Joint organization of interaction within a multimodal CSCL medium

Murat Perit Çakır
PhD Candidate
School of Information @ Drexel University

Outline

- Motivation
- Research Questions
- Conceptual Framework
- Related Work
- Methodology / Case Study
- Results

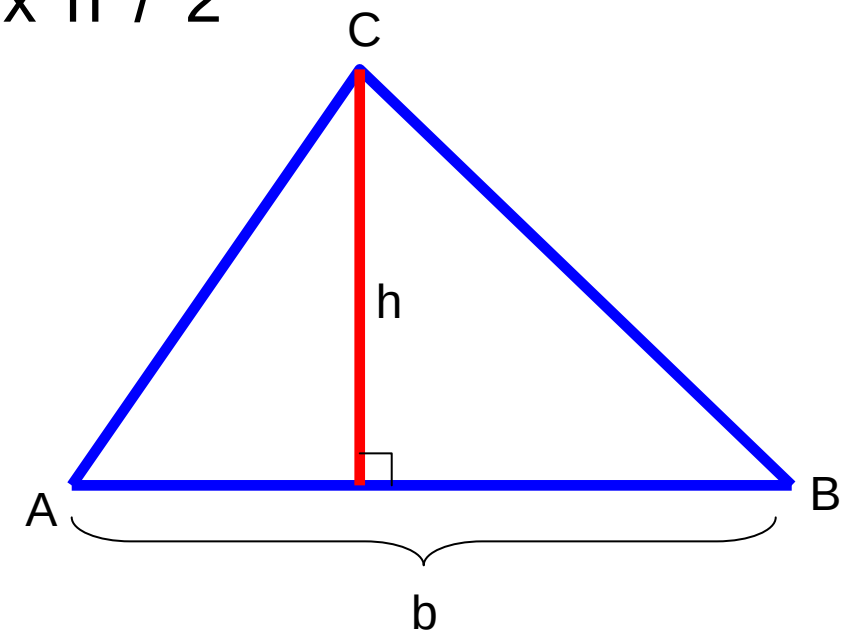
Motivation: Issues in Math Education

- Goal:
  - help students learn math with understanding
- Issue:
  - Students are told about math and asked to remember facts
  - Consequences:
    - Math as an uncontestable body of truth
    - No need to think, just plug in the formula!
- There seems to be a gulf of separation between what mathematicians practice/do and what we teach as math in the classroom

Alberts, B. (2009). Redefining science education. Science, 323, p 437

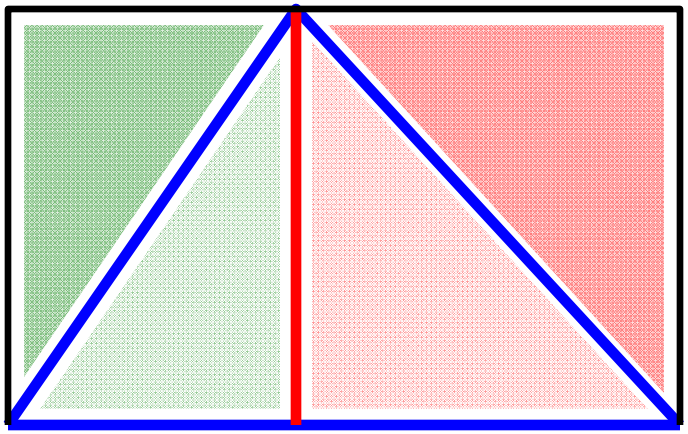
Example: Area of a Triangle

- Triangle area formula
- Area △ABC = b x h / 2
  - b: base length
  - h: height



from Mathematician's Lament (Lockhart, 2009)

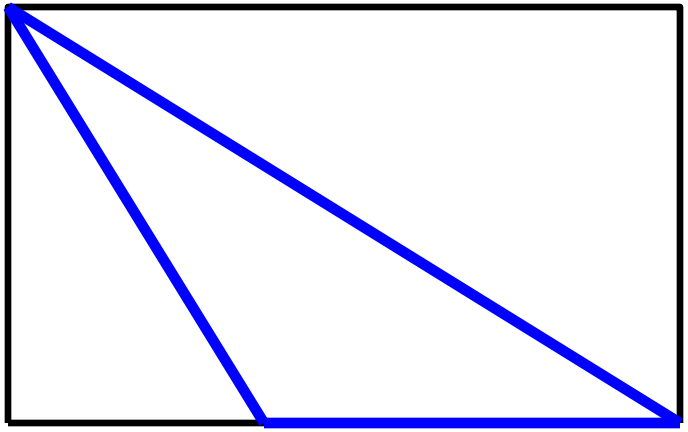
An Alternative Approach



Let's start with a rectangle

Imagine a triangle inside the rectangle

How much of the box does the triangle take up?



There is as much space inside the triangle as outside; so its half the box!

How about if we consider a triangle like this?

The difference?

