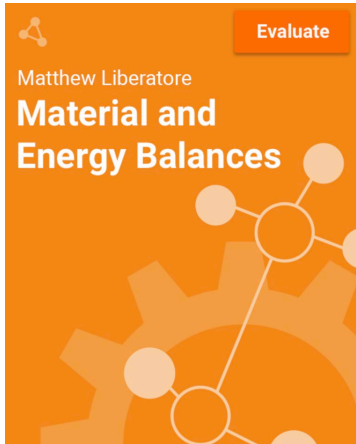


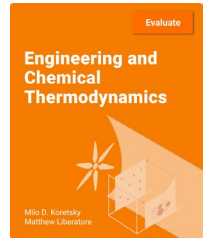
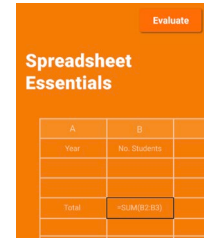
# Effects of problem type on completion and attempts on auto-graded homework problems for Material and Energy Balances

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and Matthew W. Liberatore 

October 2024



THE UNIVERSITY OF  
**TOLEDO**  
1872



# Thank you and...

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Alex Edgcomb

Disclaimer: MWL may financially benefit from sales of the books discussed in this talk



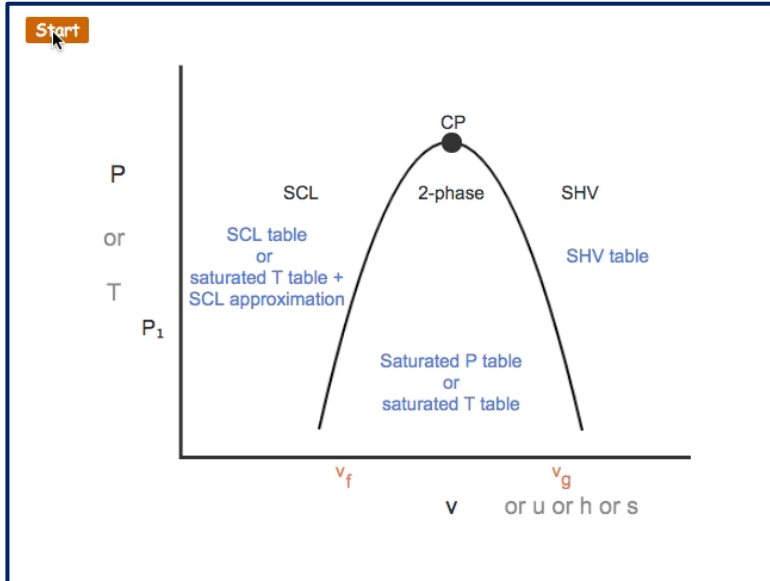
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University of Toledo IRB protocols 202214, 201808

# Do we want a rule book or a play book?



# Interactivity everywhere for 10 years



PARTICIPATION ACTIVITY 5.3.2: Reading a P-xy diagram.

T = constant

P

$P_2$   
 $P_1$   
 $P_3$

Liquid 2-phase Vapor

0  $x_A, y_A$  1

If unable to drag and drop, refresh the page.

Point 2 Point 3 Point 1

Bubble point at pressure  $P_1$

A liquid mixture

Dew point pressure

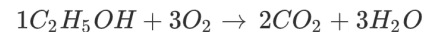
Reset

Feedback?

CHALLENGE ACTIVITY 5.3.1: Finding bubble and dew points on a P-xy diagram.

40254-1201450-act001?

