Using Example Answers to Support Student Problem Solving in Biology

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Case Study Assignments

- BIOL362: 3rd Year Cell Physiology, 50-100 students. Focus on conceptual learning and skills development within the context of cell physiology.
- Learning Objective: Students will be able to formulate and defend an argument using logical reasoning and experimental evidence.
- Assignment: Students are given real experimental data and asked to develop:
  - A reasonable hypothesis explaining it (1-2 sentences).
  - A rationale justifying their hypothesis using logical reasoning and referring to the data (1-2 paragraph).

  - They work in groups of 3-5 over the course of one class (85 min).
  - They will complete 4 case studies over the term, each with different data and questions.

Case Study Assignments

Case Study #1:
Alzheimer's Disease and Chronic Traumatic Encephalopathy

Unit 2 Case Study

Alzheimer's Disease (AD) is an incurable disease that most commonly affects the elderly. Chronic Traumatic Encephalopathy (CTE) is a brain disorder that has been shown to affect individuals exposed to repeated head impacts (e.g. boxer, football players).

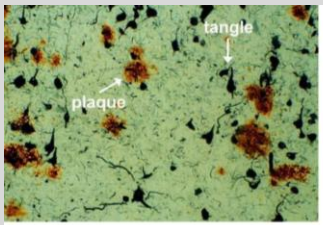
Both are progressive neurodegenerative disorders where the individual loses brain function over time, resulting in confusion, mood swings, memory loss behavioral changes and debilitating dementia. Eventually, body function can also be lost, leading to death.

Your task is to examine the evidence presented to try and find a connect between it and the neuronal dysfunction of these diseases.

Case Study 1 - Central Question:

Given this information, can you explain whether there is a relationship between the microtubule associated protein Tau and the neurodegeneration present in AD and CTE? If so, how does Tau contribute to disease pathology?

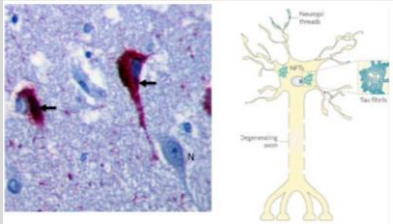
The Data



What you know

1. Images of the brain tissue in both diseases show intracellular, proteinaceous 'tangles' in the cytosol, which are composed of the microtubule associated protein, Tau.

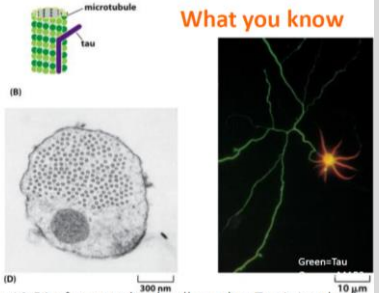
Ignore the plaques for today's exercise.



2. Immunohistochemistry for tau protein in the brain of an individual with Alzheimer's shows neurofibrillary tangles (red) visible in some neurons (arrows) but not in others (N).

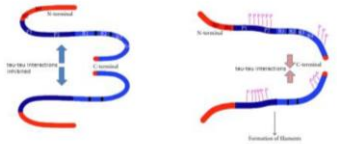
Cartoon from: Brunden KR, et al. 2009 Nat Rev Drug Discov. Oct;8(10):783-93.

What you know



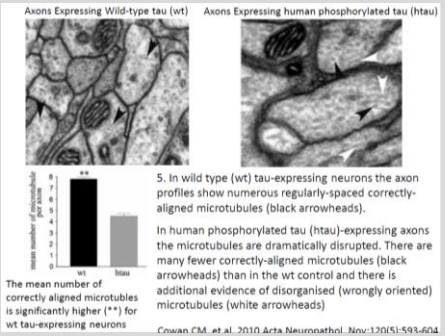
3. Figure 16-51 of our textbook tells us that Tau is involved in the formation of the MT network in the axon of neurons

What you know



4. Studies have shown that the neuronal tangles of Tau are hyper-phosphorylated and have a different shape, but if they are de-phoshorylated *in vitro*, the protein regains normal shape and function.

