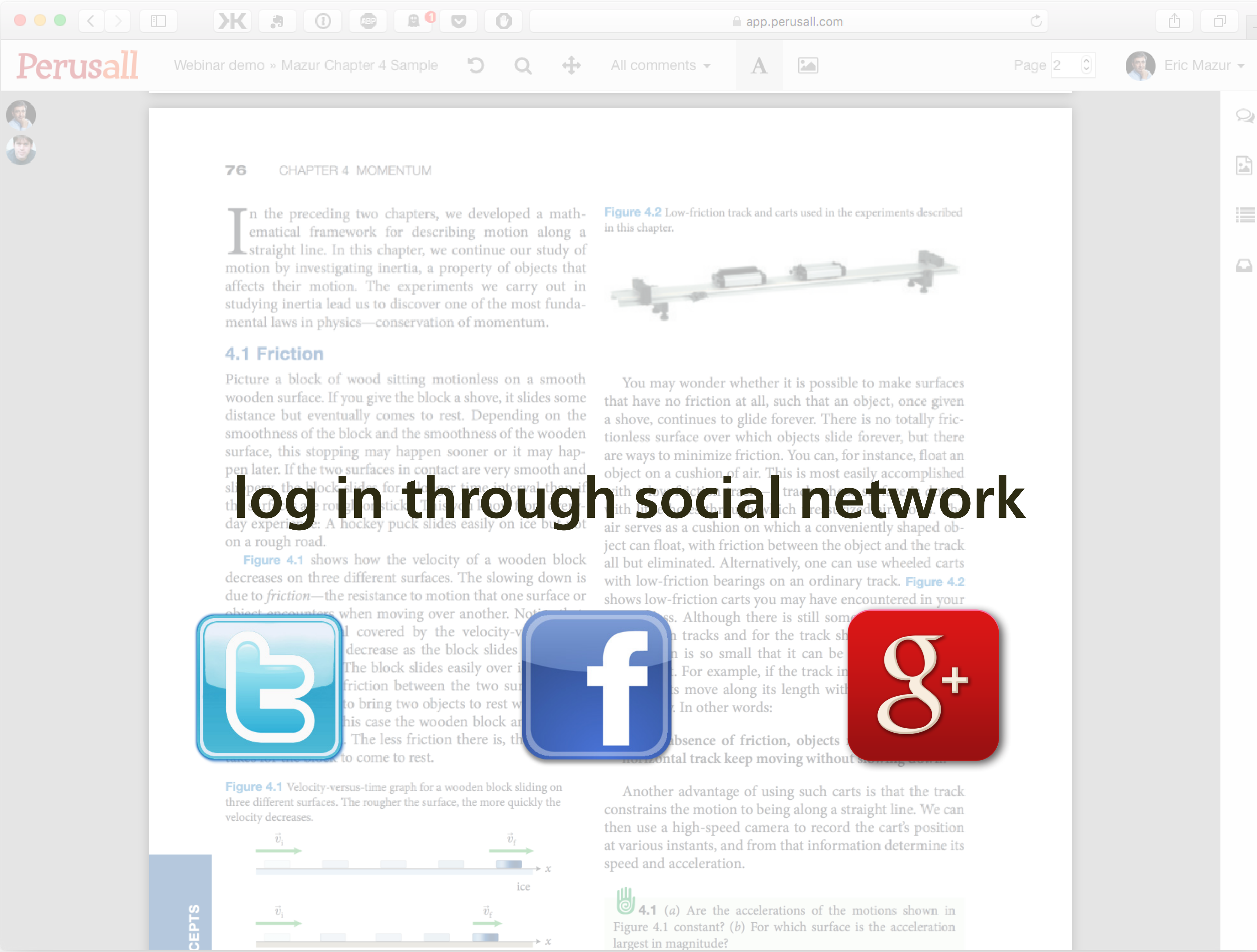
Figure 4.2 Low-friction track and carts used in the experiments described in this chapter.

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 [illegible] air serves [illegible] 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?



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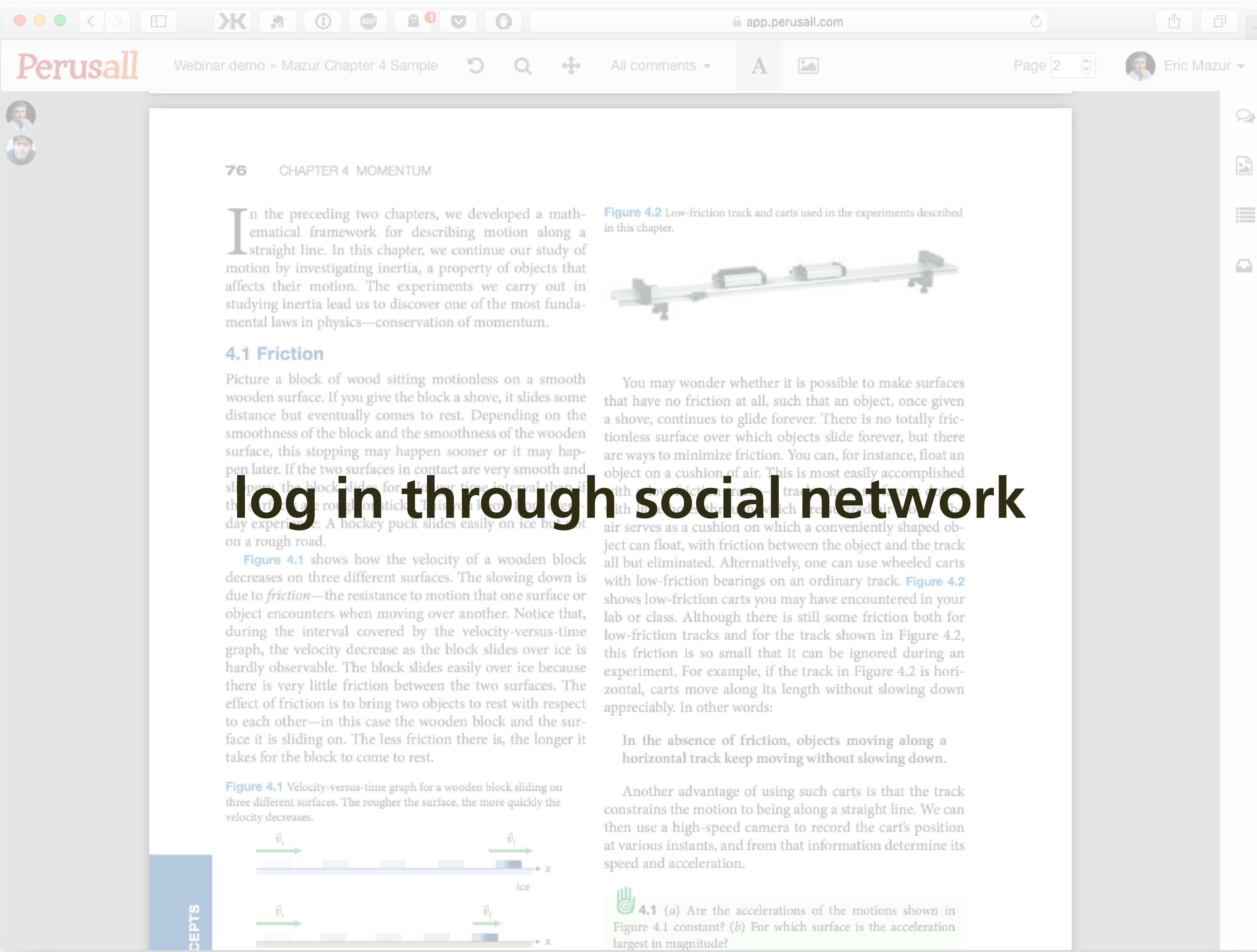
Eric Mazur
log in through social network

log in through social network



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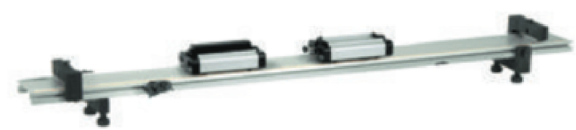

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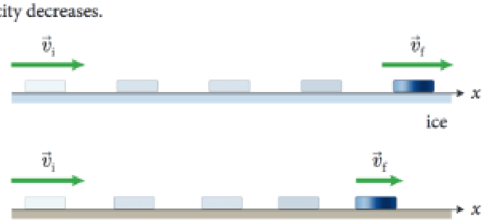

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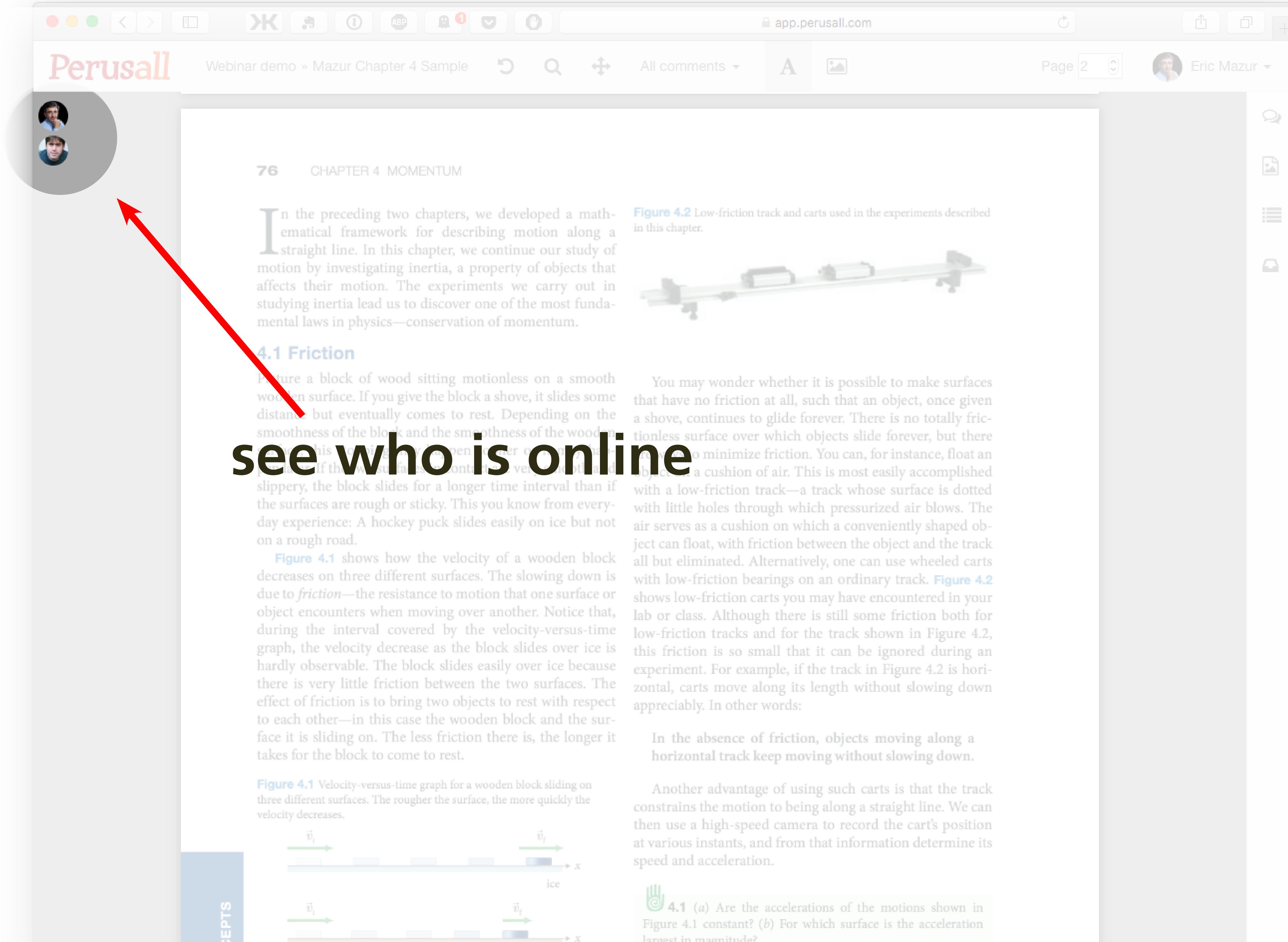

76 CHAPTER 4 MOMENTUM

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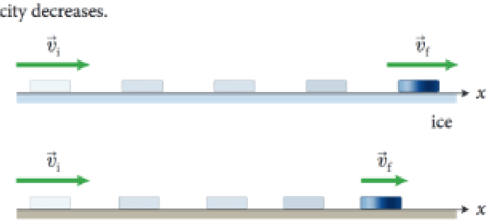

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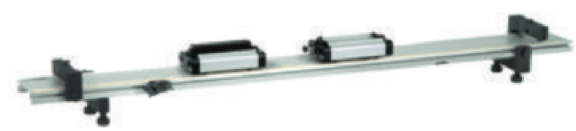

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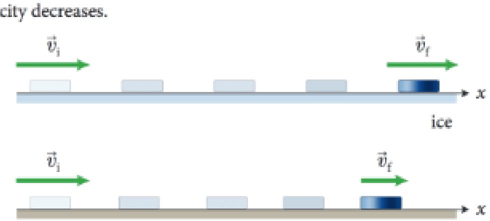

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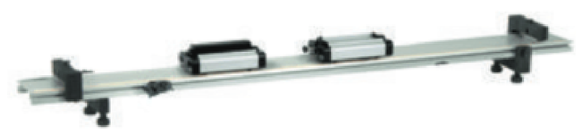

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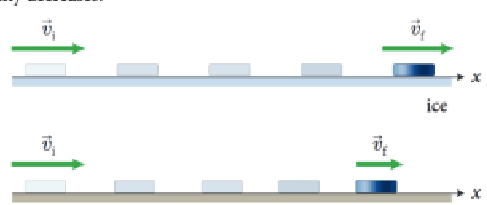

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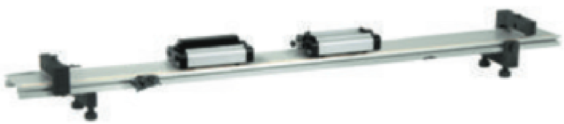

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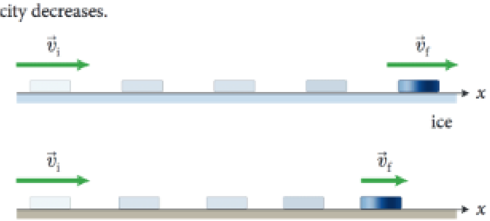

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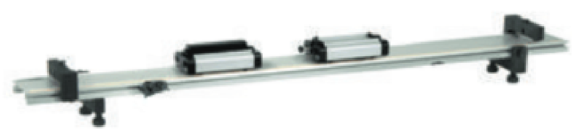

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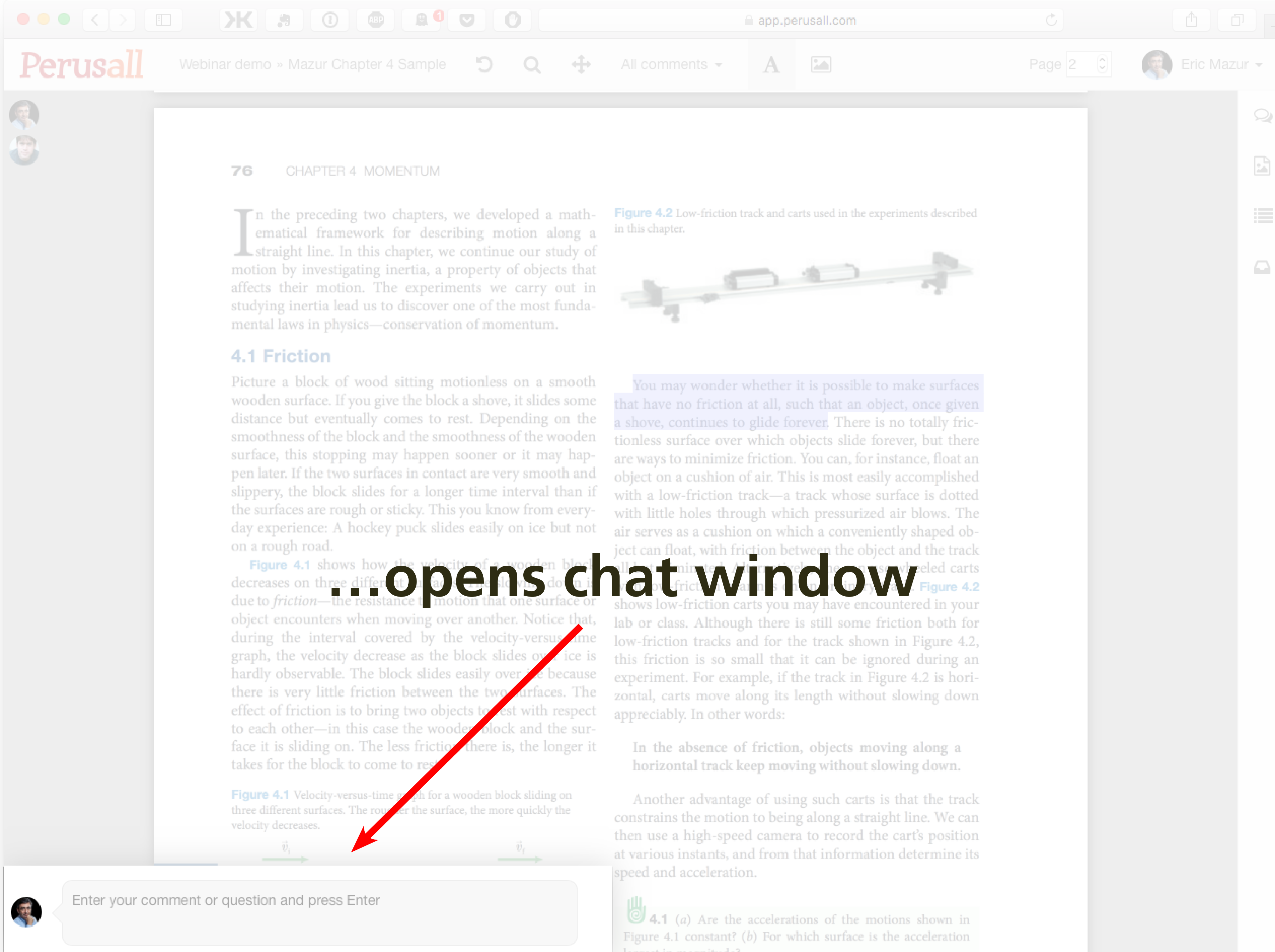
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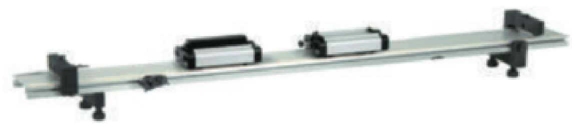

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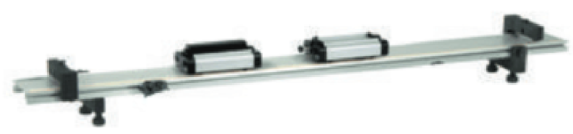

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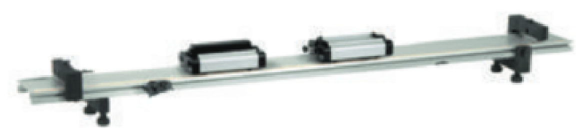

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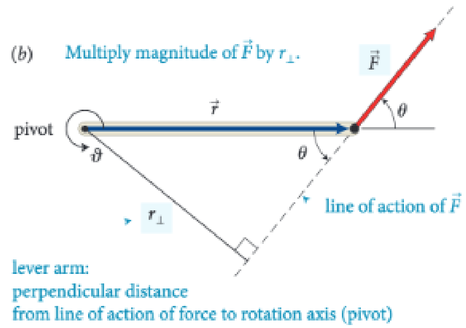

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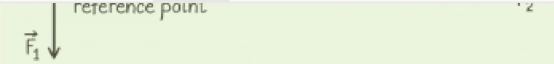
Like other rotational quantities, torque carries a sign that depends on the choice of direction for increasing ϑ. In Figure 12.4, for example, the torque caused by $\vec{F}_1$ about the pivot tends to rotate the rod in the direction of increasing ϑ and so is positive; the torque caused by $\vec{F}_2$ 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.

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 forces exerted on it, showing their points of application on the rod (Figure 12.6).



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:

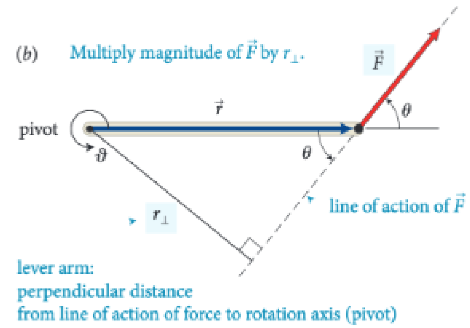
For a stationary object, the sum of the torques is zero.

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 makes an angle of 45° with the horizontal. Do these forces cause the lever to rotate about the pivot? If so, in which direction?



