

Supplemental Material

CBE—Life Sciences Education

Kramer *et al.*

Supplemental Materials

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Supplement 1: Principles of Multimedia design

Tutorial Design

Why does this tutorial exist?

- Establish the tutorial's objectives and explicitly state them
- Collaborate with course faculty

Tutorial Structure

Reduce Extraneous processing

- Be coherent (linear, no extra information)
- Use signaling (highlight essential material)
- Group related words and images near each other (proximity)
- Present narration and imagery at the same time

Manage Essential Processing

- Segment information (1-2 sentence or 8-10 second chunks)
- Pre-train the users (Define individual elements and their function before describing a system)
- Use narration and images rather than written text to convey ideas

Engage students

- Maximize interaction
 - Interspersed quizzes prevent mind wandering
- Require choice early in the tutorial
- Show position in tutorial
- Allow entrance/exit at any time
- Provide access to an instructor and/or further resources
- Personalize content (informal, 2nd person, use contractions)

Navigation

- “Pull” structure: exploration, content on demand, offer content they missed after assessment/feedback. opposite of “Push” structure
- Consistent and intuitive interface and presentation
- Transition pages after each section
- Branch designs with multiple difficulty levels and sequence control
- Offer glossaries & pop up definitions

Tutorial Evaluation

- Get feedback prior to implementation
- Beta testing, student evaluations
- Build in use comments at final submission

References

1. Blummer, B and Kritskaya, O. (2009) Best Practices for Creating an Online Tutorial: A Literature Review. *Journal of Web Librarianship*, 3: 199-216
2. Mayer, R. (2008) Applying the Science of Learning: Evidence-Based Principles for the Design of Multimedia Instruction. *American Psychologist*, November 2008. 760-769.
3. Schacter, D. and Szpunar, K. (2015) Enhancing Attention and Memory During Video Recorded Lectures. *Scholarship of*

Supplement 2: Tutorial Learning Objectives

- Module 1: Primary Literature
 1. Find Primary Literature
 2. Read primary Literature
 3. Evaluate Primary Literature
 4. Cite primary Literature

- Module 2: Ask a testable question
 1. Ask a question based on previous observations or experiments
 2. Ask a testable question

- Module 3: Propose a scientific hypothesis
 1. Propose an explanation for how the natural world works
 2. Explain how or why or provide a mechanism that supports the hypothesis
 3. Propose a testable hypothesis
 4. Identify independent and dependent variables for an experiment
 5. Propose a hypothesis based on observations or primary literature

- Module 4: Experimental Design
 1. Design an experiment that aligns with the stated hypothesis
 2. Design experiments that are feasible
 3. Identify proper controls for an experiment
 4. Identify the proper number of replicates to include in the given experiment.
 5. Describe in detail the experimental procedure

- Module 5: Collect & Organize Data

1. Organize and present data in graphs and tables
 2. Calculate averages for individual replicates
 3. Select appropriate graphs to display data
 4. Create a graph representing the data that includes labeled axes and units
 5. Identify the correct basic statistics needed to support observations
- Module 6: Analysis & Conclusions
 1. Construct an argument from data
 2. State whether hypothesis is supported or rejected
 - Module 7: Communicate & Discuss
 - Identify the ways data is exchanged and presented at conferences including oral presentations, poster sessions and casual conversations.

Supplement 3: Usability testing results

Issues Identified			Session Observed							Recommendations
#	Feature/Location	Observed Issue	1	2	3	4	5	6	Σ	Recommendation
1	Content	Thought that the content of the tutorial was too wordy	4	3		5		3	15	Ideas: - Use bullet points where appropriate (on Summary Sides in particular) - Remove redundant material - Re-examine content that users weren't looking at
1a	Content	The key concepts (i.e. independent variable, population, etc) need to be more concise and emphasized				4			4	See #1 - Be consistent in bolding only key concepts - Use color and underlining appropriately
1b	Feedback pages	Later in the tutorial stopped reading through the feedback pages		3	3	3			9	See #1
1c	Patient Selection	The questions in the initial banner were unnecessary				2			2	See #1
1d	Summary Slides	Wanted more bullet points, less text on the summary slides		3		3			6	See #1
1e	Summary Slides	The summary slide wasn't helpful because I still wasn't sure what the content meant					4		4	See #1
1f	Content	Liked that the hypothesis was repeated multiple times throughout the tutorial				x			0	See #1
1g	Content	Bolding was effective					x		0	See #1
1h	Content	Liked the visual cues. Buttons were consistent, colors, sounds helped as guideposts					x		0	See #1
1i	Content	Liked to skim content, not read everything						x	0	See #1

