

# Supplemental Material

*CBE—Life Sciences Education*

Angell *et al.*

## Supplemental Material

### Metacognitive Exam Preparation Assignments in an Introductory Biology Course Improve Exam Scores for Lower Achieving Students Compared to Assignments that Focus on Terms

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*Table S1. Sample metacognitive assignments.*

#### I. Sample Metacognitive Assignments for Exams

##### A. First Exam

What strategies do you use to study for exams or quizzes? (study with friends, on your own, read the text, test yourself by doing the end of chapter questions, read notes, highlight notes, summarize text in your own words, type notes up, talk to yourself, make flashcards, going somewhere super quiet, going somewhere with just the right amount of distraction etc...). IN other words, tell me what has worked for you in the past!

Do you think you have spent time strategizing about your learning before? Give an example.

How do you think you will study for this exam?

Is there material from lecture or material that was presented during class that you feel like you did not understand?

Why do you think you had trouble with this topic/these topics?

What do you think were the two MOST difficult (hard to read/ hard to understand) or conceptually

challenging topics of the textbook reading (list below)?  
(Look through the chapters!)

a. \_\_\_\_\_

Why do you think you had trouble understanding this concept?

b. \_\_\_\_\_

How do you think you will work to understand this concept?

How long do you expect to study for this exam? (I know it is hard to estimate but try!) (Don't include time spent simply reading the chapters.)

What grade do you think you will get? \_\_\_\_\_% (YOU WILL NOT GET CREDIT UNLESS YOU VENTURE A GUESS!!! Please do not write in a letter grade, share the actual %)

### **B. Second Exam**

First pull out your 1st exam. What grade did you get?

Did you do as well as you thought you would?

What kinds of questions did you lose points on (factual questions or conceptual questions/Short or long questions?)

Why did you lose those points? Careless mistakes? Did you simply not know what the answer was? Did you not understand the question? Did you not give enough detail? Not use terms where you could have?

Do you wish you had studied differently? Did your study strategies work for you?

Did lab help you understand the material from the text or lecture?

Name one thing you will do differently to study for this exam that you did not do for the last exam? (be creative-what works for you!)

Do you think flashcards would be a useful way to study this material? Why/Why not?

What do you think were the **three** most difficult topics of the **textbook** reading? (Flip through the chapters)

a. The **FIRST** Topic/concept I found difficult was.....

This topic was difficult because....(too many terms, too much detail, fundamentally don't understand, too hard, wasn't explained well in the text)

b. The **SECOND** Topic/concept I found difficult was.....

This topic was difficult because....(too many terms, too much detail, fundamentally don't understand, too hard)

c. The **THIRD** Topic/concept I found difficult was.....

This topic was difficult because....(too many terms, too much detail, fundamentally don't

understand, too hard)

How long do you expect to study for this exam? (I know it is hard to estimate but try!)

How will you start studying? What will you begin with?

What grade do you think you will get? \_\_\_\_\_% (YOU WILL NOT GET CREDIT UNLESS YOU VENTURE A GUESS and share as a %!!!)

### C. Third Exam

Think back to your second exam (you might actually get it out-there might be things you could review on it). Did you do as well as you thought you would?

Why did you lose those points? Careless mistakes? Did you simply not know what the answer was? Did you not understand the question or not read it carefully? Did you not give enough detail? Not use terms where you could have?

Have your study strategies changed across the semester?

This **class** has had material that is both very detailed alongside "big picture" themes and concepts. How have you managed learning both of these ends of the spectrum?

Do you think you are better at learning the details or big picture concepts?

Name one thing you will do differently to study for this exam that you did not do for the last exam? (be creative-what might work for you!)

How do you think this material is different to study for than a language class or math class? (or some other class) Why?

What parts of the material for the final exam do you feel like you already know a little or feel comfortable with?

What do you think are the **two** areas you most need to study (remember there are cumulative questions on the final)?

- a. The FIRST area or bunch of material I need to study is.....
- b. The SECOND area I need to study is.....

How long do you expect to study for this exam? (I know it is hard to estimate but try!) You might also think about what it means to "study" I had a huge range of responses when I asked this last time!

How will you start studying? What will you begin with?

What grade do you think you will get? \_\_\_\_\_% (YOU WILL NOT GET CREDIT UNLESS YOU VENTURE A GUESS!!!)

*Table S2. Representative terms students were asked to define for terms assignment.*

Note: Students asked to define terms were also asked the following at the end of their assignment.

