

Supplemental Material

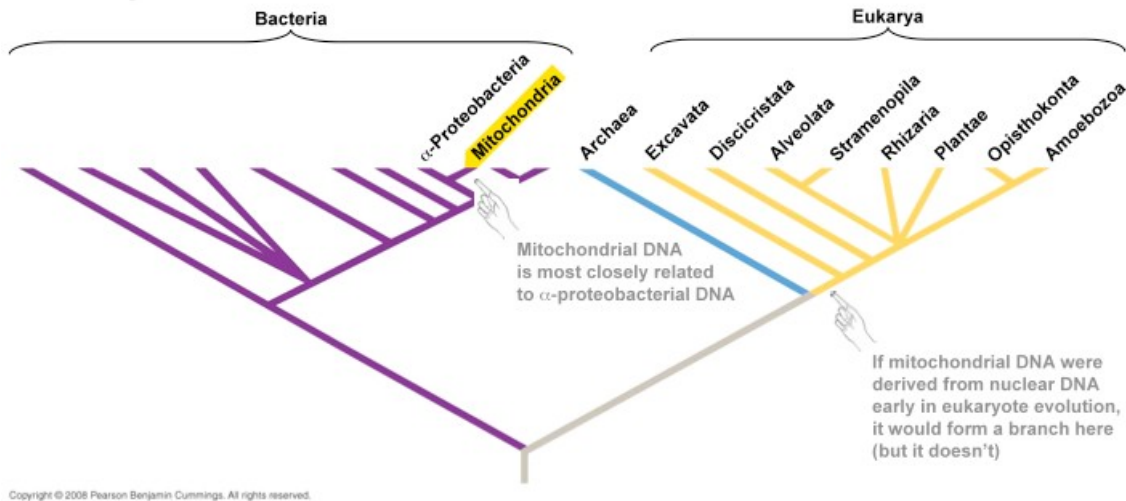
CBE—Life Sciences Education

Prevost *et al.*

Supplemental Material, Figure 1. Biology problems used in the study. Included with each problem are the preliminary Bloom's ranking as seen by students and final Bloom's ranking as determined by experts.

- In the Protists lecture I explained the endosymbiotic theory and described the evidence in support of this theory. The most convincing evidence is represented in the figure below. Based on your understanding of the endosymbiotic theory and phylogenetics, choose the response below that best explains the evidence for endosymbiosis.

Bloom's ranking seen by students: Understanding; Expert ranking: Understanding



- This figure show that mitochondria branch off from α -proteobacteria instead of from archaea or eukarya. This is what was expected from the endosymbiotic hypothesis.
 - This figure shows that phylogenetic analysis places mitochondria as most closely related to α -proteobacteria, supporting the idea that they evolved within bacterial cells and were later transferred to eukaryotic cells. If the alternative hypothesis (mitochondria evolved within eukaryotic cells) had been supported, the mitochondria branch would be found within domain Eukarya.
 - This figure shows that phylogenetic analysis places mitochondria as most closely related to α -proteobacteria, supporting the hypothesis that the mitochondrion originated from a bacterial cell that was ingested by a larger cell. If the alternative hypothesis (mitochondria evolved within eukaryotic cells) had been supported, the mitochondria branch would be found within domain Eukarya.
 - This figure shows that the mitochondrial DNA was first found in bacterial cells, suggesting that bacteria possess mitochondria.
- Which of the following is an example of resource partitioning?

Bloom's ranking seen by students: Applying; Expert ranking: Understanding

- To reduce competition, some plants such as the Black Walnut exude chemicals that restrict the growth of other nearby plants.
- In the Caribbean several islands have their own native parrot species that is different from the parrots on surrounding islands.
- Herbs growing next to each other in a grassland have different root lengths and obtain nutrients and water from different depths in the soil.
- Lizards in grassy and desert environments have evolved different color patterns in response to predation pressure.