Kolarova M, et al. 2012 International Journal of Alzheimer's Disease doi:10.1155/2012/731526



The mean number of correctly aligned microtubules is significantly higher (**) for wt tau-expressing neurons

5. In wild type (wt) tau-expressing neurons the axon profiles show numerous regularly-spaced correctly-aligned microtubules (black arrowheads).

In human phosphorylated tau (htau)-expressing axons the microtubules are dramatically disrupted. There are many fewer correctly-aligned microtubules (black arrowheads) than in the wt control and there is additional evidence of disorganised (wrongly oriented) microtubules (white arrowheads)

Cowan CM, et al. 2010 Acta Neuropathol. Nov;120(5):593-604

*"[The case studies] made me **think critically** about what we learned in class and put the material from different lectures together."*

*" [The case studies] didn't necessarily help too much with learning the material presented in class (although they did a little), but they were really useful in practicing the **problem solving skills** also needed in midterms and the final."*

*"I think that the emphasis on wording and logical flow was good because I think **it's really important** to be able to state all the steps you are taking to get to your conclusion (not just in this class of course)."*

*"The case studies were interesting but the criteria for what was expected was way too **vague**."*

*"The case studies seemed to be more **difficult** than they should be, it was hard to know what to do to improve."*

*"I did feel that the grades my group received did not accurately reflect our comprehension of the material … I believe we were **frustrated** because learning how to quickly and clearly communicate newly comprehended material takes much longer (years) than mentally or verbally forming rationales behind the data.*

Types of Support

Built-In

Designed into the assignment itself. Often designed to catch and correct misconceptions from the start. Helps motivate students to persevere with challenging tasks.

- Learning Objectives
- Explicit Instructions
- Marking Rubric
- Example Answers
- Working in Groups
- Handing-in Drafts
- Instructor Approval of Assignment Topics
- Clear Big-Picture Importance

Contingent

Support that is not planned, but offered as needed. As such, it relies on in-the-moment interactions between teachers and students. It often address unexpected issues not covered by built-in scaffolding, but can be used to make connections to prior knowledge, draw concepts together, and highlight key points.

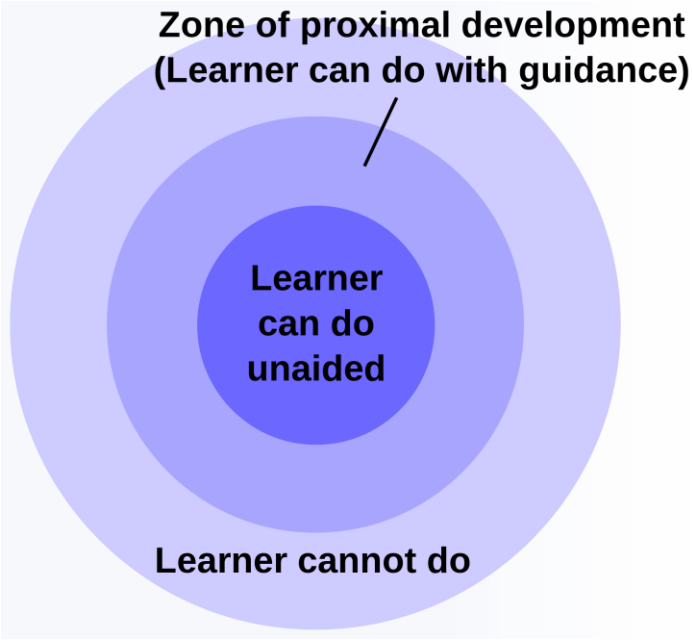
- Student-Student (eg. Online Discussion)
- One-on-One In-Class (eg. Hand Raising)
- Individual Written Feedback