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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

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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

Enter your comment or question and press Enter

reference point

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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. ✔

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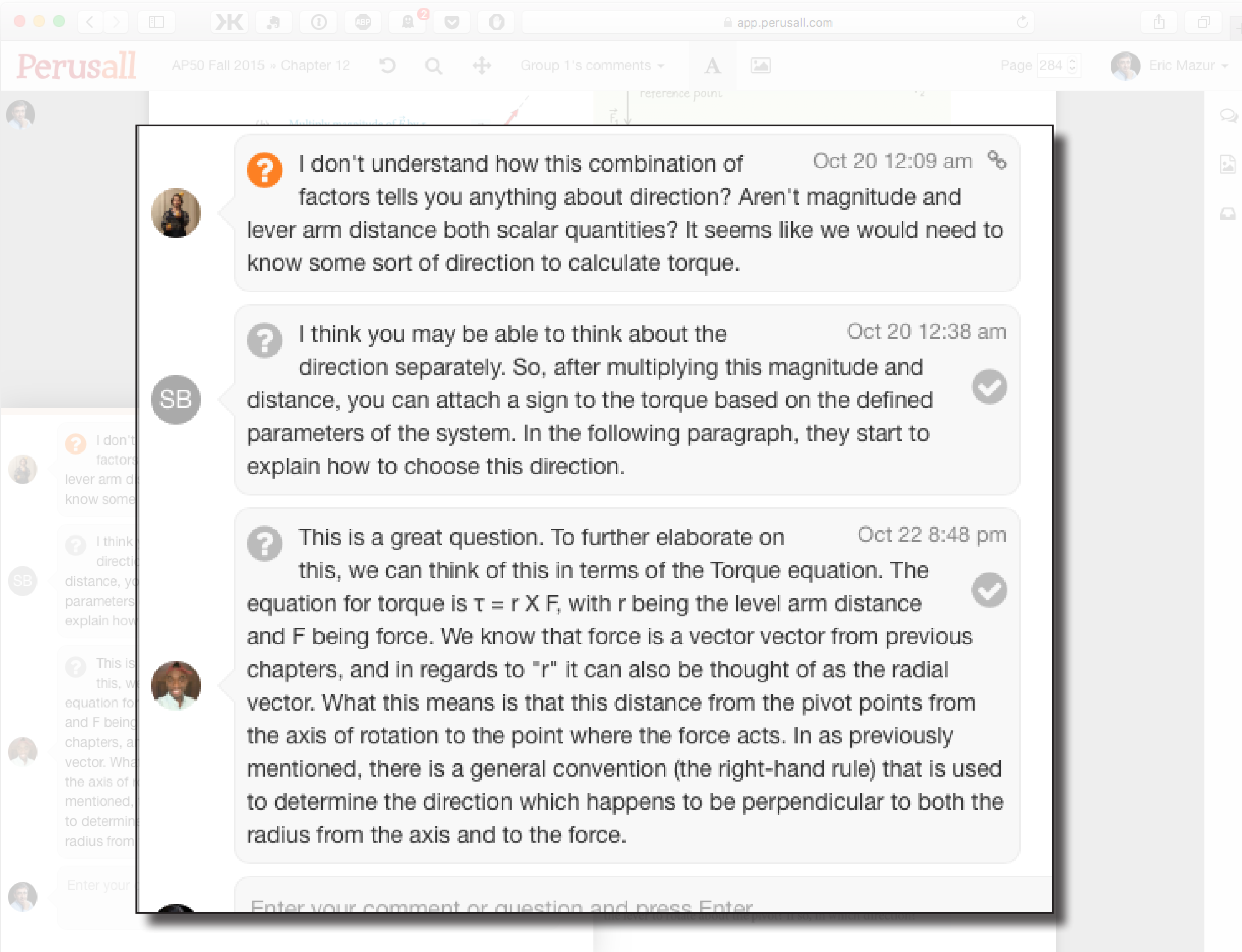
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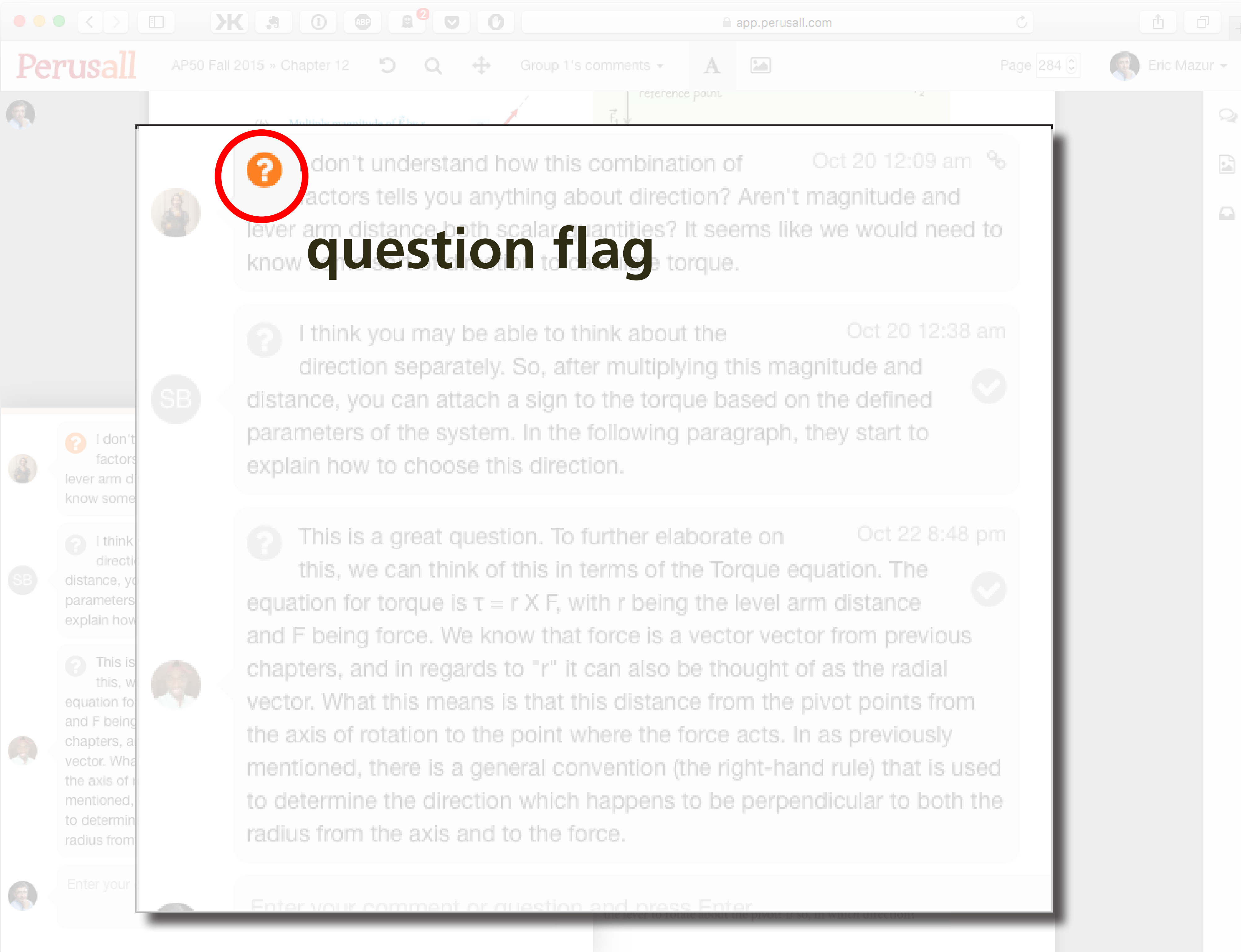

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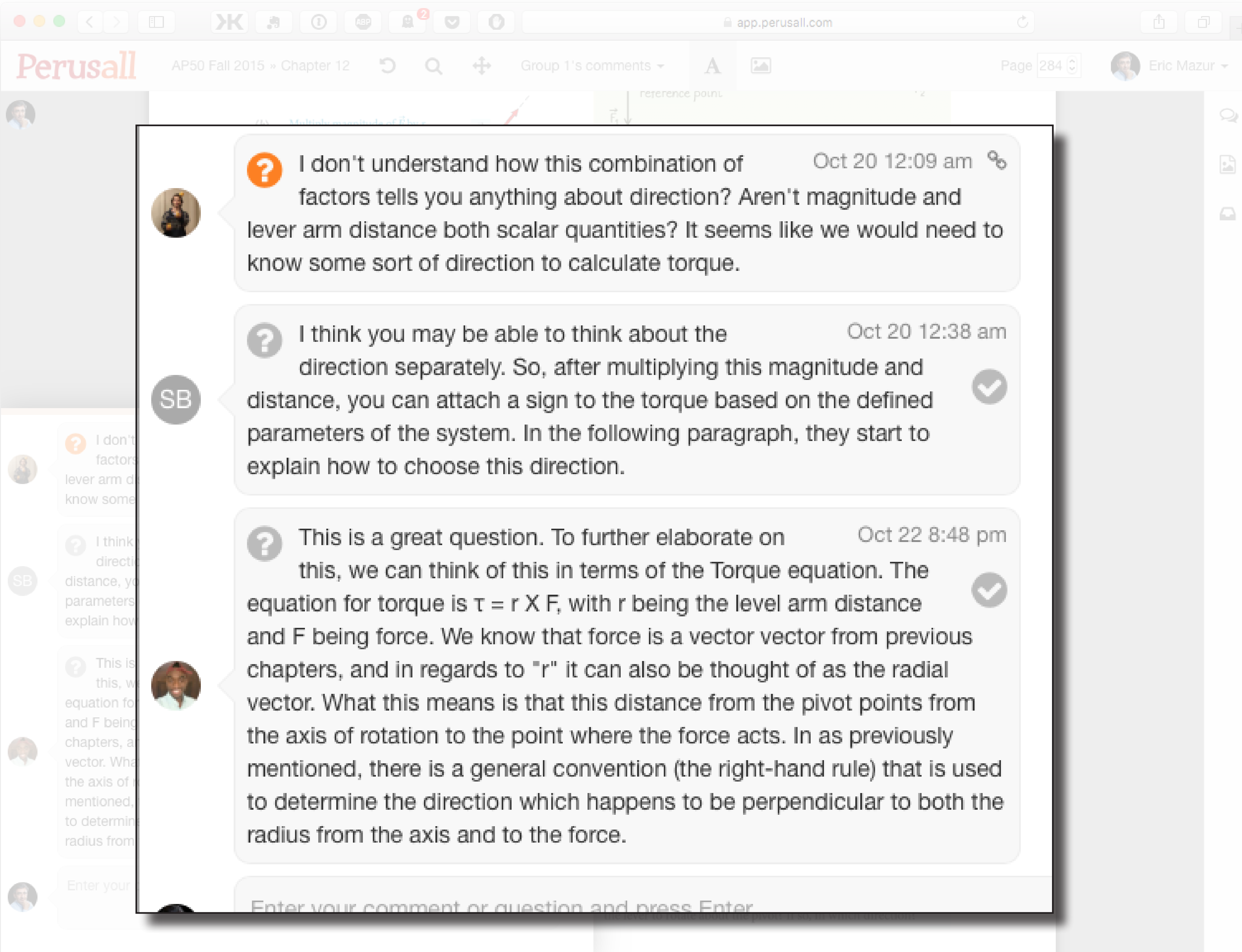
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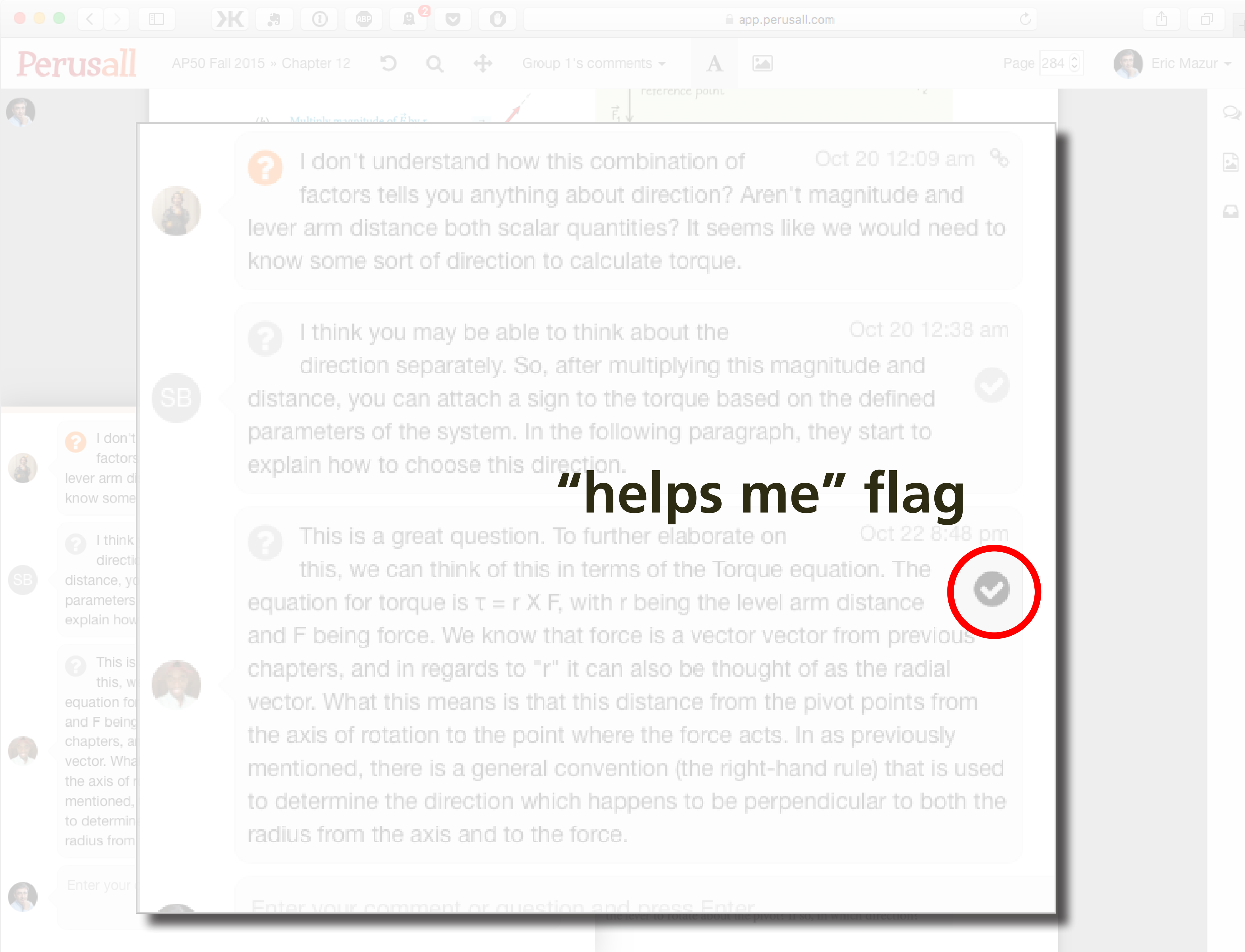
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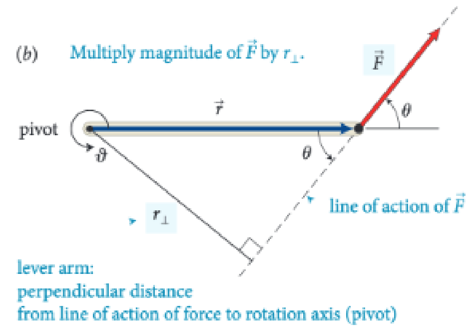

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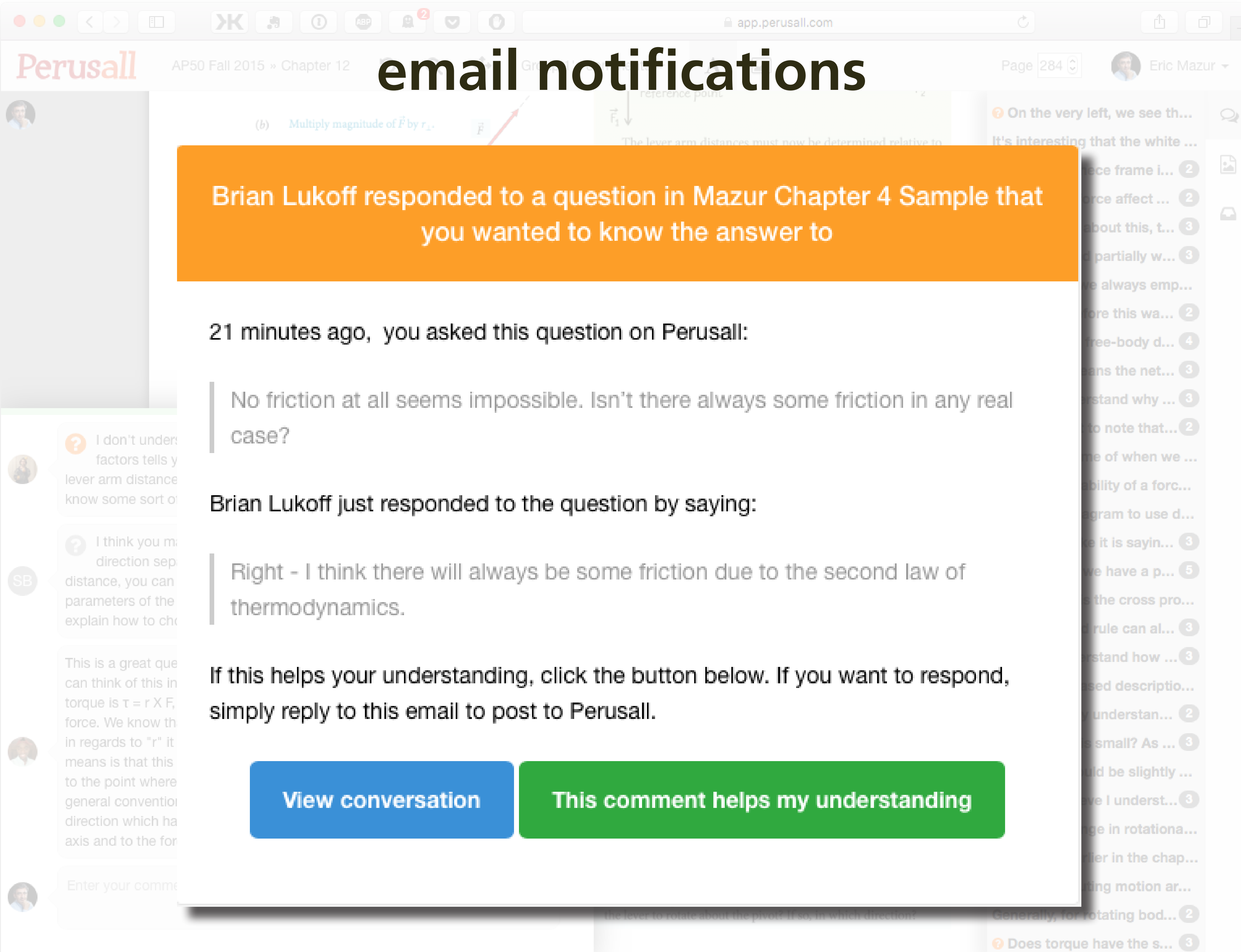

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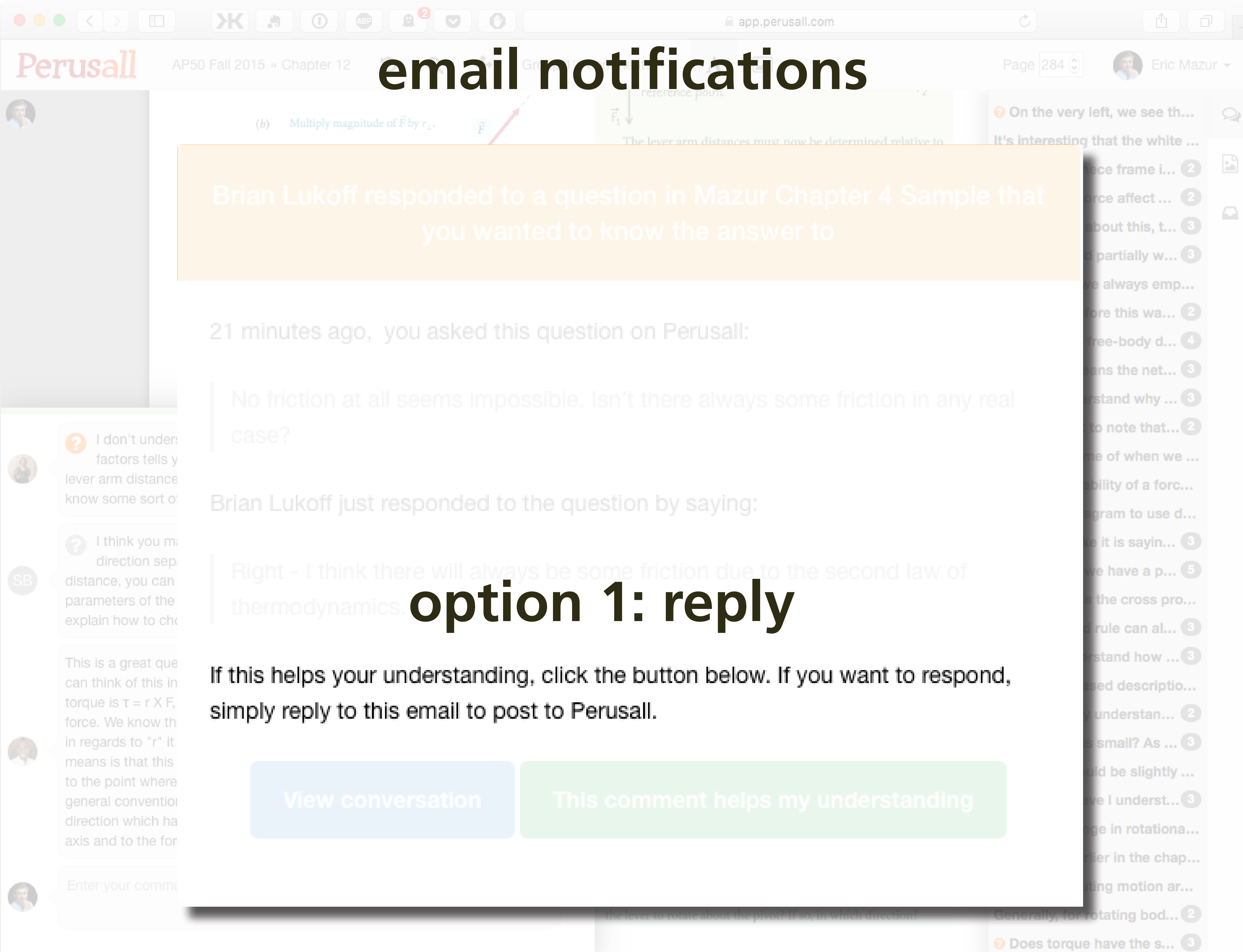