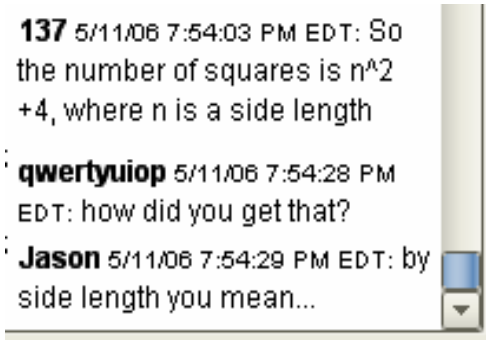
Approach 1	Approach 2
○ Introduces objects like triangle, base, height and area out of the blue ○ The formula of the area is stated as a fact, a question is asked and answered at the same time	○ Constructs a new object by using a familiar object ○ The **area** is introduced through a question ○ The **height** is introduced as a significant problem solving step, not as a given
Memorizing, rule following	Reasoning, rule eliciting

Reform Movements in Math Ed

- How can we support activities that promote math with understanding?
- Desired math skills (NCTM[1], 2000)
  - analyze and evaluate the mathematical thinking and strategies of others
  - communicating mathematical thinking coherently and clearly to peers
  - make and investigate mathematical conjectures
  - construct relationships among mathematical facts and procedures
  - i.e. help students to become active participants in mathematical discourse

[1]*Principles and standards for school mathematics (2000)*. National Council of Teachers of Mathematics (NCTM)

Recommendation: Collaborative PB Solving Activities in the Classroom



- **Practical issues:**
  - **Teachers**
    Difficult to monitor and attend to all teams
  - **Students**
    Mutual orientation to shared artifacts can be problematic
  - Interactions are not recorded, only scribbles on paper remain

Virtual Math Teams

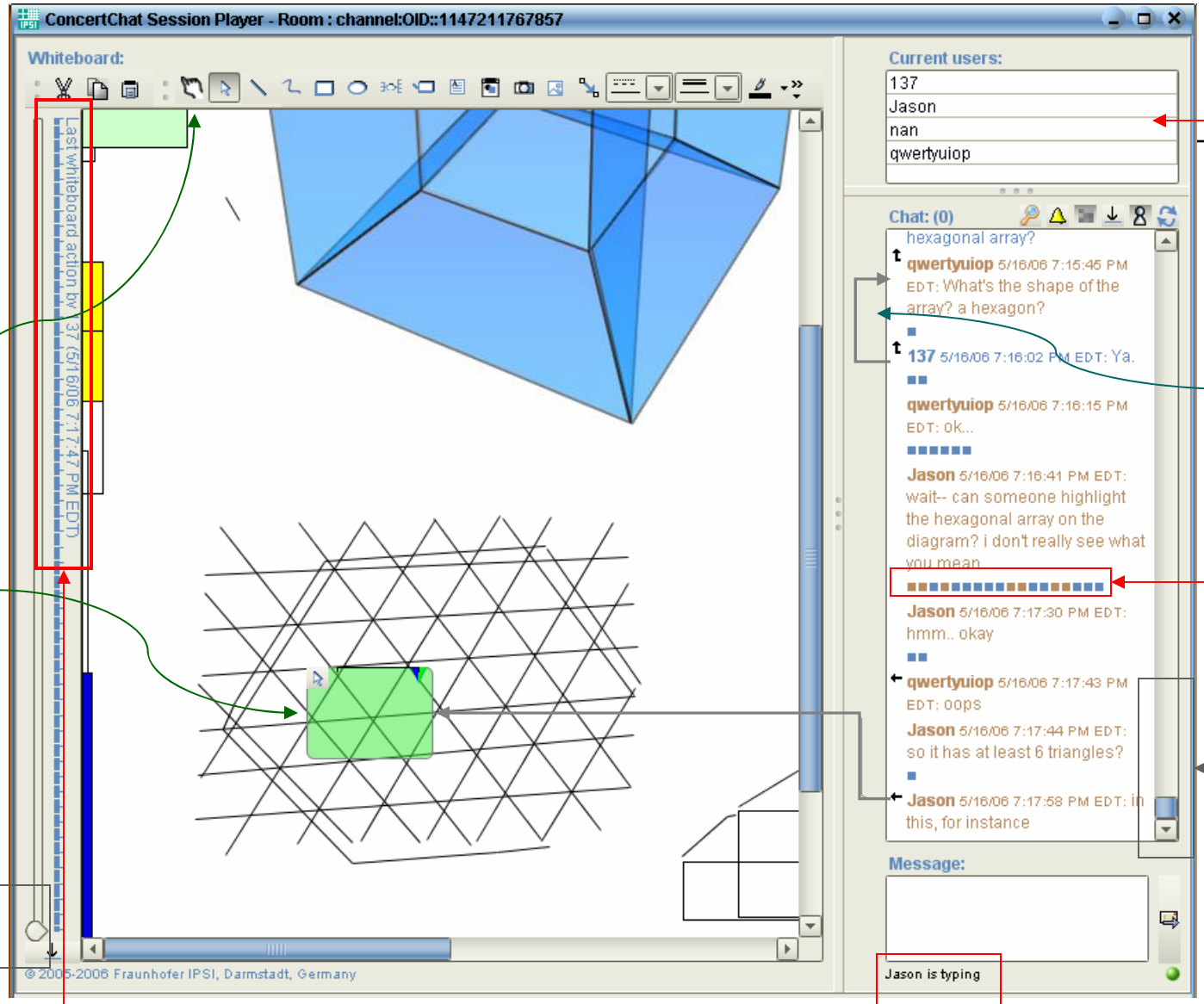
- How can we use **software** to support collaborative math problem solving activities **online**?
- Trade-offs:
  - [+] Instant Messaging, Chat, Social networking sites are popular among students[1] (Lenhart et al., 2007)
  - [–] Systems provide limited communicational resources as compared to f2f
  - [+] Interactions are persistently available for further reflection for both students and teachers
  - [+] Collaborative activities can transcend the classroom

