

Click-level Learning Analytics in an Online Medical Education Learning Platform

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MedU

NYU | STEINHARDT

Hi everyone, my name is Matt Cirigliano and I am a **Doctoral Candidate at NYU Steinhardt** working on research in medical education and the learning sciences. With me I have...

Charlie Guthrie - I just finished my Master's in Data Science at NYU, with the Center for Data Science. My background is in statistics with a focus on learning analytics.

And we're currently working with **Dr. Martin Pusic** -- who [you've just met in the last talk] is the **Director of the Division of Learning Analytics** at the **Institute for Innovations in Medical Education** at the **NYU School of Medicine** -- on click-level learning analytics in MedU, an online medical education learning platform.

[26 sec]

OBJECTIVES

Exploratory Analysis: Understand the relationships between measures of learner engagement and learner achievement in historical MED-U databases using results from focus group discussions and learning analytics.



Our objective was to understand **measures of learner engagement...**

...meaning **what learners clicked on**, interacted with, and for how long...

...and **how these behaviors related to learner achievement**. MedU's historical database of learner interactions and **learning analytics** allowed us to do that.

[14 sec]

LEARNING ANALYTICS

...is an emerging field in which analytic tools adapted from computer science, math, and statistics are used to improve learning and education by extracting usable information from very large datasets.

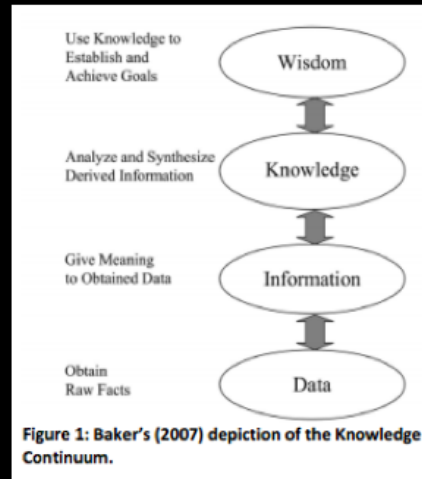


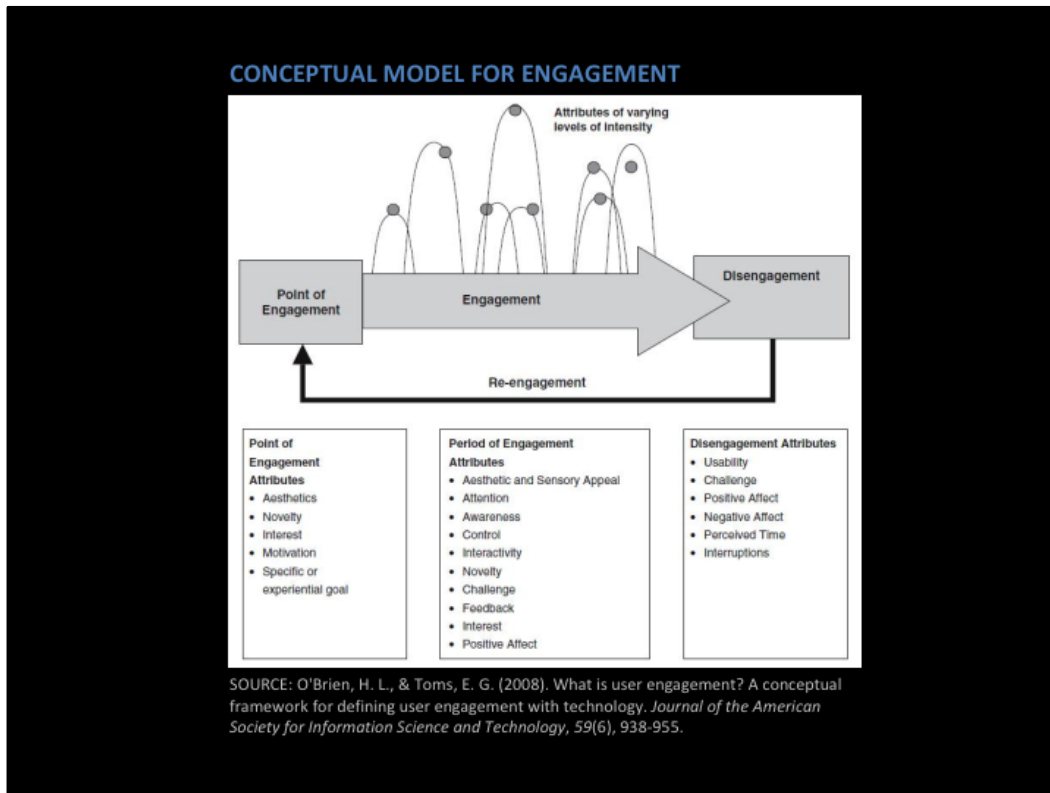
Figure 1: Baker's (2007) depiction of the Knowledge Continuum.

SOURCE: Elias, T. 2011. *Learning Analytics: Definitions, Processes and Potential*.



Briefly, learning analytics uses the **power of large datasets and analytic tools** to understand how learners engage with material and improve approaches to achieving **educational goals**.

[11 sec]

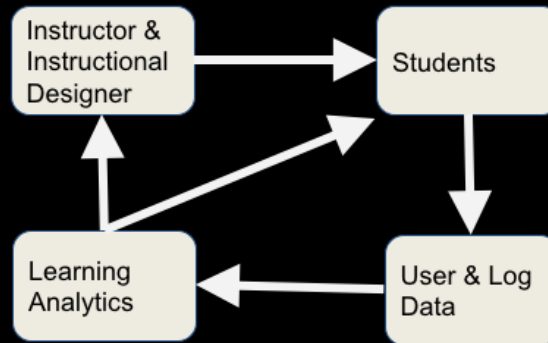


And engagement incorporates the **complex network of interactions a learner** has with content—if they become engaged or disengaged by material. **Learning analytics** and **predictive models** can help us identify what content is most/least useful.

[14 sec]

LEARNING ANALYTICS

ENHANCING ONLINE LEARNING THROUGH FEEDBACK



Adapted from Bienkowski, M., Feng, M., & Means, B.,(2012). Enhancing Teaching and Learning Through Educational Data Mining and Learning Analytics: An Issue Brief.

Overall, learning analytics can help us **generate feedback systems to help** stakeholders improve learning content and strategies.

[9 sec]

CLICK-LEVEL DATA

Features:

- Multiple choice questions
- Hyperlinks
- Page progression clicks
- Enlarging images
- Checking answers
- Time spent on images, pages, etc.

Scope:

- 2,806 North American medical students
- From June 1st, 2014 - May 5th, 2015



So with Med-U, we applied learning analytics to click-level data to reveal how learners interacted with the content. That includes [riff]

MedU itself is an online suite of case-based learning systems and courses accessed by over 150 different medical schools across North America—you can see some more information at the bottom—there were over 2800 med students who contributed (only 6). One feature of MedU is the CORE Radiology series, which has 18 modules total. We focused on one on musculoskeletal trauma.

[32 seconds]

A RELEVANT ASSESSMENT



Content
(Images, links, etc.)

Question:
What is your diagnosis based on these images? Select one.

Multiple Choice Answer:
Please select your answers.