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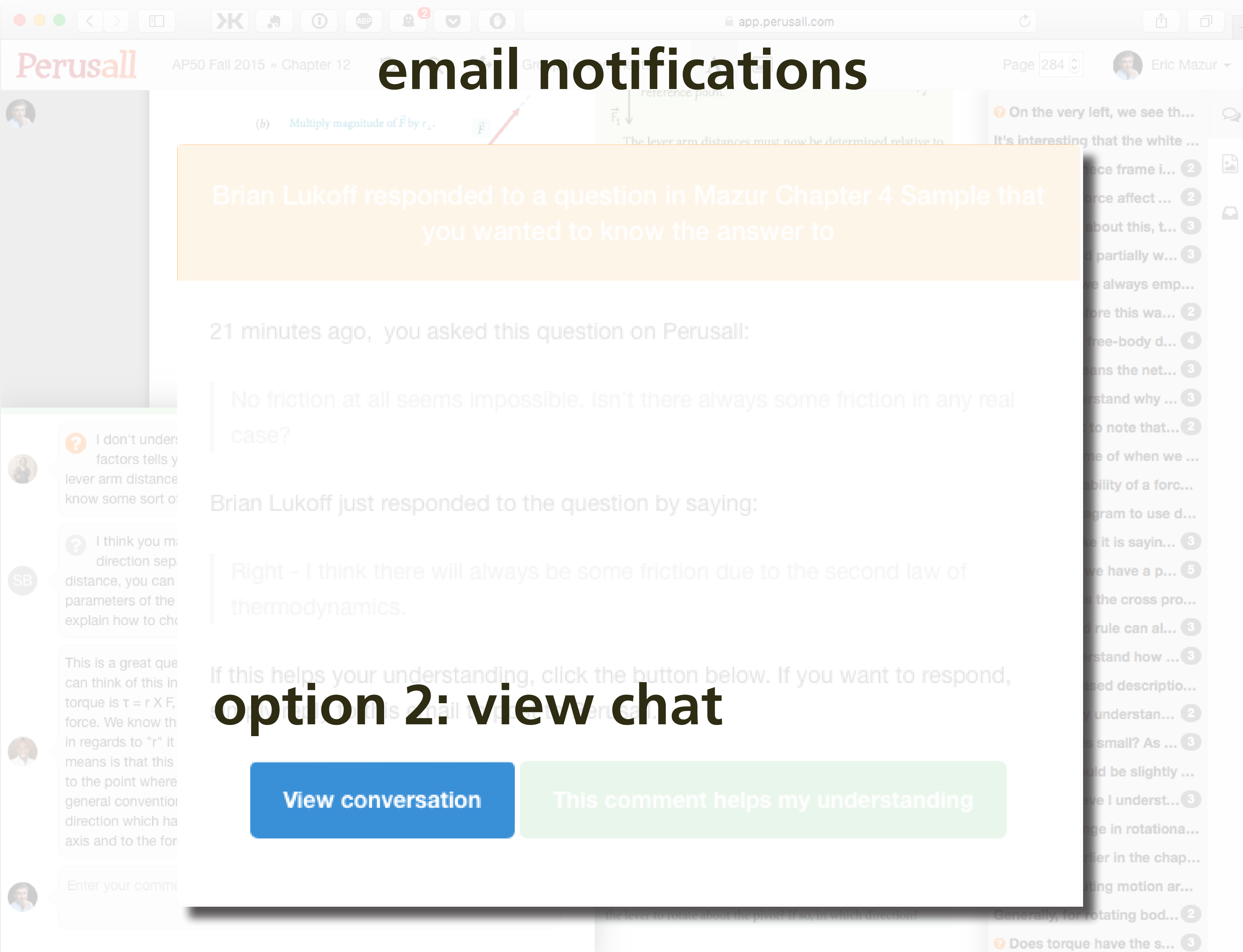

option 2: view chat

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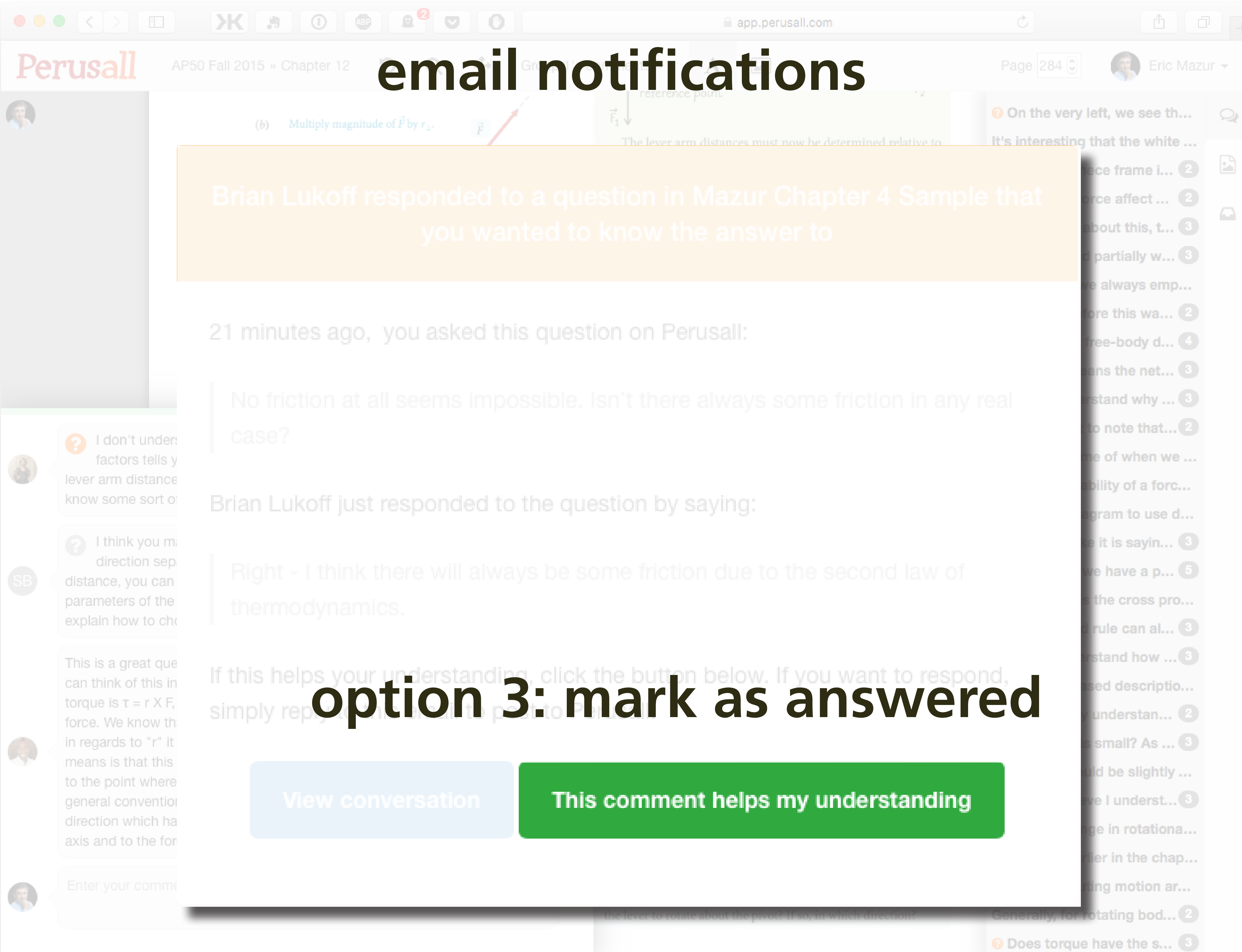


option 3: mark as answered

Example 4.5 Bullet and bowling ball

Compare the magnitude of the momenta of a 0.010-kg bullet fired from a rifle at 1300 m/s and a 6.5-kg bowling ball lumbering across the floor at 4.0 m/s.

❶ **GETTING STARTED** Momentum is the product of inertia and velocity. I have to calculate this quantity for both the bullet and the bowling ball and then compare the resulting values.

❷ **DEVISE PLAN** Equation 4.6 gives the momentum of an object. To determine the magnitude of the momentum of an object, I must take the product of the inertia m and the speed v: $p = mv$.

❸ **EXECUTE PLAN** Substituting the values given in the problem statement, I get

$$p_{\text{bullet}} = (0.010\ \text{kg})(1300\ \text{m/s}) = 13\ \text{kg}\cdot\text{m/s}\ ✔$$

$$p_{\text{bowling}} = (6.5\ \text{kg})(4.0\ \text{m/s}) = 26\ \text{kg}\cdot\text{m/s}.\ ✔$$

❹ **EVALUATE RESULT** Surprisingly, the magnitudes of the momenta are very close! I have no way of evaluating momenta because I don't have much experience yet with this quantity. However, the bullet has less inertia and a high speed and the bowling ball has greater inertia and a low speed, so it is not unreasonable that the product of these quantities is similar.

Momentum is a quantitative measure of "matter in motion" and depends on both the amount of matter in motion and how fast that matter is moving. Momentum is very different from inertia. A truck, for example, has greater inertia than a fly (it has a higher resistance to a change in its velocity), but if the truck is at rest and the fly is in motion, then the magnitude of the fly's momentum is larger than that of the truck, which is zero. In Example 4.5, the inertias of the bullet and the bowling ball are very different, yet their momenta are similar. Conceptually you can think of an object's momentum as its capacity to affect the motion of other objects in a collision.

With the definition of momentum, we can rewrite Eq. 4.5 in the form

$$p_{\text{u}x,\text{f}} - p_{\text{u}x,\text{i}} + p_{\text{s}x,\text{f}} - p_{\text{s}x,\text{i}} = 0. \tag{4.8}$$

If we write $\Delta p_{\text{u}x} \equiv p_{\text{u}x,\text{f}} - p_{\text{u}x,\text{i}}$ and $\Delta p_{\text{s}x} \equiv p_{\text{s}x,\text{f}} - p_{\text{s}x,\text{i}}$, Eq. 4.8 takes on the beautifully simple form

$$\Delta p_{\text{u}x} + \Delta p_{\text{s}x} = 0. \tag{4.9}$$

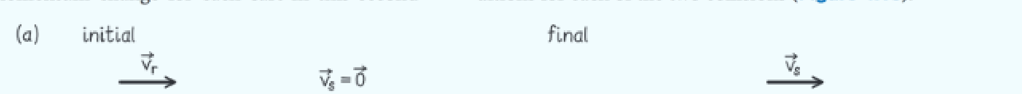
This equation means that, whenever an object of unknown inertia collides with the inertial standard, the changes in the x components of the momenta of the two objects add up to zero. In other words, the change in the x component of the momentum for one object is always the negative of the change for the other.

Example 4.6 Collisions and momentum changes

(*a*) A red cart with an initial speed of 0.35 m/s collides with a stationary standard cart ($m_s = 1.0$ kg). After the collision, the standard cart moves away at a speed of 0.38 m/s. What is the momentum change for each cart? (*b*) The experiment is repeated with a blue cart, and now the final speed of the standard cart is 0.31 m/s. What is the momentum change for each cart in this second collision? (*c*) If in the collisions $v_{\text{r}x,\text{f}} = +0.032$ m/s and $v_{\text{b}x,\text{f}} = -0.039$ m/s, what are the inertias of the red and the blue carts?

❶ **GETTING STARTED** I begin organizing the information given in the problem in a picture by showing the initial and final conditions for each of the two collisions (Figure 4.18).

Figure 4.18



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$$p_{\text{bullet}} = (0.010 \text{ kg})(1300 \text{ m/s}) = 13 \text{ kg} \cdot \text{m/s} \checkmark$$

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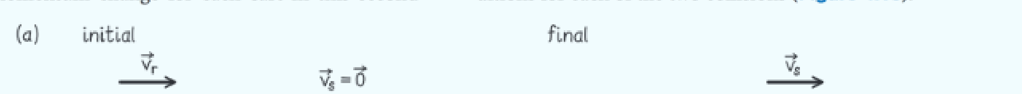
❶ **GETTING STARTED** I begin organizing the information given in the problem in a picture by showing the initial and final conditions for each of the two collisions (Figure 4.18).

Figure 4.18



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Perusall Webinar demo » Mazur Chapter 4 Sample All comments Page 2 Eric Mazur

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.

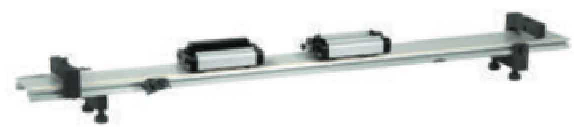
Figure 4.1 shows how the velocity of a wooden block decreases on three different surfaces. The slowing down is due to *friction*—the resistance to motion that one surface or object encounters when moving over another. Notice that, during the interval covered by the velocity-versus-time graph, the velocity 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.

+1 ? No friction at all seems impossible. Isn't there always some friction in any real case. Nov 1 12:03 pm

? Right - I think there will always be some friction due to the second law of thermodynamics. Nov 1 12:09 pm

Enter your comment or question and press Enter

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.

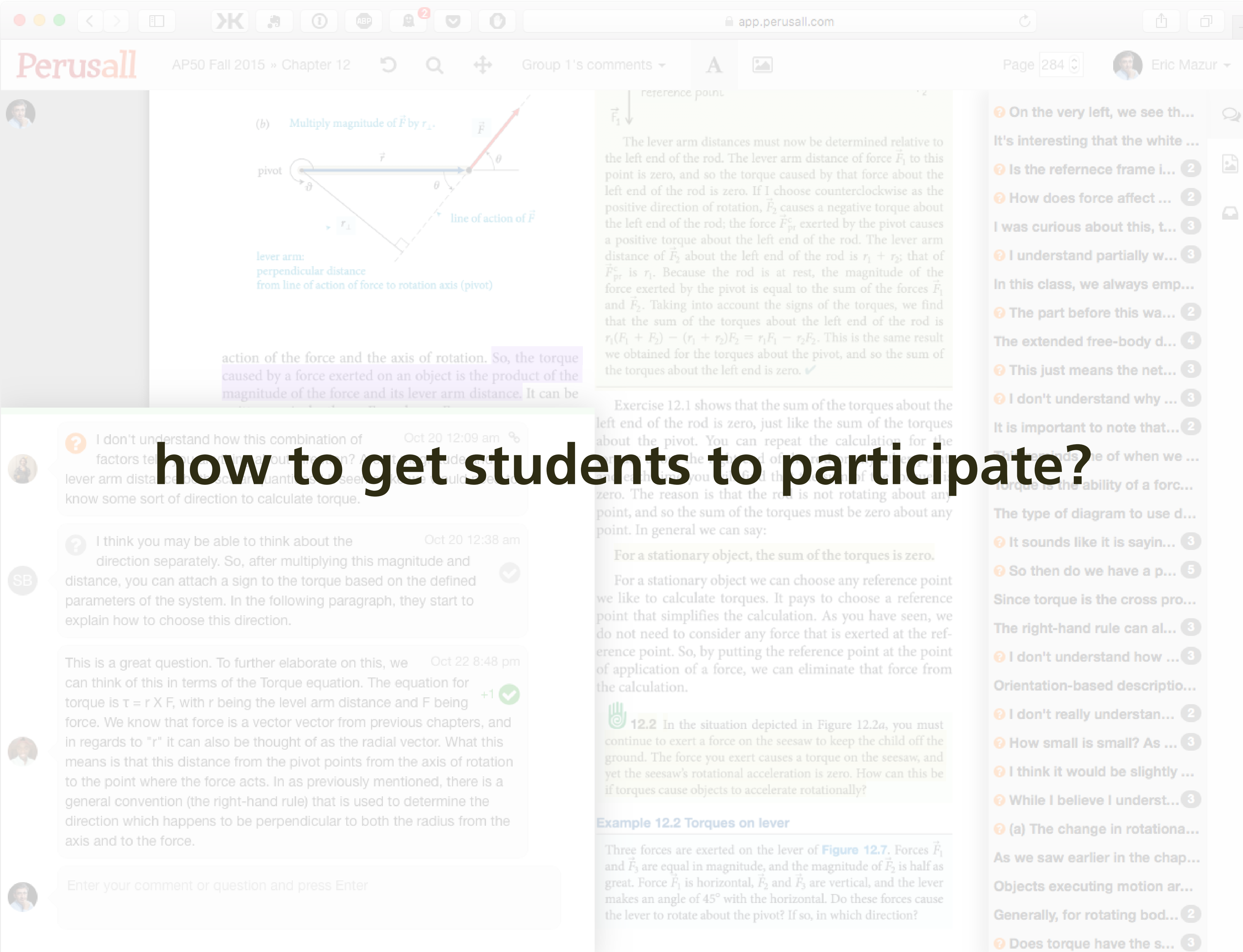
4.1 (*a*) Are the accelerations of the motions shown in Figure 4.1 constant? (*b*) For which surface is the acceleration largest in magnitude?

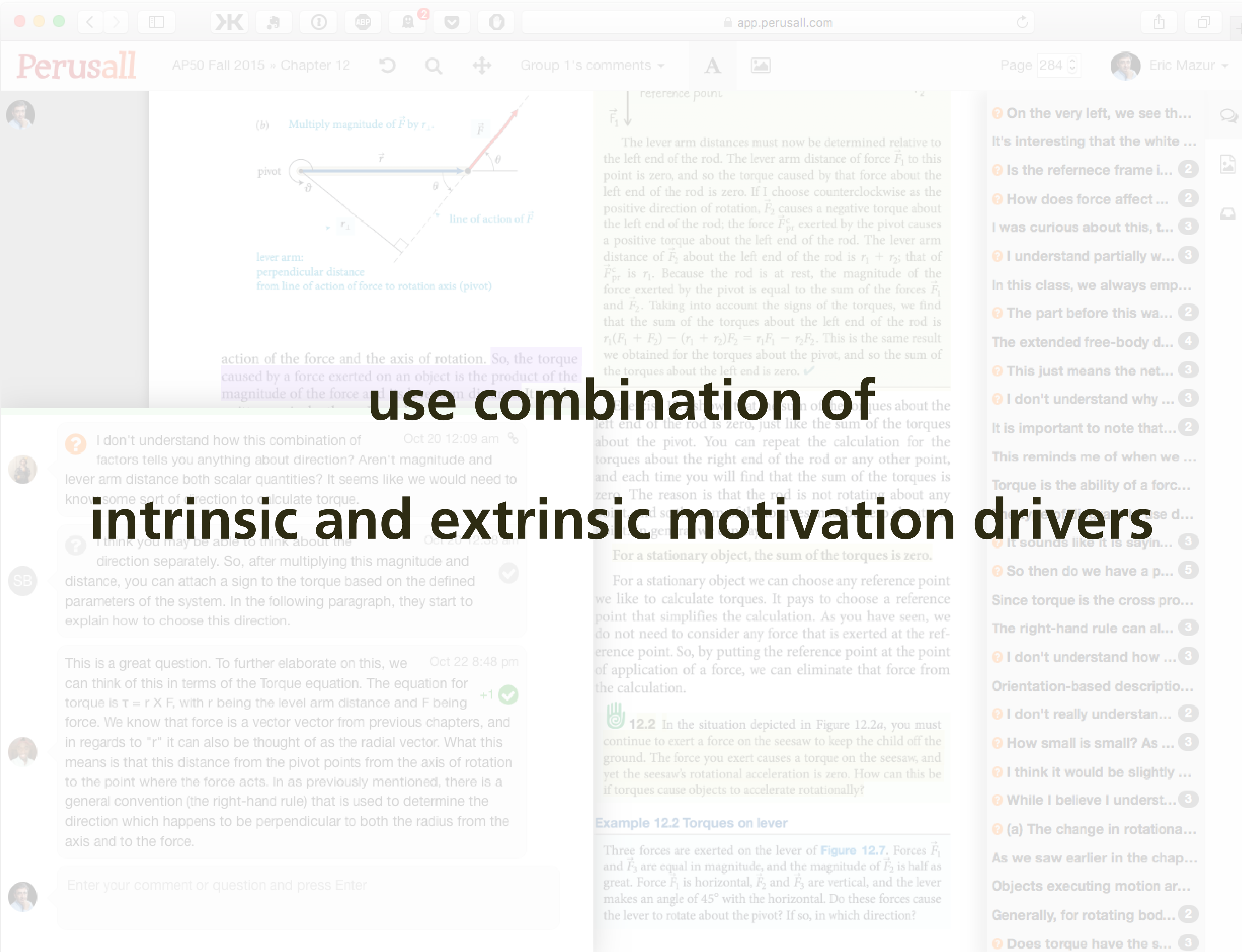
4.2 Inertia

Brian Lukoff responded to your comment: **Right - I think there will always be some friction due to the second law of thermodynamics.**

a few seconds ago

how to get students to participate?