Wilson & Devereux (2014) Scaffolding theory: High challenge, high support in Academic Language and Learning (ALL) contexts. J. Acad. Lang. & Learn. 8(3):A91-A100)

Role of Instructional Support

Zone of Proximal Development

Vygotsky (1978)



Wikipedia

Transformative Learning

Mezirow (1991)

Level of Challenge		Level of Support: Low	Level of Support: High
	High	**ANXIETY** frustration	**GROWTH** engagement
	Low	**STAGNATION** pointlessness boredom	**DEPENDENCY** busy work dumbed down

Modified from Wilson & Devereux (2014)

Vygotsky (1978) Mind in Society: The development of higher psychological processes. Cambridge MA: Harvard University Press

Mezirow (1991) Transformative Dimensions of Adult Learning. San Francisco, CA: Jossey-Bass.

Types of Support Tested

- Traditional
  - Students are given instructions
  - Instructor/TAs answer questions during assignment
  - TAs mark and give individual and general written feedback
- Step-by-Step (same as traditional plus…)
  - Worksheet deconstructing the thought process experts use when doing the assignment
  - The whole worksheet is marked in the 1st case study, but subsequently only the hypothesis and rationale are marked
- Student Marking (same as traditional plus…)
  - In the first case study only, students try writing a hypothesis, but this is not collected or marked.
  - Instead, students are shown example hypotheses and rationales and given a rubric for marking them.

Step-by-Step

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.

Peer Marking

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."

Strengths:

-
-

Areas for Improvement:

-
-
-
-

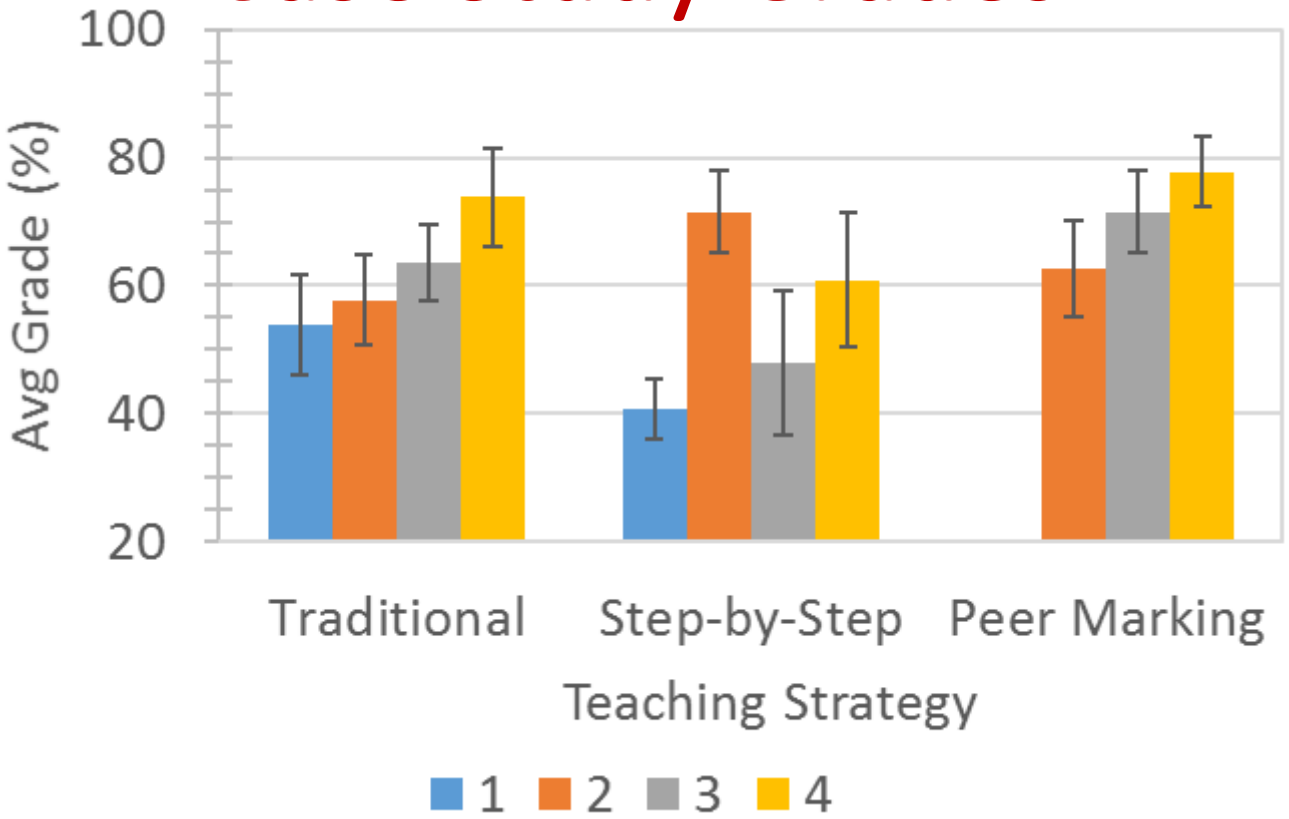
The full worksheet included two hypotheses and rationales, and the same sections in both. Here, the 'rationale' section only shows the rubric