- A Posterior shoulder dislocation
- B Anterior shoulder dislocation
- C Superior shoulder dislocation
- D Proximal humeral fracture
- E Acromio-clavicular joint dislocation

[Submit](#) Answers given so far: 2

Relevant Multiple
Choice Question

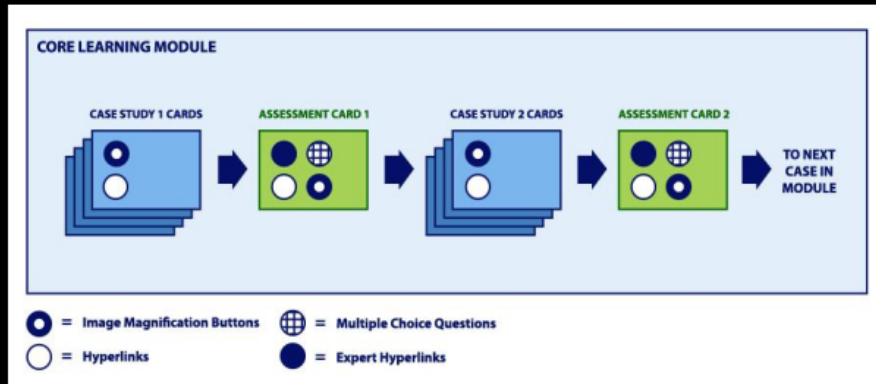


CORE
RADIOLOGY COURSE

So in sum, we wanted to understand if engaging with relevant content impacted performance on assessment questions in the module.

[7 sec]

MODULE PROGRESSION



The module was **broken down into units**, where a set of **cards** featuring content was followed by an **assessment card**, which featured a relevant multiple choice question.

[9 sec]

16. MSK: Trauma

Jump to: Card Top Question Answer

19 of 23 Cards

- 1: Introduction
- 2: Core Musculoskeletal
- 3: Mr. Stanley's Ski accident
- 4: Ankle Anatomy
- 5: Mr. Stanley's Ankle series
- 6: Fracture Descriptions
- 7: Mr. Stanley's treatment
- 8: Ms. Lawmore arrives in the ED
- 9: Ms. Lawmore's knee
- 10: Knee Effusion
- 11: Tibial Plateau
- 12: MRI or CT?
- 13: MRI of her knee
- 14: Mrs. Potter's Hip Injury
- 15: Mrs. Potter's Hip Radiographs
- 16: MRI of Mrs. Potter's Left Hip
- 17: Mrs. Potter's Right Wrist
- 18: Referral to Orthopedic Surgery
- 19: Mr. O'Neil's Shoulder
- 20: Shoulder reduction
- 21: Mr. O'Neil's Wrist
- 22: The End of a Long Morning
- 23: Link

Navigation

Mrs. Potter does well during the procedure and is transferred to the orthopedic floor.

Your next patient is Mr. O'Neil, a 21-year-old snowboarder complaining of left shoulder pain after a fall.

On exam his pupils are dilated and he smells of marijuana. You have him remove his shirt. His shoulder demonstrates a "squared off" appearance with skin depression over the deltoid muscle contour. He is unable to raise his arm. The patient is sent for radiographs.

Want to see a labeled normal shoulder series before you look at his images?
[Go to the University of Washington's musculoskeletal radiology site.](#)

Question:

What is your diagnosis based on these images? Select one.

Multiple Choice Answer:

- A Posterior shoulder dislocation
- B Anterior shoulder dislocation
- C Superior shoulder dislocation
- D Proximal humeral fracture
- E Acromio-clavicular joint dislocation

Please note: show whether YOUR choice is correct or not, to toggle highlight what the expert selected, [please click here!](#)

B has been selected by the expert.

This is an **anterior shoulder dislocation (B)**. The AP view shows the humeral head resting anterior to the glenoid fossa in a subcoracoid location. The axillary view confirms the anterior trajectory of the dislocation as the humeral head rests anterior to the glenoid.

The axillary view anatomy can be difficult to identify, so it helps if you know how it is obtained. [See the Expert for more details of the views obtained on shoulder radiographs.](#)

AP view of the shoulder

My notes

No notes taken so far

Tools/Resources

Expert

And the whole module was **23 cards** long. This is a **snapshot** of one card.

[5 sec]



But...which features would be worth exploring with learning analytics?

[3 sec]

FOCUS GROUP RESULTS

Six experts grouped and ordered candidate analytic measures (CAMs), revealing which were considered the most useful:

- (1) Thumbnail Click
- (2) Post-Answer Expert Feedback Use
- (3) Supplementary Link Click
- (4) Magnifying (Zooming-in on) Images
- (5) Time Spent on Cases

Ranking of Candidate Learning Analytics Measures (CAMs)

	Candidate Learning Analytic Measures					
	1 Thumbnail Click	2 Supplementary Link Click	3 Duration on Cases/Images	4 Zooming-in on Images	5 Post-answer Feedback Use	6 Proportion of Feedback Used
Expert 1	1	12	8	2	5	11
Expert 2	1	2	8	5	3	4
Expert 3	1	2	1	2	1	1
Expert 4	4	2	6	5	3	1
Expert 5	2	2	5	2	4	4
Expert 6	4	4	4	8	1	8
TOTAL	13	24	32	24	17	29
Std. Dev.	1.5	4.0	2.7	2.4	1.6	4.0

	Candidate Learning Analytic Measures					
	7 Labeled Peer Answers	8 Viewing Sequence	9 Relative Time on Views	10 Video Playback Speed	11 Opposing Design Choices	12 Forced Views
Expert 1	6	4	10	9	3	7
Expert 2	9	6	7	5.8	6.4	6
Expert 3	3	3	3	3	3	1
Expert 4	7	8	9	10	11	12
Expert 5	1	3	5	6	7	2
Expert 6	1	4	8	1	8	8
TOTAL	27	28	42	35	38	36
Std. Dev.	3.3	2.0	2.6	3.4	3.1	4.0

To identify **Candidate Analytic Measures**, we performed a focus group with experts in medicine and instructional design to see what they thought would be most important to know about learner behavior. **A set of 12 analytics were ranked** and the top five were selected for further study.

[18 seconds]

CAM-A: THUMBNAIL CLICK



In an image set where there is one dominant image along with several supplementary clickable thumbnails, does the rate of clicking through the thumbnails correlate with learning?

What we need is:

- (a) Whether users clicked each thumbnail, yes/no
- (b) Whether they got the relevant MCQ correct

(Card 15, MSK Trauma)

Question:
What abnormalities do you see? Select one or more.

Multiple Choice Answer:

A	<input type="checkbox"/>	Tibial plateau fracture
B	<input checked="" type="checkbox"/>	Knee joint effusion
C	<input type="checkbox"/>	Lateral tibia avulsion fracture
D	<input checked="" type="checkbox"/>	Patellar fracture
E	<input type="checkbox"/>	Proximal fibular fracture



The first was the thumbnail click, and whether clicking on relevant thumbnails impacted assessment outcomes.

Sadly, because this data was unavailable in the database, it wasn't incorporated in the model. But there's more...

[11 sec]

CAM-C: SUPPLEMENTARY HYPERLINK CLICK

In the presence of supplementary links/hyperlinks to external content, does the rate of clicking through the links correlate with learning?

What we need is:

(a) Whether users clicked links

(b) Whether they got the relevant MCQ correct

Mrs. Potter does well during the procedure and is transferred to the orthopedic floor.
Your next patient is Mr. O'Neil, a 21-year-old snowboarder complaining of left shoulder pain after a fall.
On exam his pupils are dilated and he smells of marijuana. You have him remove his shirt. His shoulder demonstrates a "squared off" appearance with skin depression over the deltoid muscle contour. He is unable to raise his arm. The patient is sent for radiographs.

Want to see a labeled normal shoulder series before you look at his images?
[Go to the University of Washington's musculoskeletal radiology site.](#)

Question:
What is your diagnosis based on these images? Select one.

Multiple Choice Answer:
Please select your answers.
A Posterior shoulder dislocation
B Anterior shoulder dislocation
C Superior shoulder dislocation
D Proximal humeral fracture
E Acromio-clavicular joint dislocation

Submit Answers given so far: 2

(Card 15, MSK Trauma)



Third was clicking on hyperlinks, and whether this predicted better assessment outcomes.

[5 sec]

CAM-D: MAGNIFYING IMAGES

Does the rate at which one magnifies an image or images correlate with learning?