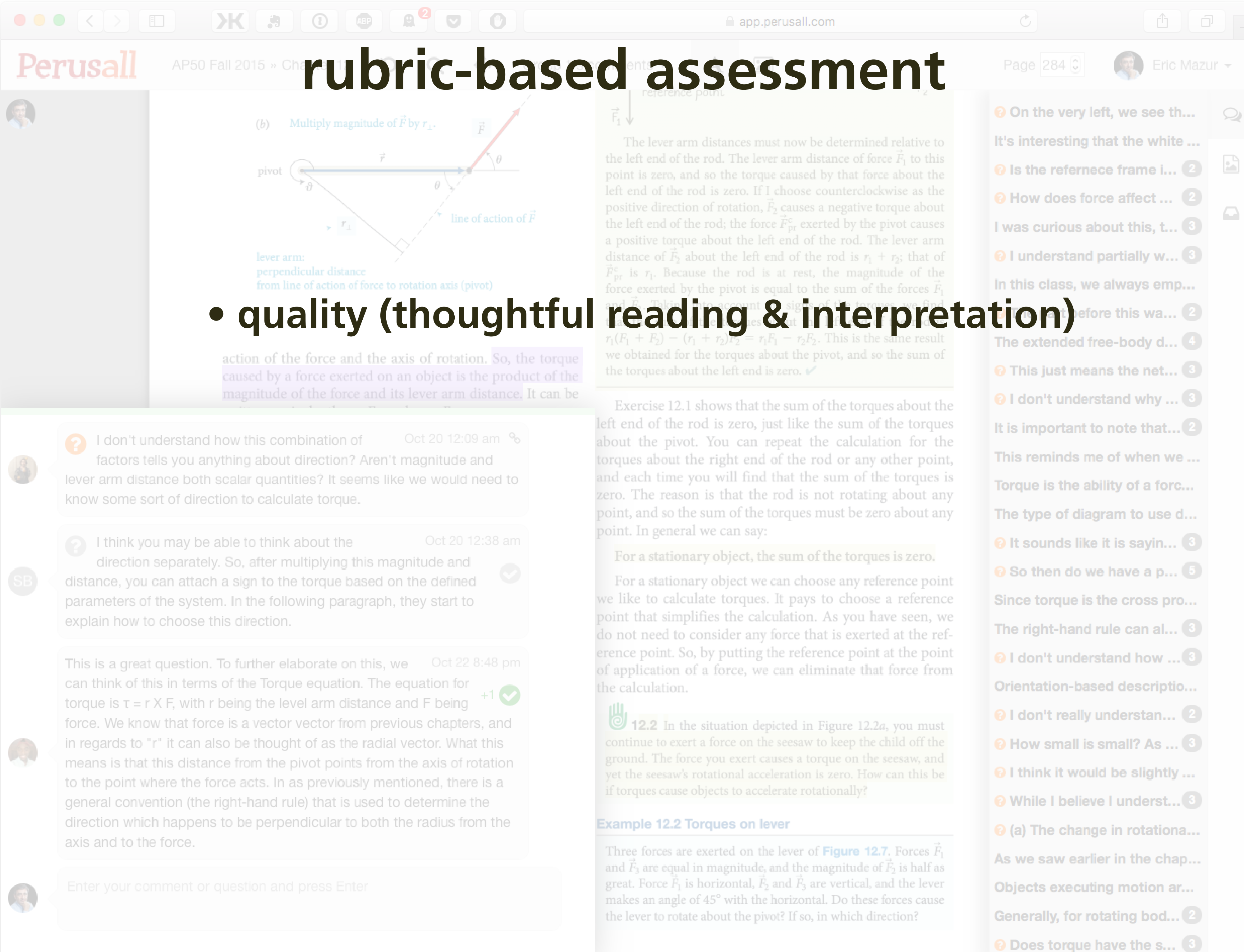




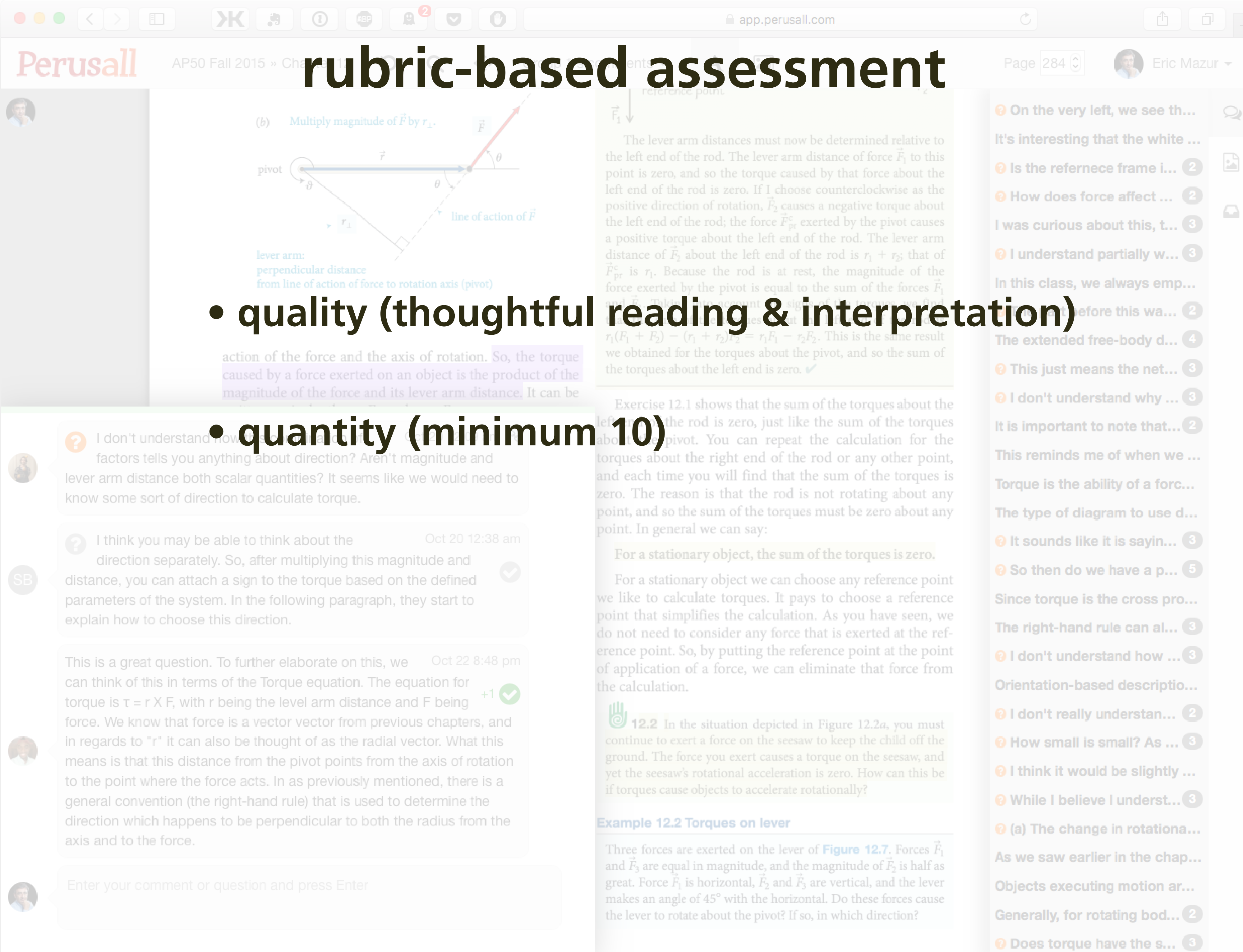
use combination of intrinsic and extrinsic motivation drivers

rubric-based assessment

- quality (thoughtful reading & interpretation)



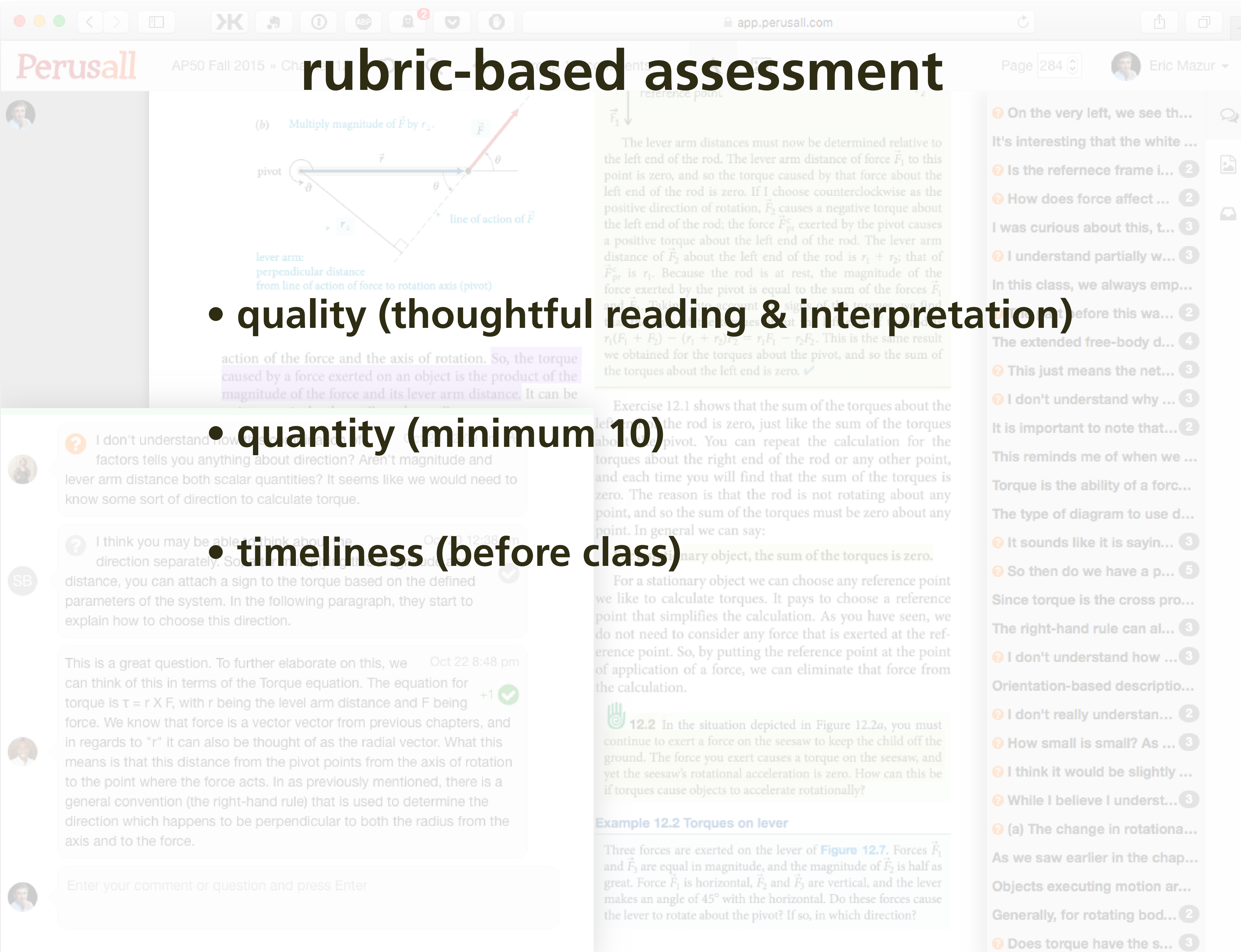
rubric-based assessment



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

rubric-based assessment

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



rubric-based assessment

- quality (thoughtful reading & interpretation)
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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.

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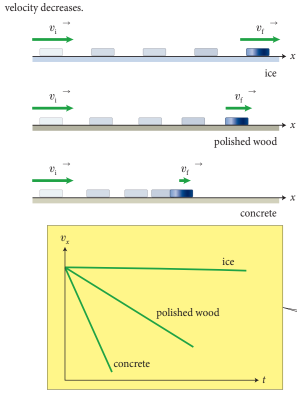

Figure 4.1 Velocity-versus-time graph for a wooden block sliding on three different surfaces. The rougher the surface, the more quickly the velocity decreases.

CONCEPTS

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:

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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 absence 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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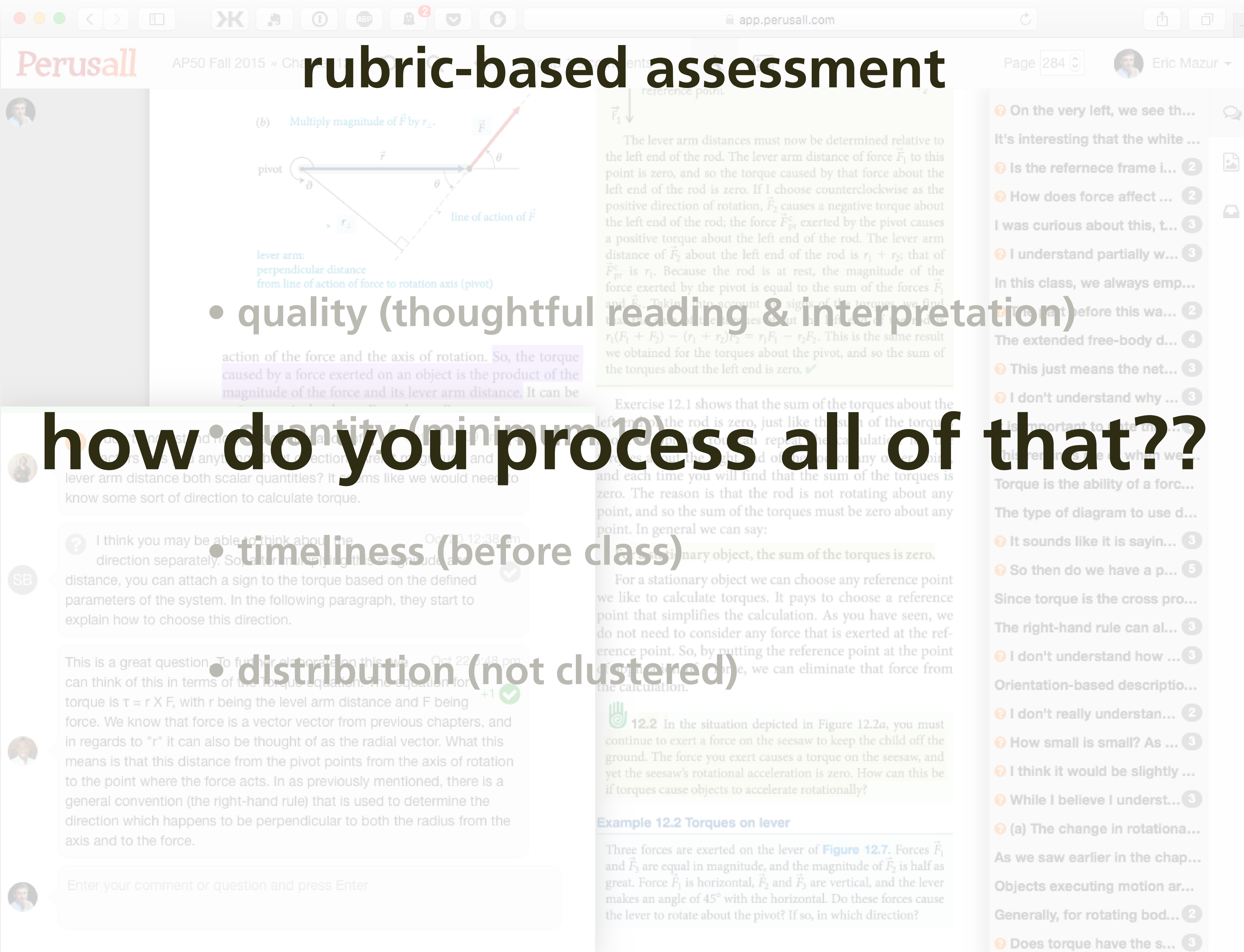
rubric-based assessment

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

over 20,000 annotations!

rubric-based assessment



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how do you process all of that??

rubric-based assessment

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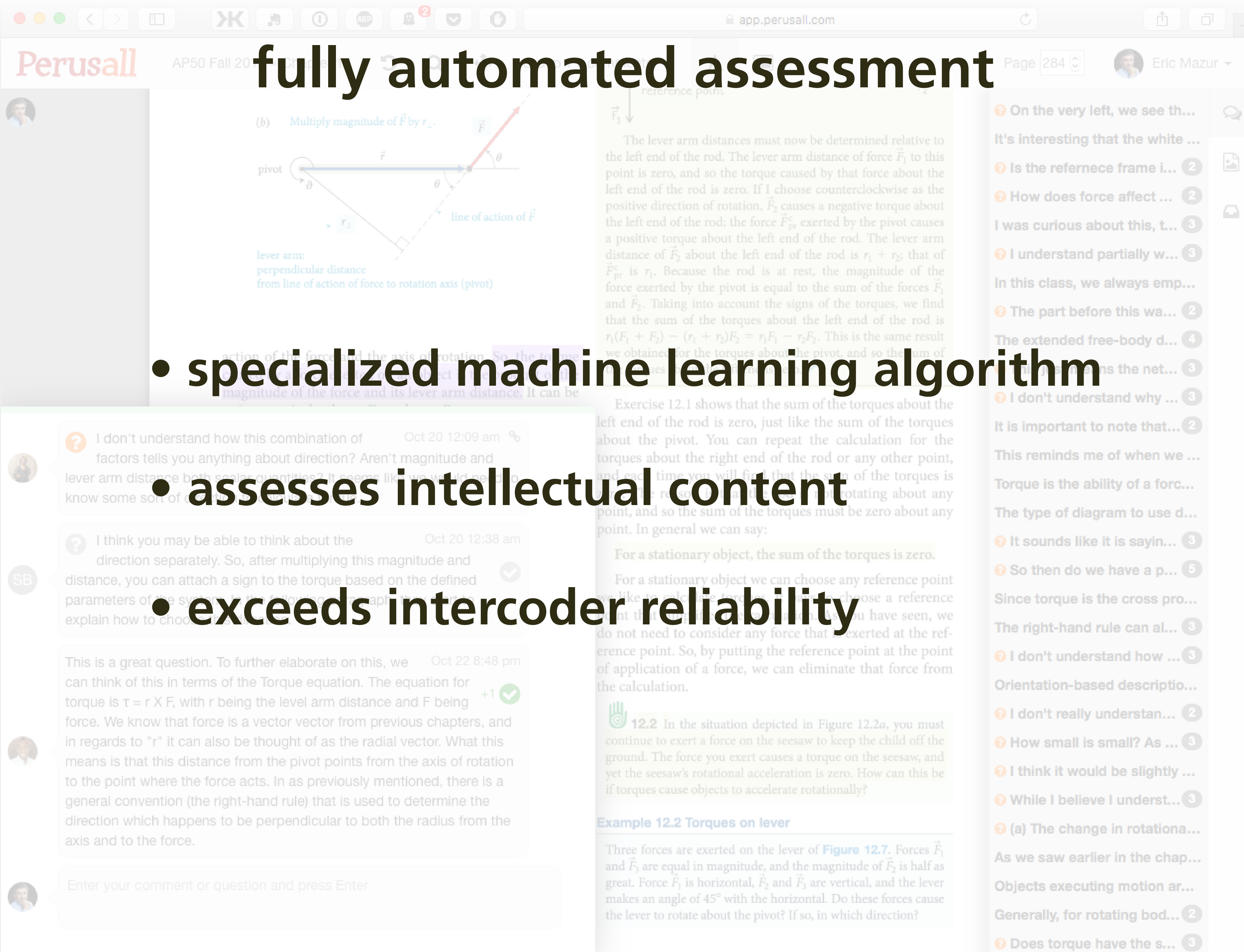
how do you process all of that??

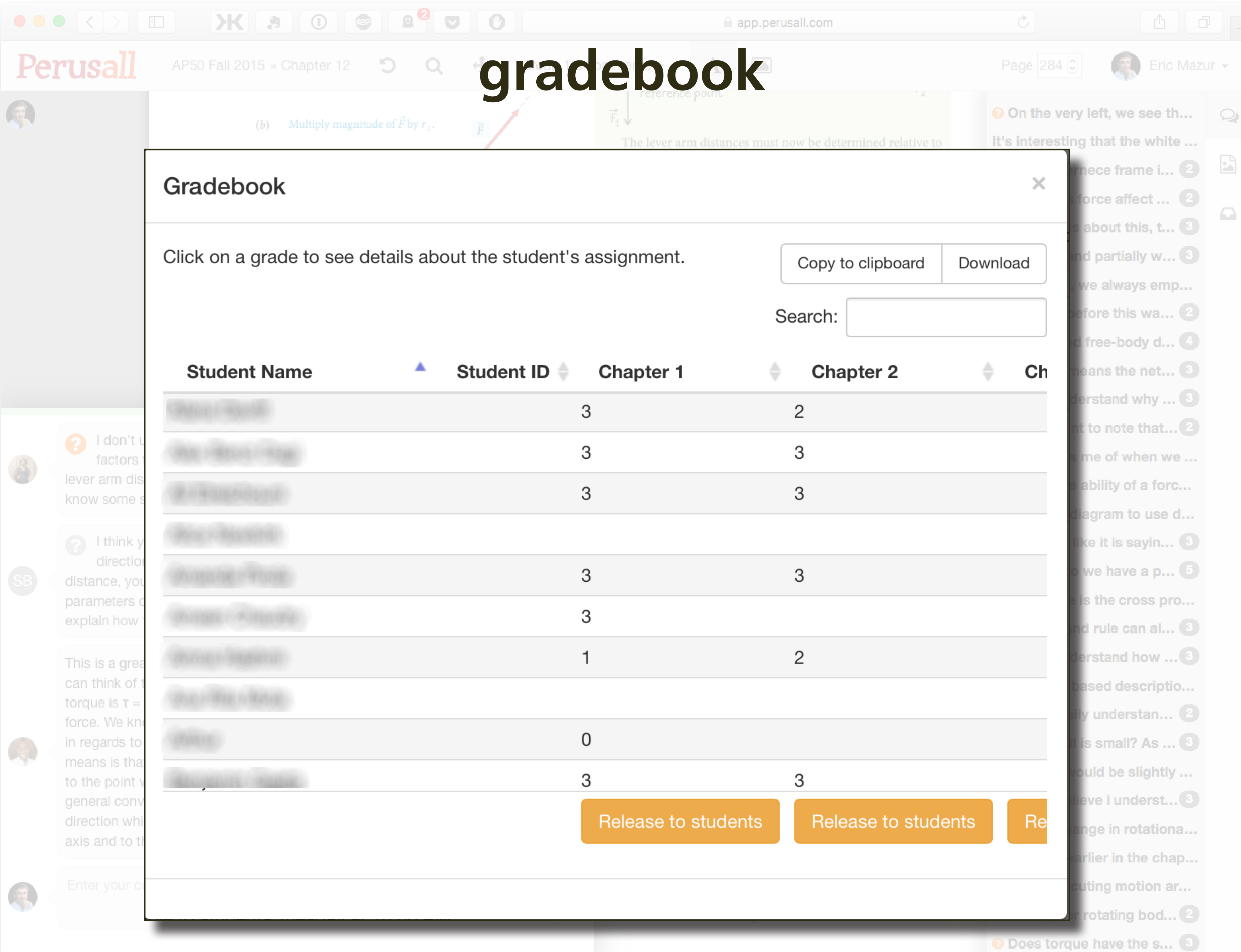
fully automated assessment

fully automated assessment



- specialized machine learning algorithm
- assesses intellectual content
- exceeds intercoder reliability

