Exploration and Exploitation:

Managing Knowledge in Turbulent Environments

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Goals of This Talk

Exploration, Exploitation, and Knowledge Ecosystems… What Do I Mean?

- provide a background as to my research
- provide definitions and examples

Discuss an In-Depth Study

Relate This Research our Distributed Problem-Solving Networks Research

Background

Strategist (part-time w/ PhD pursuits)

- Centers for Disease Control (CDC) and U.S. Department of Energy
- focused on “knowledge ecosystems”, 2005-2007

IT Chief; Associate Director of Informatics w/ CDC

- Bioterrorism Preparedness and Response Program; HIV/AIDS Prevention
- 2000-2005

Project Manager; Microsoft and Yahoo! Efforts

- 1998-2000

Background

Turbulent Environments = where knowledge-intensive changes occur rapidly with little warning

- no one individual knows enough to mitigate negative outcomes
- no one individual knows enough to capitalize on positive opportunities

Examples:

- 9/11, anthrax events in 2001
- West Nile Virus, SARS, monkeypox in 2003
- bioterrorism, national security emergencies

Turbulent Environments

Turbulent Environments = inter-individual knowledge exchanges must transcend boundaries

- of group proximity
- of individual institutions and social networks

How can human organizations better adapt to turbulent environments?

Turbulent Environments

Exchanges of knowledge allow humans to

- relay thoughts
- relay perceptions of the environment
- adapt

How can human organizations better adapt to turbulent environments?

How can we employ knowledge technologies to improve organizational responsiveness?

Exploration and Exploitation

Seminal article on organizational learning

- written by James G. March (Professor Emeritus, Stanford) in 1991
- his article resulted in over 2,800+ citations

Exploration = organizational use of new knowledge, with an uncertain return

Exploitation = organizational reuse of existing knowledge, with a certain return

Exploration and Exploitation

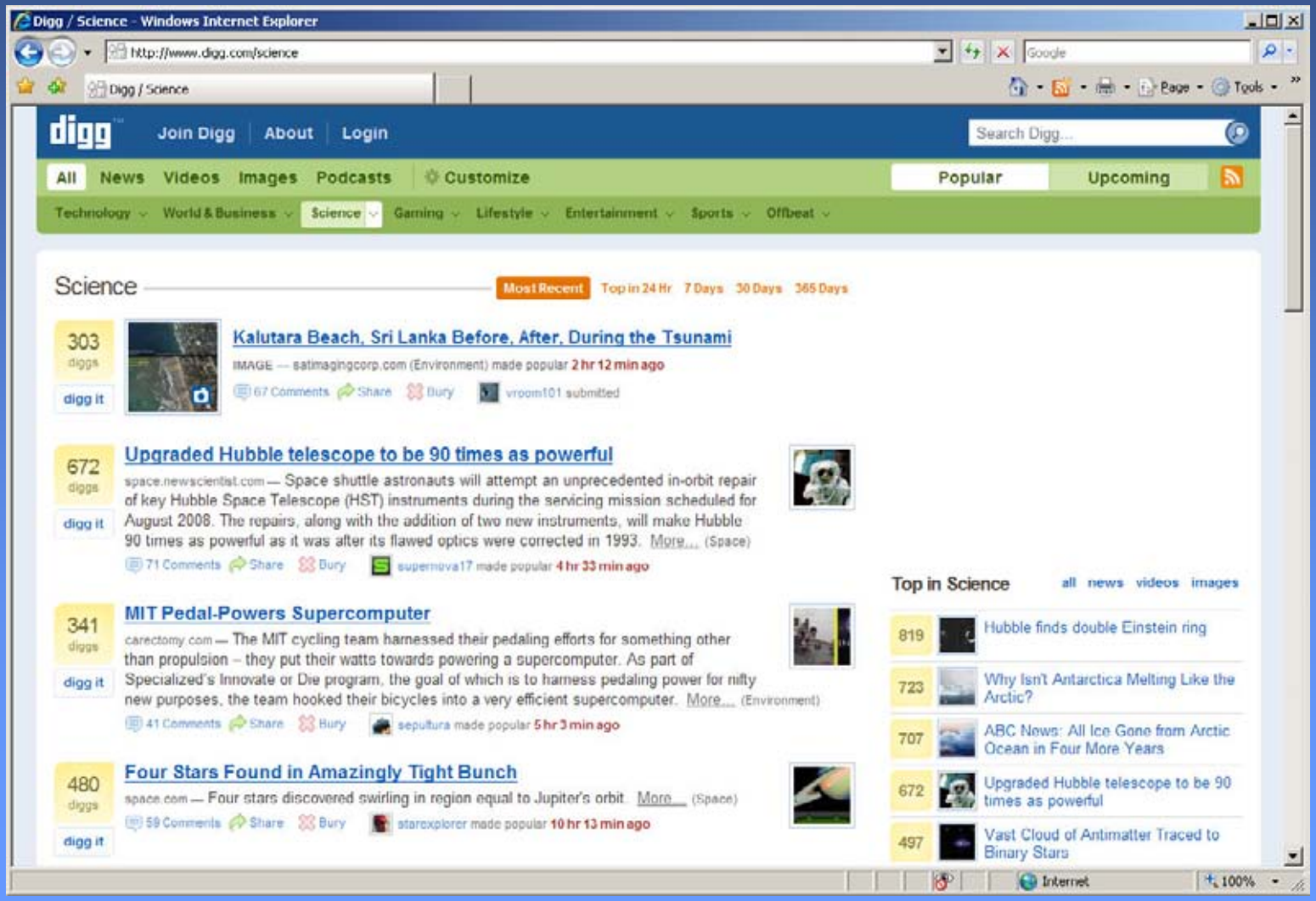
Knowledge = defined as "justified true belief"