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

Rationale Rubric

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

Case Study Grades

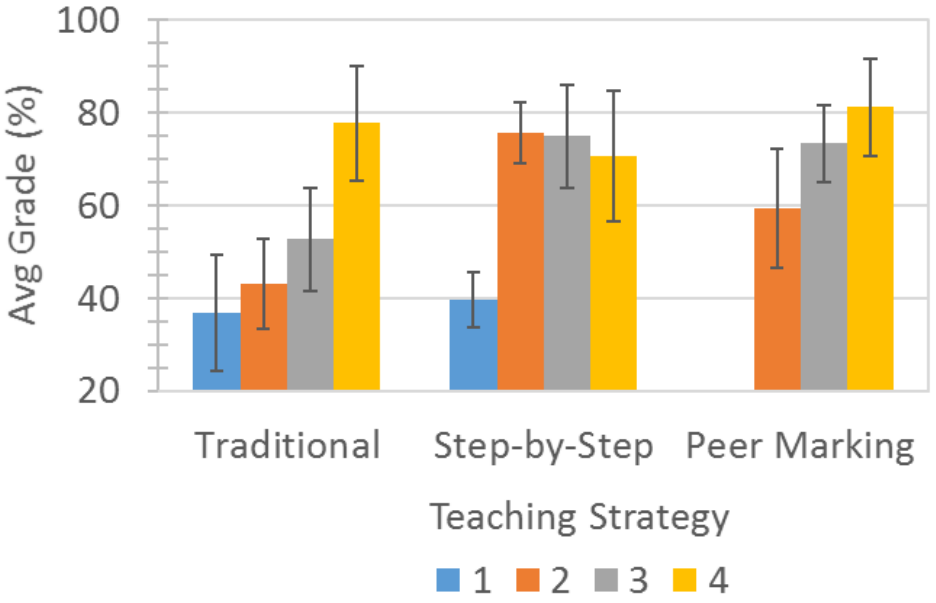


Step-by-Step: Student performance on the case study was impaired. Students did not improve steadily with practice.