gradebook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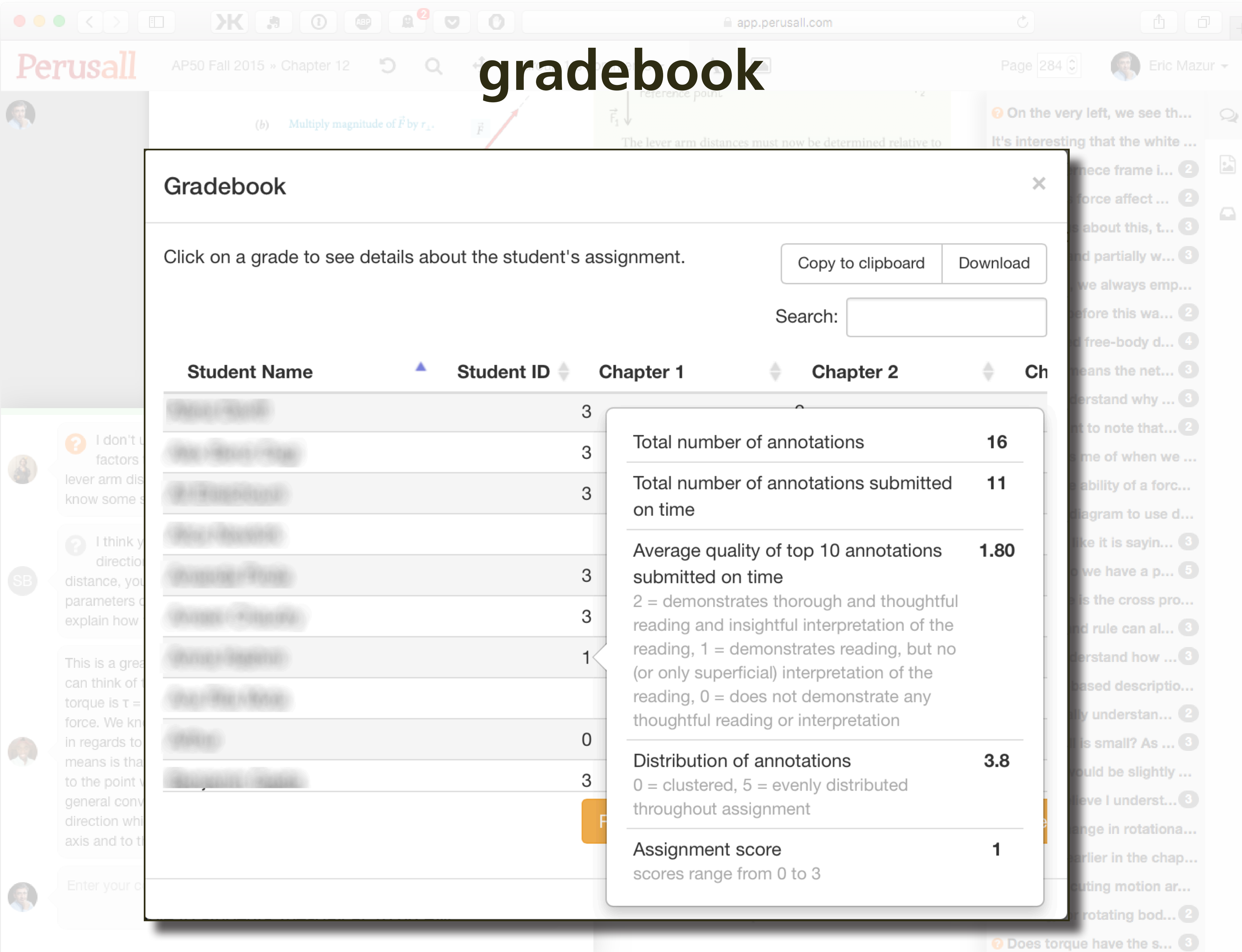
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Chapter 2
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3
3
3
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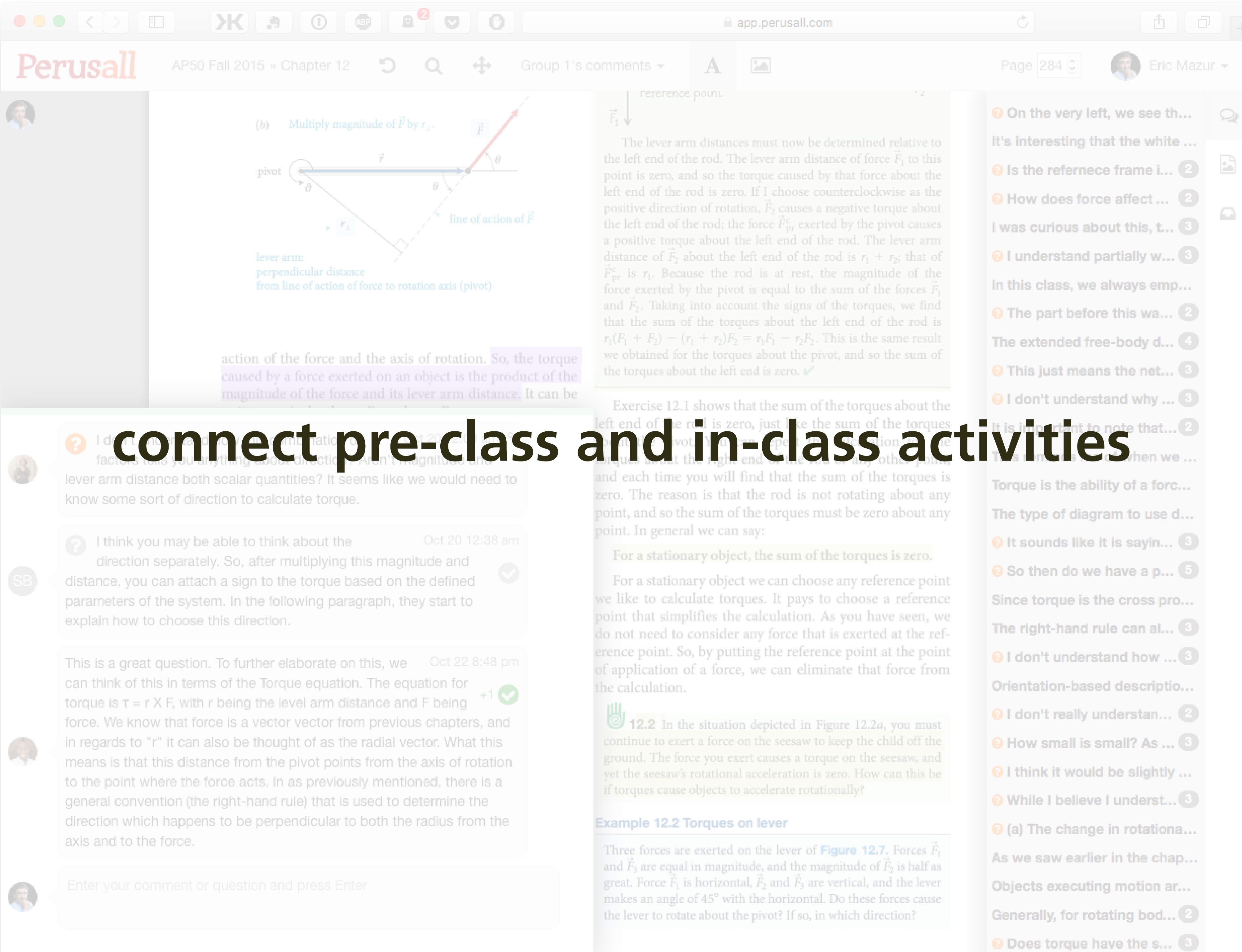
3
1
0
3
Total number of annotations
16
Total number of annotations submitted on time
11
Average quality of top 10 annotations submitted on time
1.80
2 = demonstrates thorough and thoughtful reading and insightful interpretation of the reading, 1 = demonstrates reading, but no (or only superficial) interpretation of the reading, 0 = does not demonstrate any thoughtful reading or interpretation
Distribution of annotations
3.8
0 = clustered, 5 = evenly distributed throughout assignment
Assignment score
1
scores range from 0 to 3

connect pre-class and in-class activities



confusion report

Confusion report for Chapter 24

right hand rule (11 questions)

- JB: Can someone in simpler terms explain the right- hand rule? (+1)
- WJ: Is there another way, besides the right hand rule, to find the direction of the magnetic field with a current?
- SB: Using the right hand rule, I believe the answer is D. Is that correct?

Show more...

direction magnetic field (8 questions)

- CP: Why is it that the magnet field points away from the north pole and towards the south pole? When on the previous page it stated that the direction of the magnetic field is the direction that the north pole of a compass needle points. (+2)
- AB: How can you determine which direction the magnetic field will point towards? (+1)
- KH: So whichever way the north pole faces is the direction of the magnetic field but that doesn't always mean its pointing true north? (+1)

Show more...

earth magnetic field (6 questions)

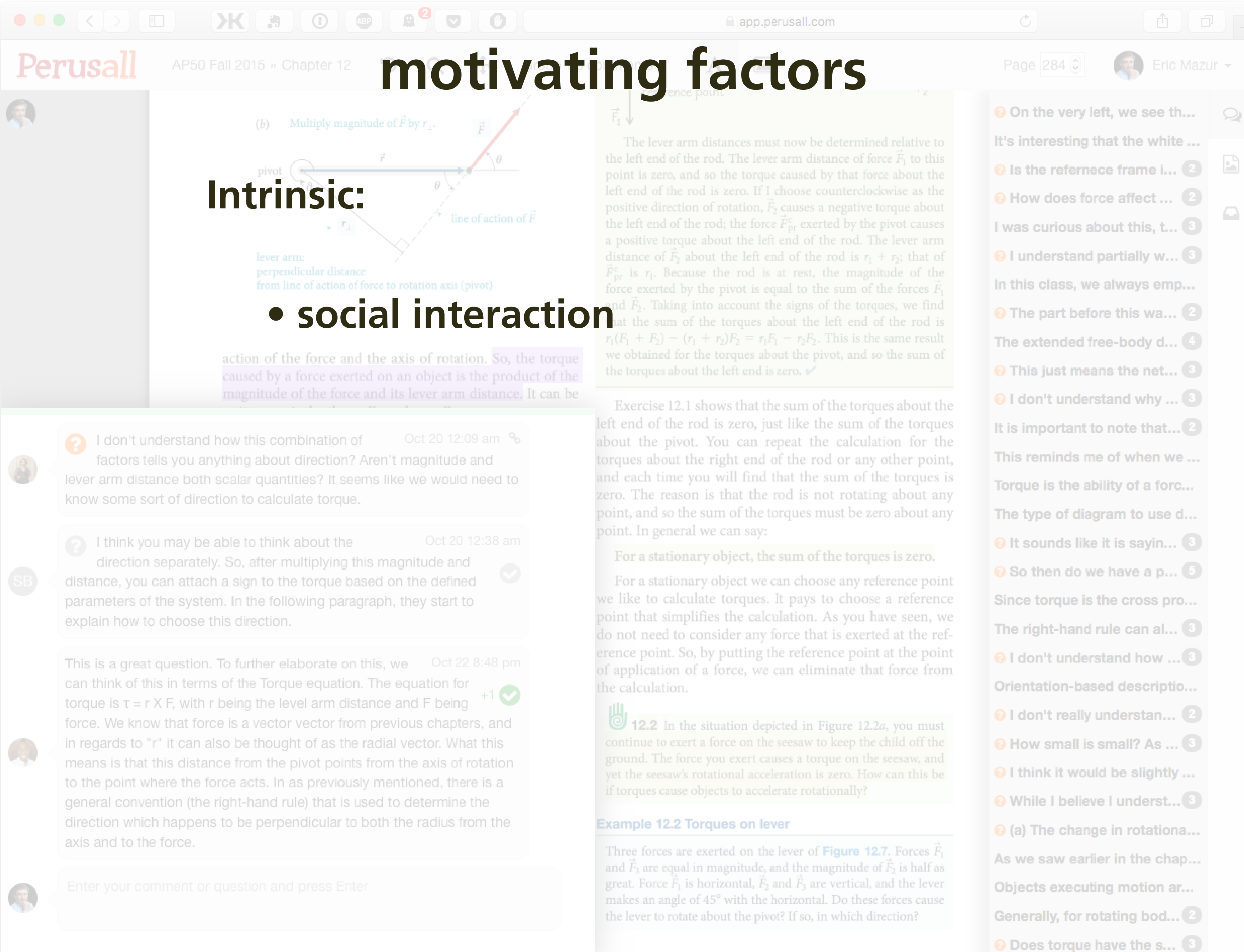
- CP: Does that mean that the compass will be distracted from the Earth's magnetic field and use the magnetic field that the current of the wire gives off?
- AK: Can someone explain why this type of bacteria knows what direction the earth's magnetic fields are facing?
- J: Does the circular loop of current have any similarities with the look of the earths magnetic field? They kind of look similar to me.

Show more...

motivating factors

Intrinsic:

- social interaction



motivating factors

Intrinsic:

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

motivating factors

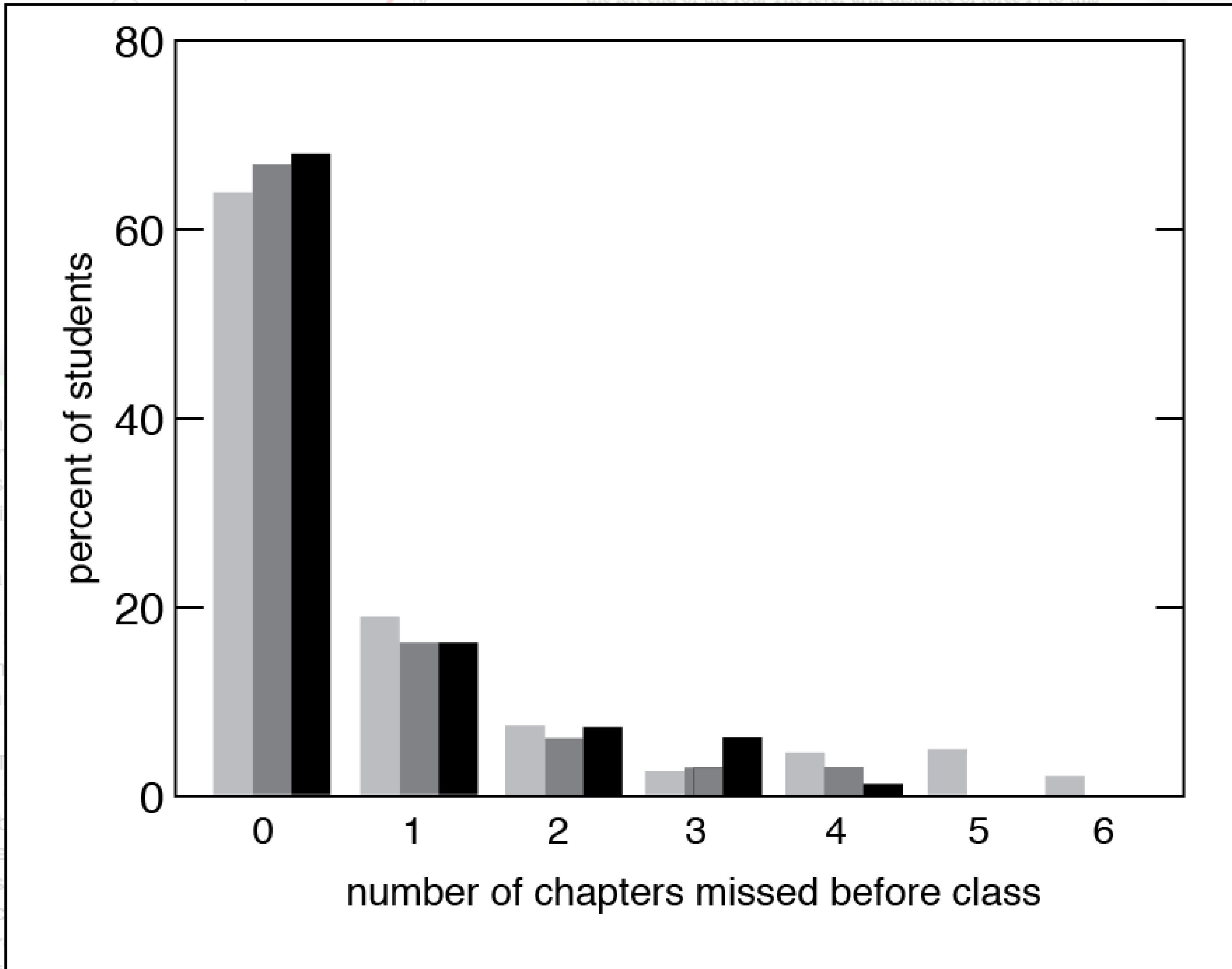
Intrinsic:

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

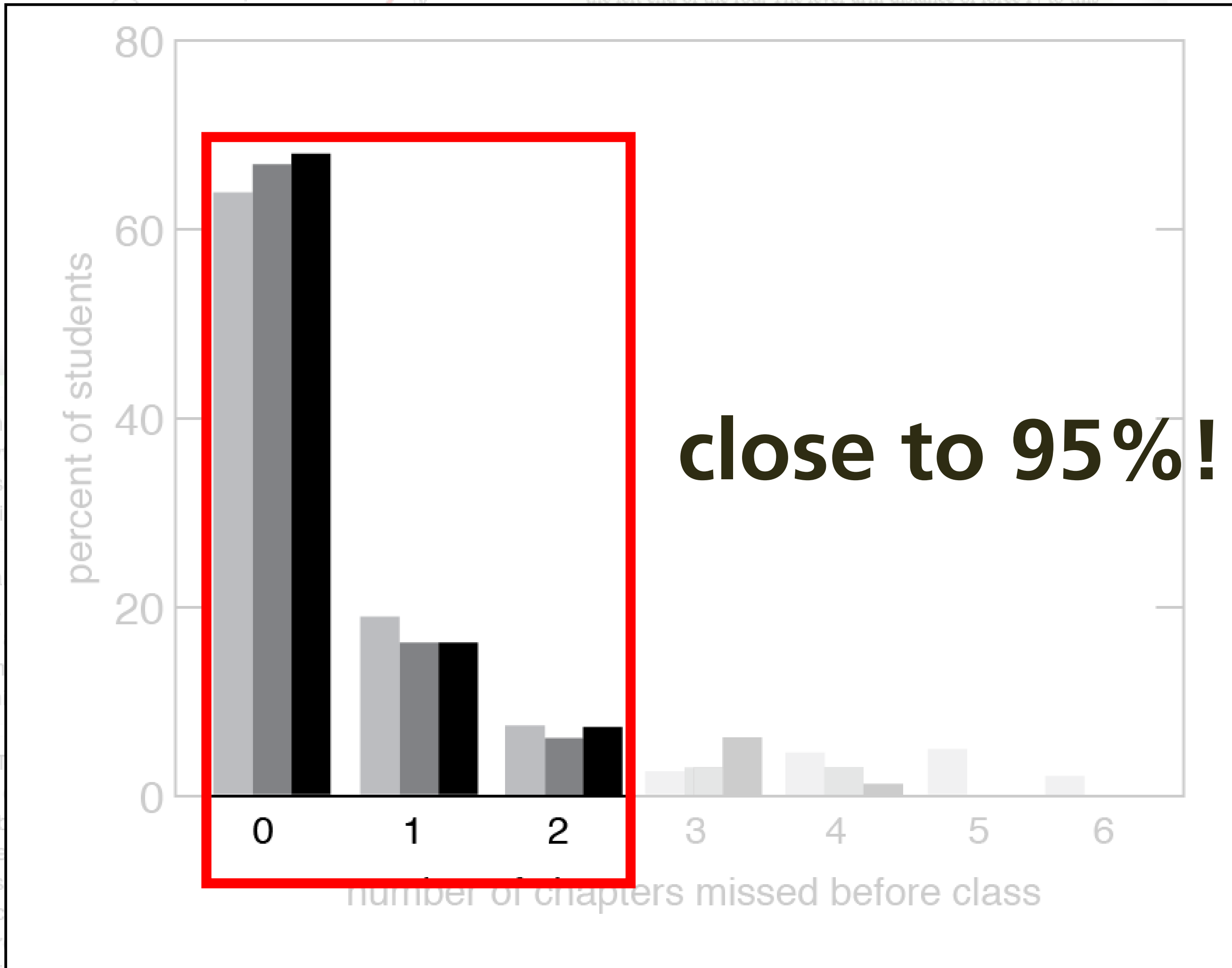
Extrinsic:

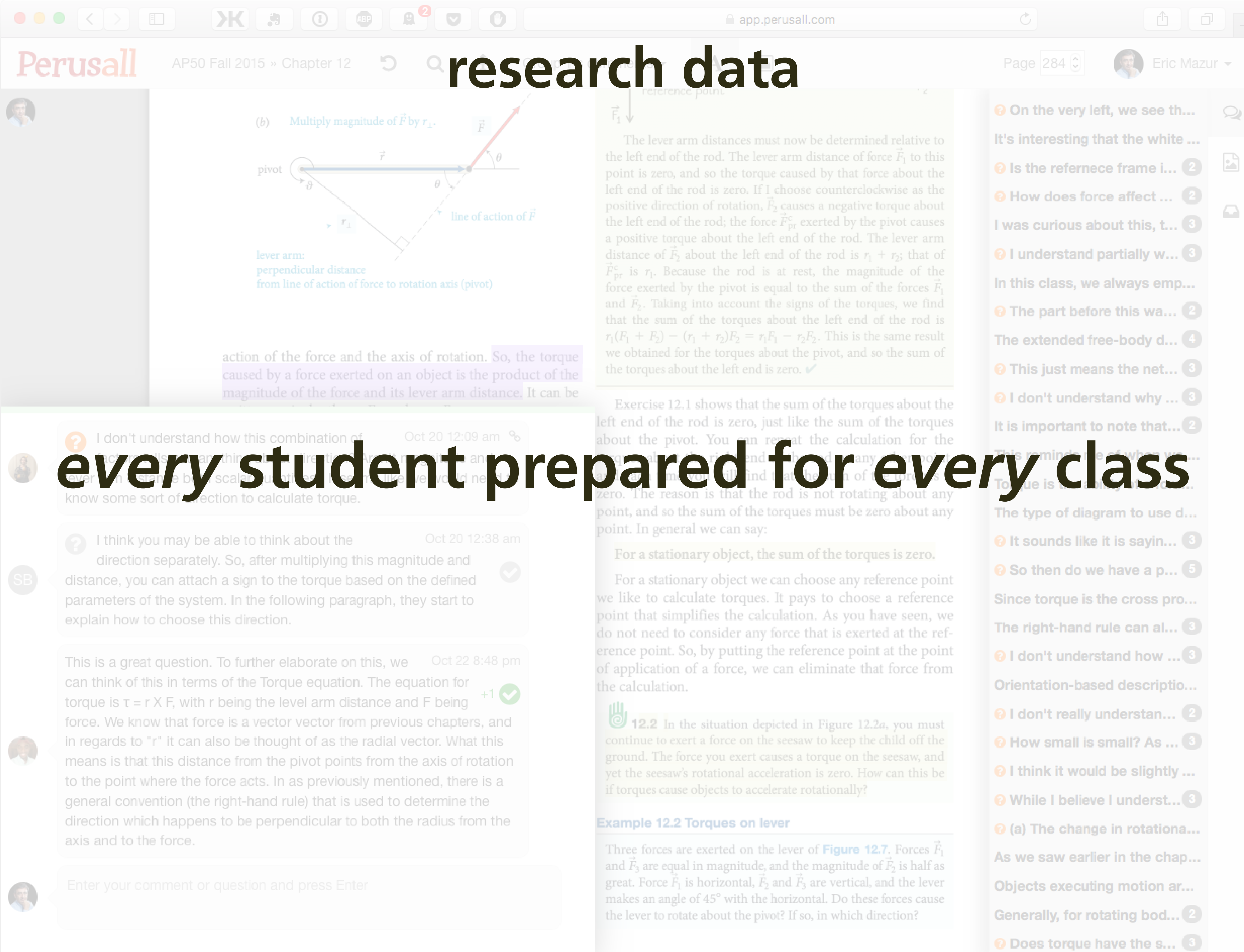
- assessment (fully automated)