Our hypothesis might be that those who magnify the images had a higher rate of correct answers on relevant MCQs...

What we need is:

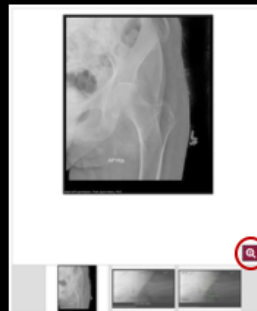
- (a) Whether users clicked magnification button
- (b) Whether they got the relevant MCQ correct

Question:
Look at the images on the right. What in (jury) do you see? Select all that apply.

Multiple Choice Answer:

A	<input checked="" type="checkbox"/>	Soft tissue swelling
B	<input checked="" type="checkbox"/>	Medial malleolar fracture
C	<input checked="" type="checkbox"/>	Distal fibular fracture
D	<input checked="" type="checkbox"/>	Widened mortise joint
E	<input checked="" type="checkbox"/>	Posterior malleolar fracture
F	<input checked="" type="checkbox"/>	Talar fracture

Please note: show whether YOUR choice is correct or not, to toggle highlight what the expert selected, [please click here!](#)



Fourth was magnifying or zooming in on images, and whether this behavior predicted better outcomes.

[6 sec]

CAM-E: TIME SPENT

Does the length of time on an image or case correlate with learning?

Our hypothesis might be that those who spent more time on images/cases have a higher rate of correct answers on relevant MCQs...

What we need is the duration of time spent viewing each:

- (a) image/case/webpage
- (b) success on MCQ

Question:
Look at the images on the right. What injury(s) do you see? Select all that apply.

Multiple Choice Answer:

- A Soft tissue swelling
- B Medial malleolar fracture
- C Distal fibular fracture
- D Widened mortise joint
- E Posterior malleolar fracture
- F Talar fracture

Please note: show whether YOUR choice is correct or not, to toggle highlight what the expert selected, [please click here!](#)



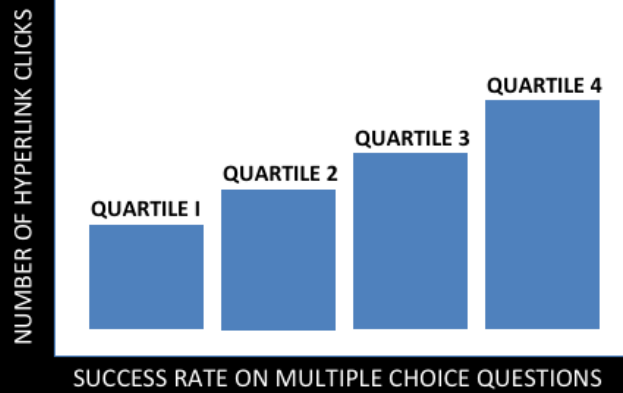
(Card 5, MSK Trauma)



And finally, the fifth measure was time spent on each card, and whether this behavior had a relationship with performance.

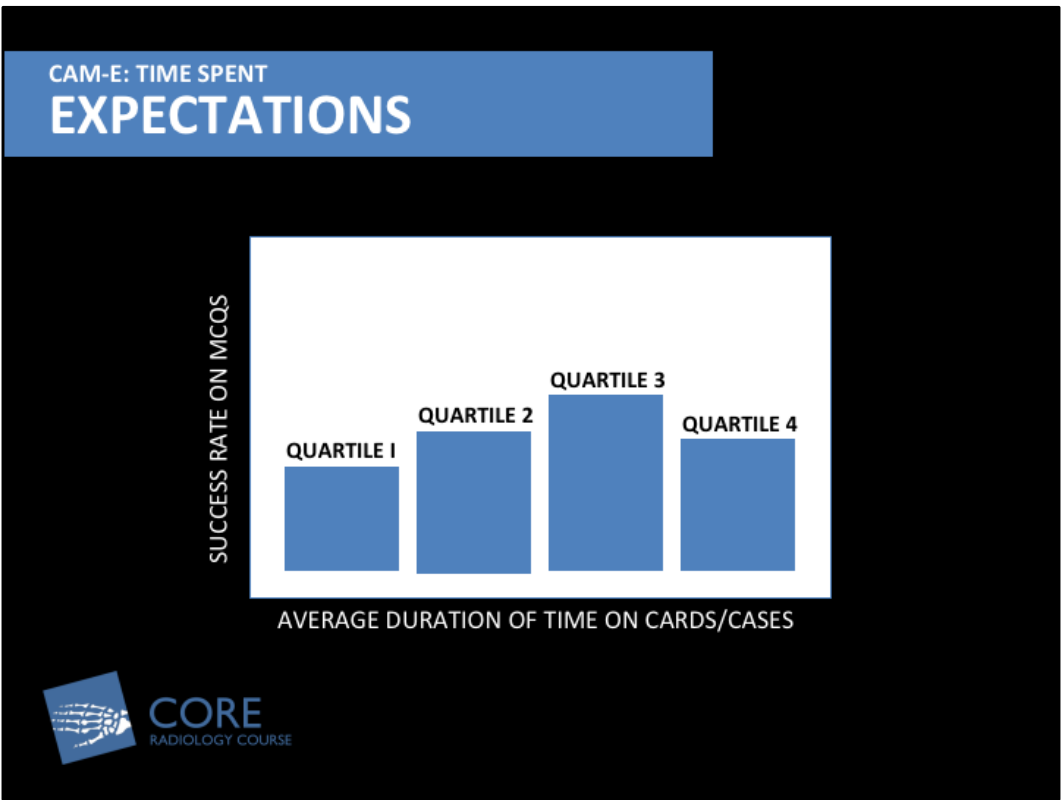
[7 sec]

EXAMPLE EXPECTATIONS



In terms of expectations, we might expect that more clicks on links and images would predict better outcomes, since those learners engaged with more content.

[9 sec]



And more time spent on a card would also be expected to result in better assessment outcomes, with the exception of very long times, as these might indicate off-task behavior.

So, what did we find? *[Hand off to Charlie]*

[15 sec]

MODELING & ANALYSIS

Having hypothesized about which activities would correlate with assessment performance,
we set out to build models to test them.

MODEL OVERVIEW

CAM
Engagement
Measures:

Expert links clicked

Hyperlinks clicked

Magnifier buttons clicked

Time spent

Assessment
Performance:

Question answered >50% correctly

There were two investigations. Both involved using engagement measures to predict assessment performance

COURSE CONTENT MAP

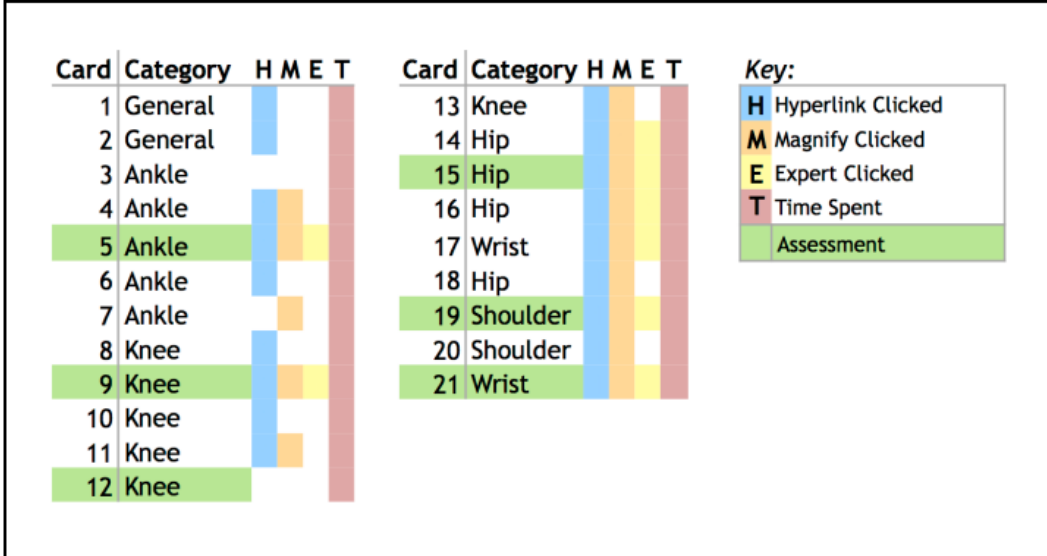
<u>Card</u>	<u>Category</u>	<u>Card</u>	<u>Category</u>
1	General	13	Knee
2	General	14	Hip
3	Ankle	15	Hip
4	Ankle	16	Hip
5	Ankle	17	Wrist
6	Ankle	18	Hip
7	Ankle	19	Shoulder
8	Knee	20	Shoulder
9	Knee	21	Wrist
10	Knee		
11	Knee		
12	Knee		

