From Local Assessment to Changing Classroom Practices Nationally and Internationally: Improving Students’ Critical Thinking Using the CAT (Critical thinking Assessment Test)

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National Science Foundation's TUES Program under grant 1022789.
99.6% agree critical thinking skills are “very important” or “essential”.

40% feel they lack the resources and training needed to effectively teach critical thinking.
Viral Nature of Misinformation

Confirmation Bias

Fallacy

Search ≠ Research
What is Critical Thinking?

Classic Emphasis

Evaluate Arguments and Conclusions

Reasoning
What is Critical Thinking?

Classical Emphasis

- Evaluate Arguments and Conclusions
  - Reasoning

Expanded Contemporary Emphasis

- Evaluate Ideas And Plans
  - Problem Solving
  - Communication
  - Creativity

- Evaluate One’s Own Understanding
  - Life-Long Learning Skills
Why Assess Critical Thinking?

Need to Measure Success for Accountability

Assessment Drives Improvement Efforts

How We Assess - Determines What Students Learn
History of CAT Development

Preliminary Work At TTU 2000 - 2004

Collaborate With Other Institutions To Refine CAT 2004 - 2007

Develop Training Methods for National Dissemination & Collect Norms 2007 - 2010

Expand National Dissemination & Support Assessment in NSF Projects 2010 - 2016
Over 250 US Institutions

+ Australia, Canada, Japan, Palestine, and Qatar Collaborating
Skills Evaluated by CAT Instrument

- Evaluating Information
- Creative Thinking
- Learning & Problem Solving
- Communication
Informed Consent

The purpose of this study is to understand the relevance of critical thinking skills foundational to the CAT across cultures (individualistic and collectivist).

By answering the questions on this survey you are agreeing to participate in our study.
CAT Features

One hour exam
Mostly short answer essay
Faculty scored in workshops
Detailed scoring guide
Reliable
Valid
A scientist working at a government agency believes that an ingredient commonly used in bread causes criminal behavior. To support the hypothesis the scientist notes the following evidence.

- 99.9% of the people who committed crimes consumed bread prior to committing crimes.
- Crimes rates are extremely low in areas where bread is not consumed.

Do the data described above strongly support the scientist’s hypothesis?  Yes____  No____

Are there other explanations from the data besides the scientist’s hypothesis? If so, describe.

___________________________________________________________________________________

What kind of additional information or evidence would help support the scientist’s hypothesis?

__________________________________________________________________________________________________
2. Other explanations for evidence offered by scientist? *(Three points maximum)*

**Step 1: Are other explanations indicated?**

<table>
<thead>
<tr>
<th>Yes (or implied by any alternative)</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Add 1 pt.</strong></td>
<td><strong>0 pts.</strong></td>
</tr>
<tr>
<td><em>Ex: Yes, there are other explanations.</em></td>
<td><em>Ex: I don’t think so.</em></td>
</tr>
<tr>
<td><em>Ex: The data are faulty.</em></td>
<td></td>
</tr>
<tr>
<td><strong>Go to Step 2</strong></td>
<td><strong>(Stop here)</strong></td>
</tr>
</tbody>
</table>

**Step 2: Evaluate relevance of the explanations** *(2 additional pts. possible)*

<table>
<thead>
<tr>
<th>Add 1 pt.</th>
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<tbody>
<tr>
<td><strong>If the explanation points out the spurious connection between bread consumption and criminal behavior.</strong></td>
</tr>
<tr>
<td><em>Ex: There is not necessarily a strong association because bread is a commonly consumed food in many households. That would be like saying that soap may be the cause because it was found in the homes of all of those who committed crimes.</em></td>
</tr>
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</table>

<table>
<thead>
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<th>Add 1 pt.</th>
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<tbody>
<tr>
<td><strong>If the answer points out that those areas where bread is not consumed may not have human residents or an infrastructure to easily report and document criminal behavior.</strong></td>
</tr>
<tr>
<td><em>Ex: Areas where bread is not consumed may have a very small population or no human residents.</em></td>
</tr>
<tr>
<td><em>Ex: Crime may not be reported and documented the same way in cultures that do not consume bread.</em></td>
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</table>
Discussion Points

Did students respond the way you anticipated?

What can we learn about students from these responses?

How can we help students improve these skills?
24 Question Survey

- Amount of experience scoring the CAT
- Obstacles related to change in courses
- Changes to teaching and assessment practices
- Motivational factors and available incentives
Amount of Experience
Scoring the CAT Instrument

Change in Teaching Strategies

Change in Assessment Strategies

Not applicable
participating in even one CAT Scoring workshop led to significant change in teaching strategies
greater level of exposure is required to make changes in assessment practices

- Overcome deficits in training related to assessment
- Provide a model for the development of course based assessment
Model for Change

- Opportunities for training/faculty development focused on high impact practices
- Obstacle—Lack of personal motivation
- Being part of a faculty community focused on improving critical thinking
- Experienced scoring responses from your own students
Experiential Development Model of CAT Scoring