1j	Summary Slides	Liked the summary slides. They overlap what I've already done and give me more points to focus on					x		x	0	See #1
2	Feedback pages	Ignored the numbers on the left when she had a correct answer	4	2	2	2	2	2	2	14	Ideas:- Highlight one of the numbers with the answer visible- Make the numbers on the left more apparent- Consider making it required to click through all of the feedback options- Consider adding a sentence about the quality of the answer - Consider having more use of the follow-up question approach (why did or didn't you select a particular option?)
2a	General	Thought some of the biology concepts were a little difficult		2				1		3	See #2
2b	No Soda Water Follow-Up Question	The follow-up question forced the participant to engage with the material in a way that she wasn't earlier in the module							x	0	See #2
3	Patient Selection	Read the main content, but ignored the banner content	2	2	1	1				6	Ideas: - Remove the banner on some pages - Move the banner to the top of the screen
4	Experimental Procedure	When an incorrect answer was selected for the experimental procedure, wanted more explanation of what they were looking for	-	4						4	Ideas: - Change the entire Experimental Procedure question - Eliminate all of the clicking in and out of options - Consider breaking the procedure into parts - Consider a side-by-side comparison of two options at a time

4a	Experimental Procedure	Wanted to be able to compare the experimental procedures side by side, it's hard to remember what the difference was between them						4	4	See #22
5	General	Wanted larger print or use of the zoom function			4				4	Ideas:- Check to see if Articulate has a zoom feature- Make sure that browser zoom worksSee also #1 (NOTE: Flash player has a zoom function built in. You can right click and select zoom in)
6	Mode Selection	Confused by "normal" vs "preview" mode options	1				1	1	1	4 Ideas: - Explore whether this can be changed in Moodle - Include some text explaining to use "normal"
7	Drag and Drop	Didn't like the drag and drop function, would rather click for information		3					3	Ideas: - Evaluate all drag and drop interactions - Make sure that the interaction is necessary to understanding of a concept
7a	Drag and Drop	Unclear that you don't have to drag the items away from the box to put another one in						2	2	See #7 - Fix the bug where the items aren't removing themselves from the box
7b	Drag and Drop	Liked the drag and drop			x				0	See #7
7c	General	Wasn't interested in the gamification of the tutorial	4					2	6	See #7 and #24
8	Full Screen	Wanted an option for a full-screen mode. It's a bit distracting having it within a Moodle page			3				3	Ideas: - See if there is a Moodle setting that can be changed - Provide directions on screen, annotated screenshot - "Remember to click the [icon] in the upper right corner for fullscreen
8a	Moodle	There was a full screen button that wasn't noticeable, so the participant had to scroll left and right within the tutorial	3	-		-	-	-	3	See #8

		window							
9	Audio Test	Clicked it, didn't hear anything and clicked "Yes" anyway		3					3 Ideas: - It's at a static level in the system, any problems will be on their computer - Make the sound test a video (more compelling and clearer that you aren't hearing something)
10	Home Map	The home map diagram was confusing. Too many arrows. What am I getting into?			3				3 Ideas:- Lighten up the arrows- Give some more context of what the map means in the first tutorial
11	Feedback pages	The numbering is not in the same order as the selection slide on the feedback pages					2		2 Ideas: - Make sure that the numbering is in the same order as the options on the previous selection screen, whether it's left to right or top to bottom
12	Welcome to the Lab	The notebook was not noticeable					2		2 Ideas: - Consider eliminating the notebook and just have a continue button
13	Background video	Didn't like that you could skip the video before it was over	2						2 Ideas: - Have the "Continue" button grayed out until the video is over - Have a note that says that the "Actual Video length is 1:30" - Have the last frame be the first frame of the video
14	Ring Bell	Took several times clicking to ring the bell before it did anything			2		-		2 Ideas: - Make the hover button larger
15	Information Buttons	The info button hover got in the way of selecting an item						2	2 Ideas: - Move the hover effect down a bit on the screen
16	Navigation	Saw the previous button and liked the idea of it, but was reluctant to use it						2	2 Ideas: - Offer a help button on some pages that provides information from a previous slide, if the student needs it