research data



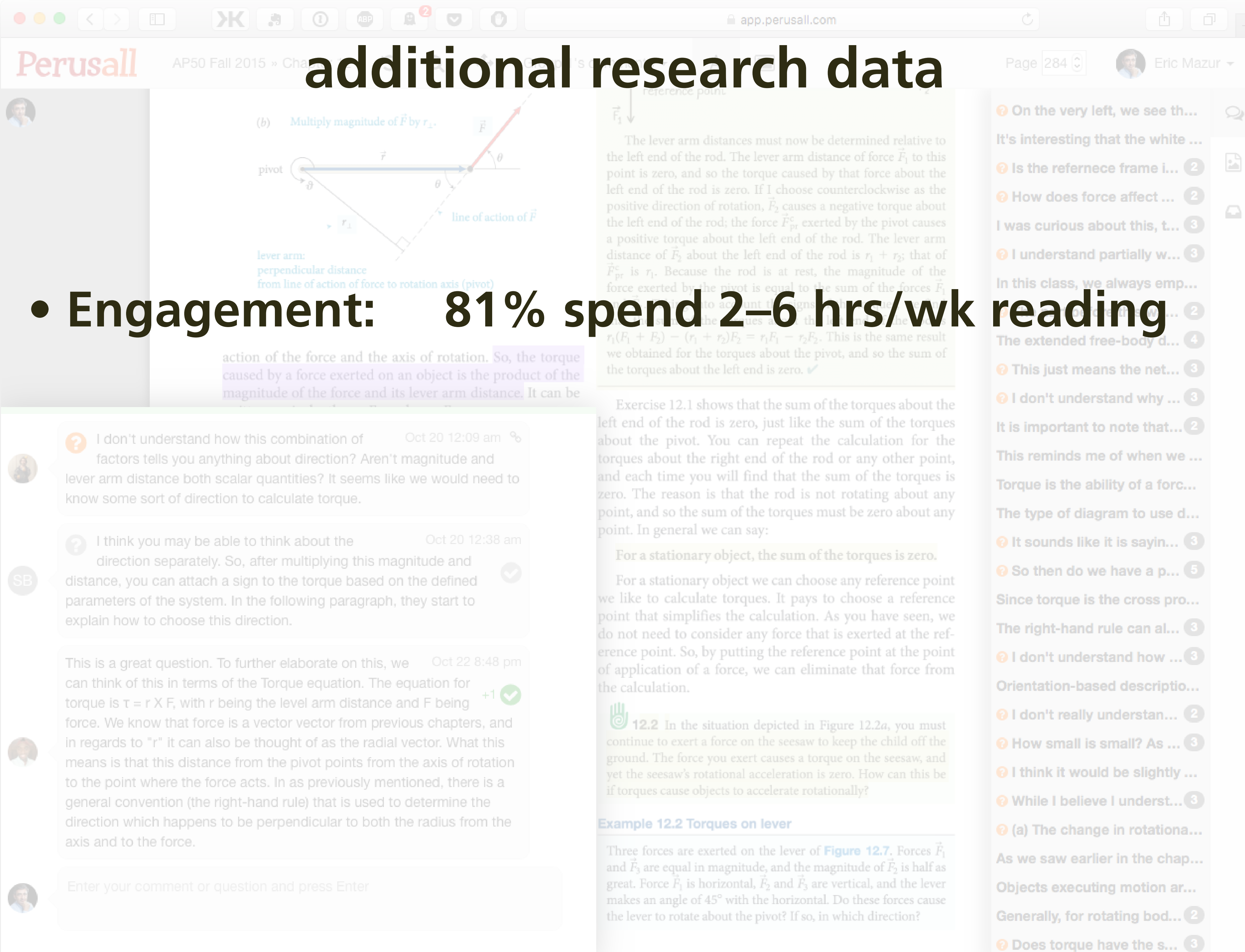
research data



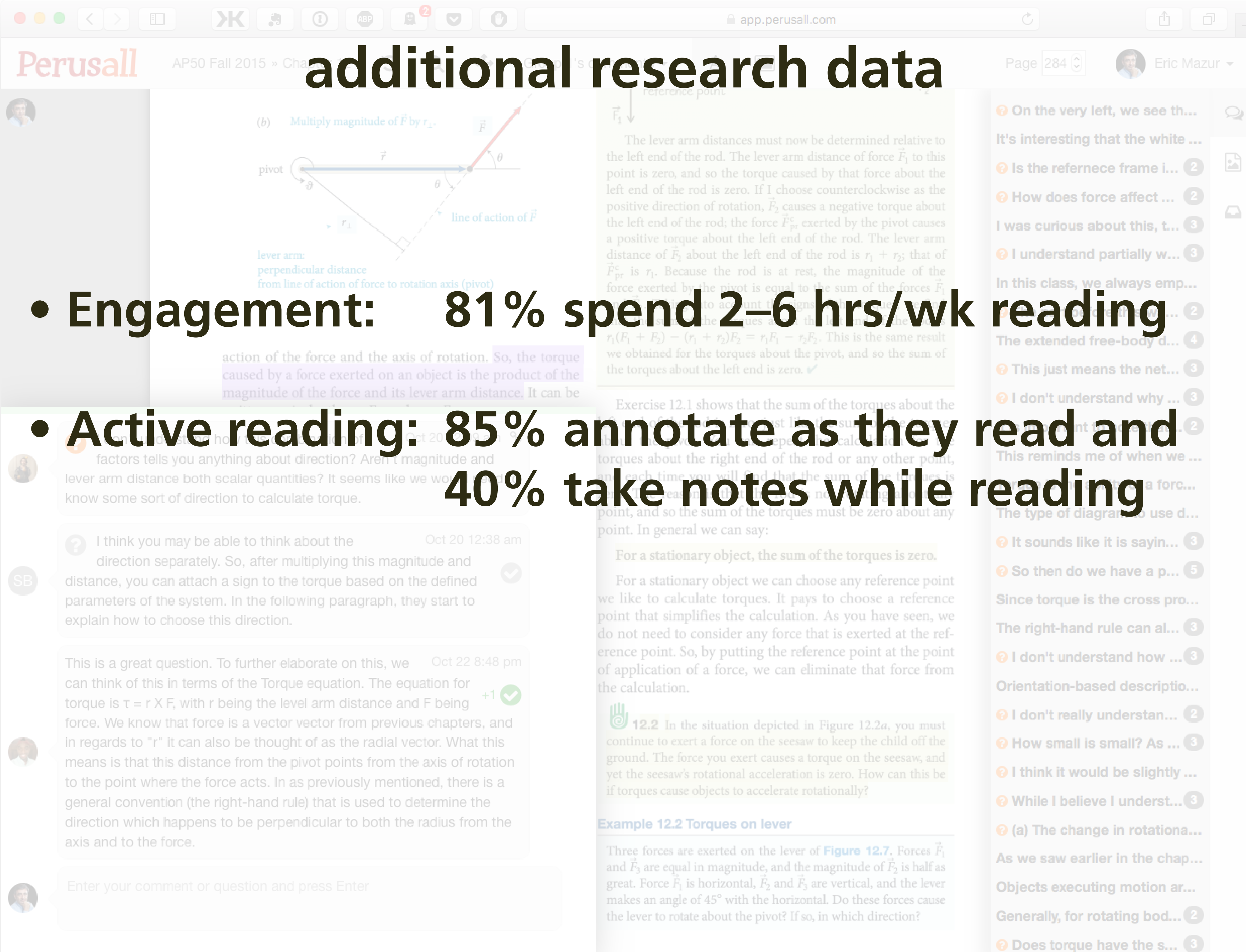

research data
every student prepared for *every* class

additional research data

- **Engagement: 81% spend 2–6 hrs/wk reading**



additional research data

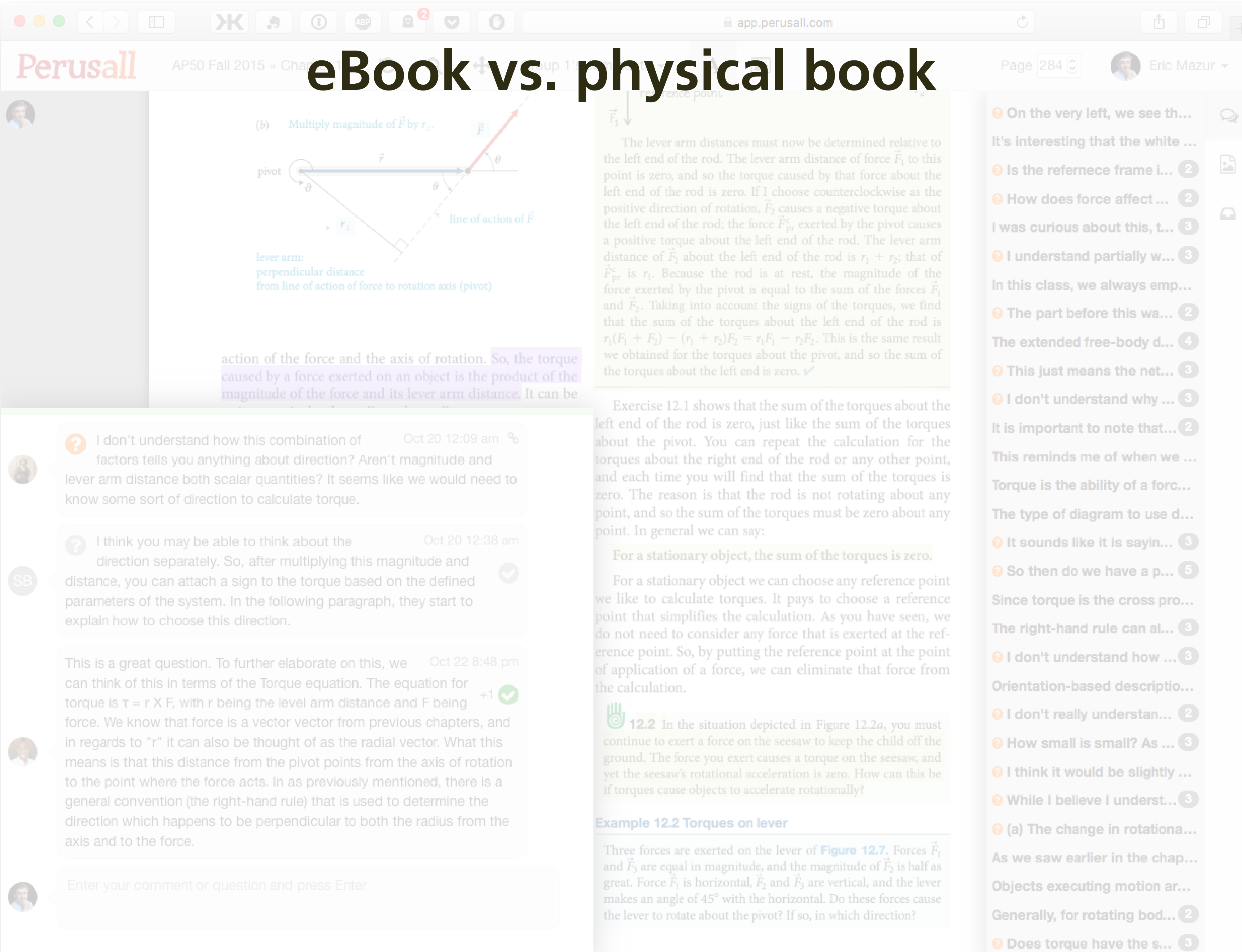


- Engagement: 81% spend 2–6 hrs/wk reading
- Active reading: 85% annotate as they read and 40% take notes while reading

additional research data

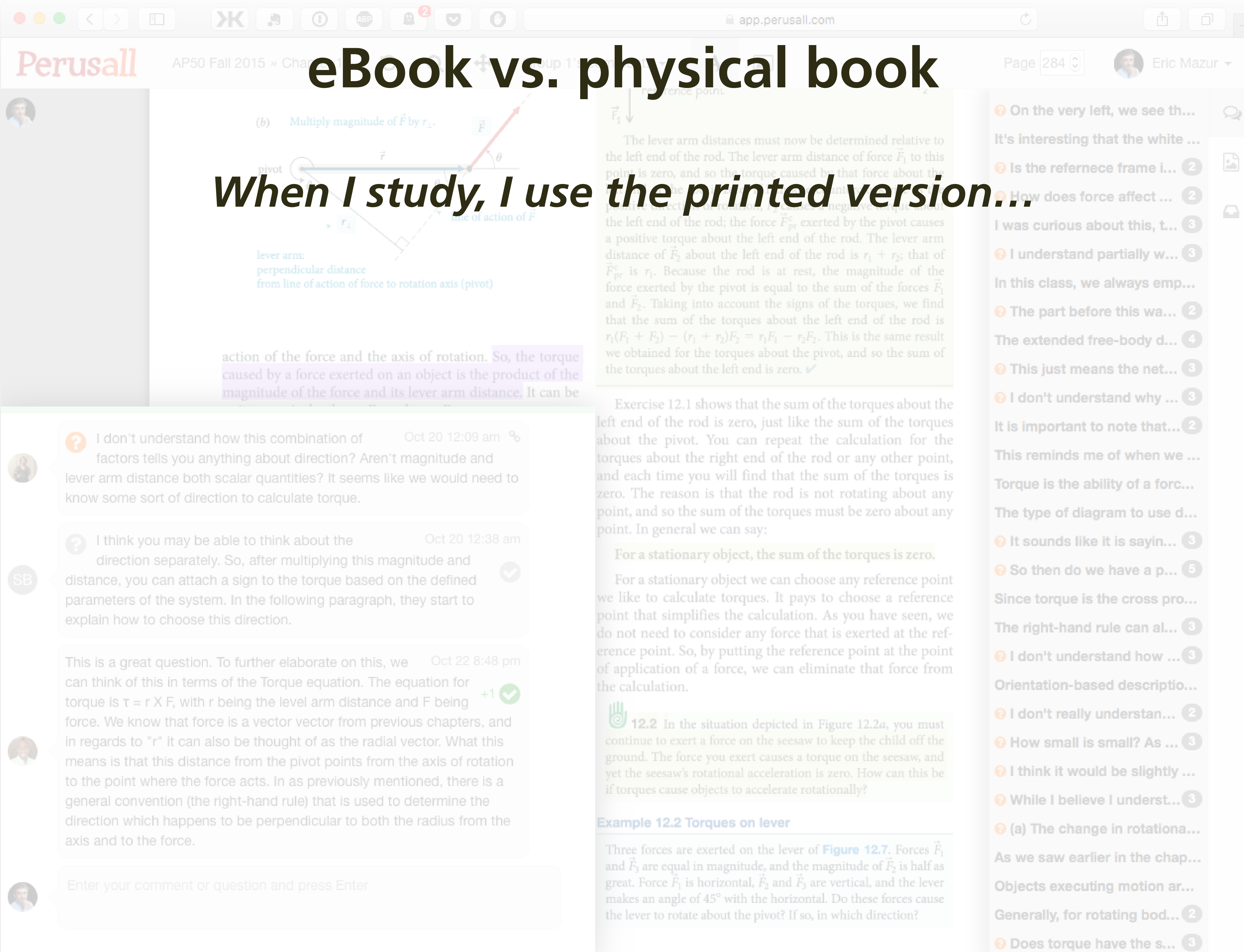
- **Engagement:** 81% spend 2–6 hrs/wk reading
- **Active reading:** 85% annotate as they read and 40% take notes while reading
- **Performance:** significantly higher scores

eBook vs. physical book



eBook vs. physical book

When I study, I use the printed version…



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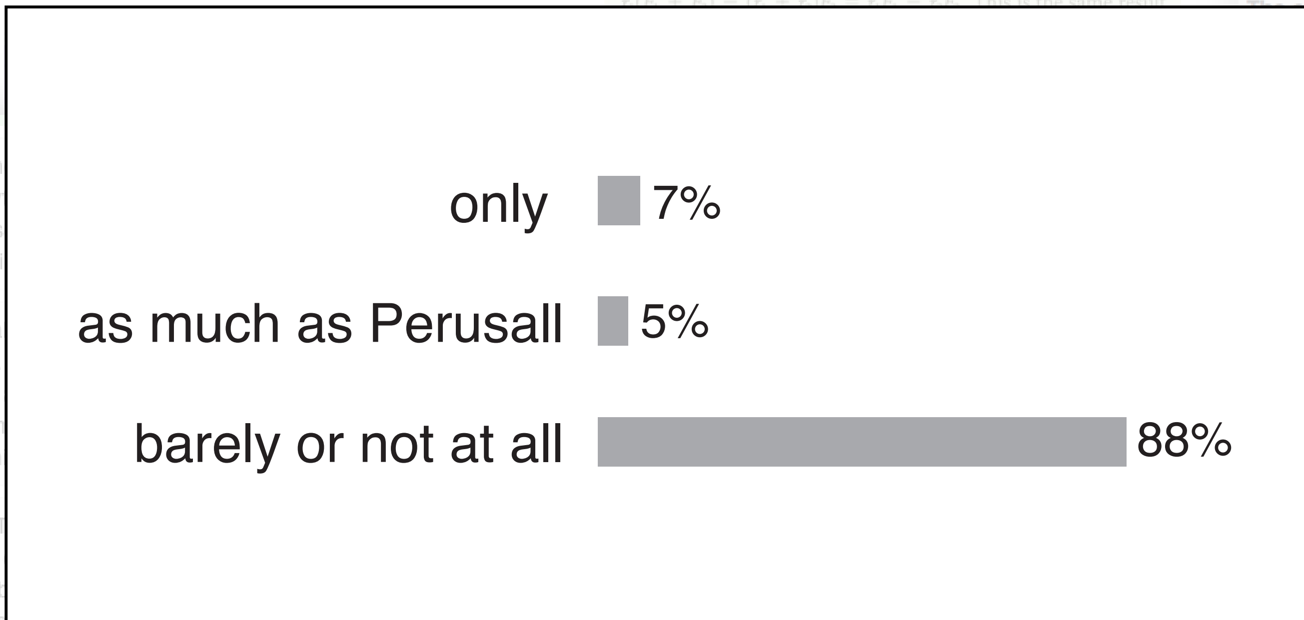

eBook vs. physical book

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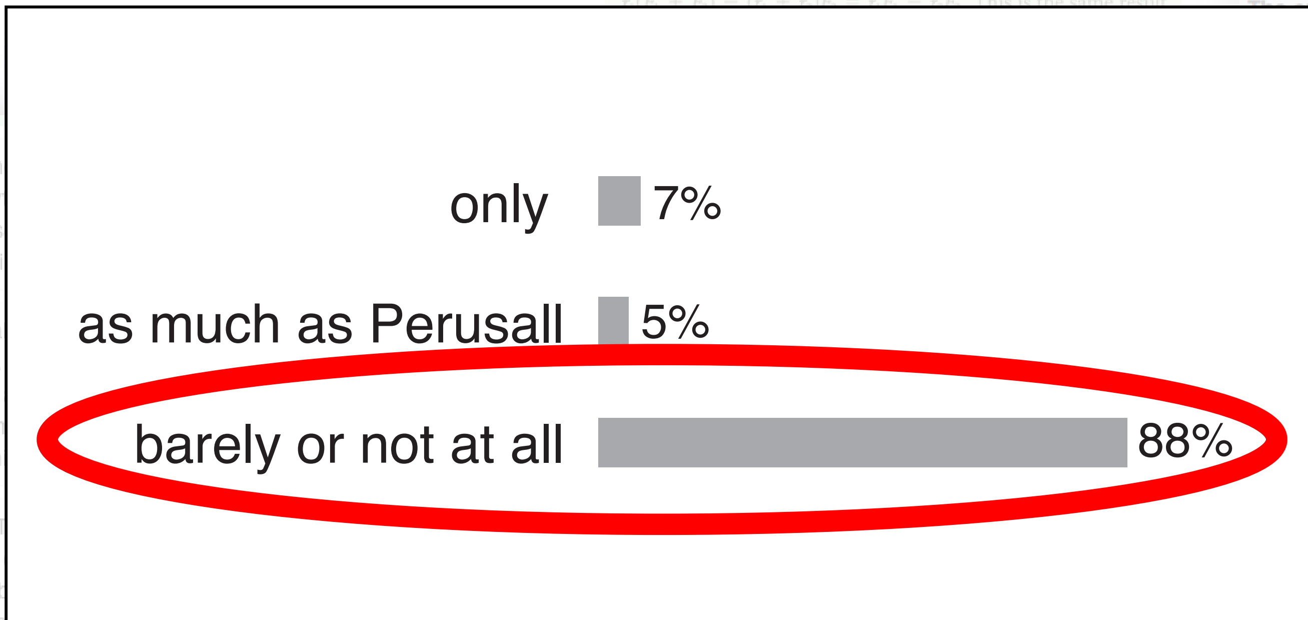

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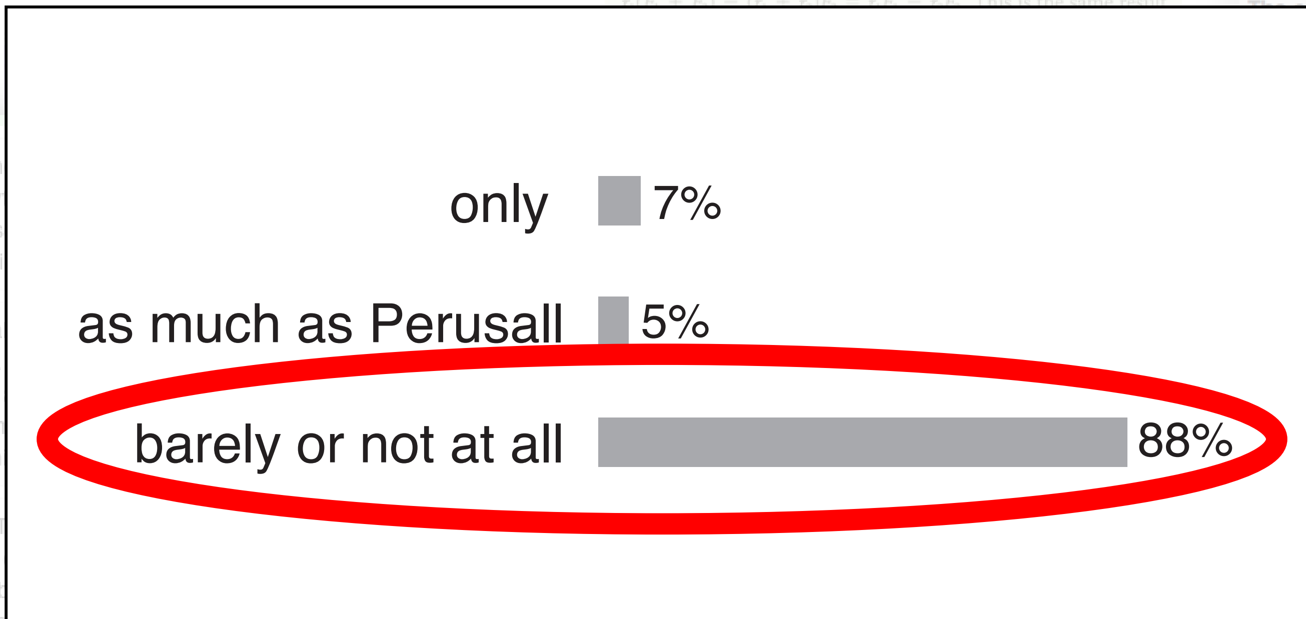
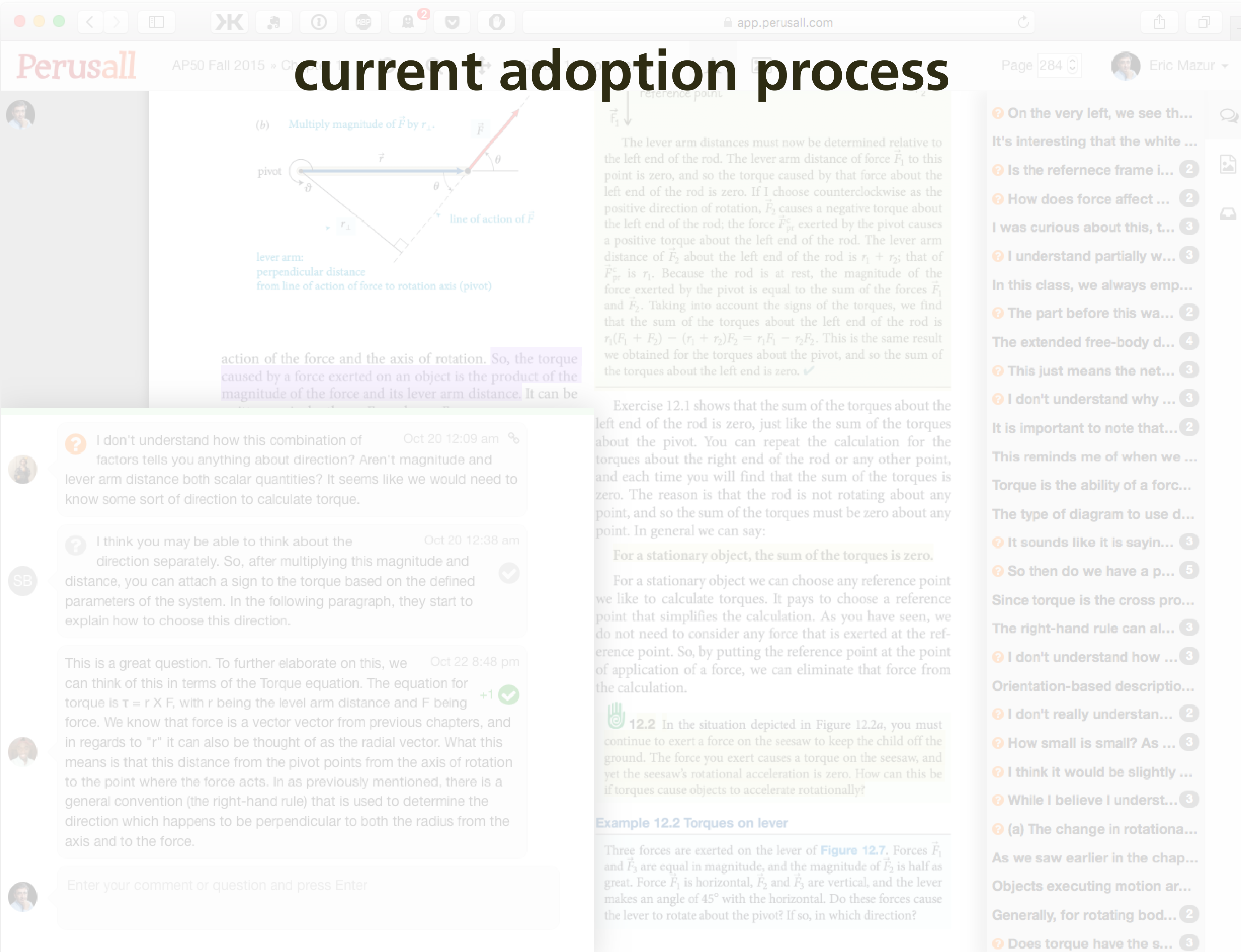


can eliminate printed books!

