Teaching Metacognition to Improve Critical Thinking Skills in Introductory Science Courses

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Teaching metacognition to improve critical thinking skills in introductory science courses

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Goals of session

- Describe exercise
- Results of study
- Suggestions/tips for implementing exercise
  - Developing instructor expertise
  - Finding time and space
    (Calibrated Peer Review™)
- Hearing from you
Why we should teach critical thinking skills

- Major learning goal
- College students not developing these skills
- High school students losing ground during college when CT is only emphasized in advanced coursework

Bloom’s taxonomy

(Bloom, B. S. 1984. Taxonomy of educational objectives. Allyn and Bacon, Boston, MA)
How can we teach critical thinking?

Metacognition
Our student learning outcomes

- Describe the logic of tackling scientific questions.
- Describe what some exam questions are like and understand how to determine the relative quality of different answers.
- Describe the components needed to completely answer questions that require critical thinking.
- Analyze your own work to determine what you should be working on to develop your own critical-thinking skills.
Our exercise

- Give assignment that requires critical thinking skills (e.g. short essay)
- In lab, give students three sample essays that they must critique using our rubric (see below)
- Students rank three sample essays
- Students evaluate their own essay
Our rubric

1. What is the pertinent content knowledge that should be included in the answer?

2. Is all the pertinent content knowledge included and stated correctly? (*Note:* Explicit definitions are not always required.)

3. Is there extraneous content knowledge that makes the answer less clear?
Our rubric

4. What critical thinking skills are needed to answer the question?

5. Does the answer make the reasoning explicit?

6. Is the given conclusion (or solution to the problem) consistent with the analysis? (Note to students: Here is where you must use your critical-thinking skills to analyze the sample responses.)
7. Assuming for the moment that the content knowledge presented is correct (and in some cases, this will be true), is the reasoning given a logical extension of those facts?

(Note to students: Here is where your must use your critical thinking skills to analyze the sample responses.)
8. Grade the sample answers on the following scale, and be prepared to explain each of your scores to your group members:

- 1 = low quality (i.e., both the content knowledge and the critical thinking components were weak)
- 2 = mediocre quality (i.e., either the content knowledge or the critical thinking component was strong, but the other was weak)
- 3 = high quality (i.e., both the content knowledge and the critical thinking components were strong)
A sample questions
When a genetic disorder is diagnosed in a family, family members often want to know the likelihood that they or their children will develop the condition. One important factor that influences a person’s chances of developing a genetic condition is how the condition is inherited (i.e., whether it is autosomal or sex-linked, dominant or recessive, simple or co-dominant).
a. In examining the pedigree above, what mode of inheritance best describes the trait indicated by the dark symbols? For full credit, you must name a mode of inheritance, explain what you think the most likely phenotype (affected or unaffected) and genotype of Individual #1 would be, and explain why. (Hint: to make an argument that one mode of inheritance is more likely than others, you will need to discuss the other modes of inheritance and explain why they are less likely).
a. In examining the **pedigree** above, what **mode of inheritance best** describes the trait indicated by the dark symbols? For full credit, you must name a mode of inheritance, explain what you think the most likely phenotype (affected or unaffected) and genotype of Individual #1 would be, and explain why. (*Hint:* to make an argument that one mode of inheritance is more likely than others, you will need to discuss the other modes of inheritance and explain why they are less likely).
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b. Currently, we know neither the phenotype nor the genotype for Individual 1 or 2. What additional information about either individual would refute the mode of inheritance you propose in Part A? Explain how this information would refute your analysis, and propose an alternative mode of inheritance that would explain the new information.
Our study

- To determine the effectiveness of this exercise at helping students develop critical thinking skills
Methods

- Pre-test (pre-lab exercise)
- Post-test (midterm question)
- Analyzed students’ self-assessments
- IRB approval
- Peer-review of test questions
- 2 independent raters assessed each student response
Table 1: A comparison of paired pre- and post-tests, n=35. Pearson correlation coefficient ($r$) was 0.85 for the pre-test and 0.80 for the post-test; both were statistically significant (p< 0.01).

<table>
<thead>
<tr>
<th></th>
<th>Mean pre-test score</th>
<th>Mean post-test score</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Content</td>
<td>86%</td>
<td>81%</td>
<td>0.19</td>
</tr>
<tr>
<td>Critical thinking</td>
<td>75%</td>
<td>86%</td>
<td>0.01</td>
</tr>
<tr>
<td>Overall</td>
<td>79%</td>
<td>83%</td>
<td>0.20</td>
</tr>
</tbody>
</table>
Analysis of students’ self-assessments

- 80% of students who had critical thinking errors on their pre-test correctly identified those errors during the metacognition exercise.
Finding time and space

- Calibrated Peer Review
- [http://cpr.molsci.ucla.edu/](http://cpr.molsci.ucla.edu/)
Developing instructor expertise

Tips for designing effective questions:
- Novel scenario
- Content knowledge
- Critical thinking skills
Improving Critical Thinking in Undergraduate Science Courses: Group discussion questions

- Writing questions/assignments?
- Grading questions/assignments?
- Teaching critical thinking?
  - Providing quality practice opportunities
  - Metacognition exercises
  - Using data from student work to guide student learning