17	Sound	Didn't like the bubbling sound with the test tube	1		1				2	Ideas: - Turn down the sound on the bubbling
18	Audio	Expected an option for audio narration from the characters						1	1	Ideas: - Consider where this approach might be useful - Give an option at the start of the module to turn character narration on
19	Videos	Didn't like the use of ALL CAPS in videos					1		1	Ideas: - Going forward the videos should have normal usage of sentence case or title case
20	Menu	Could mouseover all of the buttons and see a hover effect, even the inactive ones, but couldn't click on two of them					1		1	Ideas:- Make the grayed out circles a little bigger
21	Model Organism - Observer Note	Inconsistent about expense of mice							0	Ideas: - Be consistent about how expensive mice are. They can't be expensive and inexpensive
22	Final Review	Did not access the Final Review section	-	x	x	x	-	x	0	Ideas: - Show the review page first, and then provide a completion link. They don't need to do the activities - Could have all of the reviews as a separate tutorials, to allow for ease of access
22a	General	This would be good for homework but not for review				x			0	See #22
22b	Summary Slides	Didn't think the summary slides were necessary so soon after seeing it. "I just did it, I know what I just did"			2				2	See #22
23	Treatment Group Option	After watching the video, you had to re-select the population					4			Ideas: - Fix the bug
24	Content	Thought the questions were a little easy	x		x				0	- This is fine given the target population
24a	Content	This seems like it was written for middle schoolers or high schoolers			x		x	x	0	See #24

24b	Content	The content is at the right level for non-BIO majors							x	0	See #24
25	Terminology	Unclear what H. Pylori was at first. Thought it was a name of a person						3	5	8	- A function of starting with a tutorial from the middle of the course rather than the first tutorial
26	Background video	Said the background video was distracting	3							3	No Action
27	Content	This might be a good fit for visual learners			x	x				0	
28	Content	Liked the question-answer-apply format of the tutorial							x	0	
29	Content	Liked that the videos showed application of concepts							x	0	
30	Background video	Liked the diagramming in the background video to go along with the explanations		x	x	x	x			0	
31	Challenge Questions	Read through all of the options before making a selection		x	x	x	x			0	
32	General	Liked the continuity of the tutorial, that you were building an experiment	x	x						0	
33	General	Doing this was better than reading a book about it		x		x			x	0	
34	General	Felt comfortable designing an experiment after going through the tutorial	-	-	x	x	-	x		0	
35	Imagery	Liked that there was a female scientist in the tutorial	x							0	
36	Information Buttons	Looked at all of the hover information buttons		x					x	0	
37	Navigation	Getting from the start of the tutorial to the module was easy	x	x	x	x	x	x		0	
38	Progress Meter	Liked the progress meter and its colors				x	x			0	
39	Treatment Group Option	Liked that you could have a choice to move on or review	x		x	x	x	x		0	

Supplement 4: Assessment questions

Correct Responses are highlighted in green.

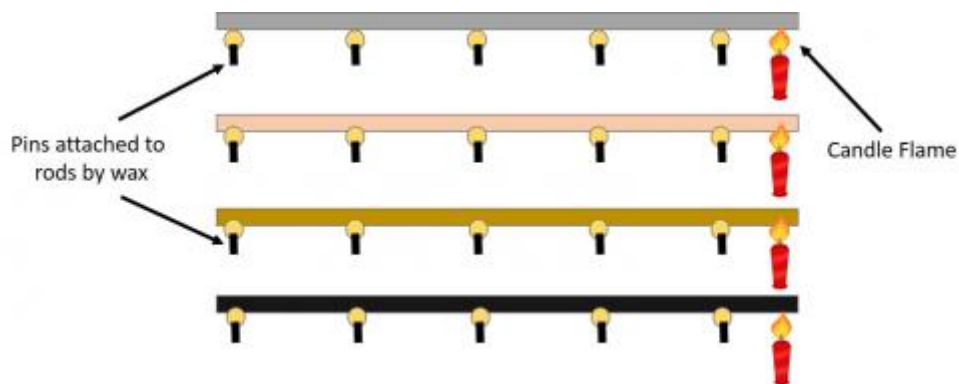
1. Sam wanted to know which of the three types of soil (clay, sand and peat), would be best for growing beans. She planted bean seedlings in three pots of the same size, but having different soil types. The pots were placed near a sunny window after pouring the same amount of water in them. The bean plants were examined at the end of ten days. Differences in their growth were recorded.