- about external reality (in organizational science literature)
- represents the most strategically valuable resource of any organization

Knowledge Technologies = interfaces and systems that enable knowledge exchanges among humans

Knowledge Technologies

Examples: Digg.com



Knowledge Technologies

Examples: Wikipedia.org and Intellipedia

Knowledge Technologies

Examples: Sermo.com

Knowledge Technologies

Knowledge Management Strategy = facilitation of inter-individual knowledge creation and transfer to best "connect the dots"

Organizational Stimuli = include incentives, values, and trust elements to motivate human actors

Knowledge Exchange Processes = knowledge creation, transfer, and protection activities

Knowledge Ecosystems

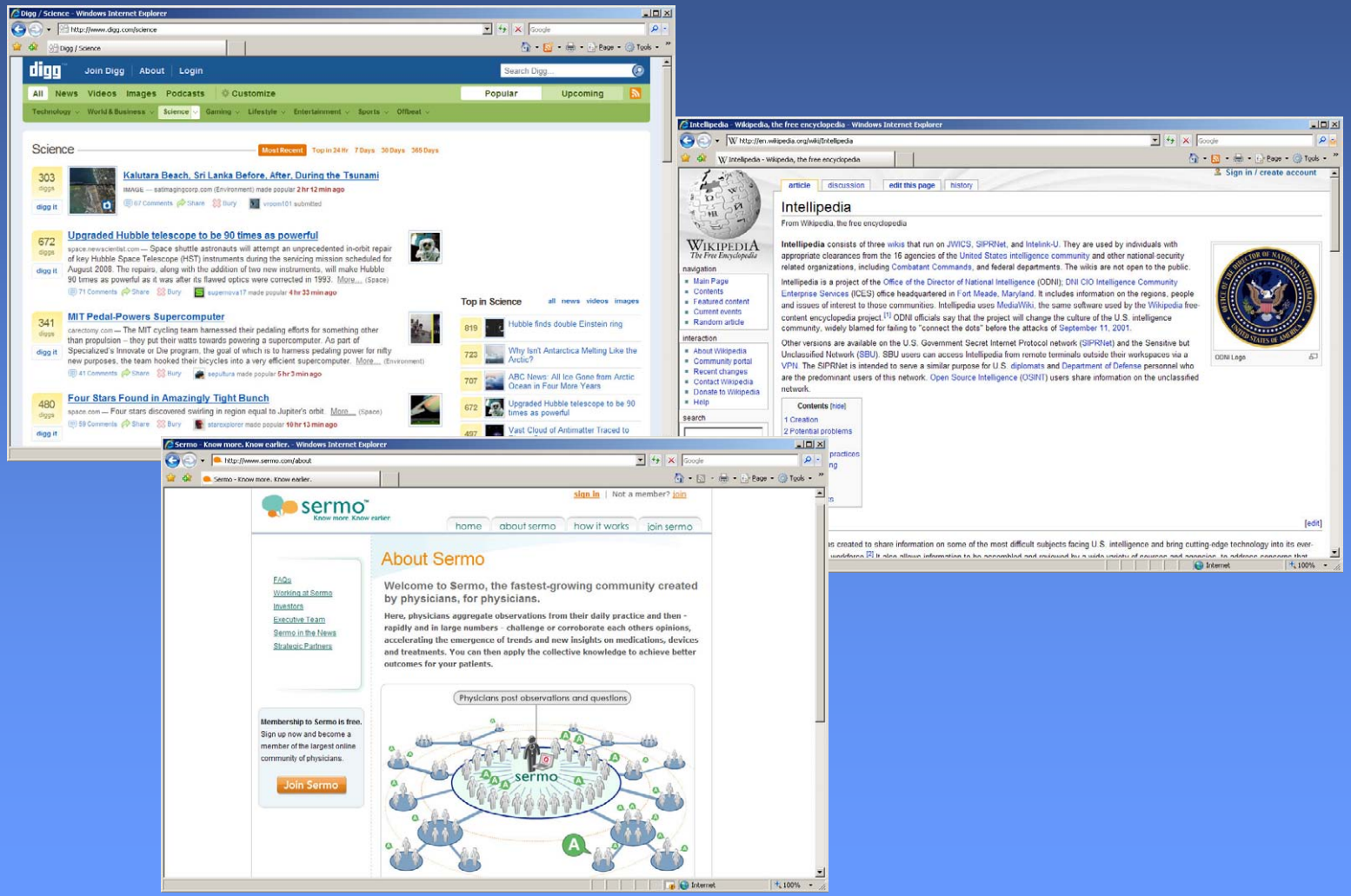
Knowledge Ecosystems = embody a "bottom-up", grassroots approach to cultivating knowledge

Ultimately influence organizational performance, to include responsiveness and efficiency

- comprise technologies, stimuli, and processes
- studying performance represents my PhD research, 3 empirical papers

Knowledge Ecosystems

Examples:



An In-Depth Study

Managing Knowledge in Turbulent Environments

An In-Depth Study

Recall March's (1991) seminal paper, organizational learning modeled as a collective tension:

- exploitation (p1) = refinement of old certainties
- exploration (p2) = experimentation of new alternatives

Organizations that engage purely in exploration suffer experimentation costs with little benefit; pure exploitation may become trapped in a "rut"

An In-Depth Study

Recall March's (1991) seminal paper, organizational learning modeled as a balance:

- exploitation (p1) = reuse of existing knowledge, with a certain return
- exploration (p2) = use of new knowledge, with an uncertain return