[1]http://www.pewinternet.org/pdfs/PIP_Teens_Social_Media_Final.pdf

Virtual Math Teams

- Joint project of ISchool @ Drexel and the Math Forum
- Math Forum
  - Popular online community devoted to mathematics education
    - students, teachers, mentors
  - Services
    - Problem of the Week → non-routine pbs requiring reasoning
    - Ask Dr. Math → mentorship
    - Math Digital Library → archives since 1992
  - Math discussion is supported asynchronously
    - discussion boards, email
- VMT is a Computer-Supported Collaborative Learning (CSCL) environment where students around the globe who are interested in math can find each other and collaborate on math problems

The VMT Chat Environment



Explicit Referencing Support

Whiteboard Scrollbar

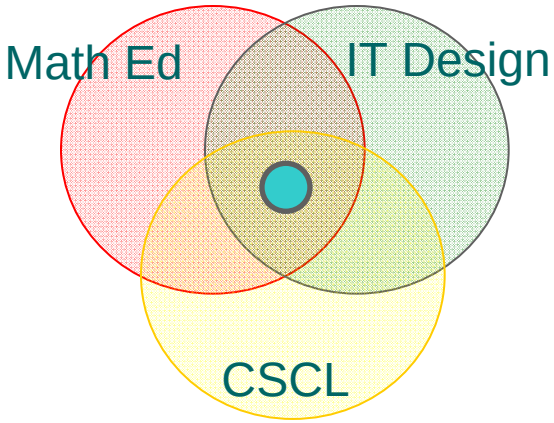
Message to message referencing

Chat Scrollbar

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

- Mathematical Affordances
  - What are the similarities and differences of the different media in VMT (text chat, whiteboard, wiki) for the exploration and use of **mathematical artifacts**?
- Coordination Methods
  - How do groups in VMT **coordinate** their actions across different interaction spaces as they co-construct and manage a shared space of mathematical artifacts?
- Group Understanding
  - How can collaborating students **build shared mathematical understanding** in online environments?

Conceptual Framework

- An **artifact** is a man made thing crafted for a practical purpose
  - brings form and function together
  - locates meaning in practices of use, not inside the head
- Co-construction of math artifacts
  - **Co:** artifacts that are collaboratively constructed and used by the groups rather than individuals
  - **Construction:** math artifacts are not passed from a platonic realm, they are produced and enacted in interaction in relation to the task at hand
- In VMT users interact by exchanging textual, graphical and symbolic artifacts
  - **Affordances** of VMT can be investigated by focusing on how users construct math artifacts in this environment

Evolution of CSCL Research I

- Is collaborative learning more effective than individual learning?
  - Pre/post test experimental design comparing groups vs individuals
  - [+] groups outperform individuals, but not always
- What factors make collaborative learning effective?
  - Independent variables: group size, achievement levels, gender
  - Dependent variable: test performance
  - [-] variables interacted in complex ways, made interpretation of statistical outcomes difficult

Evolution of CSCL Research II

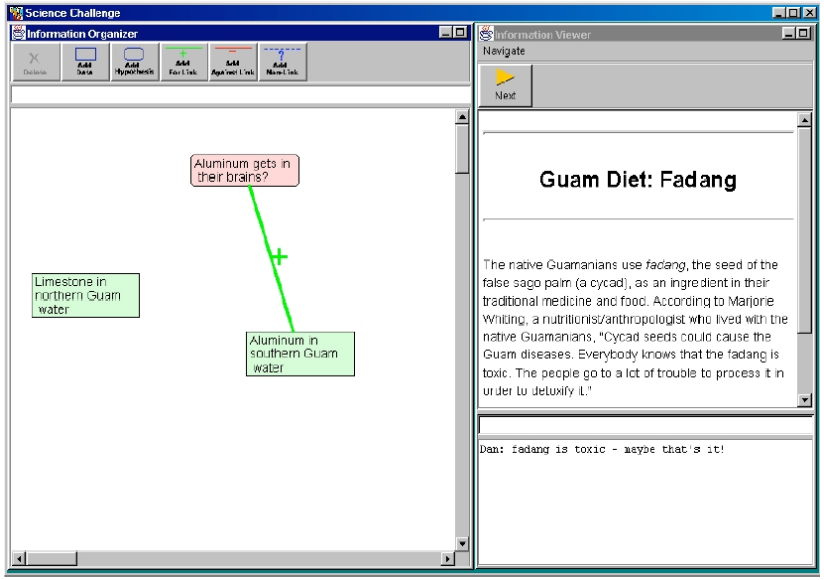
- Previous paradigms treat collaboration as a black box and revealed little insights about its nature
- Analytical focus has shifted to the collaborative learning process itself
- How do users achieve a shared sense of what they are working on in the context of their joint activity?
  - Attempt to construct and maintain of a joint problem space (Roschelle & Teasley, 1995)
  - Building common ground (Clark & Brennan, 1991)
  - Practices of meaning making (Koschmann, 2002)
  - Group cognition (Stahl, 2006)