3. Sticklebacks are small fish found in a variety of habitats in the Northern Hemisphere. Two forms of sticklebacks have been identified – the benthics and the limnetics. Examine the pictures of the two stickleback forms and the data in Table 1. What is the best conclusion you can draw from these data?
Bloom’s ranking seen by students: Applying and Analyzing ; Experts ranking: Analyzing

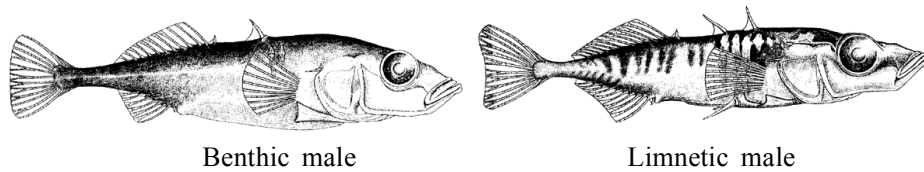


Table 1. Proportions of benthics, limnetics, and hybrids found in traps. For three different years, traps were set for fish in Paxton Lake in British Columbia. The traps were regularly checked and the type of fish (benthic, limnetic, or benthic/limnetic hybrids) and the number of each type were determined. The relative proportion of each type for a single year is presented with the actual numbers counted in parentheses (McPhail 1992).

Year	Total	Benthics	Limnetics	Hybrids
1	1057	0.50 (528)	0.48 (509)	0.019 (20)
2	962	0.50 (479)	0.49 (473)	0.010 (10)
3	994	0.49 (491)	0.49 (489)	0.014 (14)

- A. Based on the morphological species concept Benthic and Limnetic fish are different species.
- B. Based on the phylogenetic species concept Benthic and Limnetic fish are the same species.
- C. Based on the biological species concept Benthic and Limnetic fish are the same species.
- D. Based on the biological species concept Benthic and Limnetic fish are different species.
- E. I need more information to draw a conclusion about whether Benthic and Limnetics are the same or different species.

4. *Echinacea* has been used as a traditional plant remedy to treat upper respiratory infections and common colds. Figure S1 shows the results of a study by Yale and Liu 2004 that compared the effectiveness of an *Echinacea purpurea* preparation in reducing respiratory symptoms. The study analyzed the time taken for symptoms to be resolved over a 14-day period. Compared to placebo, was *Echinacea* more effective in resolving symptoms of upper respiratory infections?

Bloom's ranking seen by students: Applying; Expert ranking: Understanding

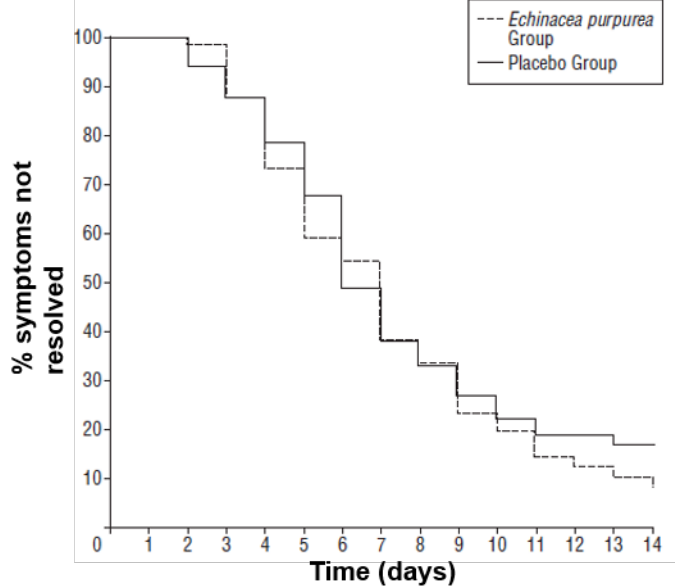


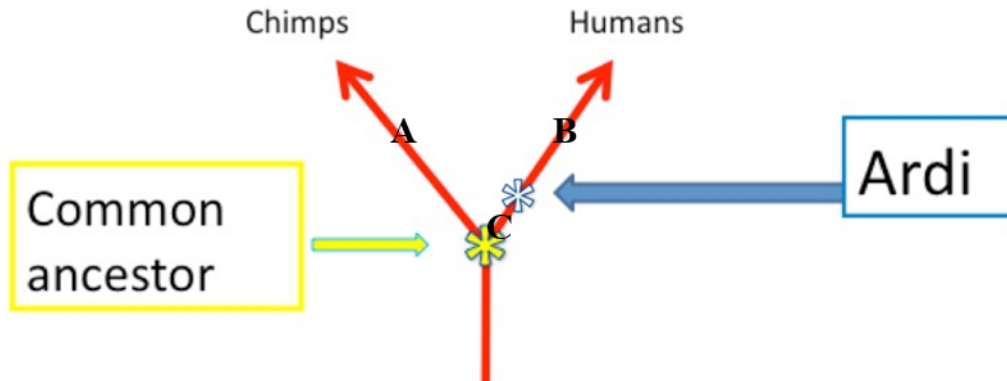
Figure S1. A comparison of time to symptom resolution for two groups, *Echinacea* recipients and placebo recipients. Statistical tests at the end of the 14 day study generated a p value of 0.73. modified from Yale and Liu 2004.