Regarding org performance, March predicted exploitation (p1) to be positive in the short-term

…but negative in the long-term…

An In-Depth Study

Individual reality

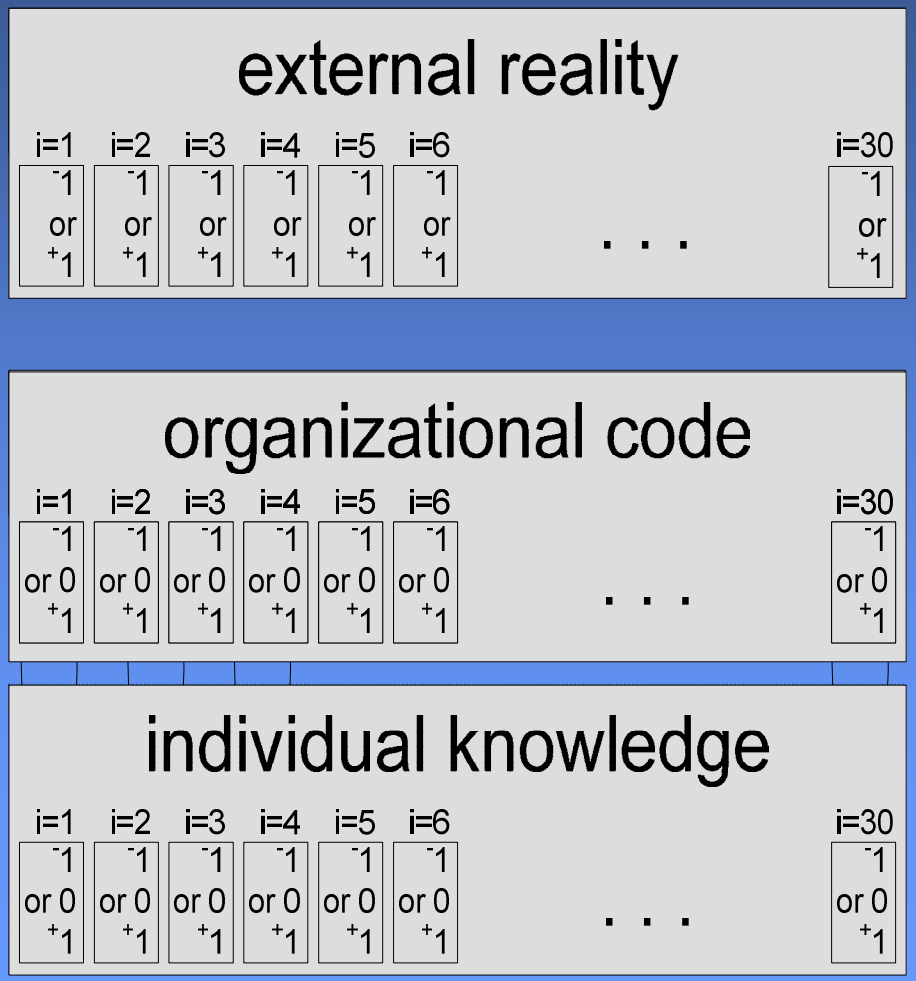
- m dimensions, each independent of one another
- can be either {-1}, {0}, {+1}, with {0} as neutral or no opinion
- n individuals in org, each initially with random values

Organizational code

- m dimensions, each independent of one another
- can be either {-1}, {0}, {+1}
- code represents collective knowledge of the org, initially all {0}

The Seminal Model

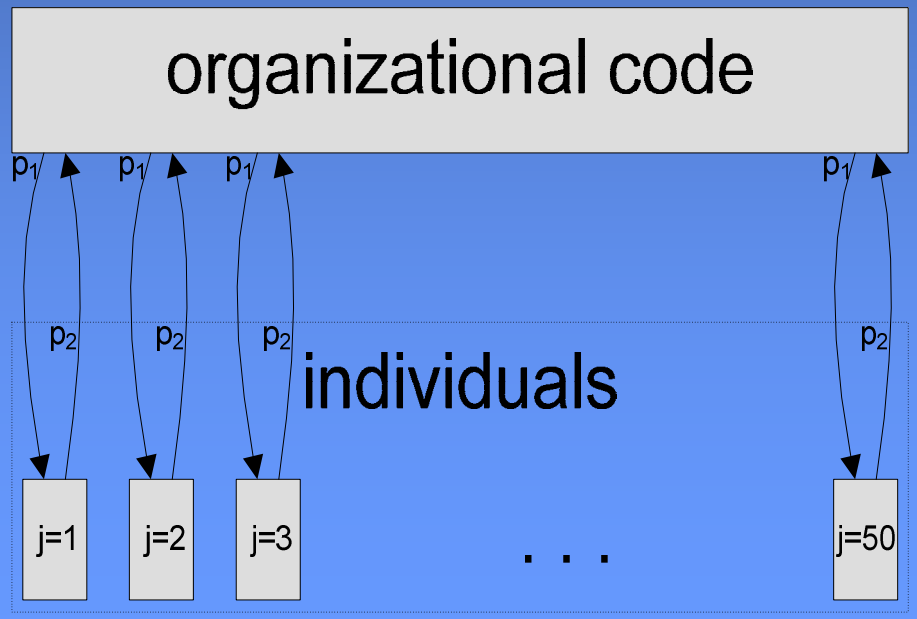
Org code and individual knowledge can learn



The Seminal Model

Organizational learning

- neither org code nor individuals directly see true external reality
- org code can only change belief to match best (expert) individual
- yet org may adopt an incorrect dimension from an expert in err