Which factor do you think made a difference in the growth rates of the bean seedlings?

Select one:

- a. The amount of sunlight available.
- b. The type of soil used.
- c. The temperature of the surroundings.
- d. The amount of chlorophyll present.

2. A teacher wants to find out how quickly different types of material conduct heat. He uses four rods with the same length and diameter but made of different types of material. He attaches identical pins to the rods using wax, at regular intervals as shown in the diagram below. All the rods were heated on one end at the same time, using candle flames. After two minutes, the pins that fell from each rod were counted.



How is the speed (rate) of heat conduction by the various rods measured in this study?

Select one:

- a. By determining the rod, which conducted heat faster when heated.
- b. By counting the number of pins that fall from each rod after 2 minutes.
- c. By counting the number of minutes taken for each pin to fall from the rod.
- d. By using wax to measure the rate of heat conduction.

3. Aria wants to find out the amount of water contained in meat, cucumber, cabbage and corn. She finely chopped each of the foods and carefully measured 10 grams of each. She then put each food in a dish and left all the dishes in an oven set at 100°C. After every 30 minutes interval, she measured the mass of each food, until the mass of the food did not change in two consecutive measurements. She then determined the amount of water contained in each of the foods.

How is the amount of water contained in each food measured in this experiment?

Select one:

- a. By heating the samples at a temperature of 100°C and evaporating the water.
 - b. By measuring the mass of the foods every 30 minutes and determining the final mass.
 - c. By finely chopping each food and measuring 10 grams of it, at the beginning of the investigation.
 - d. By finding the difference between the original and the final mass of each food.
4. A science teacher wants to demonstrate the lifting ability of magnets to his learners. He uses many magnets of different sizes and shapes. He weighs the amount of iron picked by each magnet.

How is the lifting ability of magnets defined in this investigation?

Select one:

- a. The weight of the iron picked up by the magnets.
 - b. The size of the magnet used.
 - c. The weight of the magnet used to pick up the iron.
 - d. The shape of the magnet used.
5. Doctors noticed that if certain bacteria were injected into a mouse, it developed certain symptoms and died. When the cells of the mouse were examined under the microscope, it was seen that the bacteria did not spread through the body of the mouse, but remained at the area of infection. It was therefore thought that the death is not caused by the bacteria but by certain toxic chemicals produced by them.

Which of the statements below provides a possible explanation for the cause of death of the mouse?

Select one:

- a. The mouse was killed by the cells that were removed from it to be examined under the microscope.

- b. Bacteria did not spread through the body of the mouse but remained at the site of infection.
 - c. The toxic chemical produced by the bacteria killed the mouse.
 - d. The mouse was killed by developing certain symptoms.
6. A learner observed that anthills in a certain nature reserve tend to lean towards the west, instead of being straight. In this area, the wind blows towards the direction in which the anthills lean.

Which of the following statements can be tested to determine what causes the anthills to lean towards the west, in this nature reserve?

Select one:

- a. Anthills are made by ants.
 - b. Anthills lean in the direction in which the wind blows.
 - c. Anthills lean towards the west to avoid the sun and the rain.
 - d. The distribution of anthills depends on the direction of the wind.
7. A radio advertisement claimed that "Bubble Make Pro™" produces more foam than other types of powdered soap. Abdi wanted to confirm this claim. He put the same amount of water in four bowls, and added 1 cup of a different type of powdered soap (including Bubble Maker Pro™) to each bowl. He vigorously stirred the water in each bowl, and observed the one that produced more foam.