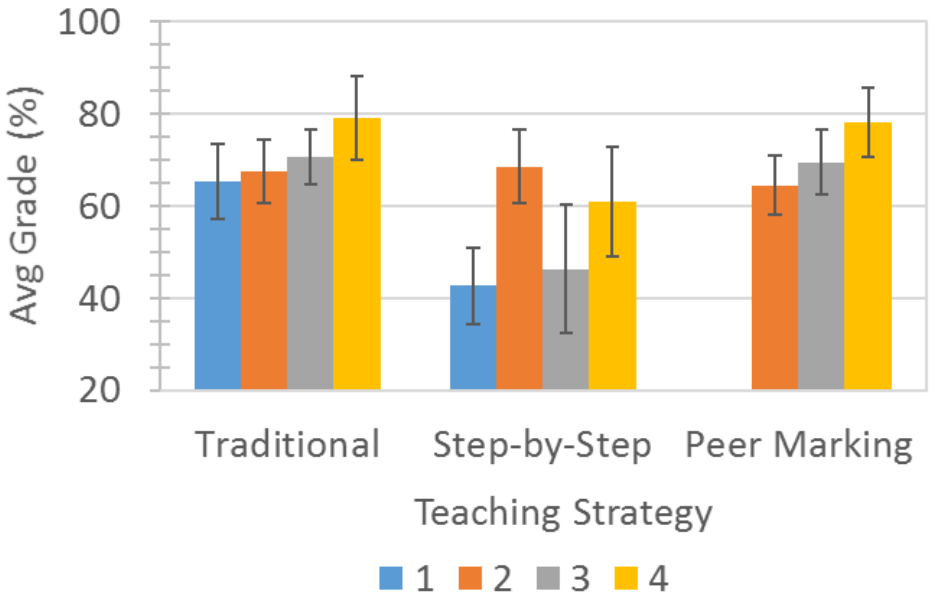
Peer Marking: Students improved faster than with the 'Traditional' approach, and did as well on the second case study, despite not writing the first case study.

Mean ± 95% CI

Hypothesis Grades



Rationale Grades



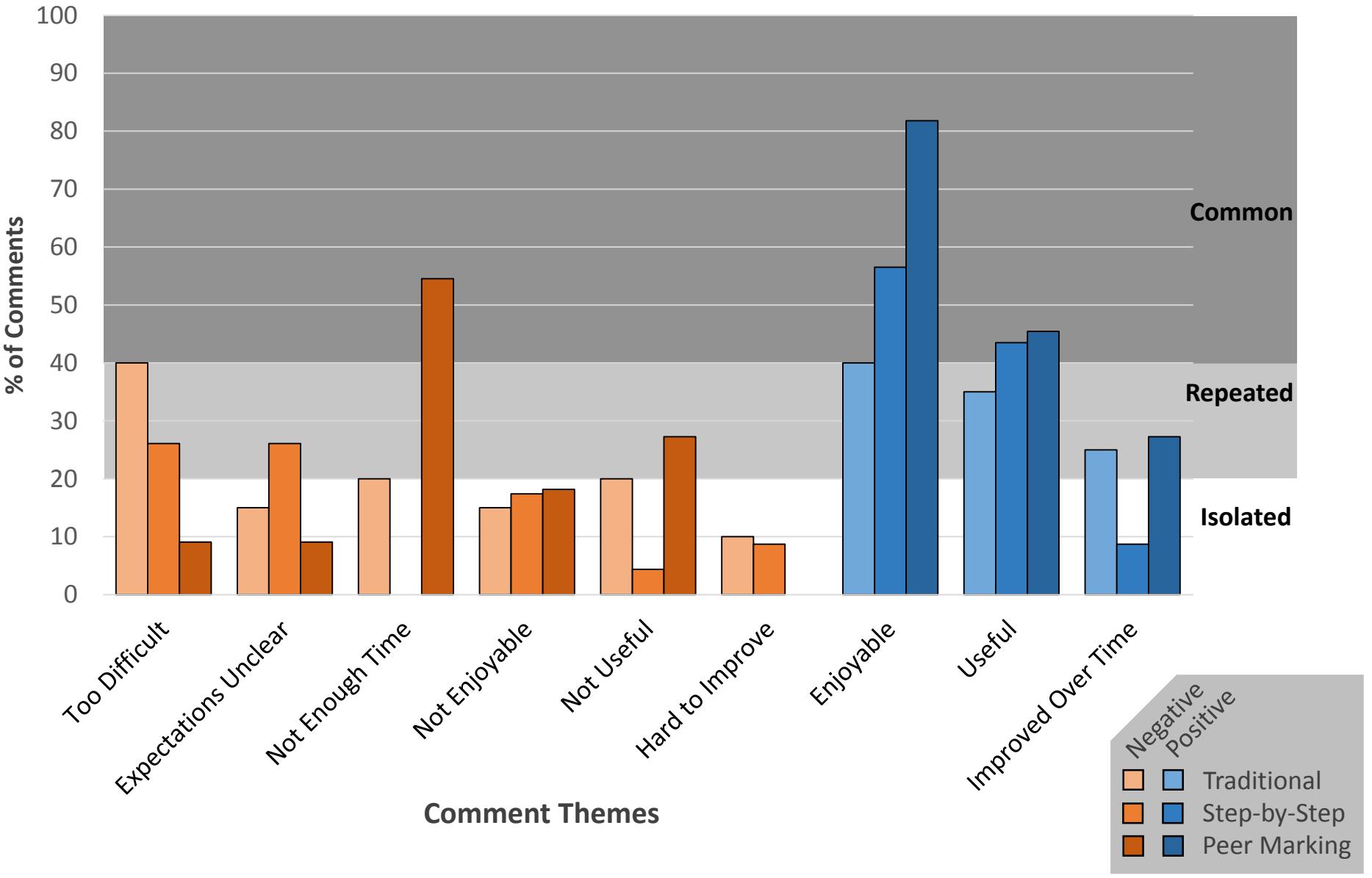
Student hypotheses improved more quickly in the 'Step-by-Step' and 'Peer Marking' years, compared to the 'Traditional' approach.