CSCL Environments for Math Ed

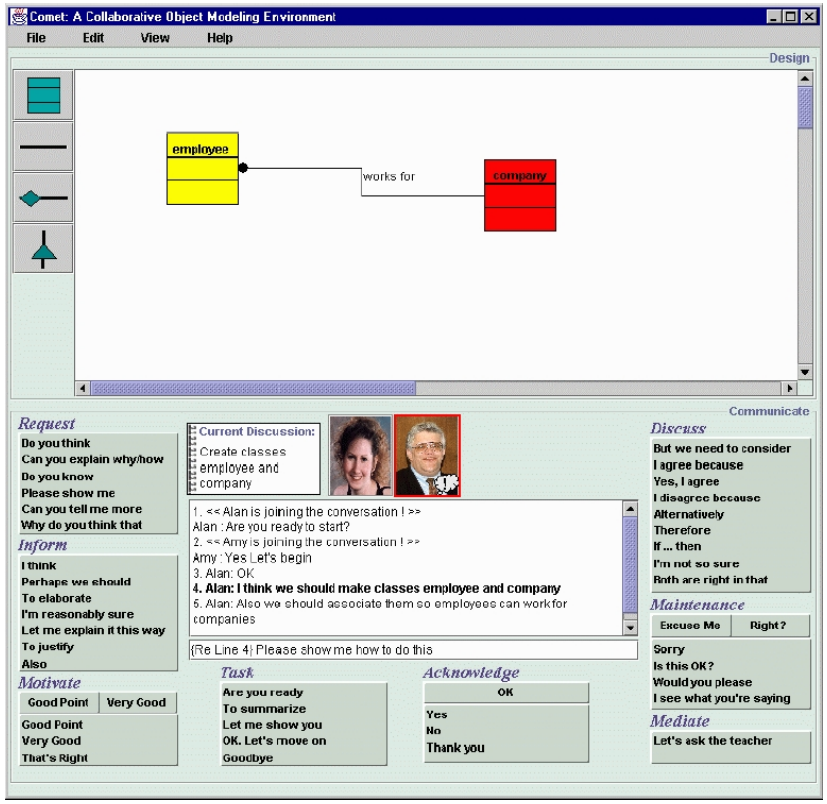
- Knowledge Forum (Moss & Beatty, 2006)
  - Asynchronous online collaboration
  - Students exchange solutions with limited graphical support
- In-class applications with math simulations (Shaffer, 2002; Ares, 2008; Healy & Hoyles, 1999)
  - Hand-held devices, shared terminals
  - Focus is on face-to-face collaboration
- Studies report
  - Improved participation in collective math reasoning
  - Help students realize connections among different solution approaches
- Synchronous tools like chat and shared whiteboards have not been explored to support math problem solving online
  - VMT attempts to address this gap

Multimodal interaction spaces in CSCL

- Integration of two or more online communication technologies
  - e.g. text-chat and a shared workspace
- Many CSCL applications and commercial suites like Wimba, Eluminate offer multiple modalities



Belvedere (Suthers et al., 2003)



Epsilon (Soller & Lesgold, 2003)

Overview of related CSCL research

System	*Features*	*Group Size*	*Task*	*Focus*
EPSILON (Soller & Lesgold, 03)	**Chat** with sentence openers, shared **workspace**	Triads	Object-oriented design	Automated assessment of effective knowledge sharing cases from sequence of codes
Representation v2 (Avouris et al., 03)	**Chat** and shared **workspace**	Dyads	Database design	A formal model that captures all connections among single actions across dual interaction spaces
C-Chene (Baker et al., 99)	**Chat** with sentence openers, shared **workspace**, strict turn taking control	Dyads	Physics problems on the transfer of energy	Facilitating joint attention via strict turn-taking control and sentence openers
Traffic Simulator (Jermann, 02)	**Chat**, shared **simulation**, interaction meters	Dyads	Optimizing traffic flow	The relationship between task and interaction regulation on effective joint work
MOO (Dillenbourg & Traum, 06)	Shared **whiteboard** and **chat** integrated into a moo environment	Dyads	Resolving a murder mystery	The relationship between grounding and problem solving. The use of whiteboard as an extended shared memory for the group.
Belvedere (Suthers et al., 2003)	**Chat** and shared **concept maps**	Dyads	Developing argument maps to describe the spread of a disease	Deictic uses of representational proxies. (Guiding partner's attention to a node by direct manipulation and/or via verbal references in chat)

Approaches in CSCL to analyzing multimodal interaction

- Content Analysis
  - Identify a uniform unit of analysis (e.g. chat line)
  - Categorize (code) units based on rules devised from a theory of communication (e.g. common ground theory, speech acts)
- Bottom-up approach to characterize collaboration
  - Compare groups based on code distributions
  - Correlate codes with outcomes (e.g. post-test scores) to characterize successful collaboration
- Design features that make this kind of analysis possible
  - Constrain user actions to partially automate coding
    - Sentence openers, strict turn taking control
  - Studies mainly focus on dyads located in the same lab
  - Tasks have well-defined ontologies (e.g. Entity-Relationship diagrams) that allow modeling of correct solutions

Typical VMT Use Scenario

- Groups larger than dyads (3-6)
  - Sequential relationships among actions becomes non-trivial due to multiple threads unfolding across modalities
- Open-ended tasks
  - We aim to engage students with inquiry-based math learning
  - Groups are encouraged to raise questions and to come up with their own problems
- No controlled lab setting
  - Users are located at their home/school and have unrestricted access to features of the VMT environment
- In short, we are interested in studying interactional achievements of small groups in complex computer mediations “in the wild” (Hutchins, 1995)

Methodological Implications

- Content analytic approach suits well to do comparative studies of dyads in controlled lab studies with tasks including specific ontological elements
- Filtering actions into codes and then aggregating them back to elicit patterns makes it difficult to take into account:
  - Sequentially unfolding relationships among actions through which groups co-construct new meanings

Methodological Implications (cont.)

