Three Strategies for Supporting Student Writing and Logical Reasoning

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To help students learn how to make an argument and support it using logical reasoning, we applied three different support strategies to the same assignment.

1. **Traditional**: Students are given instructions, the instructor is available to answer questions during the assignment, and feedback is given on student answers.
2. **Step-by-Step**: Same as traditional, but students were also given a worksheet deconstructing the thought process experts use when doing the assignment. (worksheet questions below)
3. **Student Marking**: Same as traditional, but in the first assignment students evaluate examples of student answers using a provided rubric. The first assignment is for participation only. (examples from the worksheet are on the next page)

Strategy 2: 'Step-by-Step' Worksheet

For this Case Study, you are required to come up with a hypothesis that attempts to answer the central question, as well as a short rationale for your hypothesis. To help you with this, we have built the following worksheet for you to use. You may fill out your answers directly in this worksheet and hand it in.

Hypothesis = [Subject] + [claim/interpretation]
Rationale = paragraph (ish) that explains how
the data connects to your hypothesis

Part 1. (10% of total time, 1 pt) Look at the Central Question of your Case Study. Based on the central question:
1A. What do you think the subject of your hypothesis should be?
1B. Based on the Central Question, where should you focus your attention when interpreting the experimental evidence?

Part 2. (50% of total time, 5 pts) Now look at each slide that presents experimental evidence in this case study. For each slide summarize the main conclusion of that experimental evidence, using the same format as your hypothesis (H=[S]+[C]). List each one below.

Part 3. (30% of total time, 3 pts) Look at your summaries of the experimental evidence. Try to find the thread that links them to each other and the Central Question.
3A. Look at Part 1 again to see what the question tells you about the subject of your hypothesis. Do you still agree with your answer there? Explain your answer.
3B. Now its time to write your full hypothesis. Use the subject you decided on in part 3A. Then re-examine Parts 1B and 2 to decide what the rest of your hypothesis should be. Remember that your hypothesis should summarize what the results you described in Part 2 in a way that is related to the Central Question that you described in Part 1A. Your entire hypothesis should be about one sentence long. Write it down here.

Part 4. (10% of total time, 1pt) The summaries that you wrote in Part 2 are your rationale. Copy and paste those points into the area below. Re-examine them to make sure that they are complete and address the various claims of your hypothesis, and connect to the experimental evidence. Make any wording tweaks necessary here and not in Part 2 so that we can see the progression.

Strategy 3: 'Student Marking' Worksheet

Instructions

Spend 5 minutes with your group reading and evaluating each hypothesis and rationale.
Some things to think about when marking include:

- Are all pieces of data accounted for?
- Are there leaps in the logic that aren't explained, or don't make sense?
- Is each piece of data correctly identified as being linked by correlation, or causation?
- After you decide on a mark, does it reflect your overall impression of the hypothesis/rationale? If not, think about where this disconnect is happening and readjust.

Example Hypothesis

"Phosphorylation of Tau proteins cause defects in microtubule orientation found in the neuronal axons associated with neurodegenerative AD and CTE."

Example student answers in blue

The full worksheet included two hypotheses and rationales, and the same sections in both. Here, the 'rationale' section only shows the rubric and an example of student grades.

Strengths:

- Concise, straightforward

Areas for Improvement:

- Lacking depth and completeness
- Provides no explanation of how phosphorylation of tau and defects in MTs are related to AD/CTE
- Confusing if the MTs are associated with AD/CTE or if the neuronal axons are associated
- Unclear association between Tau/MTs and AD/CTE
- Not a testable statement

Are all relevant components incorporated?	(0.5/1)
Are the relationships between components clear and accurate?	(0/2)
Is all terminology and language used correctly?	(1/1)
Hypothesis	**(1.5 /4)**

Rationale Rubric

Is the data described clearly and completely?	(1/2)
Is it made clear how the data supports the hypothesis?	(2/2)
Is all terminology and language used correctly?	(0/1)
When used, is speculation identified and reasonable?	(0.5/0.5)
Is it well written? (ideas flow naturally, no major typos/grammar problems)	(0/0.5)
Rationale	**(3.5/6)**

Improving Instructor Feedback on Argumentation and Logical Reasoning

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Over the past three years we have made improvements in what kind of feedback we give to students on their assignments. Some examples of the progression of individual feedback are below (student answers are in blue, instructor comments in orange).

