A joint presentation of the Virtual Math Teams Project at the Math Forum & the iSchool at Drexel and the Computer Science Department at Temple University

Gerry Stahl

Understanding computer-supported group cognition: Steps toward a science of virtual groups
Groups in Society

- Globalization: people work in distributed teams
- Knowledge society: more work is knowledge work, building shared knowledge in teams
- Networking: new opportunities for people to work and learn in teams
- Online collaboration is the new form of working — and working now means learning
Support for Groups

- Single-user productivity tools: known technology & design methods (HCI)
- Social networking: new technology & haphazard design (Web 2.0 user-driven)
- Groupware:
  - CSCW computer-supported cooperative work
  - CSCL computer-supported collaborative learning
  - Much more complex HCI & design & dissemination issues
Theories of Groups

- HCI was based on theories of cognitive psychology of the individual
- Now we need a science of the small group
- Especially the computer-mediated, online, virtual group
- To guide design of groupware
Sciences of Groups

- Sciences of the individual
  - Social psychology
  - Educational psychology
  - Cognitive psychology
  - Organizational management

- Sciences of society
  - sociology, cultural anthropology, linguistics, etc.

- But no sciences of the small group!
Cognition of Groups

- Psychology: group cognition is distortions of individual cognition
- AI: cognition is computation (by any substrate)
- Distributed cognition: individual extended by artifacts and external memories
- Group cognition: cognitive processes can arise through the interactions within a small group of participants — not just externalization of individual mental representations, but emergent result of situated interaction
Preliminary Explorations of Groups

- Social psychology (but reductionist)
- Organizational management (ditto)
The concept of group cognition

- “cogito ergo sum” confused relation of cognition and persistent human body
- Group cognition is not a matter of a physical group with a brain or persistent presence
- It is a matter of meaning making through the interaction of semantic artifacts (words, drawings, symbols, documents) situated in a structured network of other meaningful artifacts (situation, world, group context, indexical field)
The concept of group cognition

- E.g., we can observe group cognition in a years old chat log — in the meaning making of the chat postings in the physical absence of any group participants
- The postings are read as meaningfully designed by humans to interact with other human postings
- But the cognitive accomplishments (e.g., problem solving) are in the interactions among the textual postings.
The concept of group cognition

- The cognitive accomplishments emerge from the network of meaningful references built up by the individual textual postings

- E.g., planning, deducing, designing, describing, problem solving, explaining, defining, generalizing, representing, remembering and reflecting as a group
The concept of group cognition

- The group as actor and group cognition are not physical objects or mental objects, but theoretical constructs resulting from analysis at the group level of description (like cultural norms and social rules at the social level)

- E.g., interpersonal trains of thought, shared understandings of diagrams, joint problem conceptualizations, common references, coordination of problem-solving efforts
3 Levels of Cognitive Description

- The *individual* actor (person) is described by (various theories in) cognitive psychology
- The *small-group* cognition is what emerges in the interactions among the utterances of the individual participants
- The social / cultural / *community* of practice / linguistic community is the institutionalized, persistent, shared results of the above
- The study of these different levels requires different Units of Analysis
Mediation by small groups

- “Small groups are the engines of knowledge building. The knowing that groups build up in manifold forms is what becomes internalized by their members as individual learning and externalized in their communities as certifiable knowledge” [Group Cognition, p. 16].
Toward a Science of Virtual Groups

- When small groups engage in cooperative problem solving or collaborative knowledge building, there are distinctive processes of interest at the individual, small-group, and community levels of description, which interact strongly with each other.

- The small-group level has no corresponding science.

- A science of virtual groups is particularly needed and possible.
How to Build a Science

- Define the domain of the science
- Explore the domain
- Capture a data corpus
- Select, adapt, refine and master methods for analyzing the data
- Organize analytic findings in a framework of theoretical conceptualizations
VMT as a Model of a Science

- Design-based research: iterative cycles
- Spring Fest 2005, 2006, 2007 and others by collaborators, in my courses, misc trials
- Over 1,000 student-hours of data (370 sessions)
- Almost 200 academic research publications
- Preliminary explorations: Group Cognition
- Early Studies: Studying Virtual Math Teams
Virtual Math Teams
Create the Domain

- Design-based research evolves the technology with the pedagogy, methods of analysis, usage feedback from data analysis and theory
- From off-the-shelf AOL Instant Messenger to VMT
- From Math Forum “problem-of-the-week” to four-hour open-ended math mini-world
- From one-shot chats to Spring Fest sessions to mini-curricula
The VMT Tabbed Environment

Resources

Probability, in common terms, is the chance that something is likely to happen. Probability theory is the formal mathematical study of the principles and rules that help us understand how probability works. You can find the probability problems and strategies that the VMT community has worked on in the main Probability page.