A balanced chemical reaction is:



If the basis flow rate of  $C_2H_5OH$  is 4.8 mol/min. The feed also contains  $O_2$  in 78% excess. The feed flow rate of  $O_2$  is:

11 mol/min

# Interactive Textbook = Big Data

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Reading  
participation

Animation  
views

Challenge  
activity  
correct

Challenge  
activity  
attempts

# Two problem types and two locations



## In-chapter

Antonia and Michal are studying the unbalanced reaction:  
 $1N_2O_5 + \_\_H_2O \rightarrow \_\_HNO_3$ . While no  $HNO_3$  enters their reactor, 52.4 mol/hr exit. Calculating the extent of reaction gives:

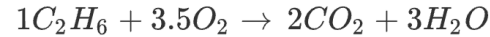
$\xi =$   mol/hr

1 2 3 4 5

Numeric

## In-chapter

A balanced chemical reaction is:



The feed to a reactor contains 8.4 mol/min  $C_2H_6$  and 94 mol/min  $O_2$ .  
The limiting reactant is:

- a.  $C_2H_6$
- b.  $O_2$
- c.  $H_2O$
- d.  $CO_2$

Select the limiting reactant. ▾

1 2 3 4

Multiple Choice

# Two problem types and two locations



## End-of-chapter

Many routes exist to make ethanol (ETOH,  $C_2H_5OH$ ), but Catharine and Patrick are investigating a much faster route than fermentation. Starting with a gas mixture of ethylene (E,  $C_2H_4$ ) and water (W,  $H_2O$ ) at  $305^\circ C$ , ethanol is produced by the balanced reaction:  $1C_2H_4 + 1H_2O \rightarrow 1C_2H_5OH$ . However, ethanol also decomposes by the unbalanced reaction:  $C_2H_5OH \rightarrow (C_2H_5)_2O + H_2O$ . Flowing into the reactor are 329 mol/hr ethylene and 436 mol/hr water. The reactor produces diethyl ether (DE,  $(C_2H_5)_2O$ ) at 29.8 mol/hr when the yield of ethanol (moles ethanol produced/mole ethylene consumed) is 0.746.

Determine some unknown component molar flow rates.

$\dot{n}_{2,E} =$   mol/hr       $\dot{n}_{2,W} =$   mol/hr       $\dot{n}_{2,ETOH} =$   mol/hr

1

2

Numeric

## End-of-chapter

Many routes exist to make ethanol (ETOH,  $C_2H_5OH$ ), but Catharine and Patrick are investigating a much faster route than fermentation. Starting with a gas mixture of ethylene (E,  $C_2H_4$ ) and water (W,  $H_2O$ ) at  $305^\circ C$ , ethanol is produced by the balanced reaction:  $1C_2H_4 + 1H_2O \rightarrow 1C_2H_5OH$ . However, ethanol also decomposes by the unbalanced reaction:  $C_2H_5OH \rightarrow (C_2H_5)_2O + H_2O$ . Flowing into the reactor are 289 mol/hr ethylene and 398 mol/hr water. The reactor produces diethyl ether (DE,  $(C_2H_5)_2O$ ) at 29.8 mol/hr when the yield of ethanol (moles ethanol produced/mole ethylene consumed) is 0.706.

Yield decreases by 3%. The flow rate of ethylene exiting the reactor would decrease, increase, or stay the same (choose one).