Assessment

Here is a map of the content for the course we studied, with each card's number and topic category

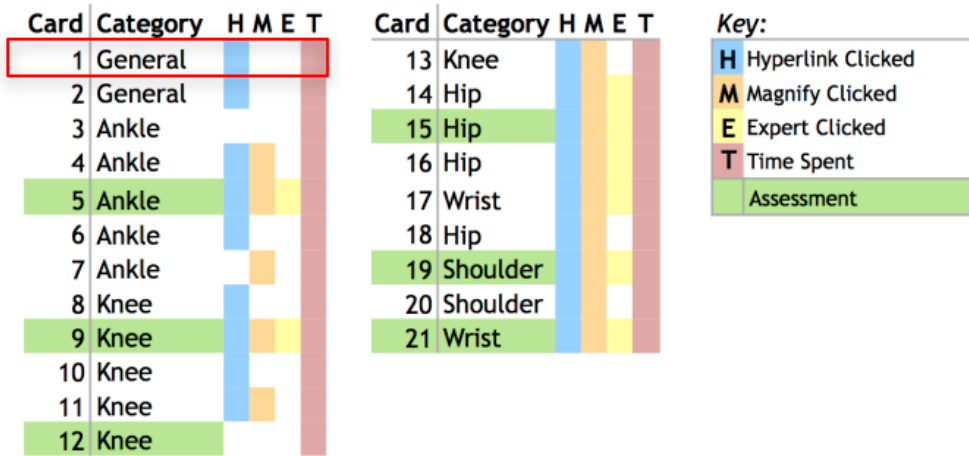
Assessments are highlighted in green.

ENGAGEMENT ACTIVITIES



Here is where those engagement activities were distributed.
 Not every engagement activity was available on every card

ENGAGEMENT ACTIVITIES



For example, card one only had an external hyperlink on it, so we only had insight into that click and time spent

ENGAGEMENT ACTIVITIES

Card	Category	H	M	E	T	Card	Category	H	M	E	T
1	General					13	Knee				
2	General					14	Hip				
3	Ankle					15	Hip				
4	Ankle					16	Hip				
5	Ankle					17	Wrist				
6	Ankle					18	Hip				
7	Ankle					19	Shoulder				
8	Knee					20	Shoulder				
9	Knee					21	Wrist				
10	Knee										
11	Knee										
12	Knee										

Key:

H	Hyperlink Clicked
M	Magnify Clicked
E	Expert Clicked
T	Time Spent
	Assessment

But card 16 had all three types of activity, plus time spent

EXAMPLE: CARD 16

19 of 23 Cards

- 1: Introduction
- 2: One Musculoskeletal
- 3: Mr. Stanley's Ski accident
- 4: Ankle Anatomy
- 5: Mr. Stanley's Ankle series
- 6: Fracture Descriptions
- 7: Mr. Stanley's treatment
- 8: Ms. Lawrence arrives in the ED
- 9: Ms. Lawrence's knee
- 10: Knee Effusion
- 11: Tibial Plateau
- 12: MRI or CT?
- 13: MRI of her knee
- 14: Ms. Potter's Hip Injury
- 15: Ms. Potter's Hip Radiographs
- 16: MRI of Ms. Potter's Left Hip
- 17: Ms. Potter's Right Wrist
- 18: Referral to Orthopedic Surgery
- 19: Mr. O'Neil's Shoulder
- 20: Shoulder reduction
- 21: Mr. O'Neil's Wrist
- 22: The End of a Long Morning
- 23: Links

Navigation

Mrs. Potter does well during the procedure and is transferred to the orthopedic floor.

Your next patient is Mr. O'Neil, a 21-year-old snowboarder complaining of left shoulder pain after a fall.

On exam his pupils are dilated and he smells of marijuana. You have him remove his shirt. His shoulder demonstrates a "squared off" appearance with skin depression over the deltoid muscle contour. He is unable to raise his arm. The patient is sent for radiographs.

Want to see a labeled normal shoulder series before you go to the next case?

[Go to the University of Washington's musculoskeletal radiology site.](#)

External Hyperlink

Question:

What is your diagnosis based on these images? Select one.

Multiple Choice Answer:

- A Posterior shoulder dislocation
- B Anterior shoulder dislocation
- C Superior shoulder dislocation
- D Proximal humeral fracture
- E Acromio-clavicular joint dislocation

Please note: show whether YOUR choice is correct or not, to locate highlight what the expert selected, please click here!

Expert Opinion link

[B has been selected by the expert.](#)

This is an **anterior shoulder dislocation (B)**. The AP view shows the humeral head resting anterior to the glenoid fossa in a subcoracoid location. The axillary view confirms the anterior trajectory of the dislocation as the humeral head rests anterior to the glenoid.

The axillary view anatomy can be difficult to identify, so it helps if you know how it is obtained. [See the Expert for more details of the views obtained on shoulder radiographs.](#)

Tools/Resources

My notes

No notes taken so far

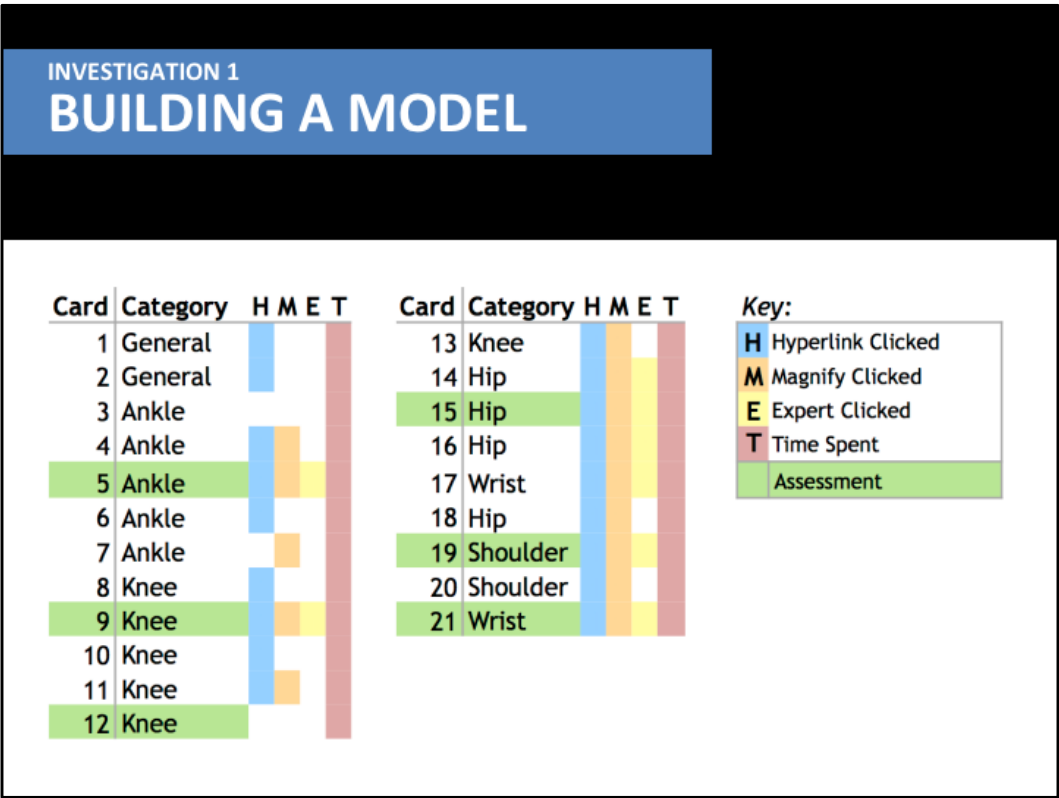
Expert
◀ ▶

Shown here

INVESTIGATION 1

**Is there a relationship
between student engagement
and performance?**

First investigation was to test our assumption that more engaged students performed better



To answer that question, we broke up the course into units...