What grade do you think you will get? \_\_\_\_\_% (YOU WILL NOT GET CREDIT UNLESS YOU VENTURE A GUESS!!!)

(6-8 terms were randomly chosen from the lists below)

1 <sup>st</sup> exam	2 <sup>nd</sup> exam	3 <sup>rd</sup> Exam
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Gene flow	Endosymbiosis	Protostome
Sympatric speciation	Eukaryotes	Deuterostome
Allopatric speciation	Prokaryotes	Hemipteran
Heterozygote advantage	Bacteria	Mollusks
Convergent evolution	Archaea	Cephalopod
Homoplasly	Meiosis	Echinoderms
Homologous	Mitosis	Annelids
Analogous	Gametes	Chordates
Vestigial trait	Zygote	Vertebrates
Directional selection	Alternation of generation	Endothermy
Stabilizing selection	Gametophyte	Metamorphosis
Genetic drift	Angiosperms	Water vascular system
Hybrid zone	Gymnosperms	Pharyngeal gills slits
Species concepts	Bryophytes	Oviparous
Founder event	Chitin	Viviparous
Genetic bottleneck	Zygomycete	Notochord
Gene pool	Basidiomycete	Tube feet
Adaptive radiation	Ascomycete	Amniotes
Synapomorphy	Spores	Notochord
Polyploidy	Vascular system	Placenta
	Autotrophic	Radula
	Hyphae	Ganglia
	Mycelium	Hydrostatic skeleton
	Fruits	
	Seeds	
	Multinucleate	
	Lateral or horizontal gene transfer	

*Table S3. Enrollment and participation by student gender/sex.\**

	Female	Male	Total
Number of students in five sections	182	129	311
Number enrolling in study and completing all three assignments	137	96	233
Percent completing all three assignments	75.3%	74.4%	74.9%

\*The information on the number of students was obtained from institutional data so gender/sex was recorded as binary. Information on race/ethnicity was not readily available.

*Table S4. Sample sizes for students in both assignment groups.*

Assignment	Higher ACT (at or above the median)		Lower ACT (below the median)	
	Metacognitive	Terms	Metacognitive	Terms
Junior	3	1	3	0
Sophomore	35	38	24	23

First Year	36	35	15	15
Not Indicated	2	1	1	1
Subtotal	76	75	43	39
Total	151		82	

Table S5. Model selection determining factors influencing exam scores.

Df	AIC	Current model- Best model	Model
<b>8</b>	<b>4904.6</b>	<b>0</b>	<b>Score ~ Achievement + Exam + Assignment + Achievement*Assignment+(1 StudID) + (1 Instructor)</b>
7	4907.4	2.8	Score ~ Achievement + Exam + Assignment +Achievement*Assignment + (1 StudID)
7	4912.1	7.5	Score ~ Achievement +Exam + Assignment + (1 StudID) + (1 Instructor)
7	4918.9	14.3	Score ~ Achievement + Assignment +Achievement*Assignment + (1 StudID) + (1 Instructor)
7	5093.4	188.8	Score ~ Achievement + Exam + Assignment + Achievement*Assignment + (1 Instructor)
6	5113.0	208.4	Score ~ Achievement + Exam + Assignment+ Achievement*Assignment

Table S6. Model selection determining factors influencing predicted scores.

Df	AIC	Current model- Best model	Model
<b>8</b>	<b>4232.0</b>	<b>0</b>	<b>PredictedScore ~ Achievement + Exam + Assignment + Achievement*Assignment+(1 StudID) + (1 Instructor)</b>
7	4233.5	1.5	PredictedScore ~ Achievement + Exam + Assignment +Achievement*Assignment + (1 StudID)
7	4235.6	3.6	PredictedScore ~ Achievement +Exam + Assignment + (1 StudID) + (1 Instructor)
7	4325.1	93.1	PredictedScore ~ Achievement + Assignment +Achievement*Assignment (1 StudID) + (1 Instructor)
7	4423.6	191.6	PredictedScore ~ Achievement + Exam + Assignment + Achievement*Assignment + (1 Instructor)
6	4434.2	202.2	PredictedScore ~ Achievement + Exam + Assignment+ Achievement*Assignment

Table S7. Model selection determining factors influencing accuracy.