Contents [hide]

1. Introduction to Probability
2. Basic Terminology of Probability Theory
3. Probability of an event
4. Basic Probability Theorems
5. Conditional Probability
6. Independent Events
7. A Review of Concepts on Permutations and Combinations
8. Probability in Our Lives
9. Some Sample Questions and Answers on Probability from Ask Dr. Math Archives
10. Other Resources

Elizabeth 5/17/07 9:19 PM EDT: It's easy to recognize and easy to see.

bkmu 5/17/07 9:51 PM EDT: don't forget about errors

bkmu 5/17/07 9:45 PM EDT: I think with question 9 we want to answer the follow question: Does this system help a user recover from a error that they made. And if so how

bkmu 5/17/07 9:42 PM EDT: this sound good

bkmu 5/17/07 9:38 PM EDT: Seven and ten are ready

bkmu 5/17/07 9:12 PM EDT: I agree

bkmu 5/17/07 9:13 PM EDT: Olivia how is six it looks like someone stop in the middle of a sentence

Olivia 5/17/07 9:13 PM EDT: yes im on it, whoops

Message:

Take a look at that definition of probabil
Probability

Here are a set of challenges related to probability problems. You can contribute by adding your ideas about applying a strategy to a problem (adding content to a P#S# page), proposing a new strategy (adding a new column) or adding a new challenge (row).

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>P1. The sock drawer</td>
<td>P1S1</td>
<td>P1S2</td>
<td>P1S3</td>
<td>P1S4</td>
<td>P1S5</td>
</tr>
<tr>
<td>P2. Box with three cards</td>
<td>P2S1</td>
<td>P2S2</td>
<td>P2S3</td>
<td>P2S4</td>
<td>P2S5</td>
</tr>
<tr>
<td>P3. Seating arrangements</td>
<td>P3S1</td>
<td>P3S2</td>
<td>P3S3</td>
<td>P3S4</td>
<td>P3S5</td>
</tr>
<tr>
<td>P4. Baseball_World_Series</td>
<td>(P4-S1 Example)</td>
<td>(P4-S2 Example)</td>
<td>(P4-S3 Example)</td>
<td>(P4-S4 Example)</td>
<td>P4S5</td>
</tr>
<tr>
<td>P5. Duck hunters</td>
<td>P5S1</td>
<td>P5S2</td>
<td>P5S3</td>
<td>P5S4</td>
<td>P5S5</td>
</tr>
<tr>
<td>P6. Clock hands</td>
<td>P6S1</td>
<td>P6S2</td>
<td>P6S3</td>
<td>P6S4</td>
<td>P6S5</td>
</tr>
<tr>
<td>P7. Length of Random Chords</td>
<td>P7S1</td>
<td>P7S2</td>
<td>P7S3</td>
<td>P7S4</td>
<td>P7S5</td>
</tr>
<tr>
<td>P8. New Problem</td>
<td>P8S1</td>
<td>P8S2</td>
<td>P8S3</td>
<td>P8S4</td>
<td>P8S5</td>
</tr>
</tbody>
</table>

If you need them, here are some resources for probability

Categories: ProblemSolving | VMT
There are some situations where you can only travel along the lines of a grid - for example, driving in a city like Manhattan or Philadelphia. What difference does this make?

In the picture below, what is the length in grid units of the shortest path you can travel between the two points, A and B, staying along the grid?