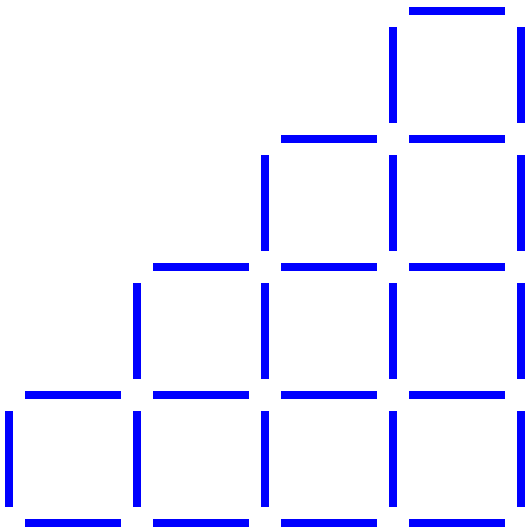
- We opt for a more exploratory approach based on **case studies** of excerpts from VMT sessions
- Ethnomethodological Conversation Analysis
  - Systematic study of order/organization of social action
  - Social actions are meaningful for those who produce them, and thus they have a natural organization that can be discovered and analyzed by close examination (Psathas, 1995; Garfinkel & Sacks, 1970)
  - Goal: explicate the **methods** participants use to organize their actions
- VMT Player
  - Allows us to replay chat sessions and study sequential unfolding of actions in real time

Case Study – VMT Spring Fest

- 5 Virtual Math Teams
  - 3 teams from the US (2+4+3 students)
  - 2 teams from Singapore (4+4 students)
- Upper-middle school, early high school level (14-16 years old)
- Each team completed 4 sessions within 2 weeks
- Students joined the online sessions from their home
- 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:



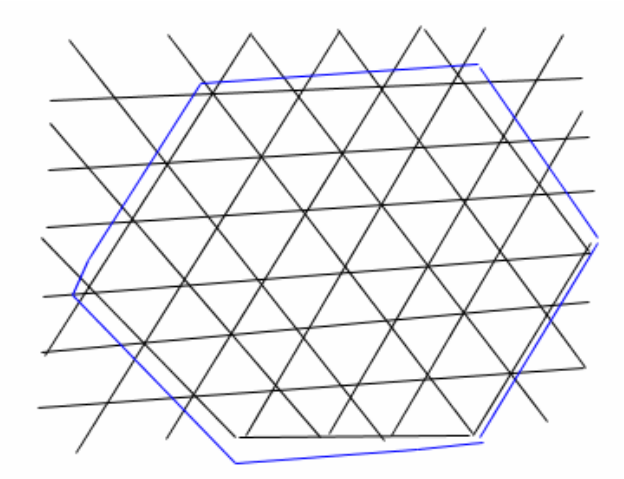
N	Squares	Sticks
1	1	4
2	3	10
3	6	18
4	10	28

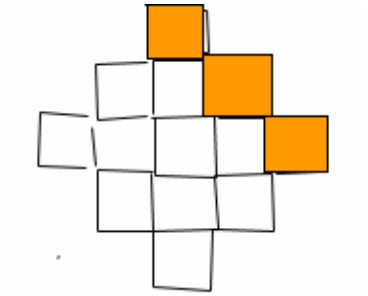
1. How many squares will be in the Nth example of the pattern?
2. How many sticks will be required to make the Nth example?

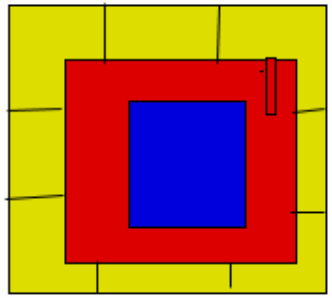
Task Description (cont.)

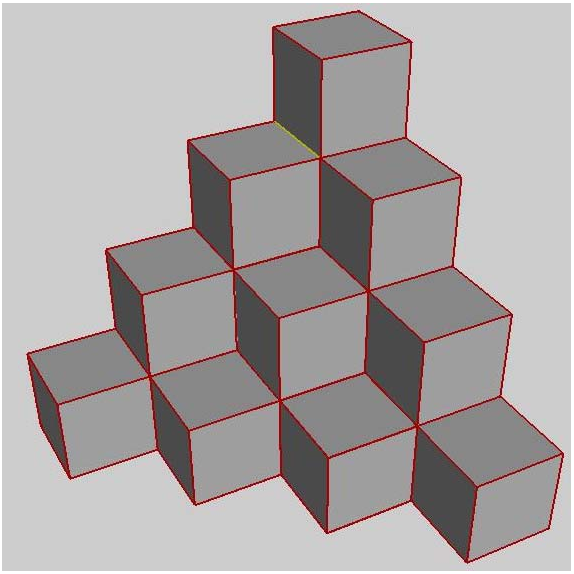
Mathematicians do not just solve other people's problems, they also explore little worlds of patterns that they define and find interesting. Think about other mathematical problems related to the problem with the sticks.