INVESTIGATION 1

BUILDING A MODEL

Unit	Card	Category	H	M	E	T	
1	1	General					
	2	General					
	3	Ankle					
	4	Ankle					
	5	Ankle					
2	6	Ankle					
	7	Ankle					
	8	Knee					
	9	Knee					
3	10	Knee					
	11	Knee					
	12	Knee					
4	13	Knee					
	14	Hip					
	15	Hip					
	5	16	Hip				
		17	Wrist				
		18	Hip				
6	19	Shoulder					
	20	Shoulder					
	21	Wrist					

Key:

- H Hypertlink Clicked
- M Magnify Clicked
- E Expert Clicked
- T Time Spent
- Assessment

And for each unit...

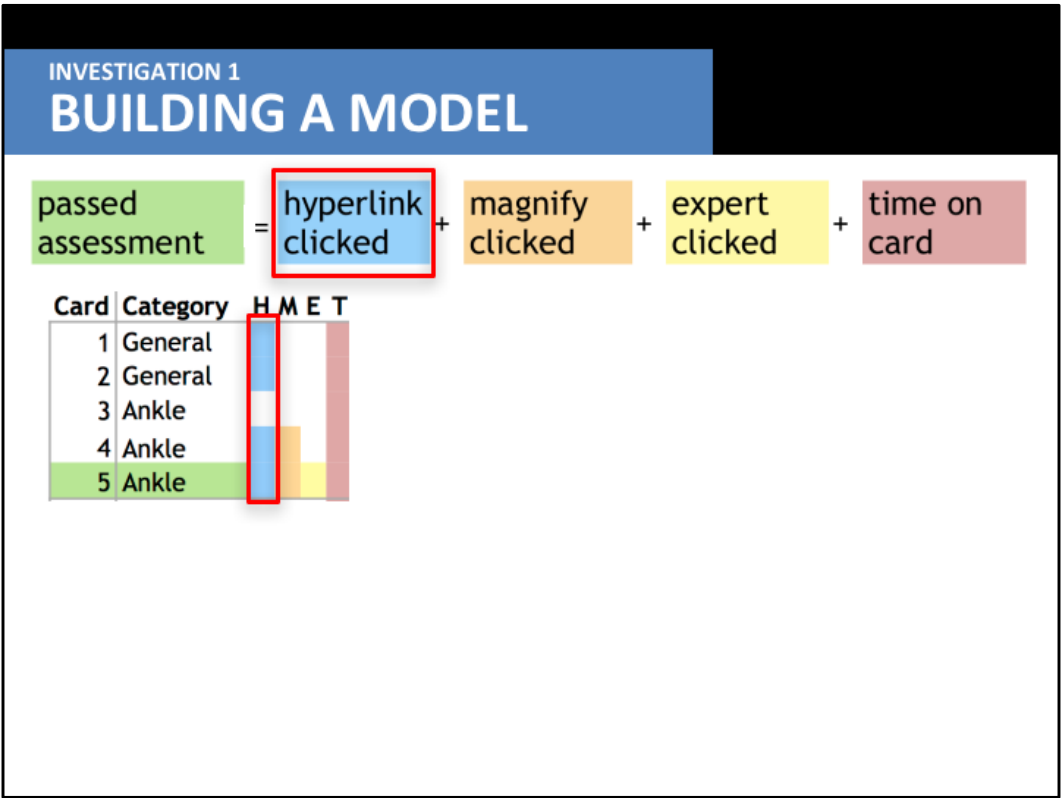
INVESTIGATION 1

BUILDING A MODEL

$$\text{passed assessment} = \text{hyperlink clicked} + \text{magnify clicked} + \text{expert clicked} + \text{time on card}$$

Card	Category	H	M	E	T
1	General				
2	General				
3	Ankle				
4	Ankle				
5	Ankle				

The model predicts whether a student will pass the end-of-unit assessment given...



Given whether the student clicked on any of the available links,

INVESTIGATION 1
BUILDING A MODEL

passed assessment = hyperlink clicked + magnify clicked + expert clicked + time on card

Card	Category	H	M	E	T
1	General				
2	General				
3	Ankle				
4	Ankle				
5	Ankle				

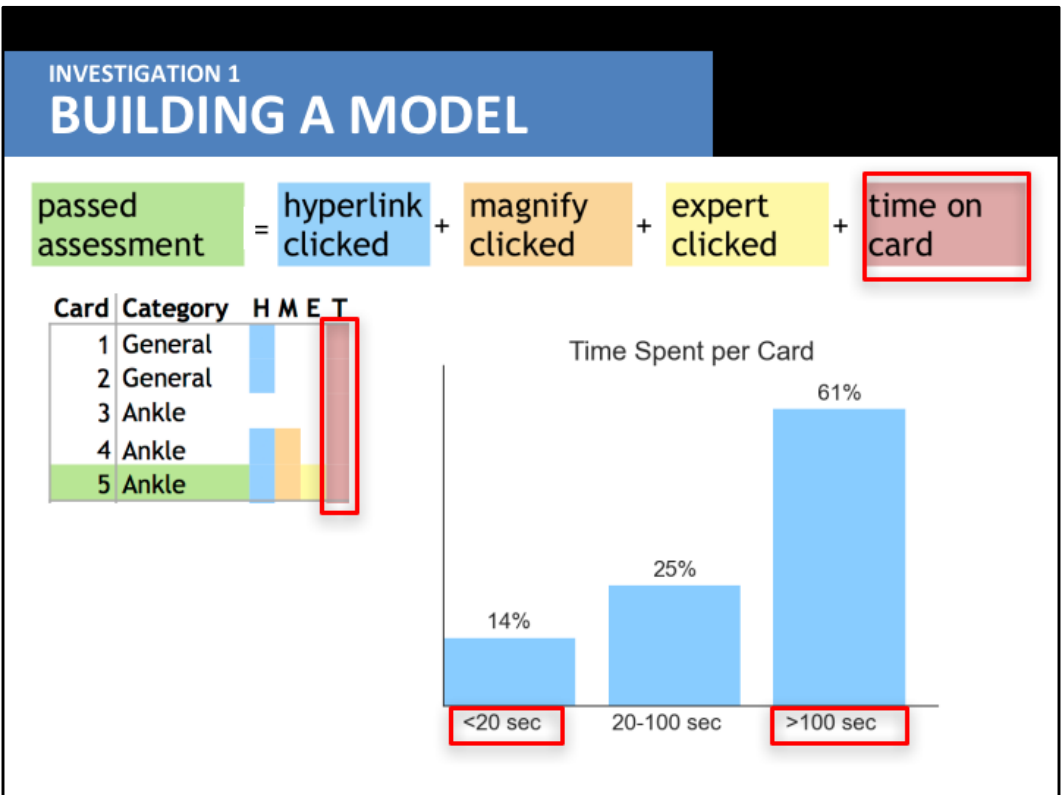
Any of the magnify image buttons,

INVESTIGATION 1
BUILDING A MODEL

passed assessment = hyperlink clicked + magnify clicked + expert clicked + time on card

Card	Category	H	M	E	T
1	General				
2	General				
3	Ankle				
4	Ankle				
5	Ankle				

Any of the expert links



And how much time the student spent on each card.