Which of the factors below is NOT likely to affect the production of foam by powdered soap?

Select one:

- a. The amount of time used to stir the water.
 - b. The amount of stirring done.
 - c. The type of bowl used.
 - d. The type of powdered soap used.
8. Frank noticed that the steel wool that he uses to clean his pots rusts quickly if exposed to air after using it. He also noticed that it takes a longer time for it to rust if it is left in water. He wondered whether it is the water or the air that causes the wet exposed steel wool to rust.

Which of the following statements could be tested to answer Frank's concern?

Select one:

- a. Steel wool cleans pots better if it is exposed to air.
- b. Steel wool takes a longer time to rust if it is left in water.
- c. Water is necessary for steel wool to rust.
- d. Oxygen can react with steel wool.

9. A science class wanted to test the factors that might affect plant height. They felt that the following is a list of factors that could be tested: the amount of light, amount of moisture, soil type, and change in temperature.

Which of the statements below could be tested to determine the factor that might affect plant height?

Select one:

- a. An increase in temperature will cause an increase in plant height.
 - b. An increase in sunlight will cause a decrease in plant moisture.
 - c. A plant left in light will be greener than one left in the dark
 - d. A plant in sand soil loses more water than one in clay soil.
10. Arnold is worried about how the cold winter will affect the growth of his tomatoes. He decided to investigate the effect of temperature on the growth rate of tomato plants. He planted tomato seedlings in four identical pots with the same type of soil and the same amount of water. The pots were put in different glass boxes with different temperatures: One at 0°C, the other at 10°C, and another at room temperature and the fourth at 50°C. The growth rates of the tomato plants were recorded at the end of 14 days.

Which of the following factors were kept constant in this investigation?

Select one:

- a. The difference in seasons.
 - b. The growth rate of tomato plants and the amount of water used.
 - c. The type of soil and the amount of water used.
 - d. The temperature and type of soil used.
11. Zach thinks that the more the air pressure in a soccer ball, the further it moves when kicked. To investigate this idea, he uses several soccer balls and an air pump with a pressure gauge. How should Zach test his idea?

Select one:

- a. Kick the soccer balls with different amounts of force from the same point.
- b. Kick the soccer balls having different air pressure from the same point.
- c. Kick the soccer balls having the same air pressure at different angles on the ground.
- d. Kick the soccer balls having different air pressure from different points on the ground.

12. A driver wants to find out if a car uses more fuel when it is driven at high speed. What is the best way of doing this investigation?

Select one:

- a. Ask several drivers how much fuel they use in one hour, when they drive fast, and find the average amount of fuel used per hour.
- b. Use his own car to drive several times at different speeds, and he should record the amount of fuel used each time.
- c. He must drive his car at high speed, for a week, and then drive it at low speed for another week, and record the amount of fuel used in each case.
- d. Ask several drivers to drive different cars covering the same distance many times, at different speeds, and record the amount of fuel used for each trip.

13. Table shows the amount of diesel pumped per minute

Size (diameter) of hose (mm)	Amount of diesel pumped per minute (Liters)
8	1
13	2
20	4
26	7
31	12

Which of the following statements describes the effect of the size of the hose on the amount of diesel pumped per minute?

Select one:

- a. The larger the diameter of the hose, the more amount of diesel pumped.
- b. The more the amount of diesel pumped, the more the time used to pump it.
- c. The smaller the diameter of the hose, the higher the speed at which the diesel is pumped.
- d. The diameter of the hosepipe has an effect on the amount of diesel pumped.

14. Sandy carried out an investigation in which she reacted magnesium with dilute hydrochloric acid. She recorded the volume of the hydrogen produced from the reaction, every second.