Select the best option. ▾

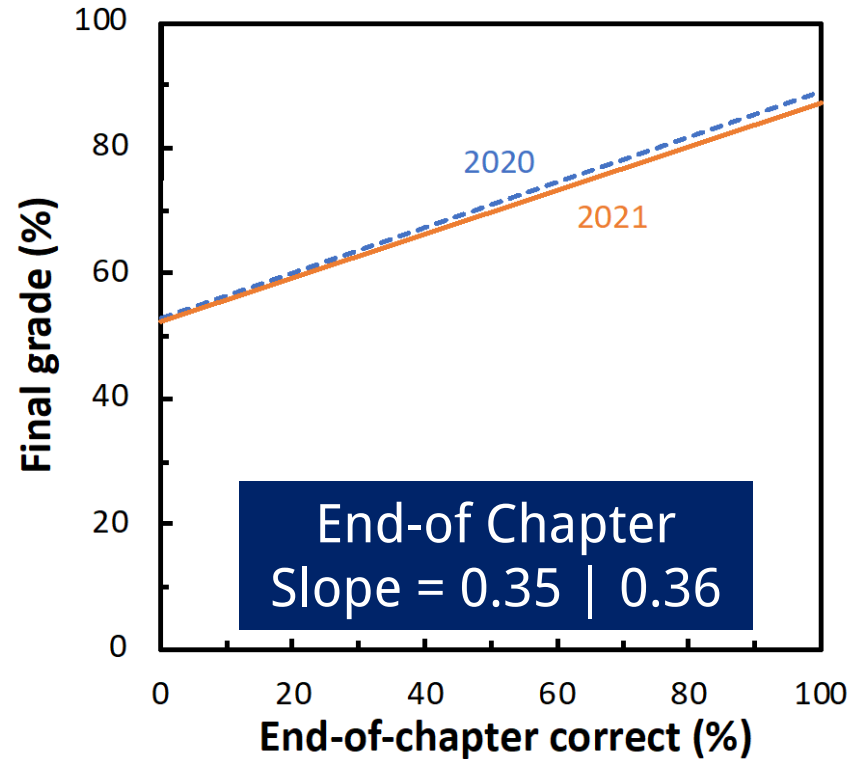
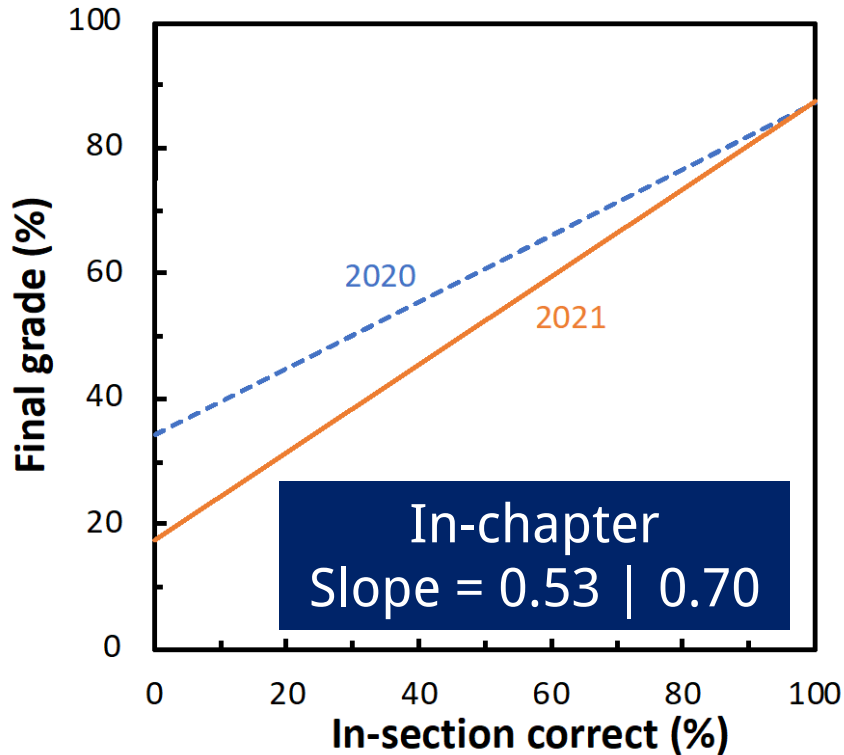
1