- A. No, because there is little difference between *Echinacea* and placebo in the % of symptoms unresolved between Days 11-14.
- B. Yes, because there is a substantial difference between *Echinacea* and placebo in the % of symptoms unresolved between Days 11-14.
- C. No, because the difference between *Echinacea* and placebo shown at Day 14 is statistically insignificant as shown by the p-value of 0.73.
- D. Yes, because the difference between *Echinacea* and placebo shown at Day 14 is statistically significant as shown by the p-value of 0.73.
5. In the Animal Evolution lecture, we considered evidence supporting the hypothesis that a particular protist (named elsewhere on this exam) is the closest relative of animals. Each of the following is evidence for this hypothesis except . . .

Bloom's ranking seen by students: Understanding; Expert ranking: Recalling

- A. The phylogeny obtained from whole-genome sequencing places this protist species as the closest relative to all animals.
- B. Multicellularity has evolved independently multiple times in Domain Eukarya (i.e., eukaryotic cells).
- C. Some members of this protist species are able to switch from unicellular forms to colonial forms.
- D. This protist species is nearly identical in morphology to one cell type found in sponges.
- E. Cells that morphologically resemble this protist species have been found in several animal lineages but have never been found in fungi or land plants, or other protists.

6. The phylogeny below was taken from Lecture 11: *Humans as a Species*. There have been many human- like fossils found besides *Ardipithecus ramidus*. One of those is *Australopithecus afarensis* (“Lucy”- briefly mentioned in class). At what letter on the phylogeny would you place “Lucy?”
Bloom’s ranking seen by students: Understanding; Expert ranking: Applying

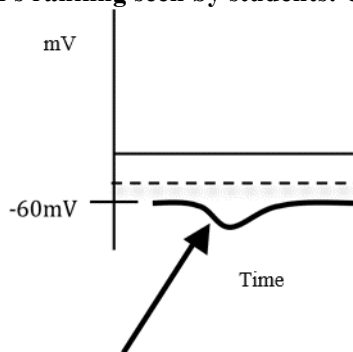


7. Which of the following is NOT an example of blood cell structure matching blood cell function?
Bloom’s ranking seen by students: Understanding; Expert ranking: Recalling

- A. Red blood cells are biconcave disks.
- B. Red blood cells primarily contain hemoglobin.
- C. White blood cells (i.e., leukocytes) contain numerous lysosomes.
- D. White blood cells have a lobed nucleus.
- E. Platelets contain “sticky” proteins.

8. Consider the oscilloscope reading shown below in which an electrode is inserted into a neuron. Which of the following could explain the graph at the point indicated?

Bloom’s ranking seen by students: Understanding; Expert ranking: Understanding



- A. Voltage-gated K^+ channel closed. Voltage-gated Na^+ channel closed.
- B. Voltage-gated K^+ channel open. Voltage-gated Na^+ channel open.
- C. Voltage-gated K^+ channel open. Voltage-gated Na^+ channel closed.
- D. Voltage-gated K^+ channel closed. Voltage-gated Na^+ channel open.

9. A type of sea snake known as krait has a diet that includes eel. Krait snakes have toxins in their venom that are capable of paralyzing eel. Imagine you carry out an experiment to determine how krait toxin works. You bathe neurons with krait toxin. Then you add current beyond threshold and measure the resulting membrane potential changes. Given these data, which of the following is the best hypothesis for krait toxin's mechanism of action?

Bloom's ranking seen by students: Applying and Analyzing; Expert ranking: Analyzing