But since we expected a nonlinear relationship between time and performance,
we split time spent on card into bins:
and had indicators for each

INVESTIGATION 1 RESULTS		
Independent Variable	Odds ratio	95% Conf. Interval
Hyperlink clicked	1.21	(1.12,1.31)
Magnify image clicked	1.20	(1.11,1.31)
Expert link clicked	1.21	(1.05,1.39)
< 20 seconds per page	0.74	(0.66,0.83)
>100 seconds per page	1.38	(1.27,1.51)

Top half of students spent 23% longer per card than the bottom half

We tried several models, including decision trees and logistic regression for various transformations of the data, but the best-performing model was logistic regression, [with AUC of 0.594].

***** All features statistically significant**

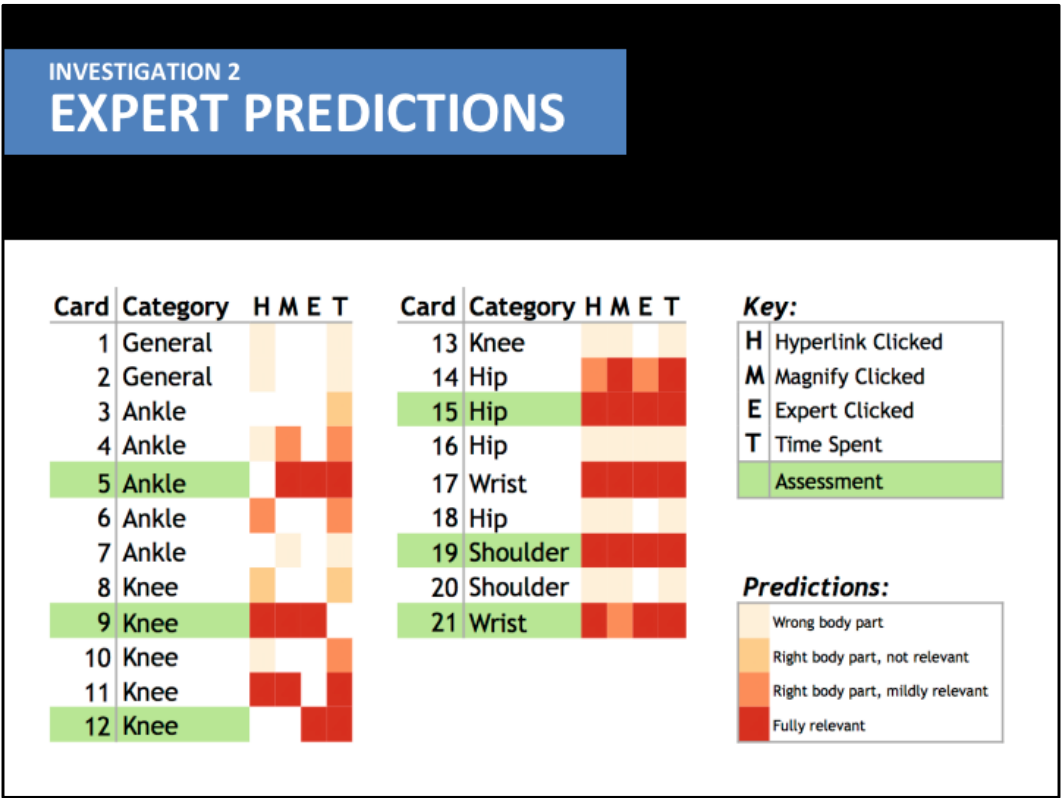
As expected, engagement and performance were related. Students that rushed through the cards had lower performance on assessments.

But that’s relatively obvious. What we really want to know is, which of the materials provided are useful to the students?

INVESTIGATION 2

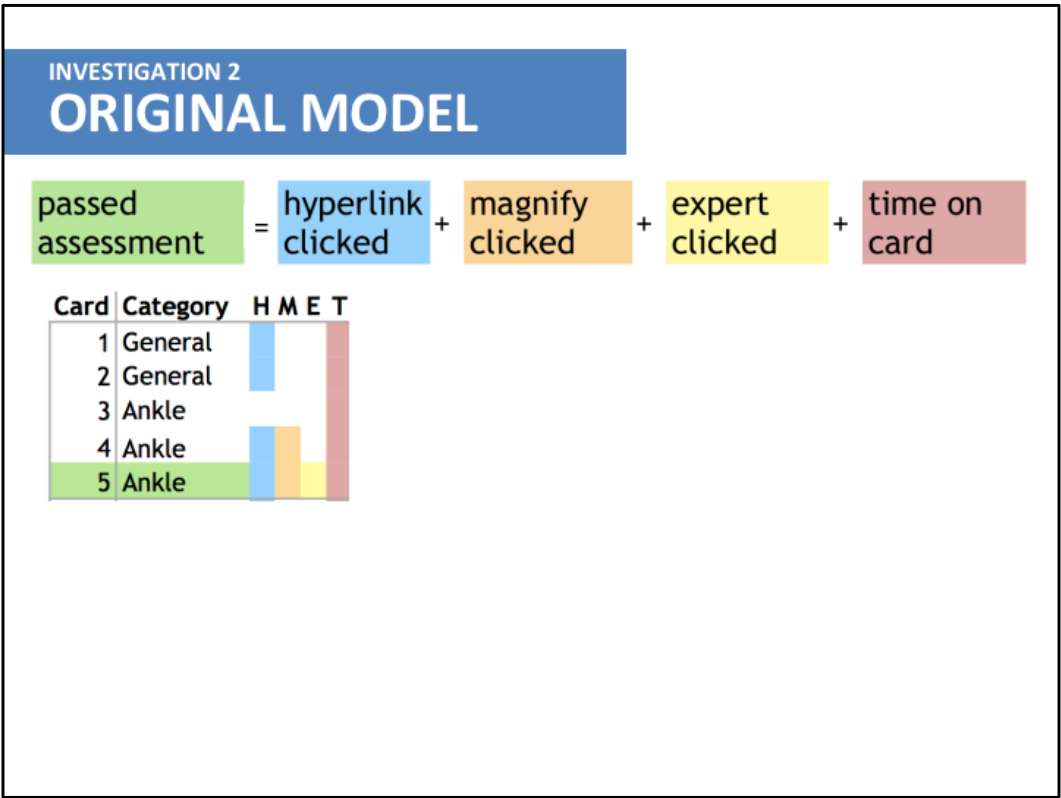
**Which engagement activities
impacted assessment score?**

Yes studying helps pass tests, but which materials are useful and which are not?
Which materials should be removed and replaced with others?