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







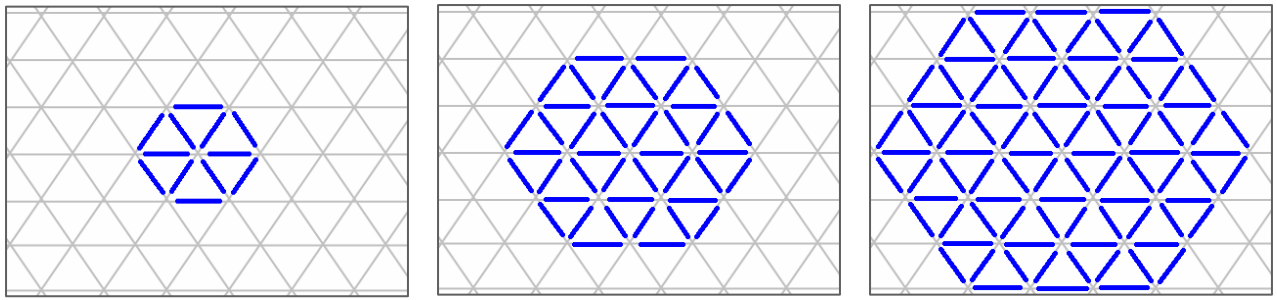


Task Design Rationale

- Allows various solution approaches
  - ranging from simple counting to more advanced methods (e.g. recursion, combinatorics)
- Has both algebraic and geometric aspects
  - various features of the environment could potentially be put into use
- Has an open-ended nature
  - requires teams to discuss and agree upon what would be a mathematically interesting pattern
- Encourages reflection on group work
  - via wiki summaries

Video-clips from a VMT Chat Session

- A team of 3 upper middle school students
  - Qwertyuiop, Jason, 137 (self selected pseudonyms)
- We focus on how they co-construct a new stick pattern that they called **"hexagonal array"**
- Then we will see how they figured out how many triangles are there in the nth case



N=1 N=2 N=3

Excerpt 1

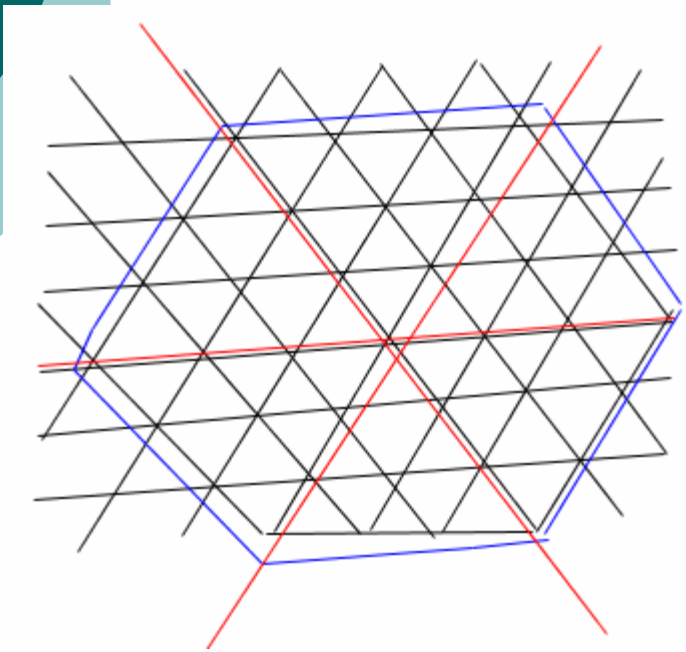
Co-construction of a new stick pattern

Observations on Interactional Organization

- Affordances
  - The whiteboard affords an **animated evolution** of its contents that makes the visual reasoning process available
- Coordination Methods
  - **Indexical-referencing:** isolate objects in the shared visual field and associate them with local terminology
    - 1. Marking the shared drawing to highlight an object
    - 2. Explicitly pointing at a region on the drawing with the referencing tool
- Group Understanding
  - “Hexagonal array” is co-constructed as a meaningful math artifact for the team via sequential organization of the methods listed above

Excerpt 2

Coordination of graphical and narrative realizations



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.