See the next page for a summary of how the feedback changed.

First Year

Hyper-phosphorylation of the microtubule-associated protein Tau results in the inability of Tau to stabilize microtubule networks in the cell (how?), and causes abnormal neurofibrillary tangles in the brain cells (why?) of patients with Alzheimer's disease. **The microtubule networks are essential for normal cell functioning. Without the stabilization of these networks in the cell, these cells undergo massive death in Alzheimer's disease patients, resulting in shrinkage of the brain.** (I'm not sure what this adds to the hypothesis)
This hypothesis is too general and needs to contain more specific information.

Second Year

The hyper-phosphorylation of Tau results in fewer correctly aligned microtubules (how are these connected?), causing neurofibrillary tangles (are you saying the incorrectly aligned microtubules cause the tangles? This is incorrect) which leads (are you saying the tangles themselves lead to the neurodegeneration?) to the neurodegeneration characteristic of AD and CTE.

Third Year

The pathogenic plant bacterium *Pseudomonas sp.* is able to avoid detection by plant cells by secreting the protein AprA, which degrades flagellin monomers, preventing the~~m~~ monomers (it wasn't clear to me if you were talking about flagellin or AprA binding to FLS2) from binding the FLS2 receptor on the plant cell and ~~as a result~~ which would (as written it implied that LACK of flagellin binding triggered immunity, rather than binding) activate~~ing~~ the plant's immune response. By degrading these monomers before they can bind to this receptor, the bacterium evades detection. (I'm not sure this last sentence is necessary as it seems to be repeating part of the first sentence.)

Your hypothesis contains all the important pieces of information, and I find it pretty easy to follow. I've included some wording suggestions to improve clarity. These may seem minor, but as written it's not always clear to me exactly what you mean.

How Can Feedback Be Improved?

1. Use in-text Feedback

Students often have a hard time applying general feedback to the specifics of their assignment. You can help them by integrating your feedback into the assignment, so they know exactly where you think they can improve.

E.g. "The protein Tau interacts with itself to form tangles (When does this occur?)"

2. Use "I" Statements

There are different correct ways to make an argument, so it is often good to stay away from absolute statements. Instead, try using "I" statements to highlight problems, in your opinion as an expert.

E.g. Try saying "I'm not sure what you mean by 'modified'." rather than "Saying 'modified' is vague."

3. Focus on the Logic

If the primary learning objective is to teach argumentation and logical reasoning, your feedback should focus on how they can improve these aspects, and less on the course content.

E.g. Saying "Your argument would be easier to follow if you provided more background information on the methods" is more important for the learning objective than "I think you should explain how SDS-PAGE works."

4. Explain Why

Students often find it hard to decipher why you make some comments. You can help them make the connection by explaining why you think there's a problem.

E.g. "I find this unclear because I can't see a logical connection between the production of this protein and the formation of tangles, which weakens your argument."

5. Give a Better Alternative

Your students probably tried really hard to be clear, so when you point out an issue they often don't know how they could have done it any better. Unlike you, they probably haven't seen lots of examples of good writing. One way to help them, is to show them how it could be better. You can use in-text corrections, or give examples in the comments.

E.g. "It's not clear if the protein is produced by the bacteria or the plant, you can clarify this by saying 'the bacterial protein' instead of just 'the protein'."

6. Provide Summary Feedback

Students can find it hard to differentiate between 'important' and more 'trivial' feedback. You can help them clarify this by providing summary feedback that highlights the most important areas for improvement.

E.g. "I often found it hard to follow the connection between the conclusions from the data and the argument you were making (see in-text comments)."

7. Explain What is Done Well

Don't forget to tell them when they are doing a good job, and why! It's most disappointing when students 'fix mistakes', only to take out something you liked. It also helps students remember that not everything they did is wrong. Use the same rules as above!

E.g. "I really like that you included this background information, it helps me understand how the data supports your argument."