current adoption process



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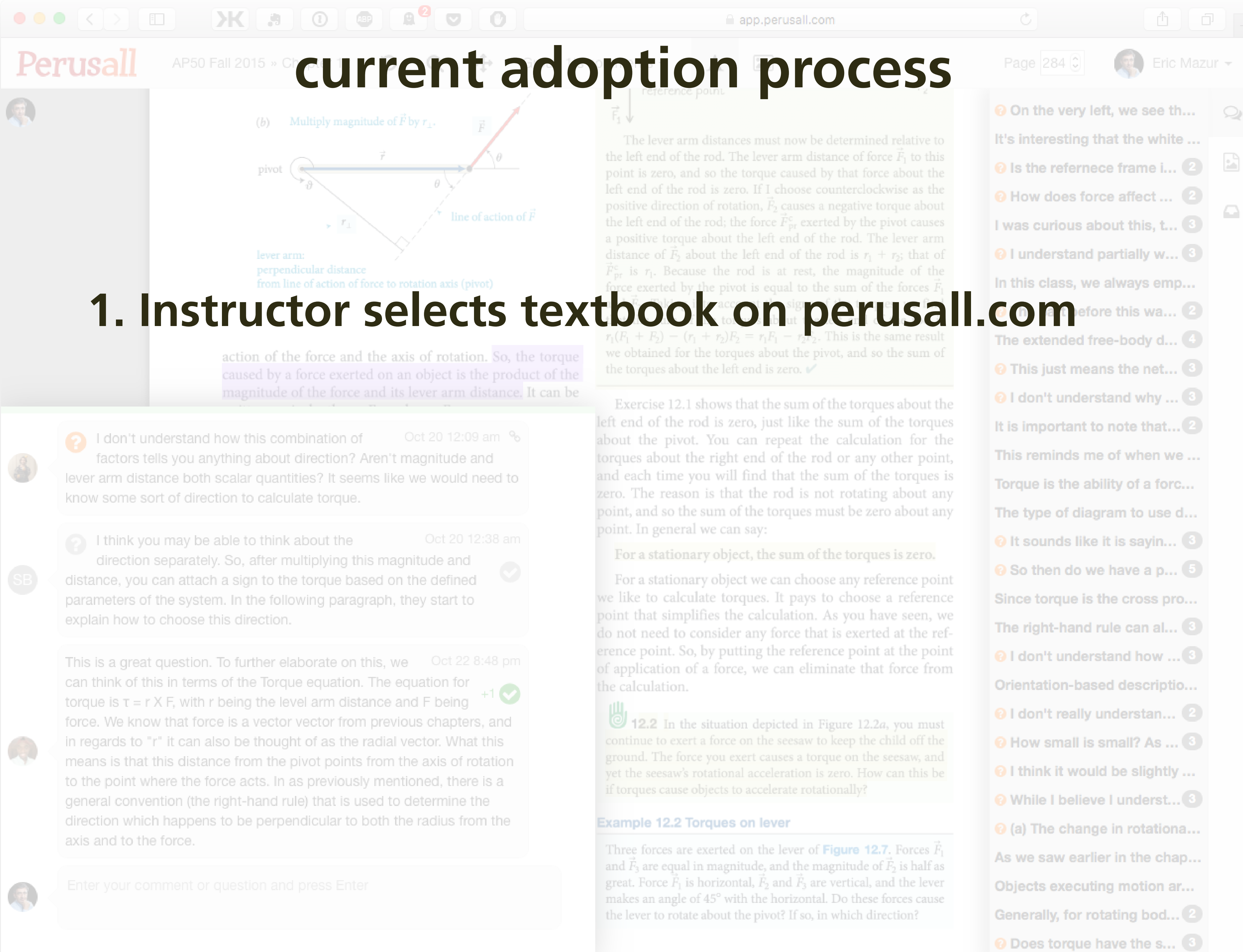

current adoption process

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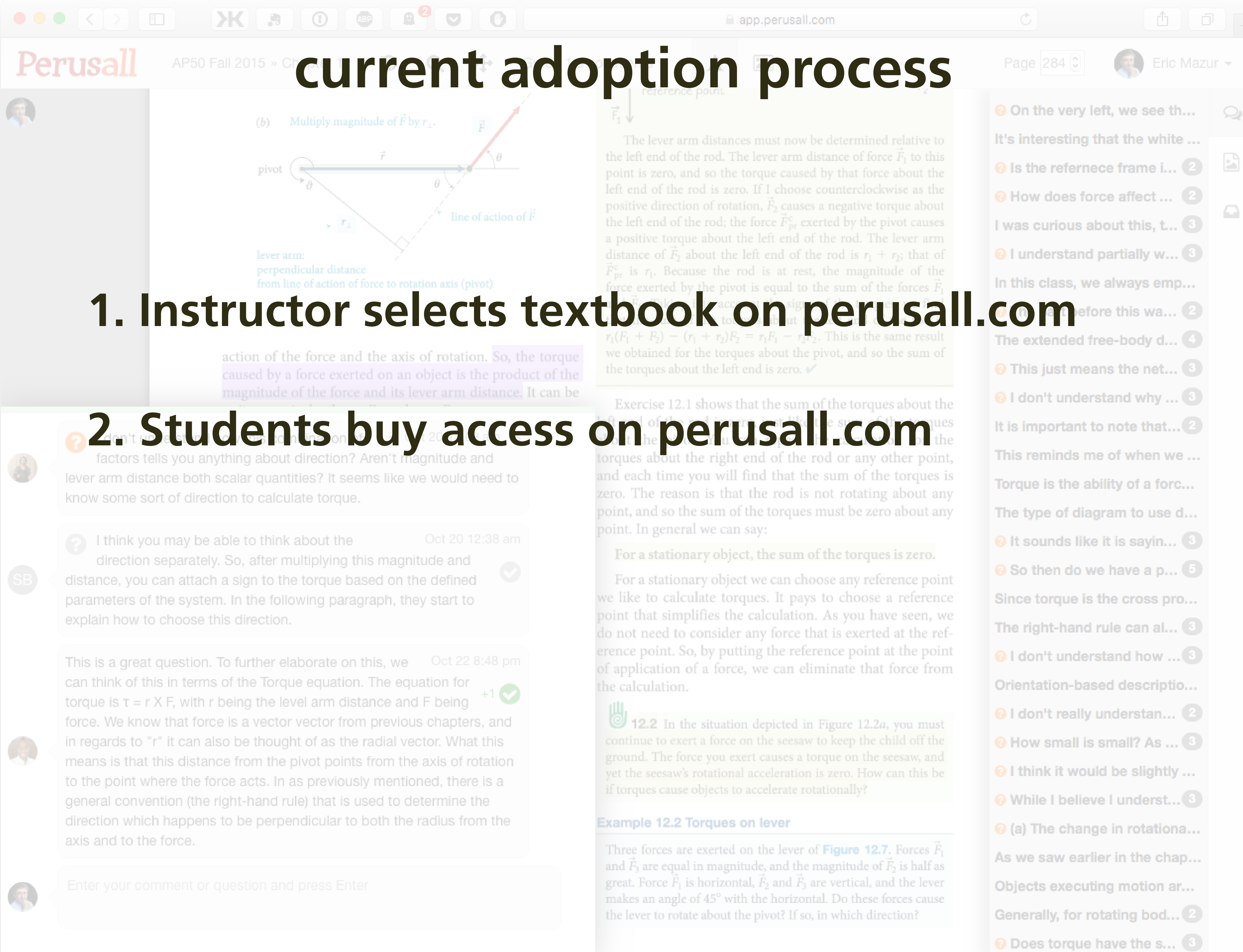

current adoption process

1. Instructor selects textbook on perusall.com

2. Students buy access on perusall.com

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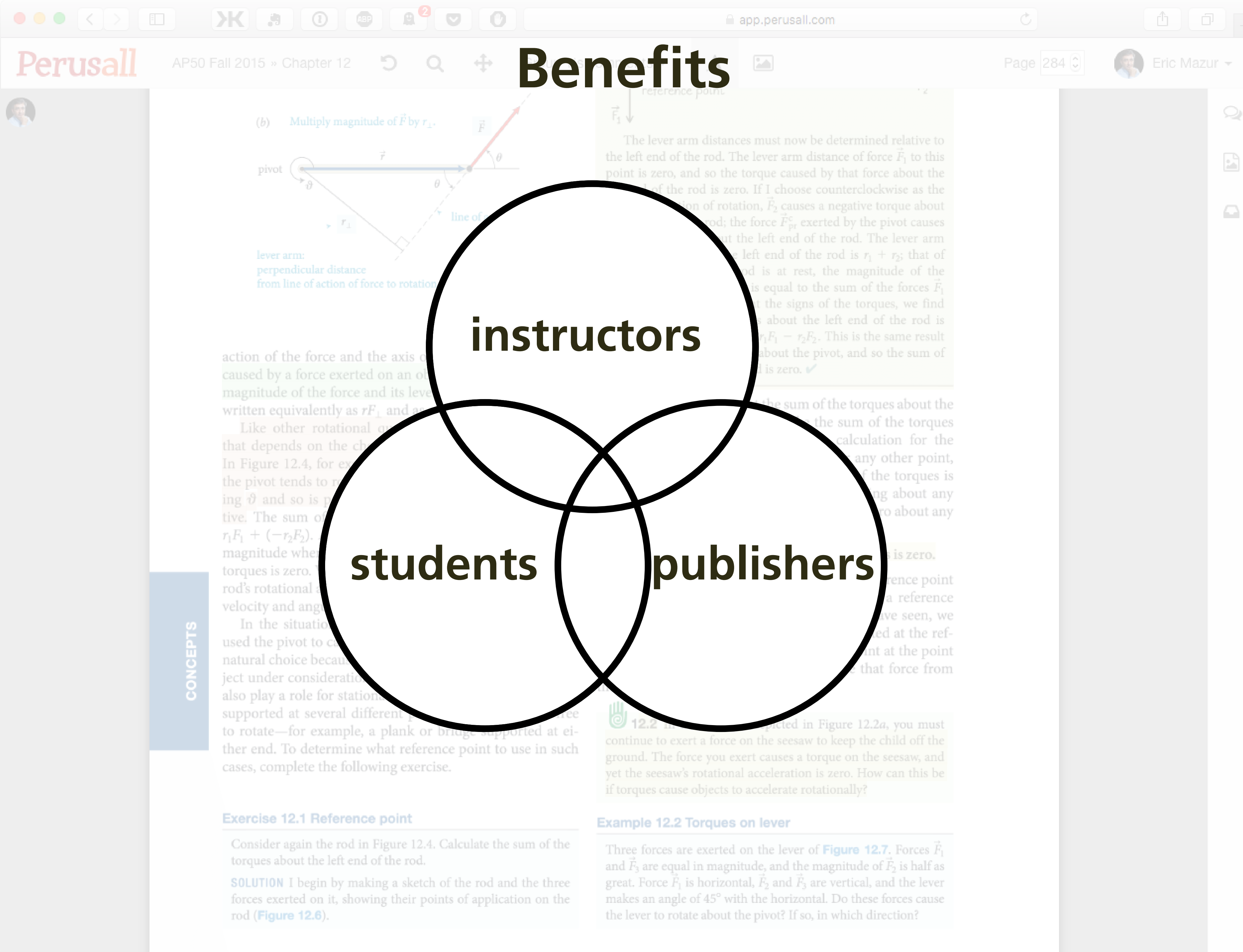
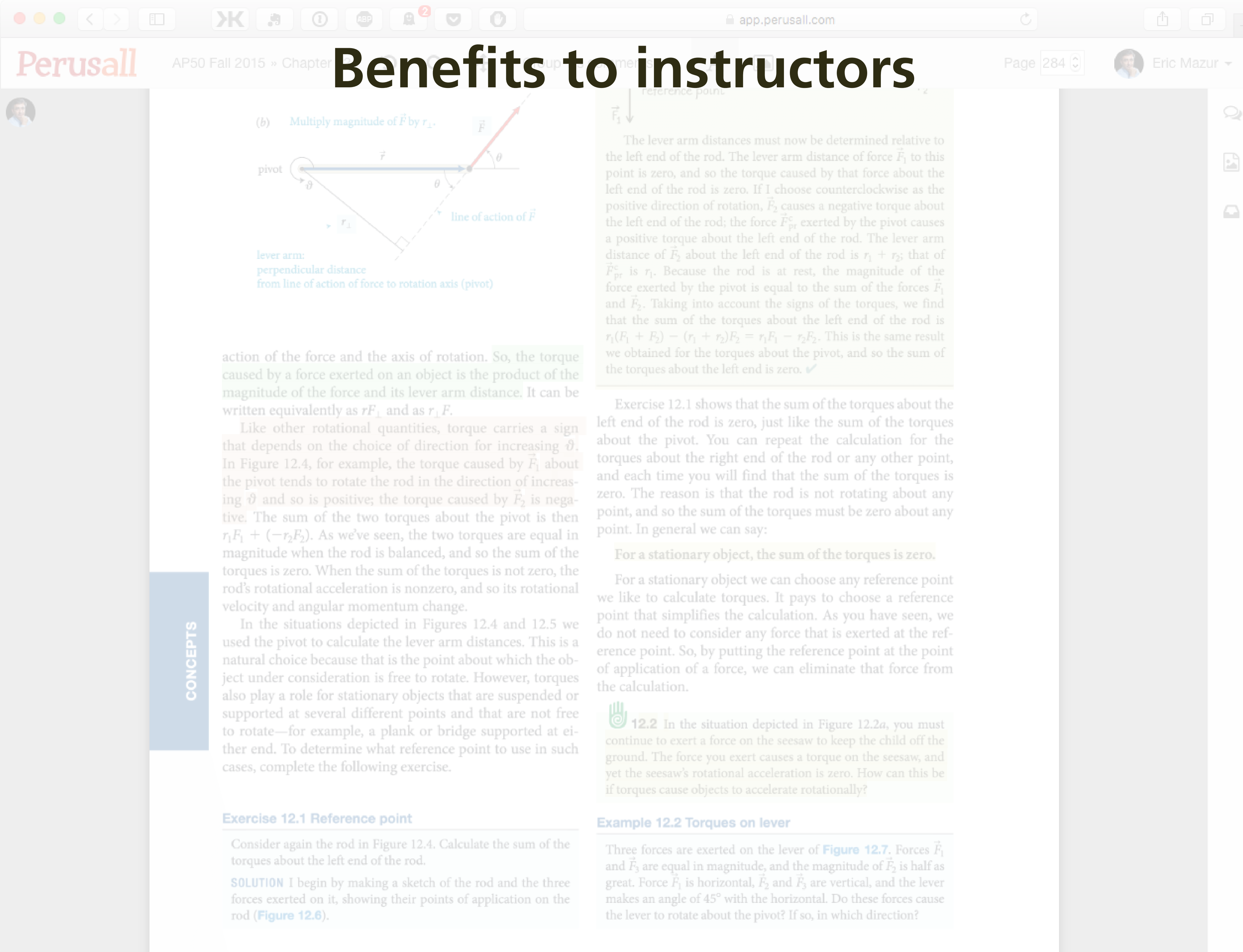
Benefits



Benefits to instructors



Benefits to instructors

- time recovery

Benefits to instructors

- time recovery
- improved use of class time

Benefits to instructors

- time recovery
- improved use of class time
- enhanced respect and understanding for students

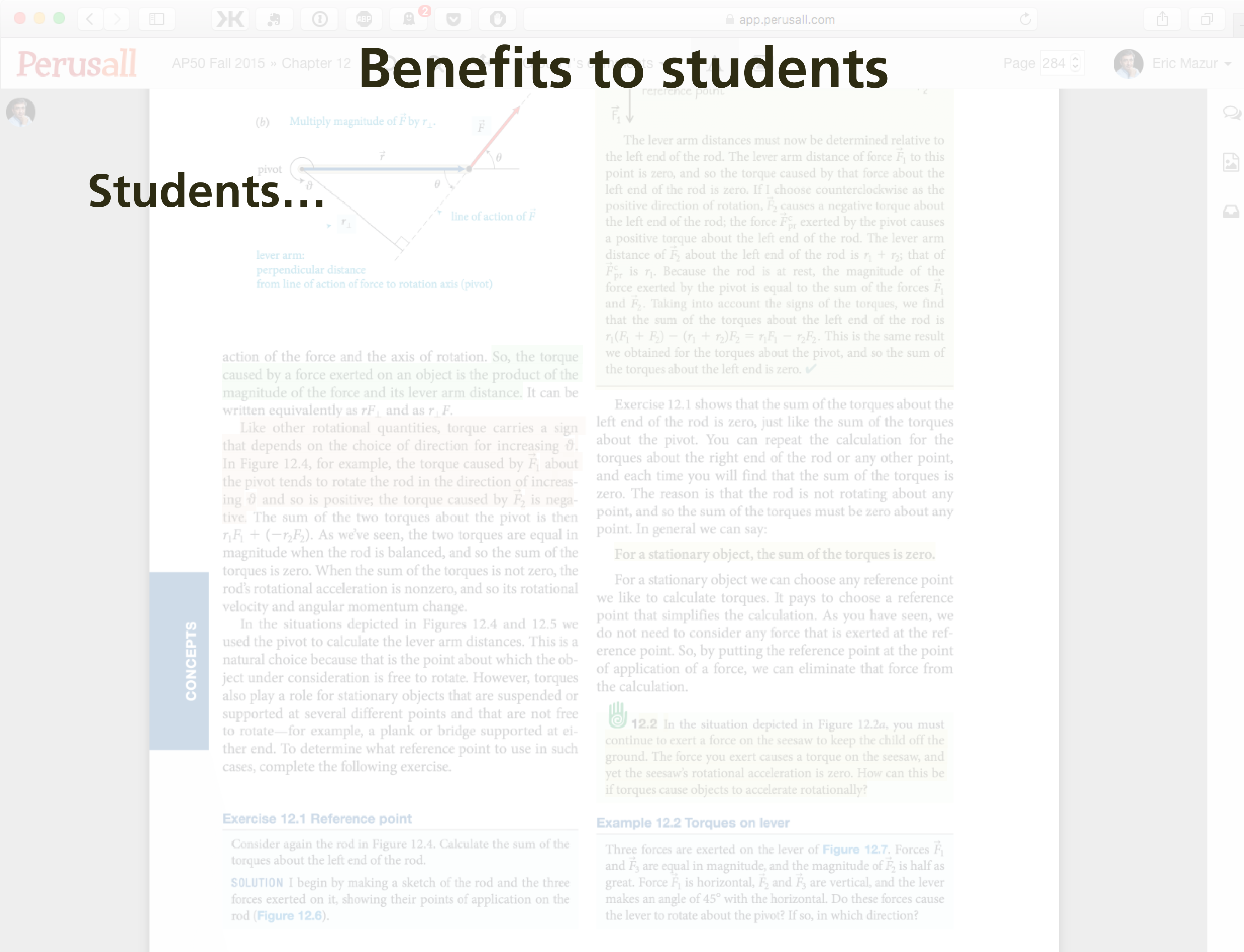
Benefits to instructors

- time recovery
- improved use of class time
- enhanced respect and understanding for students

all at no cost & no additional effort!

Benefits to students

Students…



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.

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 forces exerted on it, showing their points of application on the rod (Figure 12.6).