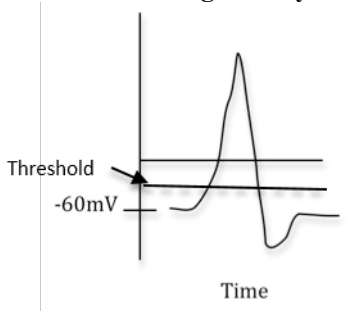
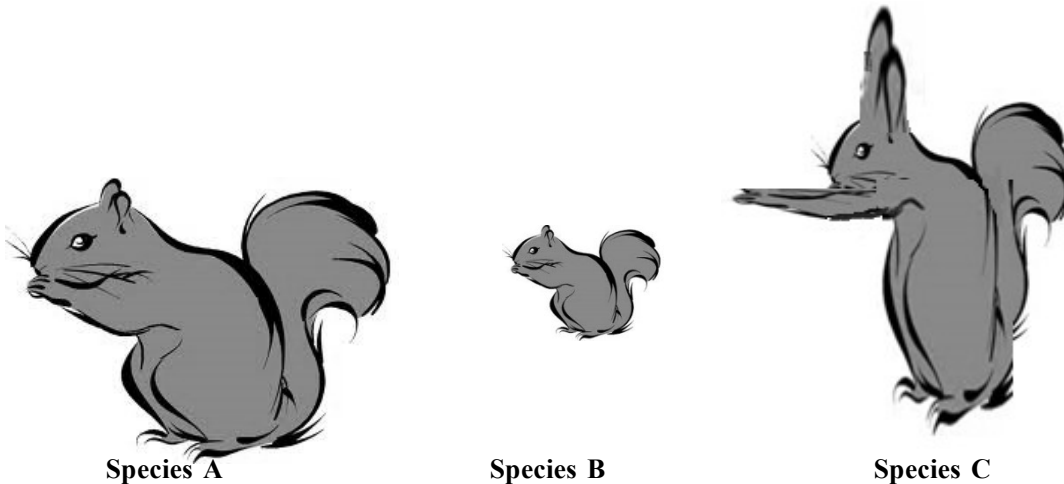


Figure 1. Membrane potential changes in neurons in the presence of krait toxin.

- A. Blockage of Na^+ -voltage-gated channels in neurons.
- B. Blockage of K^+ -voltage-gated channels in neurons.
- C. Blockage of neurotransmitter receptors on the muscle cell.
- D. None of these hypotheses could explain the mechanism of action

10.



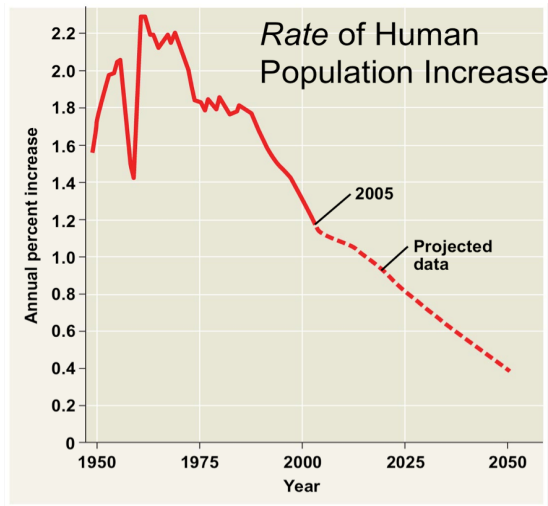
The three species of squirrel seen above vary in size. According to Bergmann's and Allen's rules, which would be the most likely region where these species would be found?

Bloom's ranking seen by students: Applying and Analyzing; Expert ranking: Applying

- A. Species A would occur near the equator and species B would occur near the poles.
- B. Species B would occur near the equator and species A would occur near the poles.
- C. Species C would occur near the equator and species A would occur near the poles.
- D. Species C would occur near the equator and species B would occur near the poles.

11. We looked at the figure below in Lecture 22. What does this figure, including the projected data, suggest about human population growth?

Bloom's expert ranking: Recalling

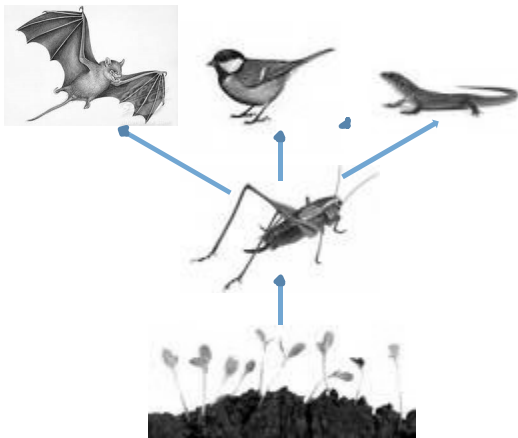


- A. Currently human population growth is most like logistic population growth.
- B. Currently human population growth is most like exponential population growth.
- C. The carrying capacity for the human population is approximately 2.2 billion.
- D. The ingenuity of humanity will enable the human population to keep growing at its current rate.

12.