The Seminal Model

Turnover

- revolution or significant deviation in an individual's beliefs regarding reality
- March considers both "no" and "moderate" levels of turnover

Environmental Turbulence

- allows examination of how well the org maintains situational awareness
- theatres of operation can change

The Seminal Model

Turnover

- for each iteration, probability (p3) individual will be replaced
- new individual has a random collection of knowledge (i.e., beliefs)

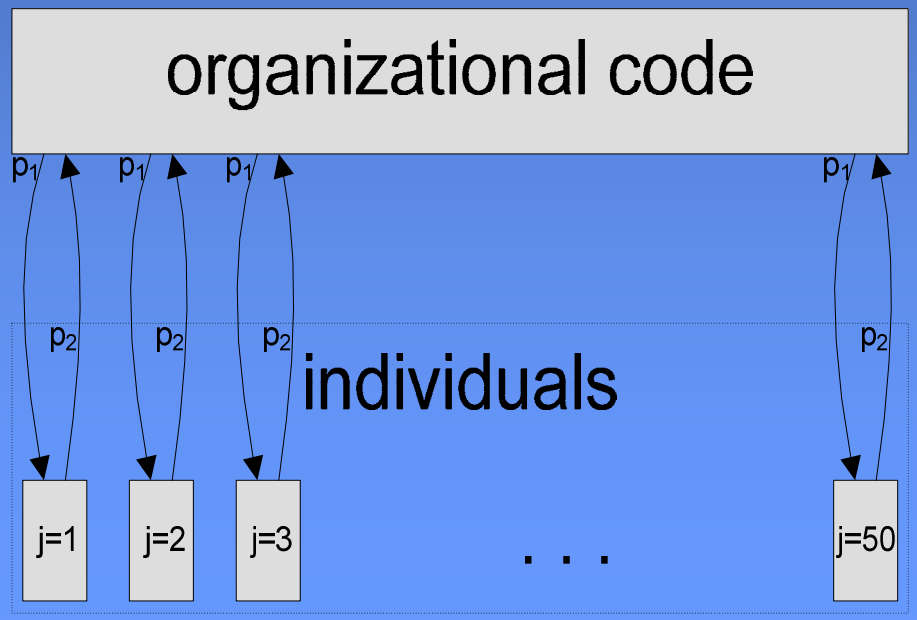
Environmental Turbulence

- for each iteration, probability (p4) a dimension of reality will "flip"
- each flip can be from either {-1} → {+1} or from {+1} → {-1}

This Study: Extending the Model

March's model only considered a flat organization

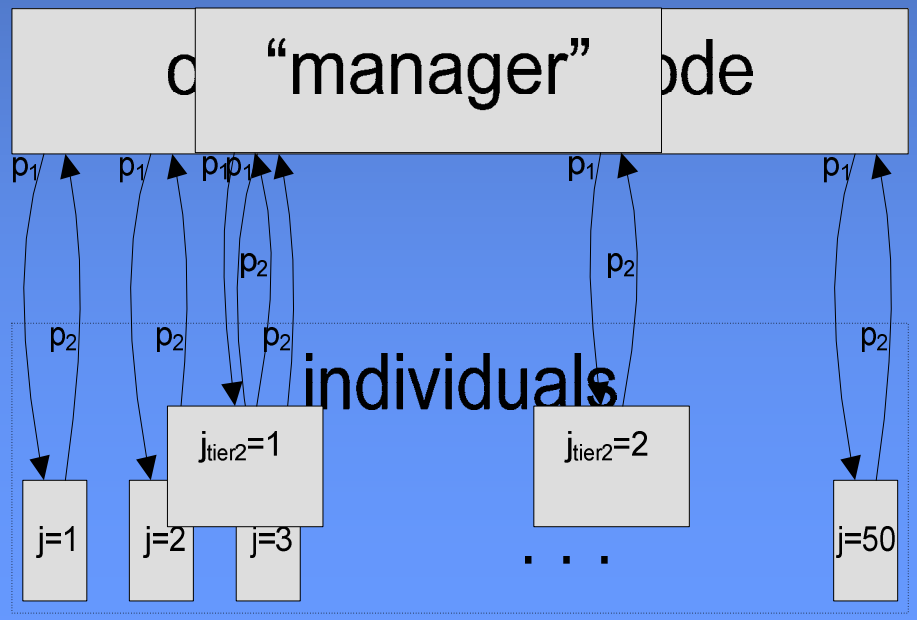
- no reporting structure between individuals
- no use of technology to try and manage knowledge



This Study: Extending the Model

Consider a reporting structure

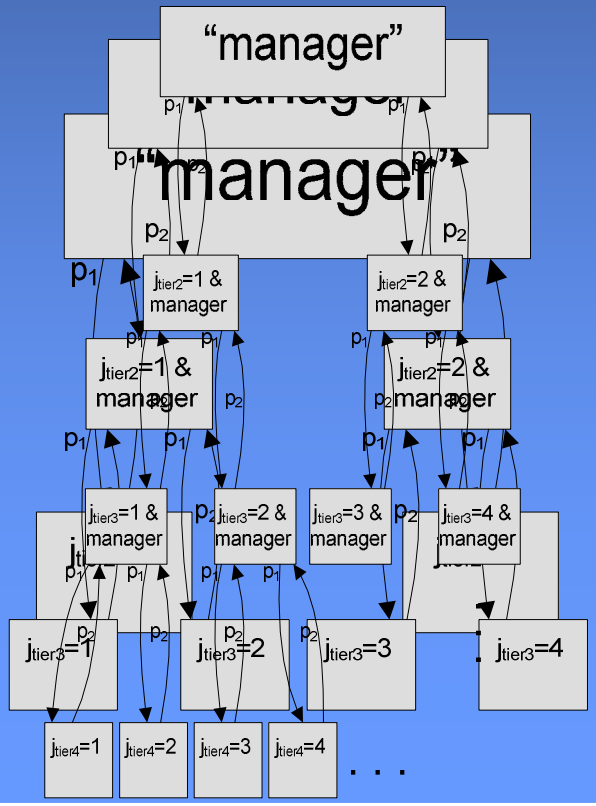
- org code becomes a manager to a set of (b) reporting individuals
- each direct report still has a probability (p1) of learning from their manager
- each manager has a probability (p2) of learning from expert report



