Cognitive flexibility gained through collaborative reflection on cognitive traces

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Cognitive traces

• Could mean different things for different agents…
• This creates collaborative situations
  – effective for learning
  – interesting to study
Cognitive traces in collaboration

• Collaborative situations tend to collect externalized cognitive traces.

• Externalized cognitive traces function to yield solutions/interpretations differing in their degrees of abstraction.

• Cognitive efforts to integrate these promote conceptual understanding.
Cognitive traces in collaboration

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…

*Establish the case and we could test this design methodologically.*
Task

“Shade 2/3 of 3/4 of the *origami* paper with oblique lines.”

What would you expect?

• Do people calculate?
• Would $\frac{2}{3}$ of $\frac{3}{4}$ be different from $\frac{3}{4}$ of $\frac{2}{3}$?
• What if not origami paper but thick construction paper, or acrylic board?
Less than 10% calculate

<table>
<thead>
<tr>
<th>Operation</th>
<th>Arithmetic</th>
<th>Non-arithmetic</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/4 of 2/3</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>2/3 of 3/4</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Thick cardboard</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Acrylic board</td>
<td>9</td>
<td>9</td>
</tr>
</tbody>
</table>
“What’s the answer?”

- “Huh?”
- “This is it.”
- “Two-thirds of three-fourths.”

- They do not always describe the outcome as “one-half.” (Four out of 15, for example.)
Sequential trials?

First trial : 2/3 of 3/4
↓
Second trial : 3/4 of 2/3
Solo subjects

2/3 of 3/4       3/4 of 2/3

First trial
Second trial

Non-arithmet
i
Arithmetic

Non-arithmetic
Arithmetic

Solo subjects
Paired subjects

2/3 of 3/4  3/4 of 2/3

13  4

11  2

Non-arithmetic
Arithmetic
What happens in pairs??
Getting $\frac{2}{3}$ of $\frac{3}{4}$ (1)

i) Original
Getting 2/3 of 3/4 (1)

i) Original
Getting $\frac{2}{3}$ of $\frac{3}{4}$ (2)

i) Original

ii) 1st Re-interpretation
Getting 2/3 of 3/4 (3)

i) Original

ii) 1st Re-interpretation
Getting 2/3 of 3/4 (5)

i) Original  ii) 1st Re-interpretation  iii) 2nd Re-interpretation
Getting $\frac{2}{3}$ of $\frac{3}{4}$ (6)

\begin{itemize}
  \item i) Original
  \item ii) 1st Re-interpretation
  \item iii) 2nd Re-interpretation
  \item iv) Calculation
\end{itemize}
Getting $2/3$ of $3/4$ \( (7) \)

**Person 1**

- Task-doing → Monitoring → Task-doing

- \( 3/4 \) → \( 3/4 \times 2/3 \)

**Person 2**

- Monitoring → Task-doing → Monitoring

- i) Original
- ii) 1st Re-interpretation
- iii) 2nd Re-interpretation
- iv) Calculation

CREST 2002
Collaboration yielded abstraction

- Among Paired subjects, 11/15 went up to 3rd to 4th level of abstraction.
- Solos did so only 4/15 times.
- Role exchange appears to be responsible.
Collaboration works because…

• Variations of solutions differing in the degree of abstraction, which could create a “ladder” for subjects to climb up the levels.

• Integration process involves language use for abstracted schema formation.

• Motivation for integration.
Designing collaboration for fostering understanding

1) Encourage externalization
2) Solicit multiple re-interpretations

3) Iterate re-interpretation efforts
4) Support integration of different solutions/re-interpretations.
Context

• Teaching cognitive and learning sciences to undergraduates (grades 13 to 14)

• Main task: Integrate different research findings to come up with “applicable” theory-like understanding
1: Integrations of research results

e.g., “What are the characteristics of human problem solving?”

- Report categories changes from “narrowly self-centered” to “integrated” (qualitative change rather than quantitative).
Integration of different research findings of a shared theme

e.g. “What should we make out of series of research done on the ‘Wason selection task’?”

• “Theorize” and explain varying results
• Iterate presentation for three times

• Changes in integration and evaluation skills
Further research questions:

• Guiding variations? (Currently mostly depending on spontaneous generation)
• Does this mechanism work situationally in emergent ways, or is it “guidable” as a cognitive skill?
Summary:

- Theorizing effects of cognitive traces for effective collaboration seems possible, and
- Getting guidelines for designing effective collaborative learning environments of this kind may be due.
Performances

• Quality of final reports
  – 1998: Students started to turn in more integrated term papers, referring to many of the research covered in the class (50% to less than 10% in previous years).
  – 2000: 80% of the papers applied integrated “theory-like” understanding, referring to more than three concrete research examples.
Analyses of performances

• Numbers of notes and links
• Content types of notes and links
  – What kinds of links did students make?
  – Any effects of raised “visibility” of links to the use of notes?
“What’s the answer?”

<table>
<thead>
<tr>
<th>Categories</th>
<th>Non-arithmetic</th>
<th>Arithmetic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Explicit 1/2</td>
<td>10</td>
<td>4</td>
</tr>
<tr>
<td>Vague</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>No verbalization</td>
<td>19</td>
<td>1</td>
</tr>
</tbody>
</table>

N.B. 3 hard to analyze cases omitted
Solo subjects

2/3 of 3/4

3/4 of 2/3

Non-arithmetic
Arithmetic

CREST 2002
Paired subjects

2/3 of 3/4  3/4 of 2/3

13 Non-arithmetic
2 Arithmetic

4 Non-arithmetic
11 Arithmetic
Schematic shifts

Levels

4
3
2
1

?
Expected moves

Level 1 to Level 2   7
Level 2 to Level 3   5 (7)
Level 3 to Level 4   3 (5)

Sum                   15 (19)
Who initiated the shifts?

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>Monitor</th>
<th>Doer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1 to Level 2</td>
<td>7</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>Level 2 to Level 3</td>
<td>5 (7)</td>
<td>3 (4)</td>
<td>2 (3)</td>
</tr>
<tr>
<td>Level 3 to Level 4</td>
<td>3 (5)</td>
<td>1 (1)</td>
<td>2 (4)</td>
</tr>
<tr>
<td>Level 2 to Level 4</td>
<td>2 (0)</td>
<td>1 (0)</td>
<td>1 (0)</td>
</tr>
<tr>
<td>Sum</td>
<td>17 (19)</td>
<td>12 (12)</td>
<td>5 (7)</td>
</tr>
</tbody>
</table>

Note. Numbers in parentheses are those when implicit Level 3 is included as Level 3.
Possible solutions (2/3 of 3/4)
Possible solutions (2/3 of 3/4)

pleats

squares
Possible solutions (2/3 of 3/4)

pleats

squares
Visibility of 1/2-ness

pleats higher

squares lower
Objective visibility

- works differently from individuals to pairs.
- Individuals tend to see what they want to see, while
- Pairs tend to change their views.