How many paths of that length connect A and B?
Spring Fest 2006

(1) 4 sticks, 1 square

(2) 10 sticks, 3 squares

(3) 18 sticks, 6 squares

<table>
<thead>
<tr>
<th>N</th>
<th>Sticks</th>
<th>Squares</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>18</td>
<td>6</td>
</tr>
<tr>
<td>4</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>5</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>6</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>N</td>
<td>?</td>
<td>?</td>
</tr>
</tbody>
</table>
## Collect the Data

<table>
<thead>
<tr>
<th>Line #</th>
<th>Date</th>
<th>Time Start Typing</th>
<th>Time Posting</th>
<th>Duration</th>
<th>Bwang8</th>
<th>Aznx</th>
<th>Quicksilver</th>
<th>Blackstar</th>
<th>3222</th>
</tr>
</thead>
<tbody>
<tr>
<td>1322</td>
<td>5/18/06</td>
<td>19:19:46</td>
<td>19:19:47</td>
<td>0:00:08</td>
<td></td>
<td>Yeah.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1323</td>
<td>5/18/06</td>
<td>19:19:48</td>
<td>19:19:55</td>
<td>0:00:10</td>
<td></td>
<td>We can always double check, and it’s darn right.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1324</td>
<td>5/18/06</td>
<td>19:19:56</td>
<td>19:20:05</td>
<td>0:00:10</td>
<td></td>
<td>So we solve it by really looking at a bigger picture.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1325</td>
<td>5/18/06</td>
<td>19:20:10</td>
<td>19:20:15</td>
<td>0:00:05</td>
<td></td>
<td>or bigger square in this case</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1326</td>
<td>5/18/06</td>
<td>19:20:12</td>
<td>19:20:20</td>
<td>0:00:03</td>
<td></td>
<td>In this case, the “square” itself.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1327</td>
<td>5/18/06</td>
<td>19:20:22</td>
<td>19:20:23</td>
<td>0:00:11</td>
<td></td>
<td>Yeah.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1328</td>
<td>5/18/06</td>
<td>19:19:52</td>
<td>19:20:34</td>
<td>0:00:09</td>
<td></td>
<td>I think the 4 corner is growing like this</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1329</td>
<td>5/18/06</td>
<td>19:20:35</td>
<td>19:20:43</td>
<td>0:00:05</td>
<td></td>
<td>0, 1, 3, 6, 10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1330</td>
<td>5/18/06</td>
<td>19:20:44</td>
<td>19:20:48</td>
<td>0:00:03</td>
<td></td>
<td>what is the pattern</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1331</td>
<td>5/18/06</td>
<td>19:20:49</td>
<td>19:20:51</td>
<td>0:00:05</td>
<td></td>
<td>[user erased message]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1332</td>
<td>5/18/06</td>
<td>19:20:53</td>
<td>19:20:56</td>
<td>0:00:02</td>
<td></td>
<td>Triangular numbers.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1333</td>
<td>5/18/06</td>
<td>19:20:52</td>
<td>19:20:58</td>
<td>0:00:02</td>
<td></td>
<td>triangular numbers!</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1334</td>
<td>5/18/06</td>
<td>19:20:59</td>
<td>19:21:00</td>
<td>0:00:03</td>
<td></td>
<td>yes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1335</td>
<td>5/18/06</td>
<td>19:20:57</td>
<td>19:21:03</td>
<td>0:00:07</td>
<td></td>
<td>We had already figured that out.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1336</td>
<td>5/18/06</td>
<td>19:21:08</td>
<td>19:21:10</td>
<td>0:00:00</td>
<td></td>
<td>[user erased message]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1337</td>
<td>5/18/06</td>
<td>19:21:01</td>
<td>19:21:10</td>
<td>0:00:01</td>
<td></td>
<td>we can use the equation from session 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1338</td>
<td>5/18/06</td>
<td>19:21:10</td>
<td>19:21:11</td>
<td>0:00:09</td>
<td></td>
<td>yes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1339</td>
<td>5/18/06</td>
<td>19:21:19</td>
<td>19:21:20</td>
<td>0:00:16</td>
<td></td>
<td>Yup.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1340</td>
<td>5/18/06</td>
<td>19:21:35</td>
<td>19:21:36</td>
<td>0:00:03</td>
<td></td>
<td>n(n+1)/2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1341</td>
<td>5/18/06</td>
<td>19:21:39</td>
<td>19:21:39</td>
<td>0:00:02</td>
<td></td>
<td>[Quicksilver moved some object/s]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1342</td>
<td>5/18/06</td>
<td>19:21:41</td>
<td>19:21:41</td>
<td>0:00:02</td>
<td></td>
<td>[Quicksilver moved some object/s]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1343</td>
<td>5/18/06</td>
<td>19:21:43</td>
<td>19:21:43</td>
<td>0:00:04</td>
<td></td>
<td>[START: TextEditing]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1344</td>
<td>5/18/06</td>
<td>19:21:47</td>
<td>19:21:47</td>
<td>0:00:07</td>
<td></td>
<td>[END: TextEditing]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1345</td>
<td>5/18/06</td>
<td>19:21:54</td>
<td>19:21:54</td>
<td>0:00:02</td>
<td></td>
<td>[Aznx moved some object/s]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1346</td>
<td>5/18/06</td>
<td>19:21:44</td>
<td>19:21:56</td>
<td>0:00:01</td>
<td></td>
<td>4*n(n+1)/2= the four corners</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1347</td>
<td>5/18/06</td>
<td>19:21:53</td>
<td>19:21:57</td>
<td>0:00:01</td>
<td></td>
<td>this right?</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Establish a Data Corpus

