How Online Small Groups Co-construct Mathematical Artifacts to do Collaborative Problem Solving

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Outline

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- Research Questions
- Conceptual Framework
- Methodology
- Results
- Q & A
Introduction

  - Economic growth and prosperity in the knowledge-based economy depends on fostering scientific & technological innovation
    - STEM education has strategic importance
  - Important considerations for fostering innovation
    - Problems are of interdisciplinary nature
    - Globalized economy -> distributed work
    - Collaborative team work at a distance is vital
Introduction

- US Department of Education study (Dynarski et al., 2007)
  - on effectiveness of educational technology in STEM education
    - Traditional vs tech-supported learning
    - 33 districts, 132 schools, 439 teachers
    - 1st, 4th, 6th grades
    - No significant differences in student test scores are found across treatment and control conditions

- How technology can be used to effectively support STEM education?
  - remains to be an open problem
Virtual Math Teams (VMT) Project

- Joint research project of IST and the Math Forum
- Investigate how virtual communication technologies can be effectively used to support collaborative learning of mathematics online
- Design-based research approach
  - Comparison of learning outcomes across conditions does not reveal the interactional mechanisms through which potential benefits of technology and collaboration are realized for math education
  - Focus on practices of mathematical meaning making enacted by groups in online environments
VMT Dual-Media CSCL Environment

Explicit Referencing Support

Whiteboard Scrollbar

Message to message referencing

ChatScrollbar

awareness messages
Research Question

- How do small groups of students co-construct mathematical artifacts, make sense of them jointly, and incorporate them into solution accounts through textual and graphical online communication tools?
Research Questions

- **RQ1. Mathematical Affordances**
  - What are the similarities and differences of the different media in VMT (e.g., chat, whiteboard) for the exploration and use of mathematical artifacts?

- **RQ2. Coordination Methods**
  - How do groups in VMT coordinate their actions across different interaction spaces?

- **RQ3. Group Understanding**
  - How can collaborating students build shared mathematical understanding in online environments?
Conceptual Framework

- **Artifact**
  - a man made thing crafted for a practical purpose
  - brings form and function together

- **Affordances**
  - possibilities and constraints for producing actions with and around artifacts

- Locate meaning in practices of use, not in mental states
Conceptual Framework (cont.)

- **Construction**
  - Math concepts are not simply acquired as ready-made entities, but actively constructed by learners as they engage with math artifacts in problem-solving contexts.

- **Co prefix**
  - Artifacts that are collaboratively constructed and used by groups rather than individuals.
  - Artifacts are produced to be shared with the group, and hence made to be meaningful for others.

- **Co-construction of math artifacts**
  - The sequential organization of actions in which math artifacts are produced and embedded, i.e. made meaningful for the participants.
Conceptual Framework (cont.)
Deep mathematical understanding as constructing relationships among different realizations

Solution of $7x + 4 = 5x + 8$

Solution of $2x + 4 = 8$
Solution of $2x = 4$

$x = 2$

Adapted from Sfard, 2008, p. 165
Methodology
Ethnomethodological Conversation Analysis

○ Discipline within Sociology

○ Takes up practice as the central object of study
  ● Concerned with practical reasoning and the procedures (i.e., “methods”) participants (i.e., “members”) routinely employ in making sense of their own actions and the actions of others

○ Assumption
  ● Social actions are meaningful for those who produce them, and thus they have a natural organization that can be discovered and analyzed by close examination
Methodology
Ethnomethodological Conversation Analysis

- Qualitative, naturalistic approach based on case studies
  - Analysis focuses on uncovering **shared methods** participants use to organize their actions as evidenced in excerpts from recordings of naturally occurring activities

- Reliability/Validity
  - Data sessions
    - analysis subjected to inter-subjective agreement
  - Data is presented as part of analysis

- Generalizability
  - Focus on routine practical concerns observed to be **relevant** to participants
  - Identify the contingency which the method systematically handles in actual occasions
    - e.g., how to relate a drawing to ongoing chat discussion
Data

- Math artifacts co-constructed by a VMT team
  - Qwertyuiop, Jason, 137 (self selected pseudonyms)

- Upper-middle school students (14-16 years old)

- Participants were recruited via their teachers, who are Math Forum users

- Completed 4 online sessions in 2 weeks

- A VMT project member was present in the room in case of technical difficulties
Task Description

Here are the first few examples of a particular pattern, which is made using sticks to form connected squares:

<table>
<thead>
<tr>
<th>N</th>
<th>Squares</th>
<th>Sticks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
<td>18</td>
</tr>
<tr>
<td>4</td>
<td>10</td>
<td>28</td>
</tr>
</tbody>
</table>

1. How many squares will be in the Nth example of the pattern?
2. How many sticks will be required to make the Nth example?
Task Description (cont.)