This Study: Extending the Model

Consider a reporting structure

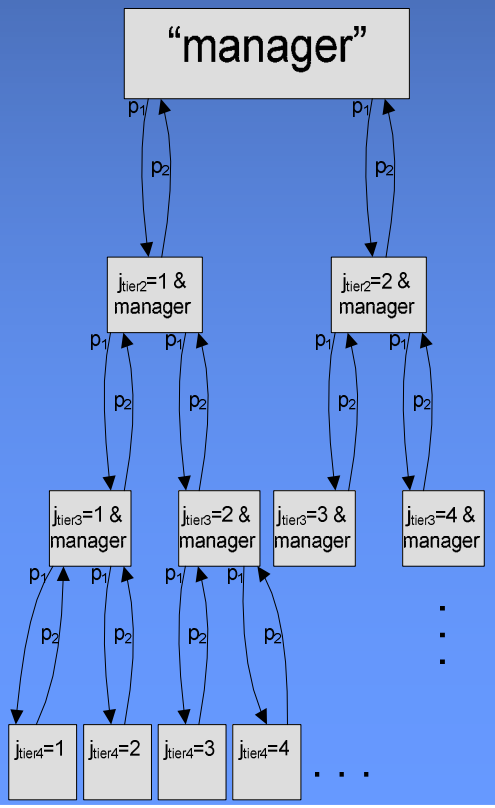
- a report can in turn become a manager to other reporting individuals
- each direct report still has a probability (p1) = exploitation
- each manager has a probability (p2) = exploration from direct reports



This Study: Extending the Model

Allows for multi-tier organizational hierarchies

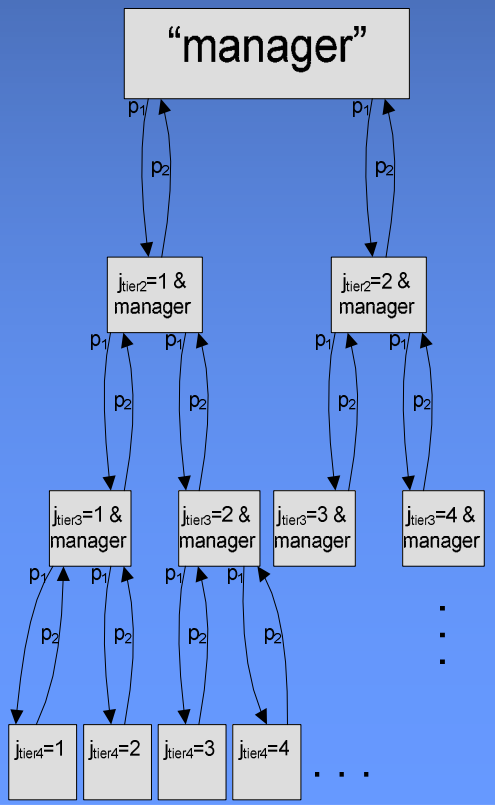
- what effect does increasing the depth of a hierarchy (d) have?
- what effects do turnover (p3) and turbulence (p4) now have?

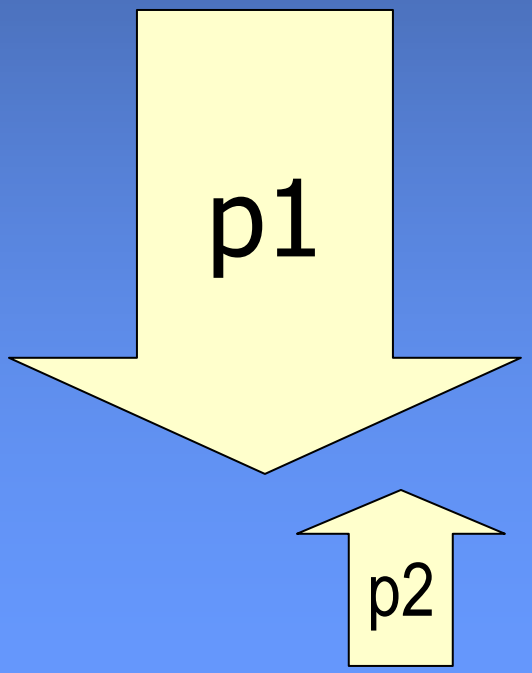


This Study: Extending the Model

Can now evaluate a "top-down" knowledge management strategy

- high exploitation (p1)
- low exploration (p2)