2

Multiple Choice

Concept

# Wider lens: Correlations by location





# Two cohorts, big data



2021 cohort (online synchronous)  $n = 66$



2022 cohort (in person)  $n = 57$



Data shown in aggregate, no significant differences

712 available problems

440-480 problems assigned

400 in-chapter problems

40-80 end-of-chapter problems

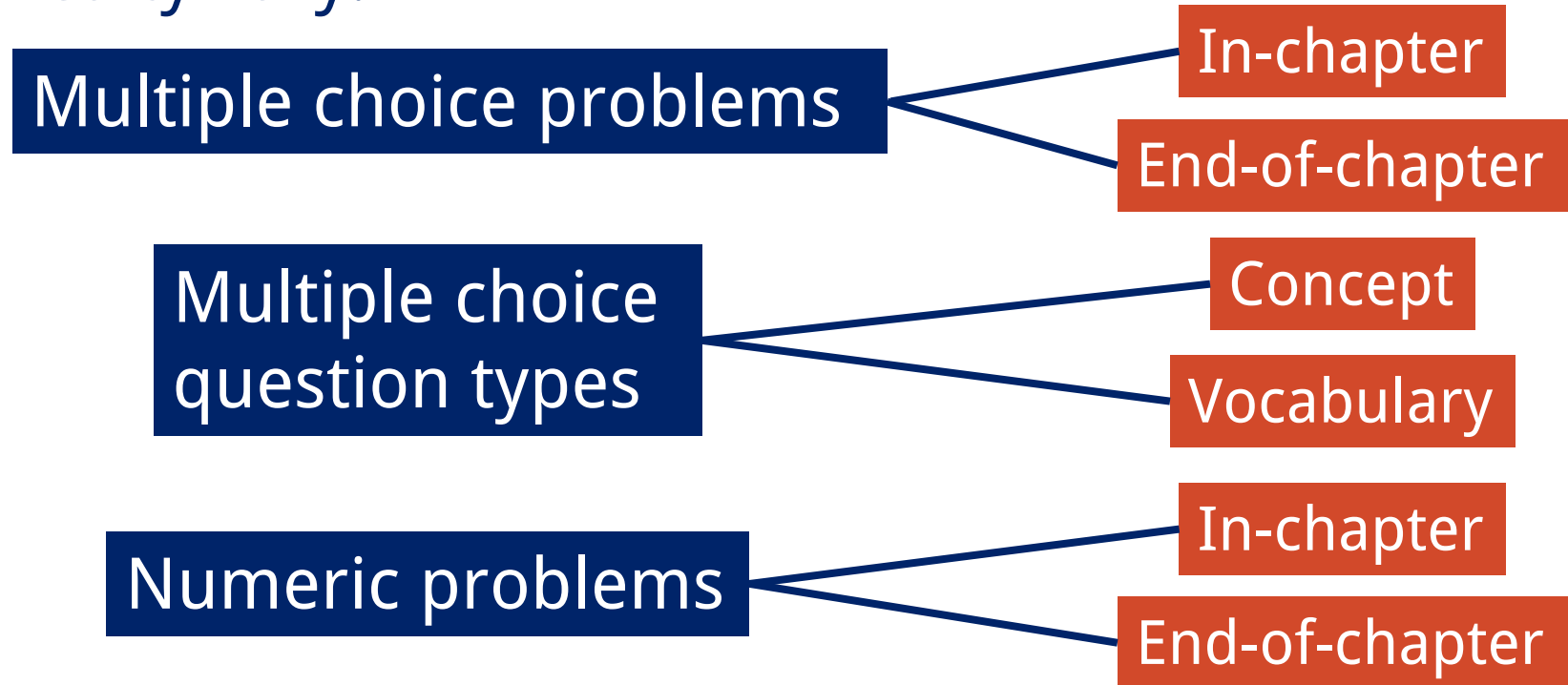


Over 50,000 problems analyzed

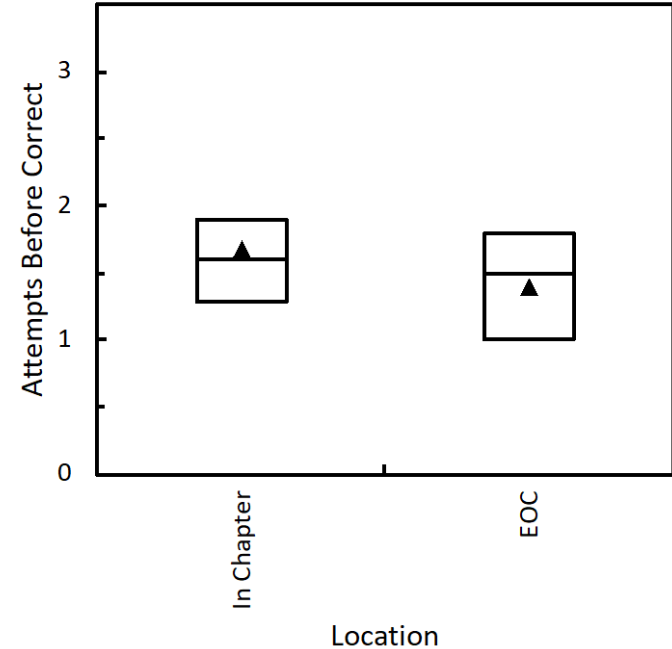
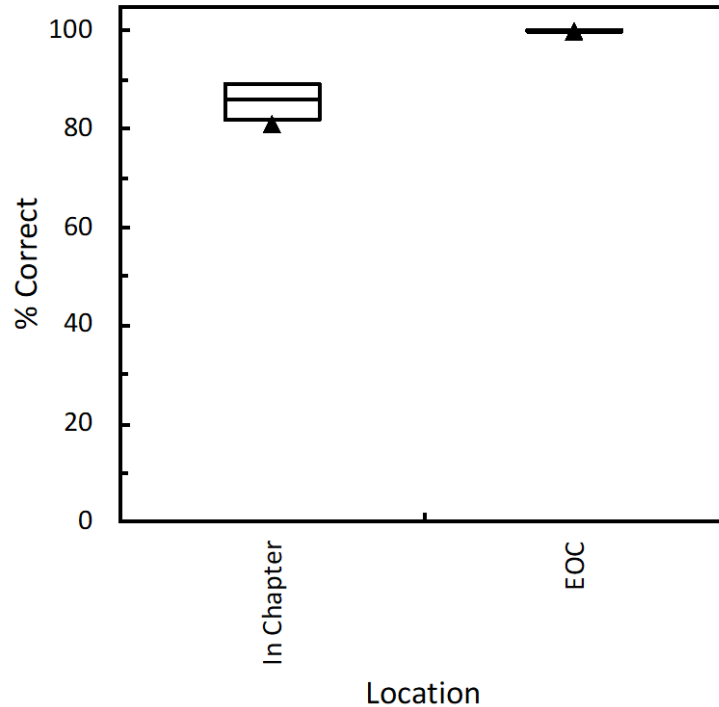
# Three research questions



How does correctness, attempts, and problem difficulty vary:

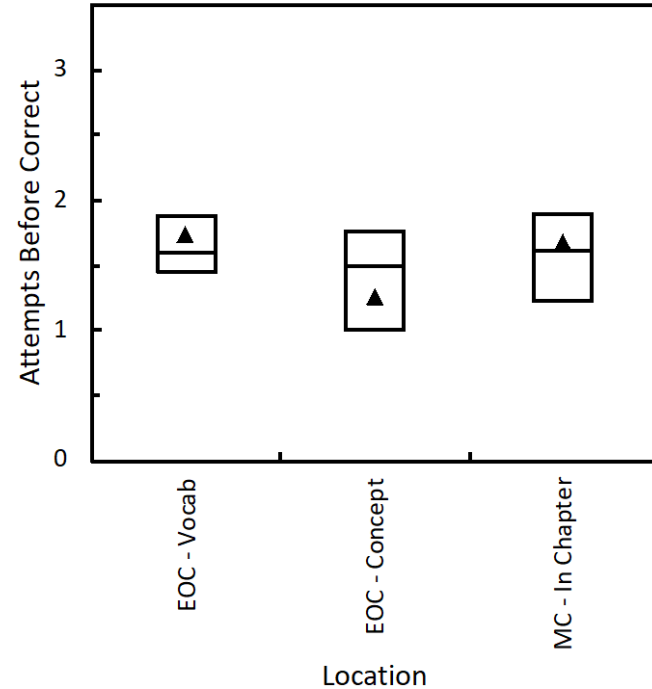
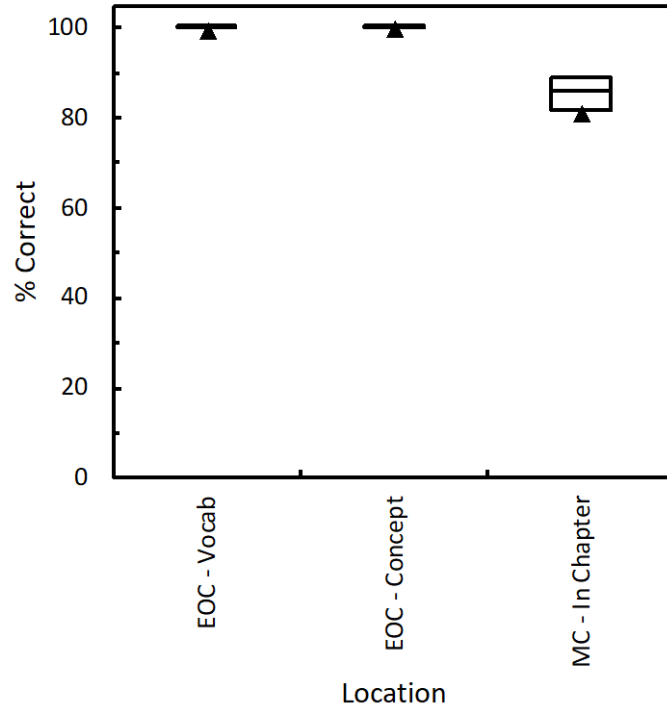