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

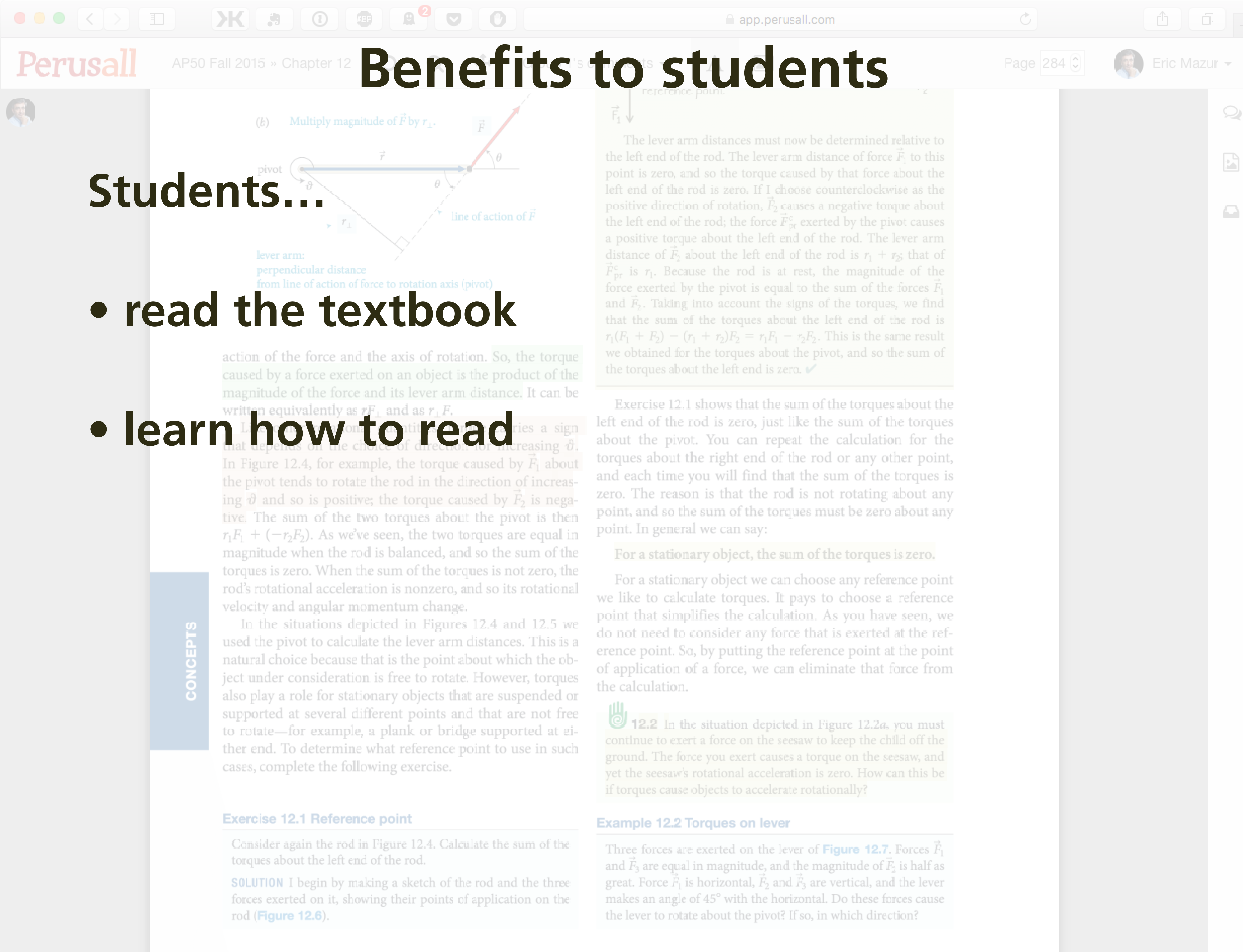
Three forces are exerted on the lever of Figure 12.7. Forces $\vec F_1$ and $\vec F_3$ are equal in magnitude, and the magnitude of $\vec F_2$ is half as great. Force $\vec F_1$ is horizontal, $\vec F_2$ and $\vec F_3$ are vertical, and the lever makes an angle of 45° with the horizontal. Do these forces cause the lever to rotate about the pivot? If so, in which direction?

Benefits to students

Students…

- read the textbook

Benefits to students



Students…

- read the textbook
- learn how to read

Benefits to students

Students…

- read the textbook
- learn how to read
- learn how to read critically

Benefits to students

Students…

- read the textbook
- learn how to read
- learn how to read critically
- participate in a collaborative experience

Benefits to students

Students…

- read the textbook
- learn how to read
- learn how to read critically
- participate in a collaborative experience
- get more out of their classes

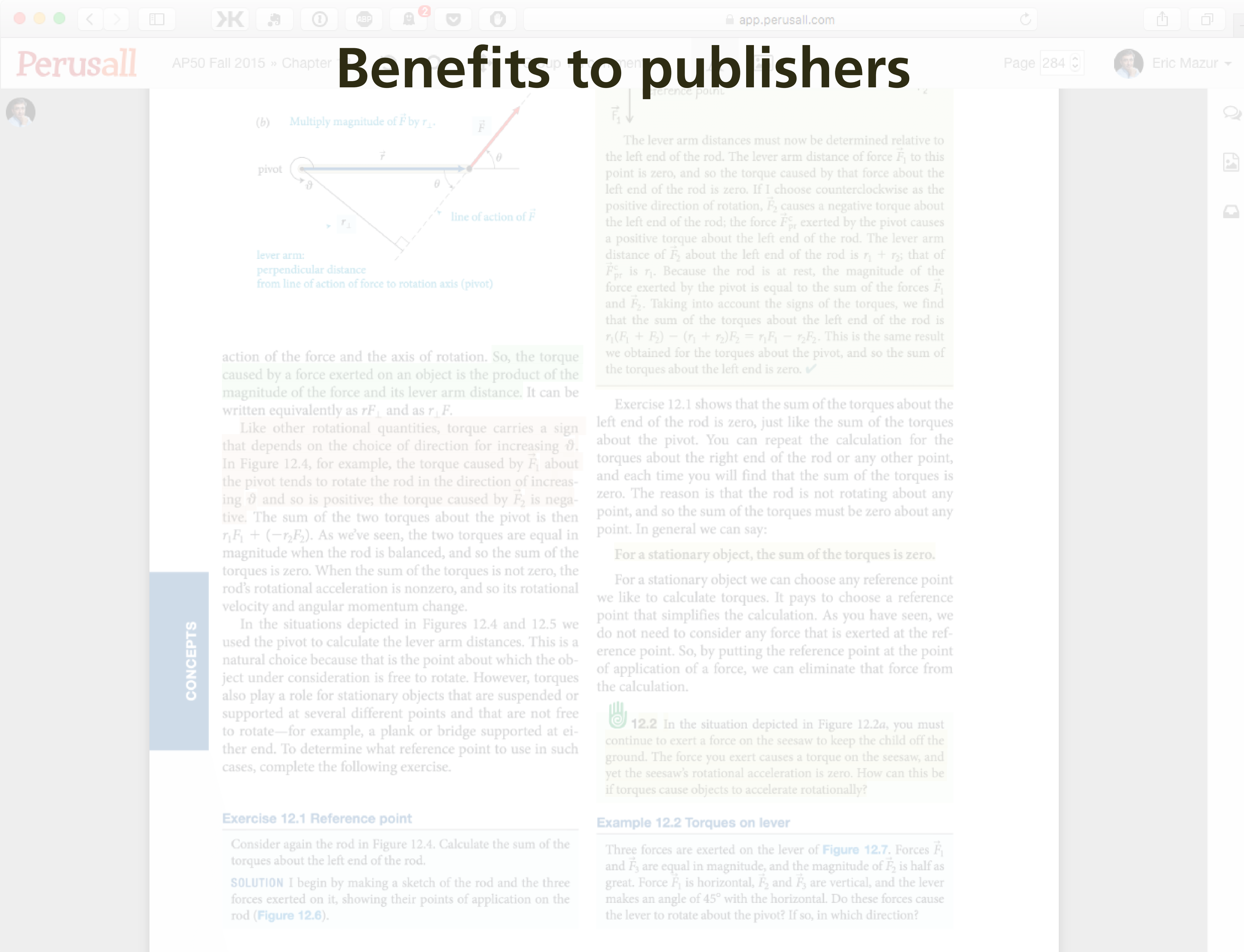
Benefits to students

Students…

- read the textbook
- learn how to read
- learn how to read critically
- learn how to study and work collaboratively
- get more out of their classes

transferable skills

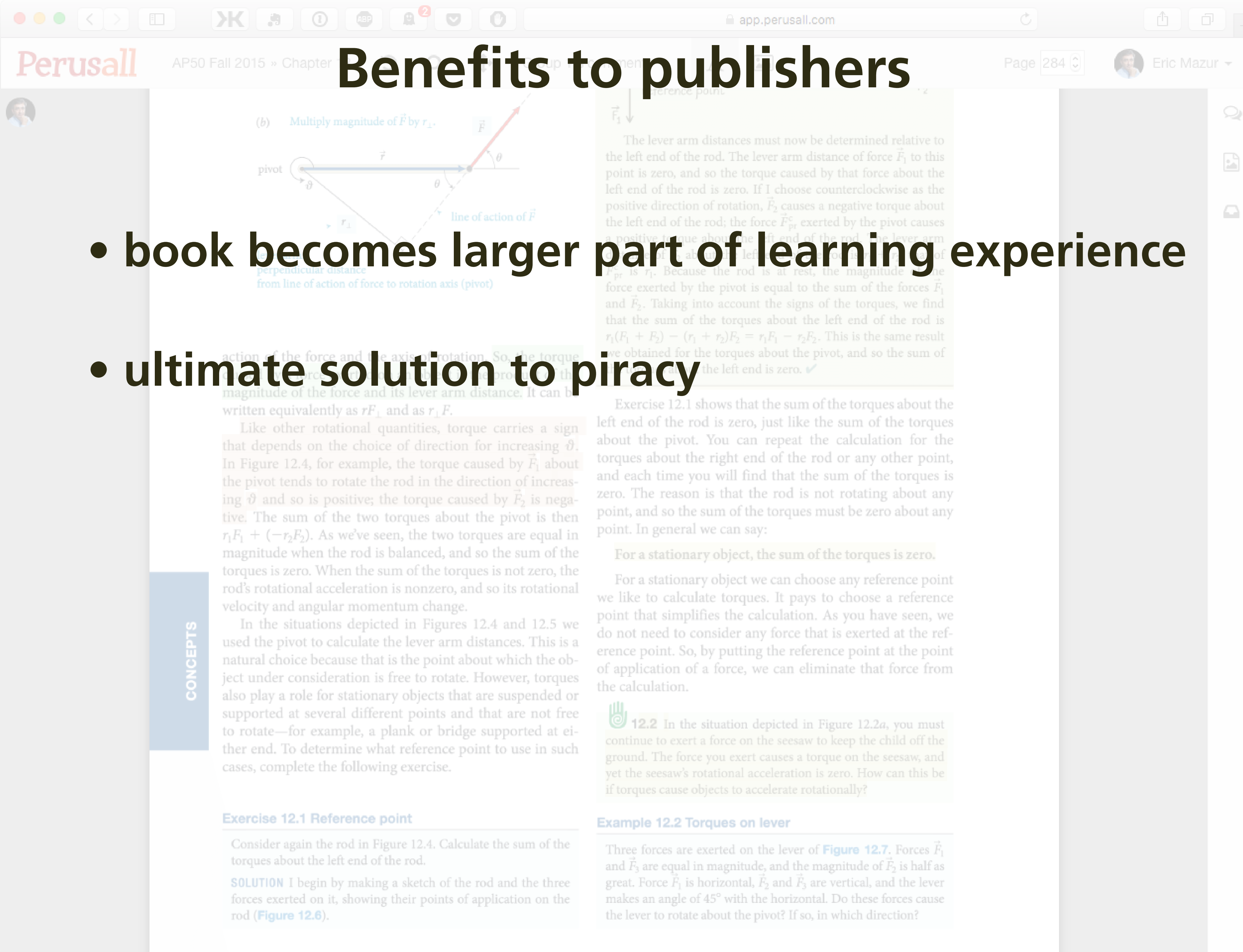
Benefits to publishers



Benefits to publishers

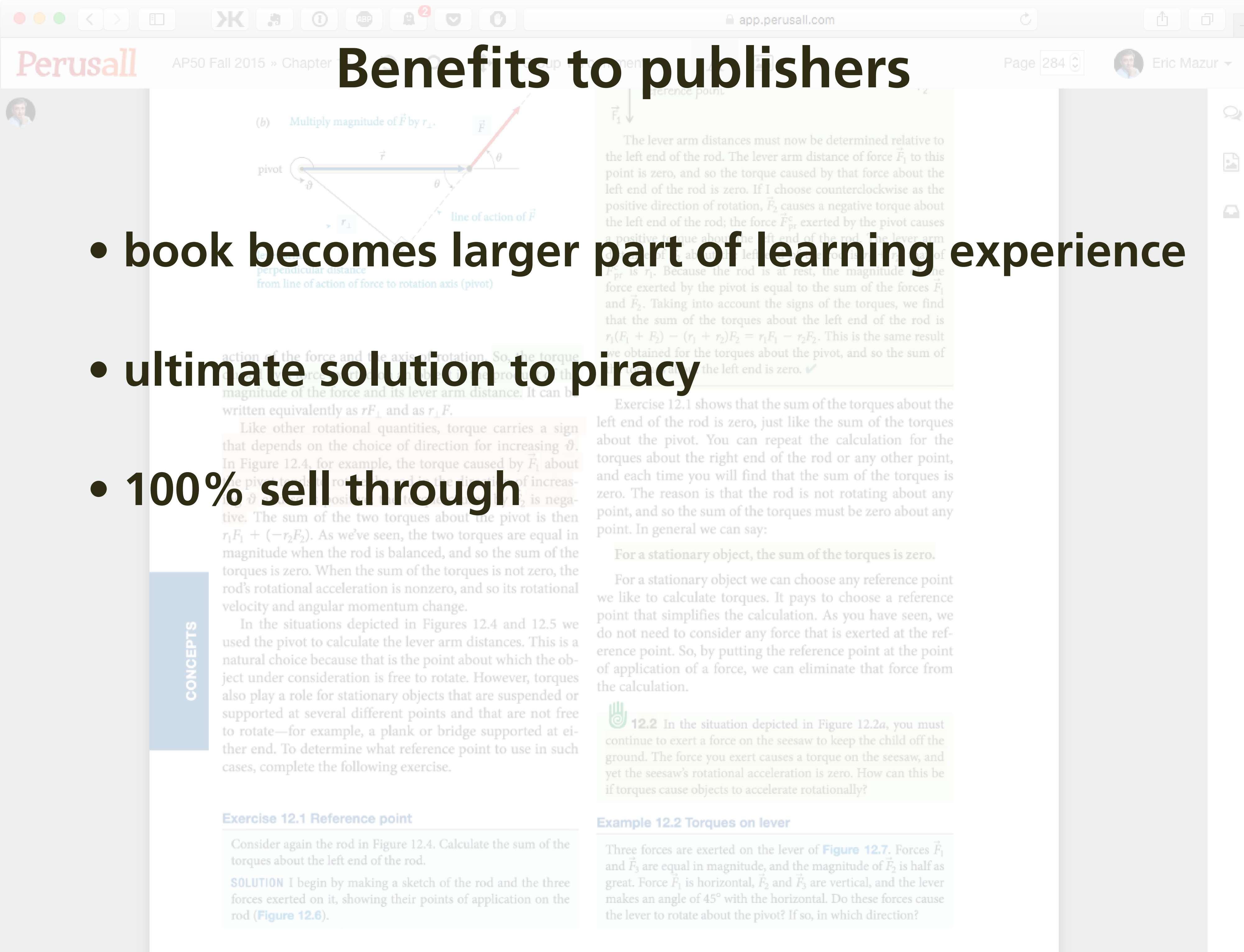
- book becomes larger part of learning experience

Benefits to publishers



- book becomes larger part of learning experience
- ultimate solution to piracy

Benefits to publishers



- book becomes larger part of learning experience
- ultimate solution to piracy
- 100% sell through

Benefits to publishers

- book becomes larger part of learning experience
- ultimate solution to piracy
- 100% sell through
- no resale

Benefits to publishers

- book becomes larger part of learning experience
- ultimate solution to piracy
- 100% sell through
- no resale
- feedback on quality and use of content

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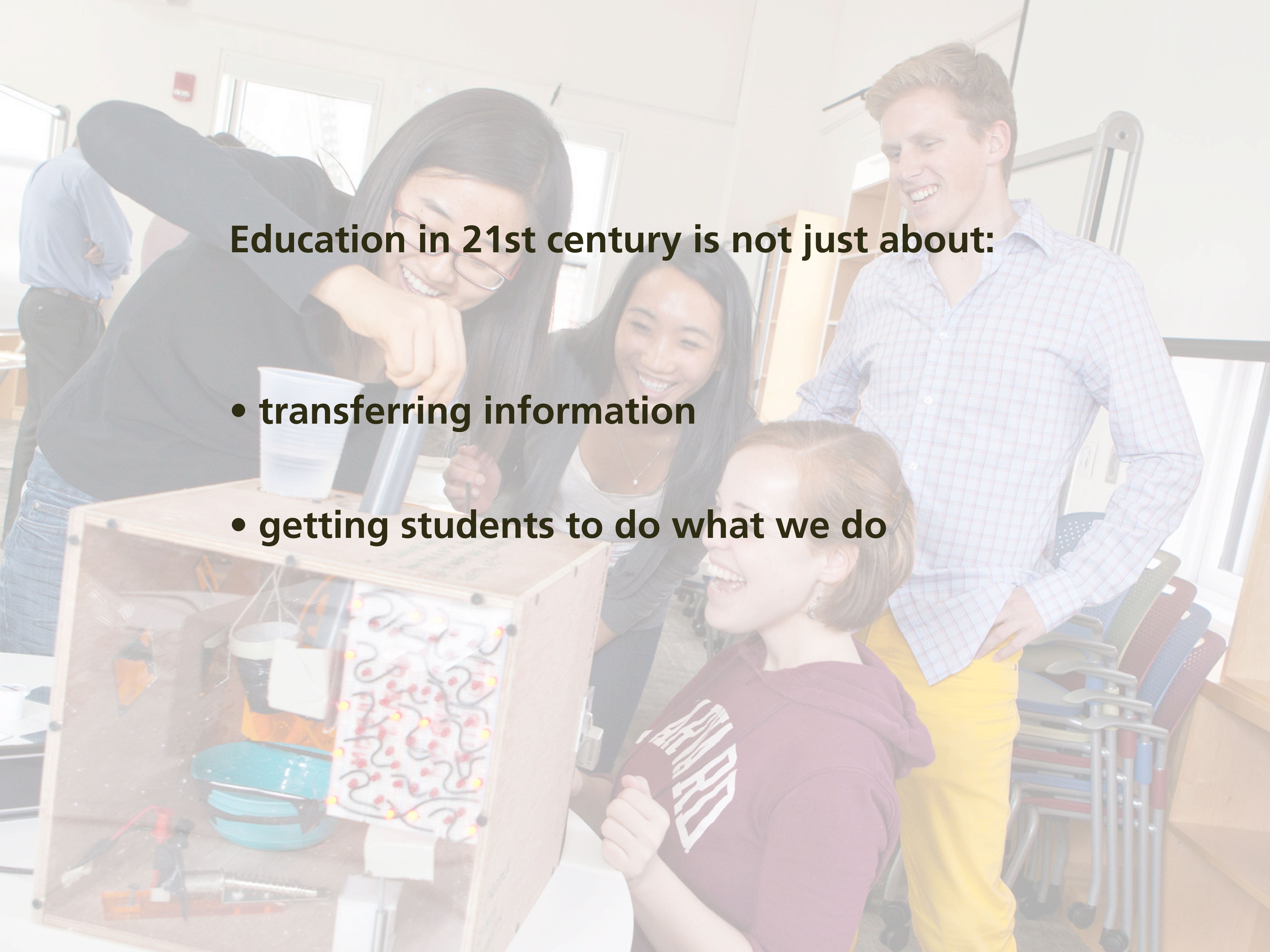
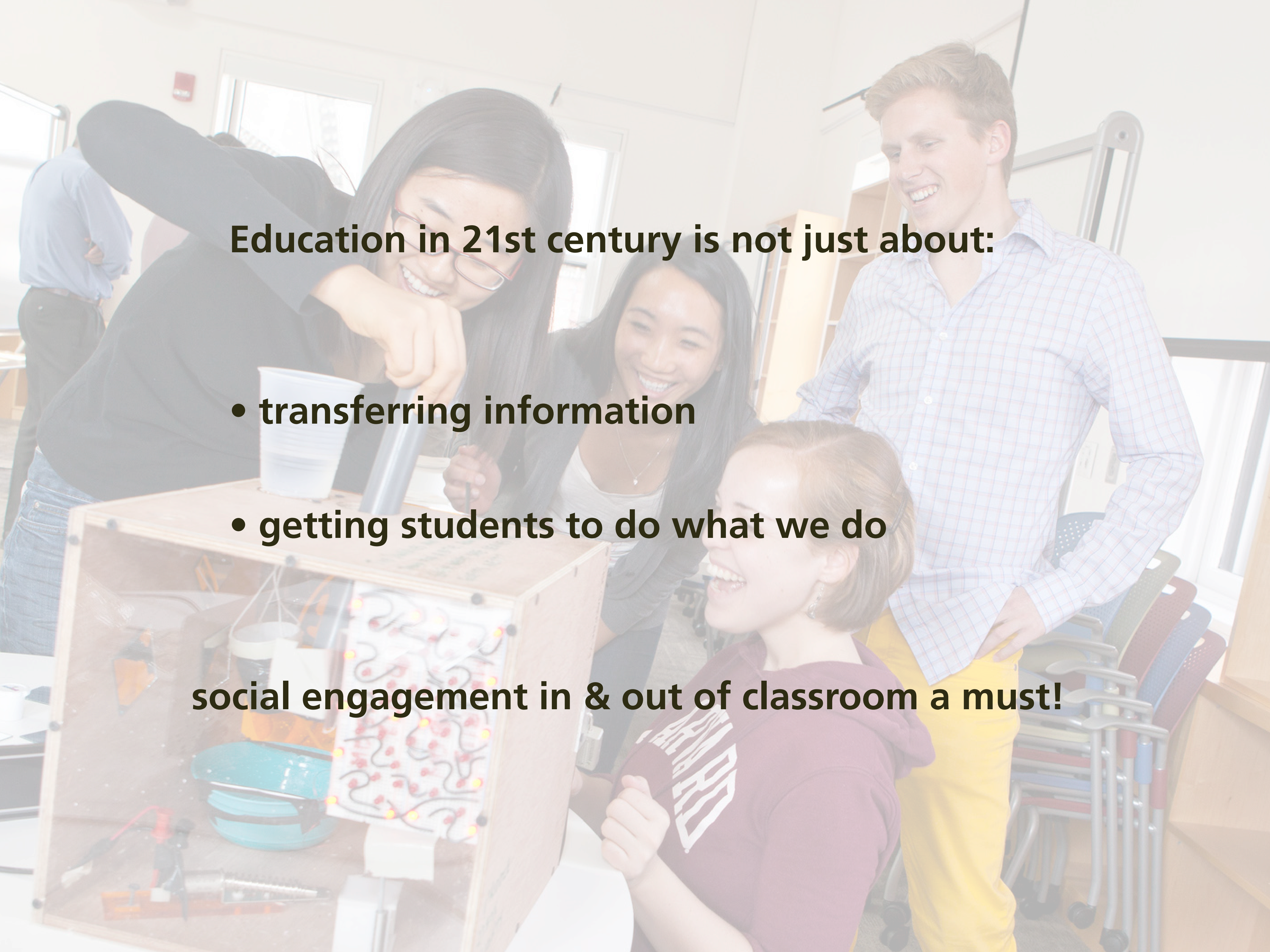
making learning fun again!



Education in 21st century is not just about:

- **transferring information**
- **getting students to do what we do**



Education in 21st century is not just about:

- **transferring information**
- **getting students to do what we do**

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