Mutual links as externalized resources for students’ collaborative reflection

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External representations

- Not always prepared by others/teachers.
- Not necessarily easy to understand or explain.
Cognitive traces

• Traces of conscious/subconscious cognitive processes we leave on external world.
• Differences of perspectives one can take on such traces.
Theory behind practice

• What are cognitive traces for?
• How does collaboration work (with traces)?
• What kinds of external representation do we want for collaboration be more effective?

• …going back to do some basic research…
Task

“Shade $\frac{2}{3}$ of $\frac{3}{4}$ of the origami paper with oblique lines.”

(Shirouzu, Miyake, & Masukawa, 2002)
Summary of findings

• People do not calculate.
• They use external resource extensively.
• There are different ways to solve this problem, which vary in degrees of abstraction.
Getting $\frac{2}{3}$ of $\frac{3}{4}$ (1)

i) Original
Getting $\frac{2}{3}$ of $\frac{3}{4}$ (1)

i) Original
Getting 2/3 of 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)
Getting $\frac{2}{3}$ of $\frac{3}{4}$ (6)

i) Original $\rightarrow$ iii) 2nd Re-interpretation

ii) 1st Re-interpretation $\rightarrow$ iv) Calculation

$\frac{3}{4} \rightarrow \frac{2}{3} \rightarrow \frac{2}{4} \rightarrow \frac{1}{2} \rightarrow \frac{3}{4} \times \frac{2}{3}$
Different solutions

• It was not easy for an individual to see the scope of this variation.
Sequential trials?

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

2/3 of 3/4

14

1

3/4 of 2/3

11

4

Non-arithmetic
Arithmetic

Solo subjects
Paired subjects

2/3 of 3/4
2
13

3/4 of 2/3
4
11

- Non-arithmetic
- Arithmetic
Getting 2/3 of 3/4 (7)

Person 1

Task-doing → Monitoring → Task-doing

3/4 → \{\text{Thirds}\} \rightarrow 2/3 \rightarrow 3/4 \times 2/3

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

Person 2

Monitoring → Task-doing → Monitoring
Collaboration works because…

• There are variations of solutions differing in the degree of abstraction, which sort of works as a “ladder.”

• Integration process involves language use for abstracted schema formation.

• Motivations for integration
Guidelines designing collaborative learning situations

1) Encourage externalization
2) Solicit multiple re-interpretations
3) Iterate re-interpretation
4) Support integration of different solutions
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
Reflective Collaboration Note
Reflective Collaboration Note

Note A

Link list to Note A

Compare/relate notes

Note B

Link list to Note B

Mutual like window

Links for both directions
Discussion with cards to help writes notes
Class with ReCoNote
1998 practice (3 months + 1 month)

• “Human problem solving”
  – 57 juniors in 23 groups
  – A semester course
  – Goal “Understand the fundamental characteristics of human problem solving”
1998 design (1/3)

- Literature study (10 weeks)

Four card problem

Tower of Hanoi

Water jar

11 tasks
1998 design (2/3)

- Relation making (4 weeks)
  - Listen carefully and make links
1998 design (3/3)

- Summary writing (4 weeks)
  - Go over all the materials contributed by the entire class.
Design changes

• 1999 introduced Jigsaw, to
• Structured jigsaw in 2000 and 2001
Put them together to get the whole
2000 practice (3 days+ a week)

- “Introductory learning sciences”
  - 57 juniors in 23 groups
  - An intensive course
  - Goal “Understand how people learn and design and evaluate a mini-course.”
## Structure of learning materials

<table>
<thead>
<tr>
<th></th>
<th>Theoretical</th>
<th>Experimental</th>
<th>Observational</th>
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</thead>
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*CREST 2002*
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<td>![Arrow]</td>
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<tr>
<td>Collaboration</td>
<td>![Arrow]</td>
<td>![Arrow]</td>
<td></td>
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</tbody>
</table>

[Image of table with arrows connecting different categories]
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.
Data analyses

• 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?
## Overall

<table>
<thead>
<tr>
<th></th>
<th>1998 (3 months)</th>
<th>2000 (3 days)</th>
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<tbody>
<tr>
<td>ReCoNote Users</td>
<td>57</td>
<td>71</td>
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<tr>
<td>Group notes</td>
<td>192</td>
<td>177</td>
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<tr>
<td>Individual notes</td>
<td>114</td>
<td>230</td>
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<tr>
<td>Mutual links</td>
<td>189</td>
<td>106</td>
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<tr>
<td>Refer notes (own)</td>
<td>379*</td>
<td>3504</td>
</tr>
<tr>
<td>Refer notes (other)</td>
<td>6786*</td>
<td>12152</td>
</tr>
</tbody>
</table>

* * without first 4 weeks
1. Link types

• Whose notes were linked?
Self-centered to among other’s

Other group → Other group

Other group

Own group

Self-centered

Other group → Other group

Other group

Own group

Other to Other
Link types by study phases

- **Literature study**
  - 1998
  - 2000

- **Relation making**
  - 1998
  - 2000

- **Summary writing**
  - 1998
  - 2000

- Colors:
  - Self–self
  - Self–other
  - Other–other
2. Links and visits

• Were notes with more links visited more frequently?
(1998) More links, more visit