# Multiple choice + unlimited attempts =



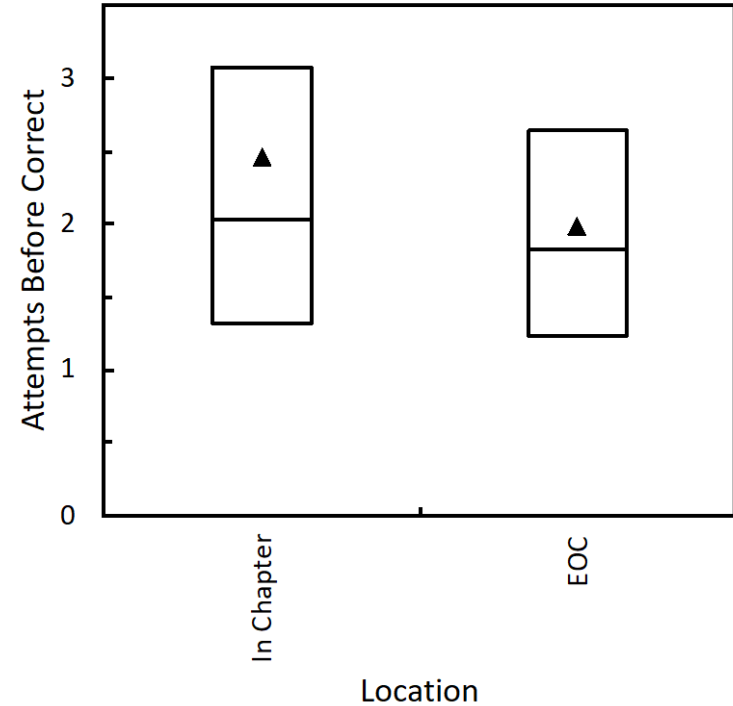
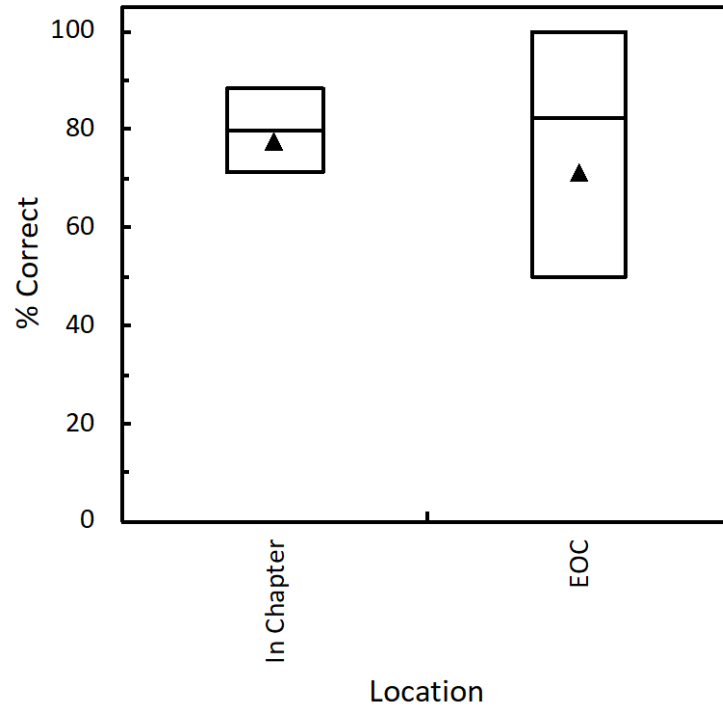
Easy. >75% of problems correct in 2 or less attempts