- Realization (through Personal Motivation)
- Experience: CAT Scoring
- Awareness (scoring student responses)
- Reflection/Discussion (community of practice)
- Application (integrated training)
- Disseminate
Teaching Critical Thinking

Assessing Factual Knowledge
Validating Evidence Based Practices

PRE

CAT Apps

Other Innovative Pedagogy

POST
Scaling a Critical Thinking Initiative Across Disciplines

Denise Drane PhD
Searle Center for Advancing Learning and Teaching
Northwestern University

Partial support for this work was provided by the National Science Foundation’s TUES Program: grant 942404.
Research Hypotheses

1. Critical thinking can be leveraged to deeply engage faculty.

2. Data on students’ critical thinking will motivate faculty to change their teaching.

3. Changes in faculty approaches to teaching will lead to greater student gains in critical thinking.
Research Program Goals

To present faculty with assessment data on student gains in critical thinking

To inspire faculty to make changes to their teaching

To see if changes in teaching result in greater gains in critical thinking in students
Study Participants

11 faculty City Colleges of Chicago
&
9 faculty Northwestern University

Anatomy
Astronomy
Biology
Calculus
Chemistry
Chemical Engineering
Electrical Engineering
Linguistics
Physics
Critical Thinking Initiative in STEM: Study Design

**Engagement**
- Faculty 11 CCC & 9 NU
- CAT scoring workshop
- Develop course specific analogs

**Baseline**
- Measure gains on CAT & analogs over quarter*

**Intervention**
- Give faculty CAT & analog data
- Critical thinking pedagogy workshop
- Faculty develop & implement changes to teaching

**Impact**
- Measure gains on CAT & analogs over quarter
- Compare CAT gains

*241 students completed both pre and post CAT
What does critical thinking look like across the disciplines?
A friend of yours is trying to grow a tomato plant in her apartment. She has it in a pot on a table by a window, but it is not growing quickly. She notices that some flowers that she keeps on her balcony are growing very quickly, and she wonders if it is because she uses fertilizer on the flowers, but not on the tomato.

• Provide three alternative explanations for the difference in growth rate between the tomato plant and the flowers, other than fertilizer usage.

• Describe an experiment that would allow her to determine if it was in fact the lack of fertilizer that was responsible for the low growth rate of the tomato plant.

Identify alternative interpretations for data or observations.
Identify new information that might support or contradict a hypothesis.
Dynamics and Control of Biological and Chemical Systems

- Start with a set of “actual” experimental data
1. Summarize/interpret these data. What conclusions can be drawn?
2. How strongly do these data support the hypothesis that the system exhibits FODT behavior?
3. Propose an alternative hypothesis that your team finds most compelling, and then propose additional experiments that could be conducted to evaluate your hypothesis. Explain why these experiments would let you evaluate which of these two hypotheses is most supported.
4. Now you repeat the experiment and measure the new data (X) shown above. To what extent do these new data support the original hypothesis and each of the alternatives proposed?
You are an engineer at Dow Chemical looking to make a new product by one of two processes A and B described in patents and summarized below. Both processes use the same reactants, have the same products, and generate the same overall yields.

You hire an experienced consultant. Dow seeks the process with lowest total costs to build and operate.

• **Consultant recommends process A** for a company that wishes to make 10,000 tons/yr of product. Does this mean that process A is lowest cost to construct?

• **Circle the most relevant pieces of information.**

• List at least **three other reasons** why consultant would have recommended this process.

• What **other info** could the consultant have used?

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**Process A: Patent 1,234,567, year 1978**

- Reactant
  - 100 m³ reactor
    - T = 200°C
    - P = 50 psig
  - 20 m tall separator
    - T = 200°C
    - P = 50 psig
  - Product
  - Byproduct

**Process B: Patent 4,567,890, year 2010**

- Reactant
  - 1 m³ reactor filled with catalyst
    - T = 200°C
    - P = 500 psig
  - compact separator
    - T = 200°C
    - P = 500 psig
  - Product
  - Byproduct

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Additional info: (omitted here)

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Thanks to faculty JN for this slide
Results: Hypothesis 1
Critical thinking can be leveraged to deeply engage faculty.

All faculty developed activities to enhance critical thinking.

All but one developed questions to assess critical thinking.
Results: Hypothesis 2
Data on students’ critical thinking will motivate faculty to change their teaching

Approaches to Teaching Inventory
(Trigwell, Prosser & Ginns, 2005)

- No group level changes
- 8/16 small to moderate increases on conceptual change
- 8/16 small to moderate decreases on information transmission
Results: Hypothesis 3 City Colleges of Chicago
Changes in faculty approaches to teaching will lead to greater student gains in critical thinking

Course Specific (Analog) Assessments
- Gains larger in Intervention Semester
- 6/8 classes
- Effect sizes 0.37 to 10.92

CAT Test
- No difference in gains between baseline and intervention semesters
Results: Hypothesis 3 University
Changes in faculty approaches to teaching will lead to greater student gains in critical thinking

Course Specific (Analog) Assessments
• Gains larger in intervention semester
• 1/2 classes
• Effect sizes 0.19