t

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

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

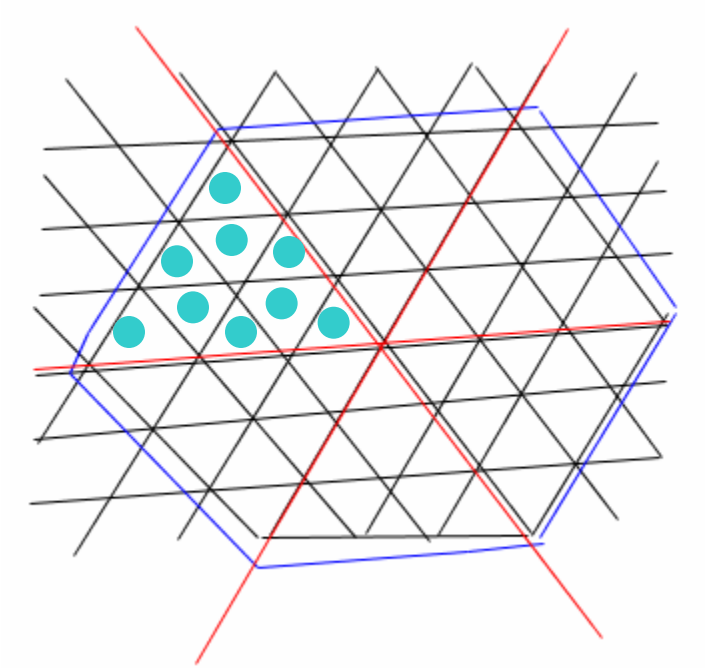
Jason 5/16/06 7:21:03 PM EDT: yup

Observations on Interactional Organization

- Affordances
  - Since users can act only in one space at a time its not possible to narrate a drawing in VMT
  - Diagrams and messages differ in terms of their illocutionary functions in interaction
    - i.e. one cannot “ask a question” with a diagram
- Coordination Methods
  - Temporal proximity of chat and whiteboard actions
  - Use of tokens such as “like” to achieve a relationship between diagrams and chat messages
- Group understanding
  - Whiteboard objects are made relevant to ongoing interaction by chat messages that either
    - Project their production as a next action
    - Refer to available objects

Excerpt 2 (cont.)

Co-construction of a symbolic realization through counting



Jason 5/16/06 7:22:13 PM EDT: so it'll just be x6 for # triangles in the hexagon

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"?

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

137 5/16/06 7:24:49 PM EDT: And there are n terms so... n(2n/2)

137 5/16/06 7:25:07 PM EDT: or n^2

Jason 5/16/06 7:25:17 PM EDT: yeah

Jason 5/16/06 7:25:21 PM EDT: then multiply by 6

137 5/16/06 7:25:31 PM EDT: To get 6n^2

Coordination of graphical and symbolic realizations

- Affordances
  - **Persistence** & **mutability** of shared drawings
  - Unlike chat postings that gradually scroll away, drawings remain in the shared visual field until they are removed.
  - Drawings serve different but related purposes as the session unfolds
- Coordination Methods
  - Verbal referencing
    - “rows” inform a particular way to orient to one of the 6 partitions
    - Motivated a systematic counting method, which associated the diagram with a sequence of odd numbers
- Group Understanding
  - The team co-constructed a formulaic realization of the pattern through counting work informed by previously produced geometric and narrative realizations

Summary

- Recurrent practical concerns for VMT participants w.r.t. math artifacts and media affordances:
  - Identify and produce relevant mathematical artifacts to constitute a common math problem
  - Refer to those artifacts and their relevant features
  - Manipulate and inspect the manipulation of those artifacts based on known math practices

Summary

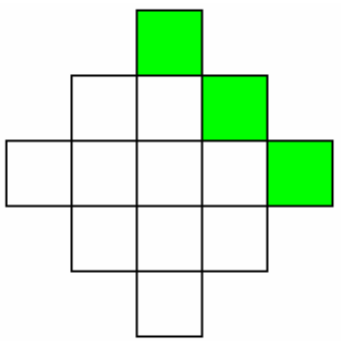
- **Persistent** whiteboard objects and prior chat messages form a shared **indexical ground** for the group members. New actions are interpreted against this shared inbdexical ground.
- By enacting coordination methods groups establish **reciprocity** and hence a sense of **sequentiality** among their actions across multiple interaction spaces
- Groups build shared mathematical understanding by co-constructing mathematical artifacts that incorporate **multiple realizations**

Future Work

- Reflect on the findings of case studies to motivate design decisions to improve VMT
- Enhance mathematical communication
  - Dynamic geometry applications
  - Shared simulations
  - Spreadsheet / plot
- Providing new communication modes is not enough; help users coordinate their actions!
- Improve wiki/chat integration to support knowledge building between teams