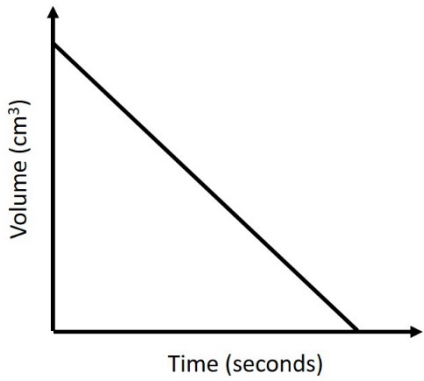
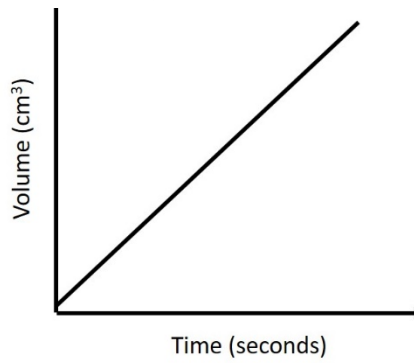
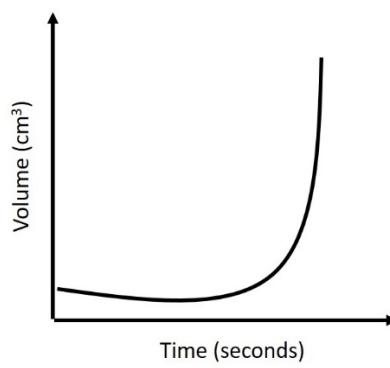
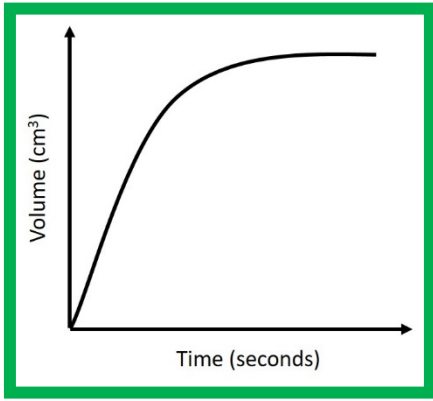
The results are shown below.

Table shows the volume of hydrogen produced per second.

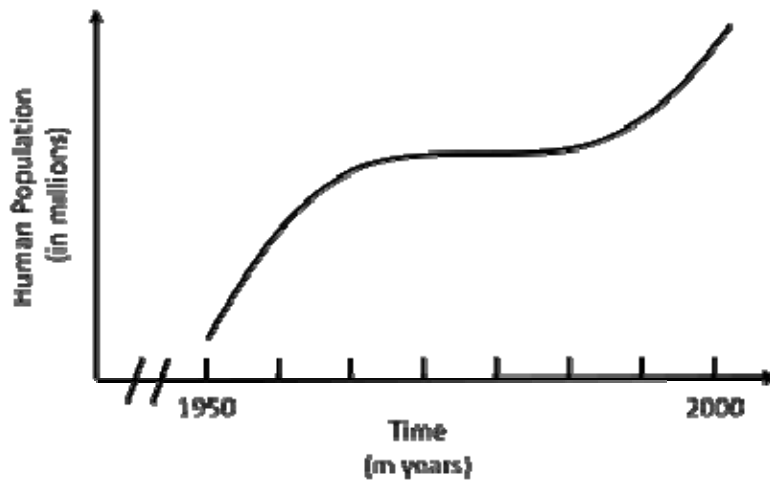
Time (seconds)	0	1	2	3	4	5	6	7
Volume (cm ³)	0	14	23	31	38	40	40	40

Which of the following graphs show these results correctly?

Select one:



15. The graph below shows the changes in human population from the year 1950 to 2000.

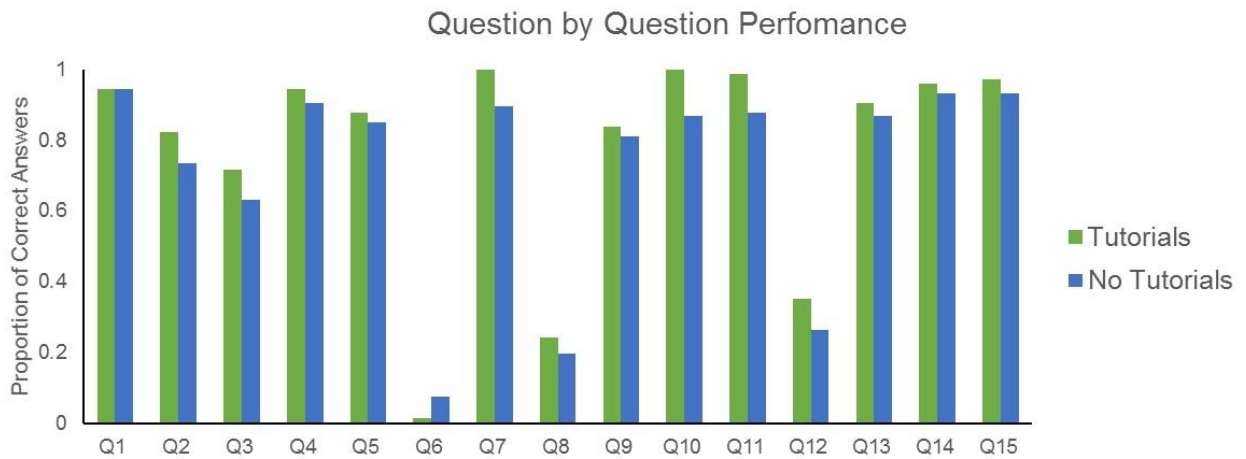


Which of the following statements best describes the graph?

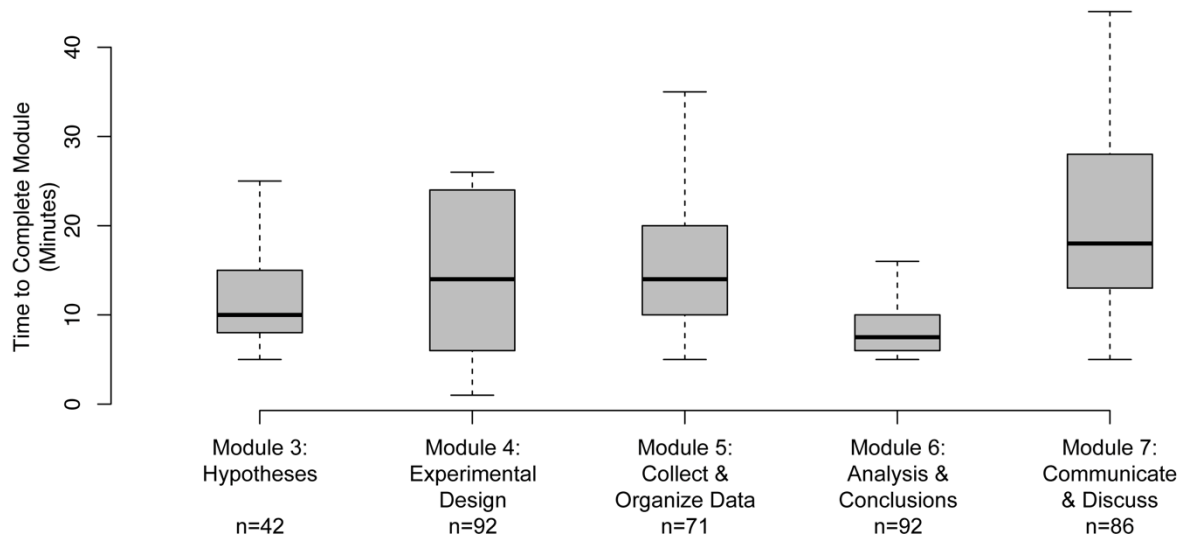
Select one:

- a. The human population increases as the number of years increase.
- b. The human population first increases, then it reduces and increases again as the number of years increase.
- c. The human population first increases, then it remains the constant and increases again as the number of years increase.
- d. The human population first increases then it remains the same as the number of years increase.

Supplement 5: Descriptive statistics for individual assessment questions



Supplement 6: Amount of time spent to complete tutorial modules



Module Number	Topic	Time to complete tutorial			n=
		Mean	Median	Standard deviation	
3	Hypotheses	13.17	10	9	42
4	Experimental Design	14.36	11	11.660417	92
5	Collect & Organize Data	18.82	14	17.02629	71
6	Analysis & Conclusions	10.65	7.5	10.93983	92
7	Communicate & Discuss	28.27	18	31.18613	86

Supplemental Figure 6: Total viewing time for students that completed the module in one session. Module 7: Communicate and Discuss included the option to watch several videos of scientific speakers, each 5-10 minutes long, likely leading to longer completion time.