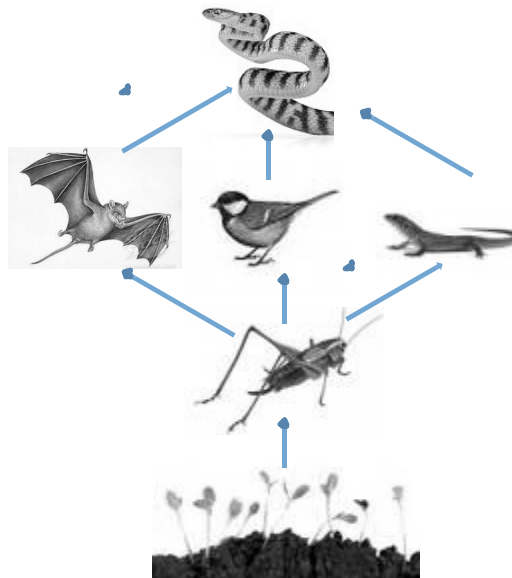
Food web

before brown snake introduction



Food web

after brown snake introduction



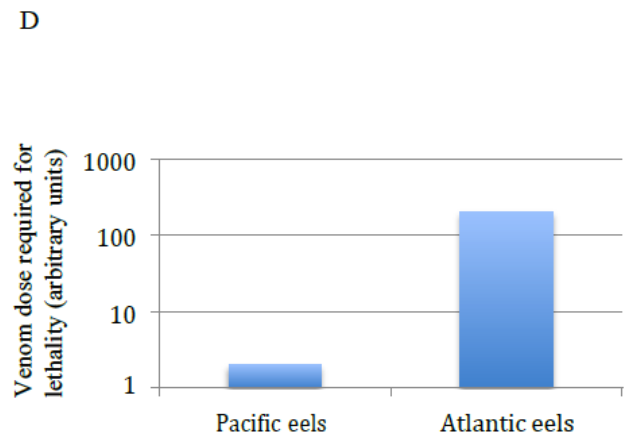
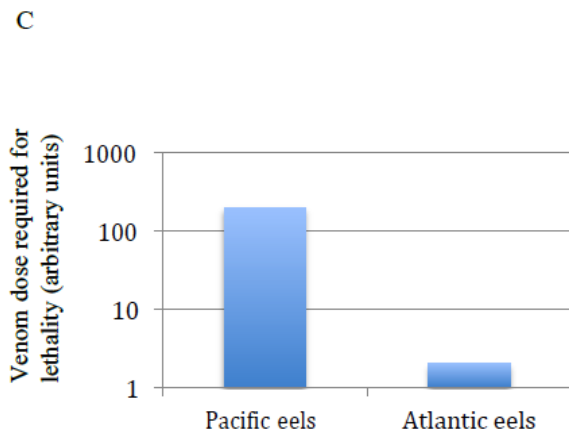
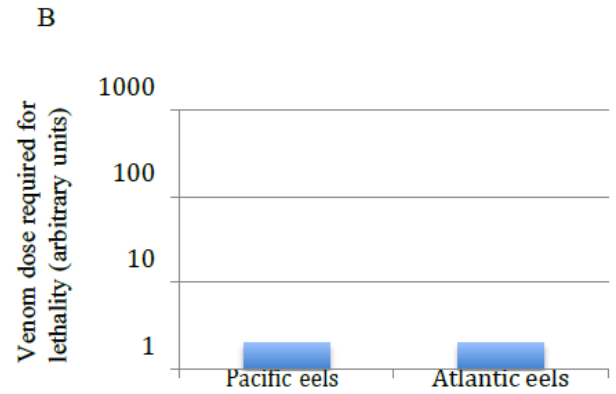
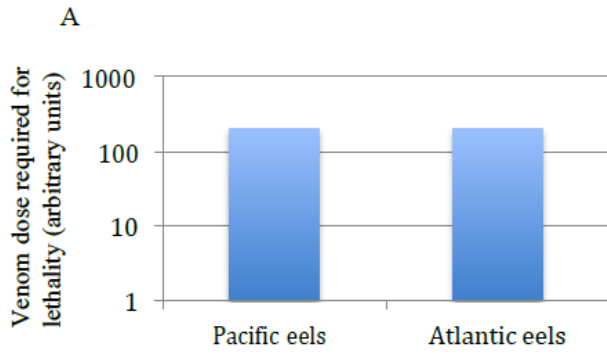
The diagrams above represent food webs in Hawai'i before and after the introduction of the brown tree snake, which is not native to Hawai'i. After introduction of the brown tree snake, what are some likely observations made by researchers in Hawai'i?