# Multiple choice: Vocab vs Concept



No notable differences

# Differences with numeric + location



Wide variation for %Correct for EOC problems

# A new metric – Deliberate Practice score



Correct

Modified  
correct

1<sup>st</sup> quartile  
Attempts  
before  
correct

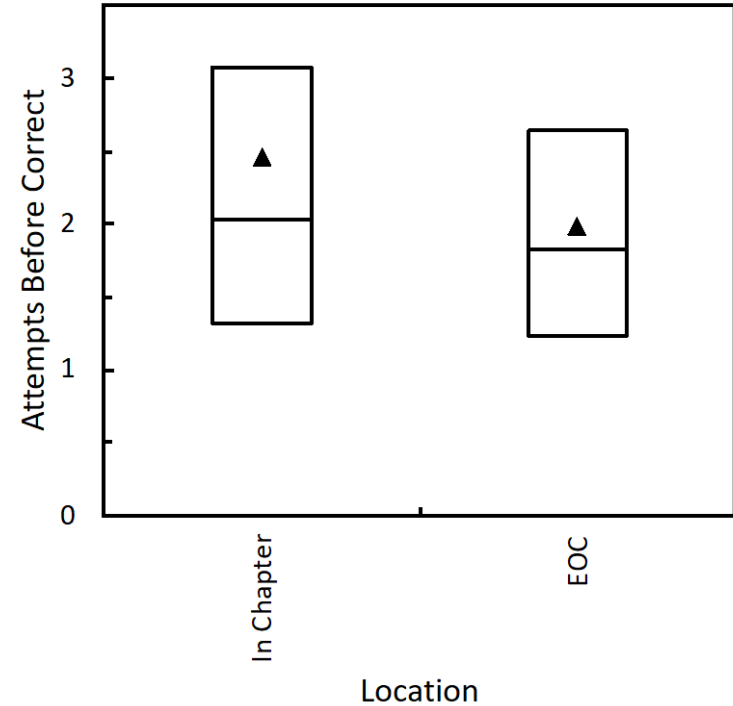
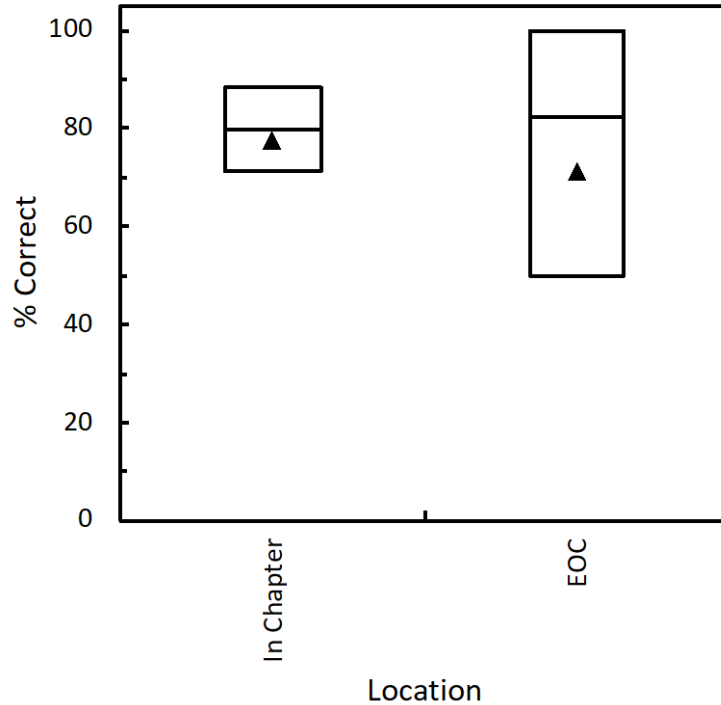
Median  
Attempts  
before  
correct