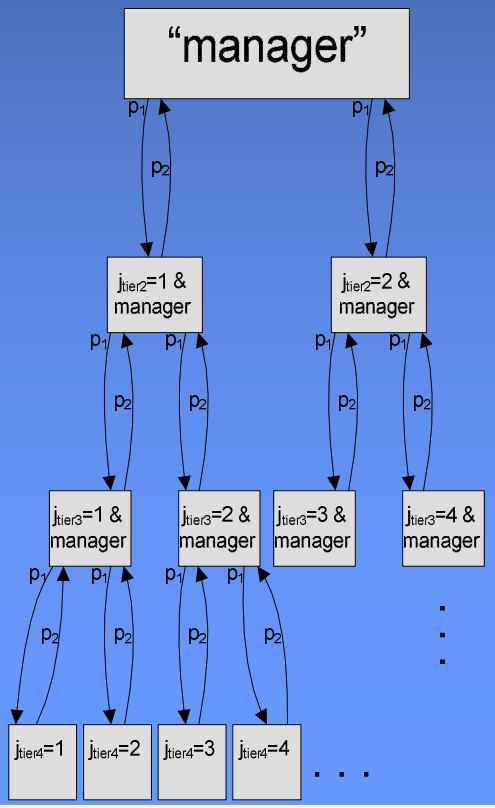


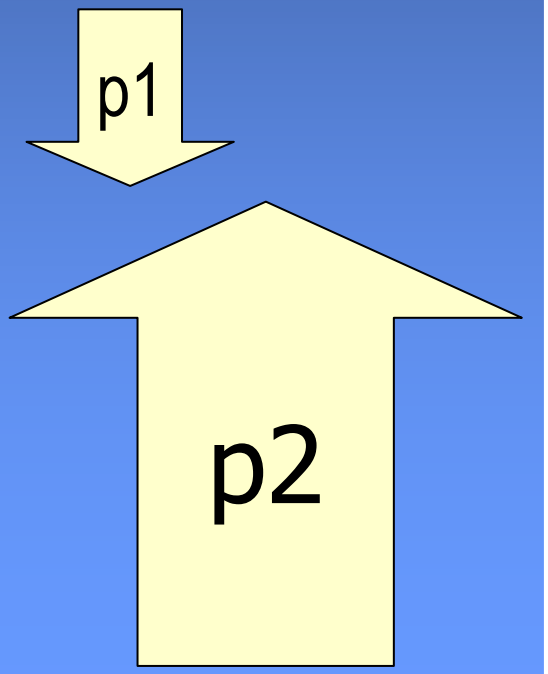


This Study: Extending the Model

Can now evaluate a "bottom-up" knowledge management strategy

- low exploitation (p1)
- high exploration (p2)





What About Knowledge Technologies?

March's model excludes consideration of knowledge technologies to help with organizational learning and situational awareness

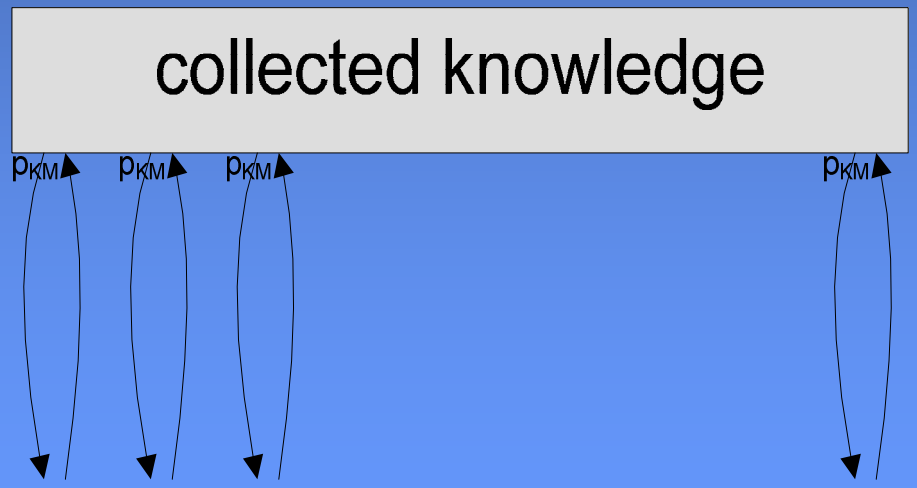
Consider the impact of knowledge technologies

- what effect does increased frequency of use have?
- what effect does including the knowledge of more experts have?

What About Knowledge Technologies?

Extend model to consider norms of use of knowledge technologies in an organization

- collect the average knowledge of the top (rEX)% expert individuals
- make this collected knowledge available to all managers in org
- each manager has a probability (pKM) of learning from this resource



Hypotheses and Methods

Expect to find

- fragmentation of knowledge in a multi-tier hierarchical organization
- multiple tiers lead to inefficient knowledge exchange
- multiple tiers lead to inefficient knowledge flow delay

With knowledge technologies

- norms of use will counter environmental turbulence
- best norms of use will not be “heavy” use (incur an over-dependence)
- best norms of use will include “top” 1% experts (vs. 10% or 100% of org)