Bloom's ranking seen by students: Applying; Expert ranking: Applying

- A. No change in bird, bat, and lizard populations.
- B. A decline in bird, bat and lizard populations only.
- C. A decline in bird, bat, lizard and insect populations
- D. A decline in bird, bat, lizard and tree seedling populations.

13. Krait are found in the Pacific Ocean, but not in the Atlantic Ocean. Assuming eels (the prey of krait) exhibit selective adaptation for co-existence with krait, which of the following graphs would best predict the amount of krait venom required to kill Pacific eels compared to Atlantic eels?

Bloom's ranking seen by students: Applying and Analyzing; Expert ranking: Analyzing



Supplemental Material Table 1. Development of problem-solving categories during the process of qualitative data analysis. In Phase 1 of our analysis, we wrote notes about our observations of student thinking based on a subset of the full dataset. In Phase 2, we used Bloom's taxonomy to develop a list of categories from our notes. We used these categories to code the complete data set of 1087 written think alouds. Throughout Phase 2, we revised the categories, including renaming and merging. In Phase 3, we aligned each category with our theoretical framework to determine if it shows domain-general or domain-specific problem procedural use. The final set of categories presented in this paper is shown in Table 1.

Phase 1 Notes from observations of a subset of written think alouds	Phase 2 Categories Developed by aligning notes with Bloom's taxonomy	Final Category Determined throughout Phase 2 analysis
Domain-General		
Comparing choice with a diagram	Executing & Implementing	Analyzing domain-general visual representations
Organizing their thinking	Clarify what question is asking or choice is saying	Clarifying
--	Noting that choices are similar or different	Comparing language of options
--	Correcting self	Correcting
--	Tabling the option	Delaying
Hybrid		
--	Identifying one choice is more complete/correct	Comparing correctness of options
Read and rule out	Recognizing	Recognizing
Using pros and cons of choice/evaluating each choice independently		
Domain-Specific		
Identify incomplete info	Providing missing or corrected information	Adding information
Showed understanding of phylogenetic tree	Executing & Implementing	Analyzing domain-specific visual representations
Interpret phylogenetic info		
Comparing choice with a diagram		
Questioning self	Questioning self	Asking a question
What is the question asking		
Refute incorrect info	Negative checking	Checking
Comparing choice to knowledge	Negative checking & positive checking	
Using pros and cons of choice/evaluating each choice independently		
Explaining the choice	Positive checking	
Justifying the selected answer		

Support statements		
Predicting: What should the answer be?	Predicting what the answer should be	Predicting
Remembering/recalling concepts	Remember/recall facts/concepts	Recalling
Identifying theory/recall theory		
Unsupportive Procedures Domain-General		
Contradicting self	Contradicting self	Contradicting self
Disregarding evidence	Disregarding evidence	Disregarding evidence
--	Misreading the question or choices	Misreading
--	Misinterpreting information provided	
"I agree" or "In my opinion"	Opinion-based judgment	Opinion-based judgment
Unsupportive Procedures Domain-Specific		
--	Incorrect assumptions	Making incorrect assumptions
Misunderstanding content	Misunderstanding content	Misunderstanding content
Other Categories		
Sequential	Sequential	--
Global	Global	--
	Superficial	--
Evaluating the language/style of the choice	Gaming the question	--
--	Interpreting by common sense not recall or understanding	--

Supplemental Material Table 2. Likelihood of Correct/Incorrect answer based on student use of domain-general/hybrid procedures. *Generalized Linear Mixed Model Results for Logistic Regression*

Domain-general/hybrid procedures	Coefficient (B)	Standard Error (SE)
Intercept	0.089	0.113
1	1.22**	0.198
2	1.03**	0.230
3.	0.944*	0.278
4	1.41*	0.407
5	1.210	0.661

**p<0.001; *p<0.01

Supplemental Material Table 3. Likelihood of Correct/Incorrect answer based on student use of domain-specific procedures. *Generalized Linear Mixed Model Results for Logistic Regression*

Domain-specific procedures	Coefficient (B)	Standard Error (SE)
Intercept	-0.725**	0.154
1	0.884**	0.241
2	1.77**	0.246
3.	2.23**	0.287
4	2.48**	0.299
5	4.34**	0.722
7	2.67*	1.08
9	1.42	1.23

**p<0.001; *p<0.05