# Four metrics become one score



Metric	Threshold	Deliberate practice score
<b>Correct</b>	$\geq 90\%$	0
	80 - 90%	1
	$< 80\%$	2
<b>Modified correct</b>	$\geq 95\%$	0
	85 - 95%	1
	$< 85\%$	2
<b>1<sup>st</sup> quartile Attempts before correct</b>	$\leq 2$	0
	2 - 3	1
	$\geq 3$	2
<b>Median Attempts before correct</b>	$\leq 2$	0
	2 - 3	1
	$\geq 3$	2

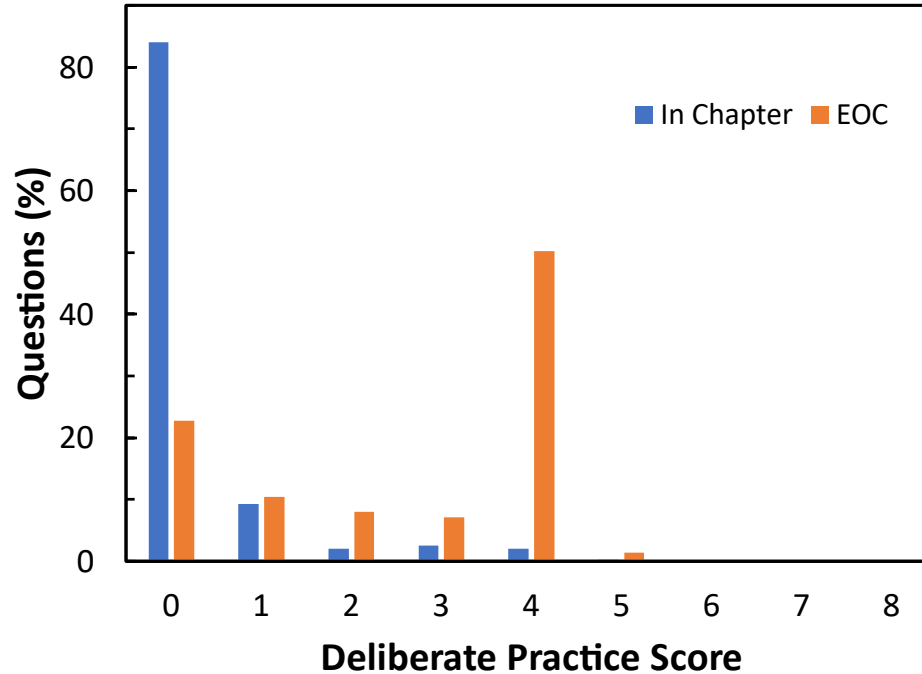
# Differences with numeric + location



Wide variation for %Correct for EOC problems



# Numeric problems = Location matters



DP score of 4+ for 50% or End-of-Chapter problems

# New findings for auto-graded problems

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Two cohorts, >100 students, >50,000 problems

Multiple choice questions relatively easy

In-chapter vs End-of-chapter

Vocabulary vs Concept

Numeric problems: End-of-chapter shows higher deliberate practice scores



2024 ASEE paper

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How is formative practice built into your courses?