Hypotheses and Methods

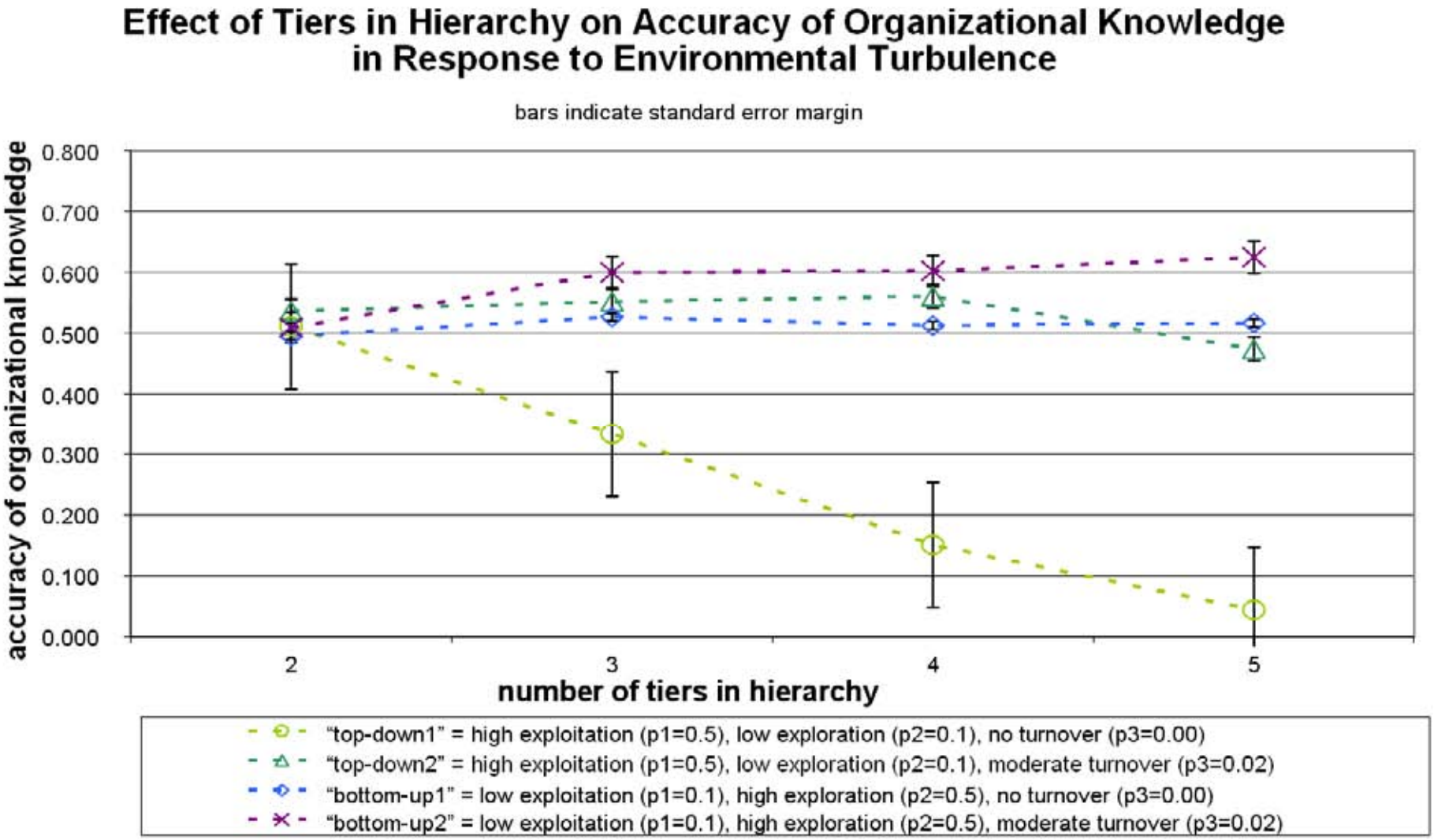
Build simulation per stated extensions

- validate that simulation matches March's original results
- then test extensions for a flat and multi-tier hierarchy
- report observed relationships