Step-by-Step: Rationales were disjointed and did not improve in quality with practice.

Peer Marking: Student grades were comparable to the 'Traditional' approach.

Mean ± 95% CI

Themes in Student Comments



The Power of Example Answers

The Worked Example Effect: Students solving problems in math, physics and computer programming have been shown to perform better when first provided with example problems that walk students through the solution (a 'worked example') (Booth et al. 2015).

Our study suggests that example answers can also be effective tools to teach problem solving in Biology.

Booth JL, McGinn KM, Young LK, Barieri C (2015) Policy Insights from Behavioral and Brain Sciences 2(1): 24-34

Better Support is More Powerful than More Support

How can you give better built-in support?

- Make your expectations clear and explicit.
- Give multiple opportunities to practice.
- Encourage students to work together.
- Provide example answers.
- Build-in check points for sub-tasks.
- Don't deconstruct the thought process too much.

How can you give better feedback (contingent support)?

- Use In-Text Feedback: tell students exactly where than can improve.
- Use 'I' Statements: avoid absolutes, but give an expert's opinion.
- Focus on the Objective: focus feedback on the learning objective.
- Explain Why: help students decipher your feedback.
- Give a Better Alternative: provide specific ways to improve.
- Provide Summary Feedback: highlight the key points.
- Explain What's Done Well: encourage them to continue good practices.

Hattie & Timperley (2007) The Power of Feedback. Rev. Ed. Research 77(1):81-112
Wilson & Devereux (2014) Scaffolding theory: High challenge, high support in Academic Language and Learning (ALL) contexts. J. Acad. Lang. & Learn. 8(3):A91-A100)

Expand Example Answers in Biology

- BIOL200 (Fundamentals of Cell Biology)
  - Large Class: 1200 students, 5 instructors, ~20 TAs
  - Problem Sets: Over 130 practice exam-style questions without answer keys.
- In 2016 we added 23 example answers ("Walkthroughs"), and we're comparing this years' class to the 2015 year.
  - Exam Performance: Paired Midterm and Final Exam Questions
  - Student Surveys: In-Class Clicker Surveys, Online Post-Term Surveys
  - Interviews: Undergrad Peer Tutors

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