Mathematicians do not just solve other people's problems, they also explore little worlds of patterns that they define and find interesting. Think about other mathematical problems related to the problem with the sticks.

Go to the VMT Wiki and share the most interesting math problems that your group chose to work on.
Data Analysis

- **Excerpt 1**
  - Focus on how the team co-constructed a new stick pattern that they called "hexagonal array"

- **Excerpt 2**
  - How does the team figure out how many triangles are there in the n-th case

![Diagram showing stick patterns labeled N=1, N=2, N=3]
Data Analysis

- Goal: to motivate the observation that...
  - Identify and produce relevant mathematical artifacts to constitute a shared problem
  - Refer to those artifacts and their relevant features
  - Manipulate and observe the manipulation of those artifacts based on math practices known to participants

- ...are recurrent practical concerns for VMT participants w.r.t. math artifacts and media affordances
Excerpt 1
Co-construction of a new stick pattern
Excerpt 2

Constituting a shared problem

*Jason* 5/16/06 7:20:02 PM EDT: so... should we try to find a formula i guess

*Jason* 5/16/06 7:20:22 PM EDT: input: side length; output: # triangles

*qwertyuiop* 5/16/06 7:20:39 PM EDT: it might be easier to see it as the 6 smaller triangles.

*137* 5/16/06 7:20:48 PM EDT: Like this?

***

*qwertyuiop* 5/16/06 7:21:02 PM EDT: yes

*Jason* 5/16/06 7:21:03 PM EDT: yup
Excerpt 2 (cont.)
Developing a systematic counting approach

137 5/16/06 7:22:19 PM EDT: Each one has 1+3+5 triangles.

Jason 5/16/06 7:22:23 PM EDT: but then we're assuming just regular hexagons

137 5/16/06 7:23:17 PM EDT: It equals 1+3+...+(n+n-1) because of the "rows"?

qwertuyiop 5/16/06 7:24:00 PM EDT: yes- 1st row is 1, 2nd row is 3...
RQ1: Affordances

- Availability of the production process
  - Whiteboard affords an animated evolution of its contents that makes the visual reasoning process available

- Persistence & mutability of contents
  - Unlike chat postings that gradually scroll away, drawings remain in the shared visual field until they are removed
  - Once posted chat messages cannot be altered, but drawings can be modified, annotated, copied etc.
  - Persistence of contributions allow users to manage multiple threads of activity

- Interactional roles of chat and whiteboard actions
  - Whiteboard objects are made relevant to ongoing interaction by chat messages that either
    - Project their production as a next action
    - Refer to previously produced whiteboard objects
RQ2: Coordination Methods

- Indexical-referencing
  - Isolate objects in the shared visual field and associate them with local terminology stated in chat
  - Establish **sequential organization** among actions across chat and whiteboard

- Methods displayed by participants
  - Annotating the shared drawing to highlight an object
  - Explicitly pointing at a region on the drawing with the referencing tool from a chat message

- Verbal referencing
  - E.g., “rows”, “the green one”

- Temporal proximity of chat and whiteboard actions

so it has at least 6 triangles? in this, for instance
RQ3: Group Understanding I

- Persistence and Sequential Organization
  - Persistent whiteboard objects and prior chat messages form a shared *indexical ground* for the group
  - New actions are shaped by the indexical ground
    - i.e., interpreted in relation to relevant features of the shared visual field and in response to prior actions
  - New actions also reflexively shape the indexical ground
    - i.e., give further specificity to prior contents
  - New actions can set up relevant action(s) to follow
RQ3: Group Understanding II

- Coordination of Multiple Realizations
  
  - Group members enact affordances of the system to construct and reason with mathematical artifacts in textual, graphical and symbolic forms.
  
  - Through sequential organization of actions group members establish relationships among different kinds of math artifacts, and deepen their shared mathematical understanding.
Summary

- Implications for research
  - Focus on co-construction of shared artifacts allowed us to study
    - the affordances of online environments for producing mathematical actions
    - the mathematical understandings and reasoning made visible in the organization of those actions

- Implications for pedagogical and system design
  - Students
    - Active engagement with math reasoning; learn from peers
    - Experience collaborative problem-solving online
  - Teachers
    - monitor their students’ activities and use their artifacts as a resource for teaching
  - Providing technologies is not enough, coordination support is vital in helping users order their activities


Thank you for your attention

Questions? Comments?