![Bar chart showing the relationship between the number of links per each note and the number of notes and average number of visits.](chart.png)
(2000) More links, more visit

```
No. of links
0  50  100  150  200  250  300
Avarage No. of visits
01 2 3,4 5+

No. of links per each note

No. of notes

No. of notes

Avarage No. of visits
```

No. of links per each note
3. Content of notes with many links

- Four notes had more than 5 links.
- “Table of contents” notes, referring to the structure of the notes below.
ReCoNote

Group notes

Individual notes

K. Representation

Everyday cognition

Conceptual change

Collaboration

7 links

Lave on adult math

Inagaki on biology

Hatano on naive economics

6 links

Motivation to understanding

Personification as a base for analogy

5 links

Interpretation

Summary

Exp.

Results

Summary

Hypotheses

Results

Procedure

Implications

2nd results

Main points

Exp.

Results

Summary
# Sub-note structures

<table>
<thead>
<tr>
<th></th>
<th>Visits</th>
<th>Papers</th>
<th>Structured sub-notes</th>
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<tbody>
<tr>
<td>K. Representation</td>
<td>536</td>
<td>3</td>
<td>1</td>
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<td>Everyday cognition</td>
<td>524</td>
<td>3</td>
<td>3</td>
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<tr>
<td>Conceptual change</td>
<td>487</td>
<td>3</td>
<td>1</td>
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<tr>
<td>Collaboration</td>
<td>366</td>
<td>3</td>
<td>1</td>
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</table>
Where and how often notes were linked

Everyday Cognition <-> Conceptual Change

Collaboration <-> K. Representation

2002CREST
Roles of externalized links

• Structure of the links seems to affect integration.

• Visibility of links helps higher-order integration, but also requires support for higher quality basic note-taking.
Solo subjects

2/3 of 3/4

3/4 of 2/3

14

1

11

4

Non-arithmetic
Arithmetic
Paired subjects

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

Non-arithmetic
Arithmetic

13 2
4 11
Schematic shifts

Levels

1 2 3 4
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>
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<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>
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<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>
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</table>

*Note.* Numbers in parentheses are those when implicit Level 3 is included as Level 3.
What would you expect?

• 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% calculated

- 3/4 of 2/3: 10 Arithmetic, 1 Non-arithmetic
- 2/3 of 3/4: 9 Arithmetic, 1 Non-arithmetic
- Thick cardboard: 9 Arithmetic, 1 Non-arithmetic
- Acrylic board: 9 Arithmetic, 1 Non-arithmetic
Creases as the trace of solving

• Come in different shapes
• “What is the answer?”
Solos vs. pairs on “what is the answer?”
“A half” or “1/2”

<table>
<thead>
<tr>
<th></th>
<th>Solos</th>
<th>Pairs</th>
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<tr>
<td></td>
<td>4</td>
<td>11</td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>Half or 1/2</td>
<td>11</td>
<td></td>
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</table>
What happens in pairs??
Collaboration yielded abstraction

• Among Paired subjects, 11/13 went up to 3rd to 4th level of abstraction.
• Solos did so only 4/13 times.
• Role exchange appears to be responsible.
Same theme, same approach…

<table>
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<tr>
<th></th>
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<th>Learning</th>
<th>Knowledge</th>
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<td>Theory</td>
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<tr>
<td>Experiments</td>
<td><img src="2" alt="Human Icons" /></td>
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<tr>
<td>Simulation</td>
<td><img src="2" alt="Human Icons" /></td>
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<tr>
<td>Brain studies</td>
<td><img src="2" alt="Human Icons" /></td>
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<td></td>
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<tr>
<td>Application</td>
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Different themes, same approach…

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<td>Application</td>
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Same theme, different methodologies…

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<td>Application</td>
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Lots of combinations…

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Project team of members with different backgrounds

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Getting $\frac{2}{3}$ of $\frac{3}{4}$ (1)

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

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

i) Original

ii) 1st Re-interpretation

iii) 2nd Re-interpretation
Getting $\frac{2}{3}$ of $\frac{3}{4}$ (5)

- i) Original
- ii) 1st Re-interpretation
- iii) 2nd Re-interpretation
Getting 2/3 of 3/4 (6)

i) Original

ii) 1st Re-interpretation

iii) 2nd Re-interpretation

iv) Calculation
Getting \( \frac{2}{3} \) of \( \frac{3}{4} \) (7)

Person 1

Task-doing \rightarrow Monitoring \rightarrow Task-doing

\[
\begin{align*}
\text{i) Original} \\
\text{ii) 1st Re-interpretation} \\
\text{iii) 2nd Re-interpretation} \\
\text{iv) Calculation}
\end{align*}
\]

\[
\frac{3}{4} \rightarrow \left\{ \begin{array}{c}
\text{Thirds} \\
\frac{2}{3} \rightarrow \left\{ \begin{array}{c}
\text{2/4} \rightarrow \frac{1}{2}
\end{array} \right.
\end{array} \right.
\]

\[
\frac{3}{4} \times \frac{2}{3}
\]

Person 2

Monitoring \rightarrow Task-doing \rightarrow Monitoring