Df	AIC	Current model- Best model	Model
<b>7</b>	<b>4972.3</b>	<b>0</b>	<b>Accuracy ~ Achievement + Exam + Assignment +Achievement*Assignment + (1 StudID)</b>
8	4974.0	1.7	Accuracy ~ Achievement + Exam + Assignment + Achievement*Assignment+(1 StudID) + (1 Instructor)
7	4982.7	10.4	Accuracy ~ Achievement +Exam + Assignment + (1 StudID)

7	5012.5	40.2	Accuracy ~ Achievement + Assignment + Achievement*Assignment + (1 StudID)
7	5015.8	43.5	Accuracy ~ Achievement + Exam + Assignment + Achievement*Assignment + (1 Instructor)
6	5021.6	49.3	Accuracy ~ Achievement + Exam + Assignment + Achievement*Assignment

Table S8. Linear model results of best-fit model for score.

Score ~ Achievement + Exam + Assignment + Achievement \* Assignment + (1 | StudID) + (1 | Course)

Fixed Effects	Estimates	St. Er.	t value	Pr(> t )	
(Intercept)	84.0337	1.3901	60.450	4.40e-08	***
Achievement	-9.0169	1.5221	-5.924	1.15e-08	***
Exam 2	-0.5740	0.5788	-0.992	0.3218	
Exam 3	1.0576	0.5788	1.827	0.0683	
Assignment	-0.5134	1.2541	-0.409	0.6826	
Achievement:Assignment	5.3107	2.1176	2.508	0.0128	*
Random Effects:	Variance	Std. Dev.			
StudID(Intercept)	46.32	6.806			
Instructor (Intercept)	2.97	1.723			
N StudID	233				
N Instructor	3				
N Observations	699				
Correlation of Fixed Effects:					
	(Intr)	Achievement	Exam 2	Exam 3	Assignment
Achievement	-0.369				
Exam 2	-0.208	0.000			
Exam 3	-0.208	0.000	0.500		
Assignment	-0.451	0.415	0.000	0.000	
Achievement:Assignment	0.267	-0.716	0.000	0.000	-0.593

Table S9. Best-fit linear model results of predicted score.

PredictedScore ~ Achievement + Exam + Assignment + Achievement \* Assignment + (1 | StudID) + (1 | Course)

Fixed Effects	Estimates	St. Er.	t value	Pr(> t )	
(Intercept)	89.40245	0.80771	110.687	1.64e-10	***
Achievement	-2.96099	0.94048	-3.148	0.00186	**
Exam 2	-3.05150	0.35570	-8.579	< 2e-16	***
Exam 3	-3.17811	0.35570	-8.935	< 2e-16	***
Assignment	-0.08076	0.77493	-0.104	0.91709	
Achievement:Assignment	1.52736	1.30838	1.167	0.24428	

<i>Random Effects:</i>	<i>Variance</i>	<i>Std. Dev.</i>			
StudID(Intercept)	17.7405	4.2119			
Instructor (Intercept)	0.8815	0.9389			
N StudID	233				
N Instructor	3				
N Observations	699				
Correlation of Fixed Effects:					
	(Intr)	Achievement	Exam 2	Exam 3	Assignment
Achievement	-0.393				
Exam 2	-0.220	0.000			
Exam 3	0.220	0.000	0.500		
Assignment	-0.480	0.415	0.000		
Achievement:Assignment	0.284	-0.716	0.000	0.000	-0.593

Table S10. Best-fit linear model results of accuracy.

Accuracy~ Achievement + Exam + Assignment+ Achievement\*Assignment +(1|StudID).

<i>Fixed Effects</i>	<i>Estimates</i>	<i>St. Er.</i>	<i>t value</i>	<i>Pr(&gt; t )</i>	
(Intercept)	5.1642	0.8258	6.253	1.10e-09	***
Achievement	6.0438	1.2349	4.894	1.86e-06	***
Exam 2	-2.4775	0.6936	-3.572	0.000391	***
Exam 3	-4.2357	0.6936	-6.107	2.15e-09	***
Assignment	0.3890	1.0181	0.382	0.702760	
Achievement:Assignment	-3.6774	1.7174	2.141	0.033311	*
<i>Random Effects:</i>	<i>Variance</i>	<i>Std. Dev.</i>			
StudID(Intercept)	20.45	4.52			
N StudID	233				
N Observations	599				
Correlation of Fixed Effects:					
	(Intr)	Achievement	Exam 2	Exam 3	Assignment
Achievement	-0.512				
Exam 2	-0.420	0.000			
Exam 3	-0.420	0.000	0.500		
Assignment	-0.620	0.415	0.000	0.000	
Achievement:Assignment	0.368	-0.719	0.000	0.000	-0.593