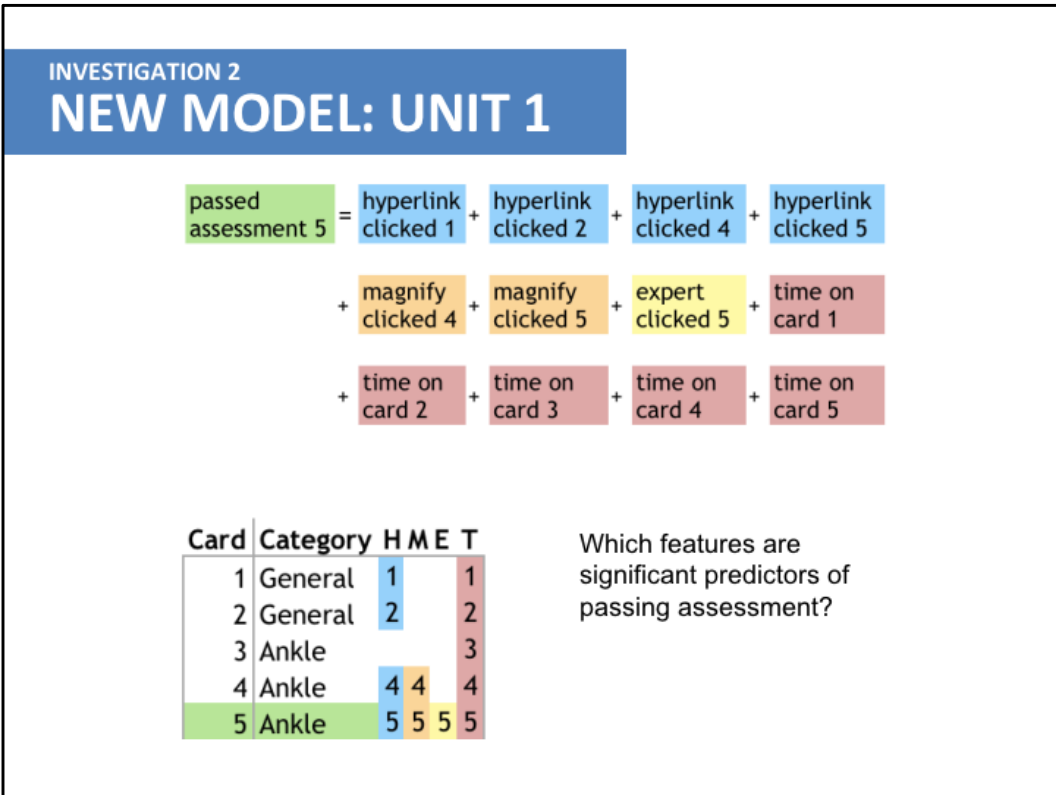


First Dr. Pusic provided his expert opinion, predicting which materials would be most useful to students in answering subsequent assessment questions.

Darker colors are expected to be more relevant. For example he predicted that card 16's materials, which were about the Hip, would not be useful for the assessment on card 19, which is about the shoulder.



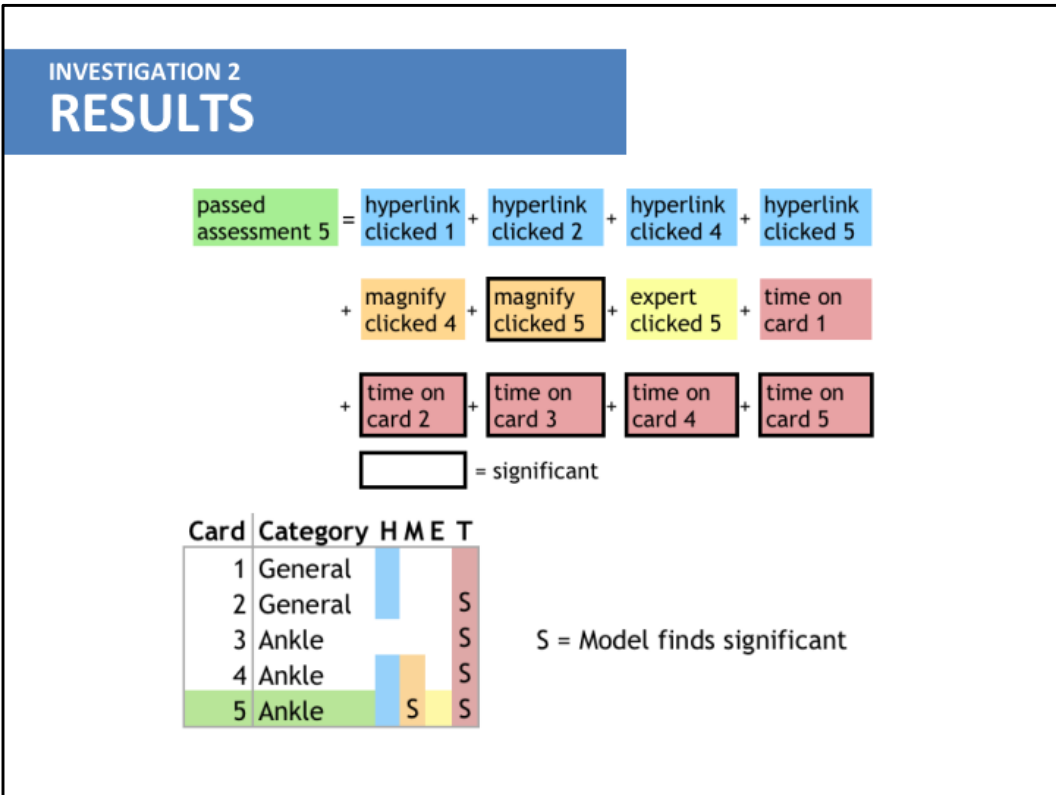
Like before, we broke up the course into units...



But this time built a separate model for each unit.
 Unlike the first model, which lumped together any engagement activities,
 Now we are looking for specific activities that contribute to performance
 To do that, we consider each event separately so that we can see its impact

Investigation 2: Procedure

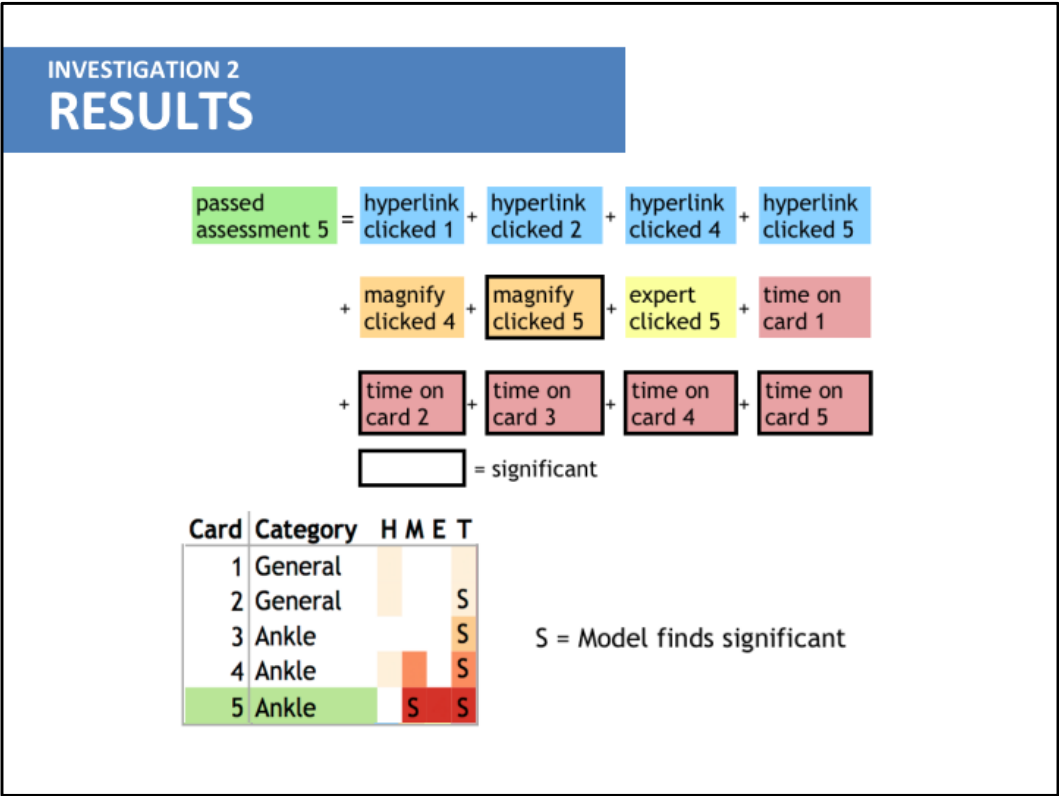
1. Run lasso-regularized logistic regression using all activities before assessment card
2. Find largest regularization parameter that is close to maximum cross-validation AUC
3. Re-run logistic with remaining variables
4. Return variables that have significant impact with p-value < 0.05