The Team's Wiki Posting

For the original problem:
sides: N(N+3)
squares: n(n-1)/2



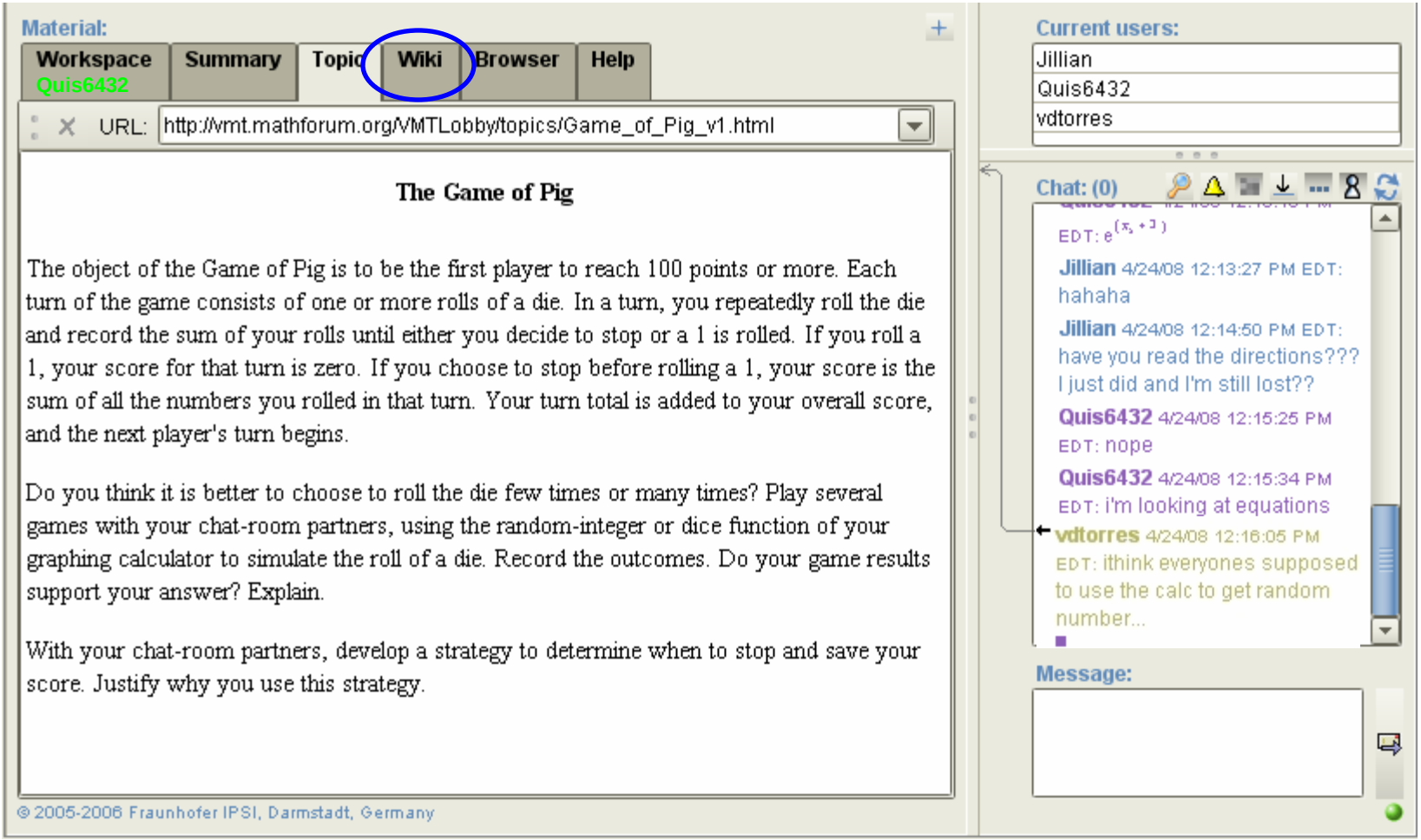
We also found formulas for a diamond-like arangement of the squares:
sides: (n^2+(n-1)^2)*2+n*3-2
squares: n^2+(n-1)^2

By "sides" we mean the three squares a side of the diamond is comprised of.

We decided that while an explicit formula to calculate the number of squares or sides is clearer for calculating, a recursive formula is easier when one is trying to determine how a particular series or pattern grows.

Next, we did a hexagon made of triangles. n is the side length, again.
The number of sides is: 9n(n+1)-6n
The number of triangles is: 6n^2

Towards Better Wiki–Chat Integration



Thank you for your attention

Questions? Comments?

For more information please visit
http://www.mathforum.org/vmt

http://www.pages.drexel.edu/~mpc48/

Overview of Instructional Technology

IT Type	Theory of Learning	Model of Instruction	Epistemological Stance w.r.t. Math Objects	Research Issue	Research Methods
CAI (60s)	Behaviorism	Programmed instruction	Platonism, absolutism	Instructional Efficacy	Pre/post test design, with a Focus on individuals
ITS (70s)	Information processing theory of cognition	One-on-one tutoring	Logic-based modeling, Formalism	Instructional Competence	Pre/post test design with more fine grained measures, with a focus on individuals
Logo (70s)	Cognitive Constructivism	Discovery based learning	Intuitionism, Subjective constructions of individuals.	Instructional Transfer	Protocol analysis (think aloud sessions), design evaluations, pre/post test design, with a focus on the development of an individual across different modeling activities
CSCL (90s)	Knowledge Building, Situated Learning, Social-constructivism	Collaborative Learning	Social co-construction in situ	Instruction as Enacted practice	Design-based research Discourse Analysis Conversation Analysis Focus on social interaction and practices within collectivities

Course management tools (e.g. Blackboard)

Evolution of the VMT System

	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5
Software	AOL IM Chat	Babylon, Blackboard	Concert Chat	VMT Chat v1	VMT Chat v2
New Features	Basic text chat	○ Text Chat ○ Shared drawings	○ Text Chat ○ Shared drawings ○ Referencing	○ Stage 3 features + ○ Awareness ○ MathML ○ Basic Wiki	○ Stage 4 features + ○ Tabs • wiki pages • summary tab • shared browser

Tasks: Math problems designed to stimulate thinking about underlying math concepts rather than rote application of formulas (Combinatorics, Probability, Geometry, Algebra, Calculus)
Users: Middle/High School and College students from US, Singapore, Brazil
Group size: 3-6
Duration: ~1 hour long online sessions facilitated by a VMT member

Ethnomethodological Conversation Analysis

- The goal of this line of analytic work is to discover the commonsense understandings and procedures group members use to organize their conduct in particular interactional settings
- Commonsense understandings and procedures are subjected to analytical scrutiny because they “enable actors to recognize and act on their real world circumstances, grasp the intentions and motivations of others, and achieve mutual understandings” (Goodwin and Heritage, 1990 p. 285)
- Members’ shared competencies in organizing their conduct not only allow them to produce their own actions, but also to interpret the actions of others (Garfinkel & Sacks, 1970)
- Since members enact these understandings/procedures in their situated actions, researchers can discover them through detailed analysis of members’ sequentially organized conduct (Schegloff & Sacks, 1973)