- 1,000 student-hours of naturalistic usage
- Variety of scenarios: math problems, ages, group sizes, lengths of sessions, technologies
- Detailed logs
- Replayer to view and study interactions
- No data on individual factors or cultural
- Capture everything that entered into the interaction and was shared in the group interaction — available in detail in data
Analyze the Data

- Inspired by conversation analysis and ethnomethodology
- Use the replayer
- Select excerpts of interest
- Threading analysis
- Identify methods of group interaction
- Identify group cognitive achievements
Represent the Data
Some Initial Findings

- Problem solving discourse is driven by proposal/response interactions
- Groups construct a joint problem space through interactions that involve temporality, positioning and concepts
- VMT participants intricately coordinate visual, narrative & symbolic reasoning/inscriptions
- Information questioning proceeds through interaction to elaborate what is sought
- Groups construct an indexical field that lends contextual meaning to elliptical utterances
Some Initial Theory

- Important cognitive processes occur distinctively on individual, group and community levels of description
- They are appropriately studied at the corresponding unit of analysis
- The levels influence each other, but are not reducible to each other
- Often, group cognition can be best observed, because it takes place publically and explicitly and has not yet been reified or institutionalized
Scientific Issues

- A rigorous science can take many forms — e.g., predictive mathematical physics vs. case-based descriptive history — but it is generally concerned with issues of:
  - Objectivity
  - Reliability
  - Generalizability
  - Etc.
Objectivity

- The data is automatically logged
- No selective perspective (camera angles, lighting, choice of heard or remembered)
- No interpretive transcription
- Logs can include relevant details of interaction
- Replayer displays everything that was shared by the participants
- Replayer allows extremely detailed analysis
Reliability

- Data sessions with multiple analysts
- Using logs, replayer
- Discuss individual chat postings & moves
- More than standard inter-rater reliability
Generalizability

- Analyst group has experience with many chat and classroom math interactions
- Ethnomethodology argues that utterances and other interactive moves are “accountable”
  - The way they are organized displays to others the means to recognize them as what they are
- Conversation analysis argues that there are necessarily general methods people use
  - Members of a linguistic community share recognizable and identifiable methods for accomplishing everyday interaction tasks
Making Group Proposals

- For instance, in F2F social conversation, groups use various “adjacency pairs”
  - Question/answer, greeting/greeting, proposal/acceptance, ….

- In VMT, math problem solving generally proceeds with math proposals followed by acceptance, question, rejection, alternate, etc.
Establishing Group Order

- Just as sociology (incl. ethnomethodology, activity theory, anthropology) studies how communities establish, maintain, reproduce and evolve social order.
- A theory of group cognition can study how small virtual groups establish, maintain, reproduce and evolve their interpersonal order and how they can accomplish cognitive tasks like working on mathematics.
Summary

- There is a scientific lacuna between sciences of the individual and sciences of communities.
- There are important cognitive achievements at the small-group level of description.
- These should be studied by a science of groups.
- Online small groups are becoming increasingly possible and important in the global networked world.
- A science of virtual groups could help the design of collaborative software for working and learning.
Future Work

- Scale up to regular Math Forum service
- Analysis of four-days of sessions
- Dynamic geometry (geometer’s sketchpad)
- Use with math teacher professional development
- Encourage collaborators to use and study VMT
- Contribute to a science of virtual groups
For Further Information

- http://GerryStahl.net
- Mail to: Gerry.Stahl@drexel.edu
- Slides and pdf of this paper:
  http://GerryStahl.net/pub/group2009.pdf and