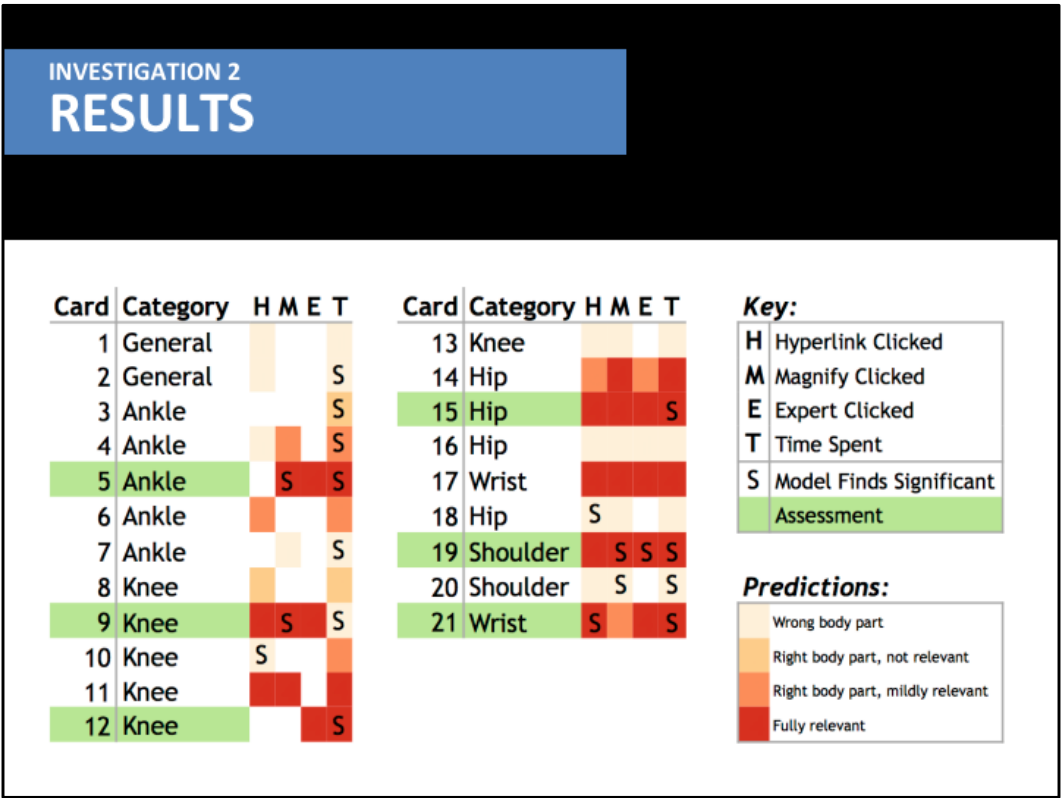
Then after running a model, we record which activities were significantly correlated with passing the assessment

In this unit’s model, we find that students who clicked the magnifier on card 5, or spent more time on cards 2,3,4,5, were more likely to pass the assessment on card 5.

But the other engagement activities were not significant predictors of passing probability



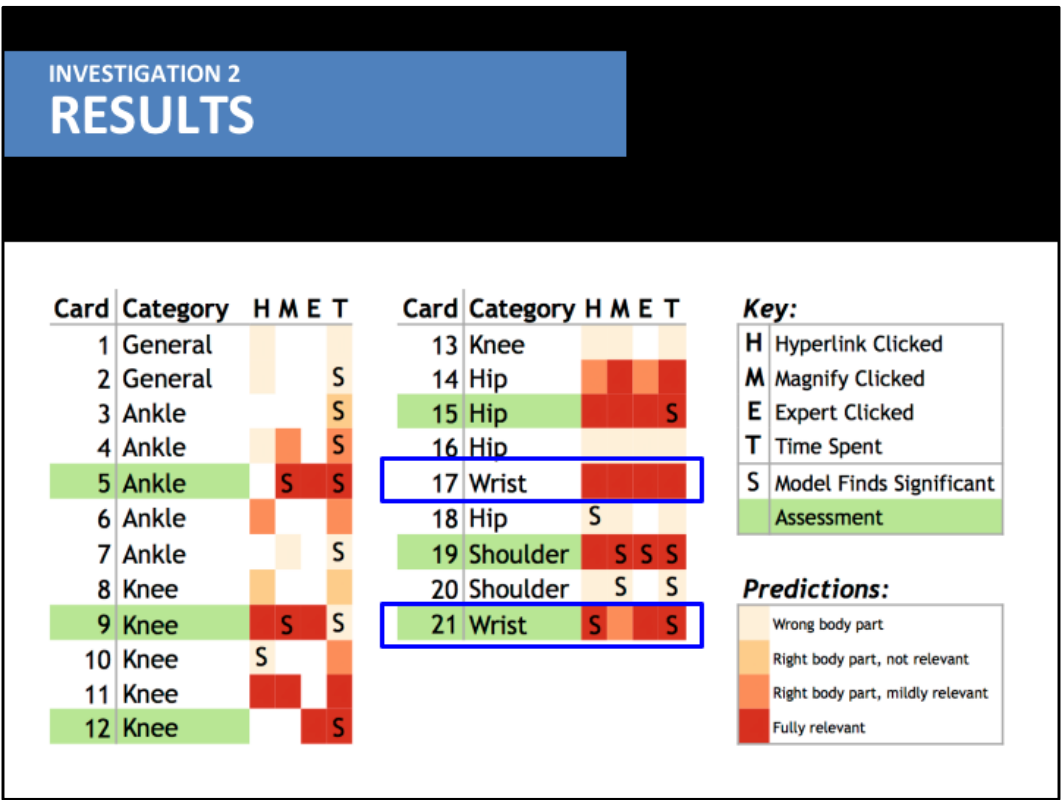
Comparing the model’s results to Dr. Pusic’s predictions shows where the predictions were and were not supported by the data.



Repeating that step for all units, we have this chart.

We can use these insights about what materials are NOT predictive of good performance, and can recommend that instructional designers replicate what is working and replace what isn't

Notable Observations:...



19. Dr. Pusic’s predictions for card 19 were consistent with model results.

You need to engage with that material in order to answer the question correctly

But

17 - Card 17, which is about the wrist, should be predictive of performance on card 21;

but perhaps there was too many cards between it and card 21 for students to see the relevance

1 - Card 5

Cards 1 and 2 comprise general content, and do not cover the assessment topic of ankles. These were understandably not predictive.

2 - Card 9

Engagement with card 6 and 8 was not associated with improved performance. Instructional designers should reconsider their inclusion.

3 - Card 12

Card 11 was expected to be fully relevant by the content expert, but the model did not consider its content predictive.

4 - Card 15

Few predictive variables were observed in this unit. Only time spent on the assessment card proved significant.

CONCLUSIONS

- **Expert predictions not always supported by data**
- **Feedback empowers instructional design**
- **Evidence that studying works**

Limitations:

- **Retroactive study, no control over data collection**



Conclusions/Strength of Innovation: Our intention was to demonstrate the merits of learning analytics within the online context, giving educators a new tool for improving experiences in educational online learning environments. Results of this analysis, where the data from thousands of learners are summarized, can serve as feedback to instructional designers as to which interaction elements are effective. It may also be useful to show students themselves evidence that there is a statistically significant relationship between engaging with the material and performing well on assessments.

DISCLOSURE

**Grant/Research support and
historical MedU data provided by:**



<http://www.med-u.org>

THANK YOU

Special Thanks to MedU,
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