CAT Test
Gains larger in intervention quarter
3/7 classes larger gains in total score
4/7 classes larger gains on target questions
Activity to Promote Critical Thinking in Solid State Electronic Devices
#1) For the following basis vectors, what is the unit cell volume?
A. \( a^3 \)
B. \( a^3/2 \)
C. \( 2a^3 \)
D. \( a^3/4 \)

\[
a = a \hat{x} \quad b = \frac{a}{2} \hat{x} + \frac{a}{2} \hat{y} \quad c = a \hat{z}
\]

#2) Select all point group symmetries (if any) that the left lattice has and the right does not have:
A. reflection through a point about vertical axis
B. reflection through a point about horizontal axis
C. rotation through a point by 90 degrees
D. translation to the right by \( a \)

#5) Crystal systems are defined by point group symmetries alone, whereas Bravais lattices are additionally defined by translational symmetries.
T. True
I. Insufficient Information
F. False
#1) For the following lattice, what is the unit cell volume?
A. $a^3$
B. $a^3/2$
C. $2a^3$
D. $a^3/4$

#2) Select all point group symmetries (if any) that the left lattice has and the right does not have:
A. reflection through a point about vertical axis
B. reflection through a point about horizontal axis
C. rotation through a point by 90 degrees
D. translation to the right by $a$

#5) Crystal systems are defined by point group symmetries alone, whereas Bravais lattices are additionally defined by translational symmetries.

T. True
I. Insufficient Information
F. False
## Case Study: Learning Outcomes in terms of CAT Skill Areas and CAT Question

<table>
<thead>
<tr>
<th>Learning Outcomes</th>
<th>CAT Skill Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Evaluate/interpret info</td>
</tr>
<tr>
<td>Dynamic group thinking skills</td>
<td>2, 5</td>
</tr>
<tr>
<td>Develop awareness of multiple perspectives</td>
<td></td>
</tr>
<tr>
<td>Present, defend, evaluate critical responses</td>
<td></td>
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<tr>
<td>Critical skills with different team partners</td>
<td></td>
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</tbody>
</table>
Results: Student Gains in Critical Thinking

EECS 384 2012 n=7
EECS 384 2013 n=9
Results: Student Gains in Critical Thinking
The Value of a Framework

“The materials helped me verbalize what we’re doing. We are doing this and making it clear to students what they are doing, they are critical thinkers.”

“Being able to review the results of the test to get at the root of what is and is not good critical thinking. The topic was subconscious to me, and this brought it to the surface.”

“How to look at learning outcomes from a different point of view. I was forced to think about what critical thinking is and define it and how to measure it.”
"It was really helpful to formalize it and validate what we are doing......I never really thought about what I was doing. We grew up doing it, but now we have words for why we are doing it."
The value of a Community of Practice

“I liked hearing other people’s ideas, especially. Immediate feedback and great ideas from the other teachers. That was the primary benefit. That was the best part”

“Seeing the diversity of ways people were going about attacking critical thinking and all accomplishing it. People got validated – I got validated. We’re all on track!”
The value of the Experience

“It forced me to develop my craft.”

“It forced me to look at what I teach differently”.

“Definitely. It allowed me to critically evaluate my teaching. It was very, very good.”
Translating the CAT across Cultures

Sami Basha PhD,
Palestine Ahliya University College
Bethlehem, West Bank
Preliminary Validation Study

• Response of students to the CAT

• Faculty Perceptions of the CAT skills
Student Response: Study 1

• Students from 2 large universities in the West Bank
• English speakers (n=30) full CAT test
• Problematic (n=2)
• “As the questions are related to cases in foreign country, it is difficult to think for possible answers.”
• “Because it was my very first time reading about purification”
A High Level of Interest

• Rated 1-7 scale (very interesting-not very interesting at all)
• 66% rated 1 or 2
• Request for instruction in critical thinking
• Gained from doing test
Test directions confusing n=10

• “When I know that it is a critical thinking assessment, I started criticizing everything and said no to almost every question. May be I should not have been told to give more accurate information.”
• “It is complicated. Too many answers needed to be written with explanations”
• “It depends on my analytical competencies”.
Study 2: Faculty Response

- Universities across West Bank & Gaza
- 75% full-time
- 74% male
- Disciplines
  - 14% medical school
  - 26% humanities
  - 13% business
  - 32% STEM
  - 15% other
## Response by Faculty

<table>
<thead>
<tr>
<th>Skill</th>
<th>Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summarize a pattern of information without making inappropriate inferences</td>
<td>52.7%</td>
</tr>
<tr>
<td>Evaluate how strongly information supports a hypothesis or interpretation</td>
<td>73.2%</td>
</tr>
<tr>
<td>Provide alternative explanations for observations</td>
<td>68.7%</td>
</tr>
<tr>
<td>Identify additional information needed to evaluate a hypothesis or particular explanation of an observation.</td>
<td>61.6%</td>
</tr>
<tr>
<td>Evaluate whether spurious relationships strongly support a claim</td>
<td>41.9%</td>
</tr>
</tbody>
</table>
Thank You

www.CriticalThinkingTest.org

Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.