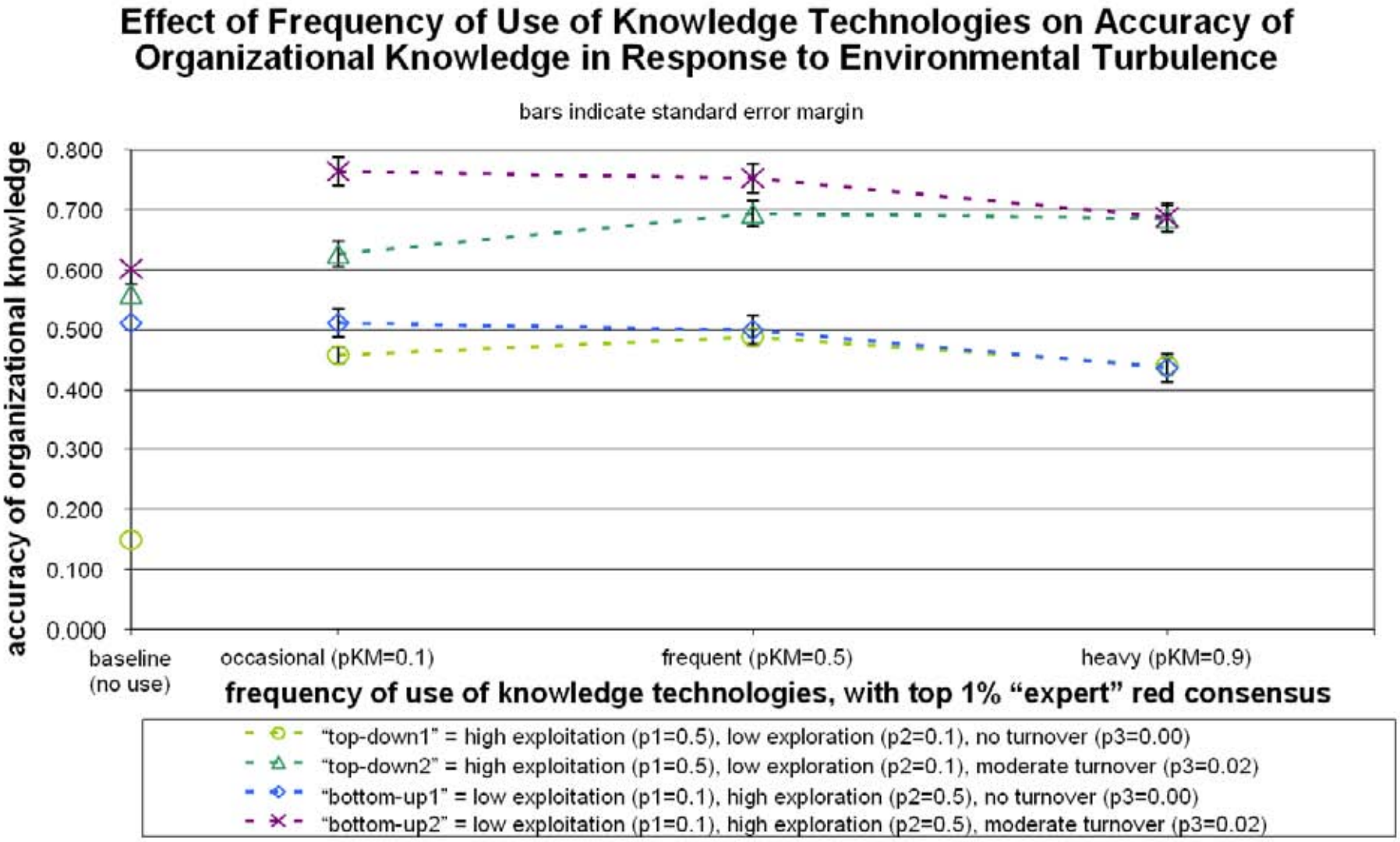
Simulation coded in Microsoft .NET

- creates model exactly as specified
- outputs results for analysis

Results


Effect of Tiers in Hierarchy on Accuracy of Organizational Knowledge in Response to Environmental Turbulence
bars indicate standard error margin
accuracy of organizational knowledge
0.800
0.700
0.600
0.500
0.400
0.300
0.200
0.100
0.000
2
3
4
5
number of tiers in hierarchy
"top-down1" = high exploitation (p1=0.5), low exploration (p2=0.1), no turnover (p3=0.00)
"top-down2" = high exploitation (p1=0.5), low exploration (p2=0.1), moderate turnover (p3=0.02)
"bottom-up1" = low exploitation (p1=0.1), high exploration (p2=0.5), no turnover (p3=0.00)
"bottom-up2" = low exploitation (p1=0.1), high exploration (p2=0.5), moderate turnover (p3=0.02)

Results


Effect of Frequency of Use of Knowledge Technologies on Accuracy of Organizational Knowledge in Response to Environmental Turbulence
bars indicate standard error margin
accuracy of organizational knowledge
0.800
0.700
0.600
0.500
0.400
0.300
0.200
0.100
0.000
baseline (no use)
occasional (pKM=0.1)
frequent (pKM=0.5)
heavy (pKM=0.9)
frequency of use of knowledge technologies, with top 1% "expert" red consensus
"top-down1" = high exploitation (p1=0.5), low exploration (p2=0.1), no turnover (p3=0.00)
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Results

Considered 6,000 possible organizations

- samples drawn from random population of all organizational knowledge management strategies

Coefficients[a,b]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	.658	.006		117.572	.000		
	probP1	.170	.014	.300	12.330	.000	.176	5.688
	probP2	.124	.006	.215	21.039	.000	1.000	1.000
	probP3	2.118	.118	.182	17.875	.000	1.000	1.000
	probP4	-5.646	.118	-.488	-47.876	.000	.999	1.001
	interactP1Depth	-.055	.003	-.446	-17.104	.000	.153	6.549
	countBreadth	-.001	.000	-.297	-21.028	.000	.520	1.922

a. Dependent Variable: corrOrgCMatch

b. Weighted Least Squares Regression - Weighted by countDepth

Results

Negative performance impacts

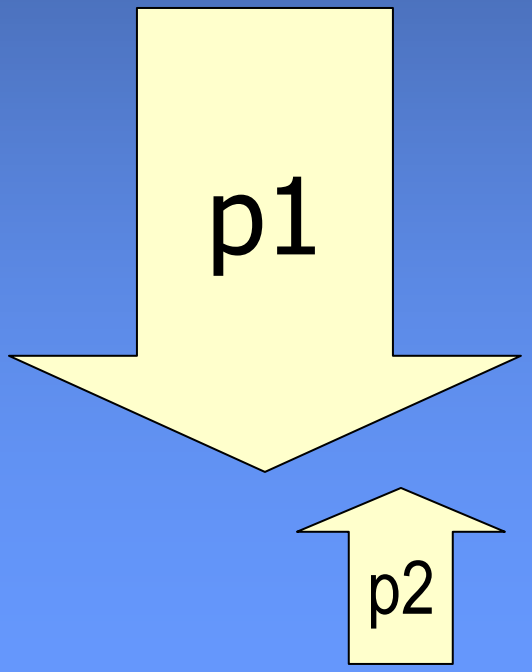
- increasing exploitation has negative consequences for multi-tiered organizations, but not for flat organizations on average
- this reduction in accuracy increases as the number of tiers increase

Coefficients[a,b]

Model		Unstandardized Coefficients		Standardized Coefficients
		B	Std. Error	Beta
1	(Constant)	.658	.006	
	probP1	.170	.014	.300
	probP2	.124	.006	.215
	probP3	2.118	.118	.182
	probP4	-5.646	.118	-.488
	interactP1Depth	-.055	.003	-.446
	countBreadth	-.001	.000	-.297

a. Dependent Variable: corrOrgCMatch

b. Weighted Least Squares Regression - Weighted by countDepth



Results

Positive performance impacts

- a moderate level of turnover is beneficial
- across the board, a “bottom-up” strategy of low exploitation and high exploration best counters environmental turbulence

Coefficients[a,b]

Model		Unstandardized Coefficients		Standardized Coefficients
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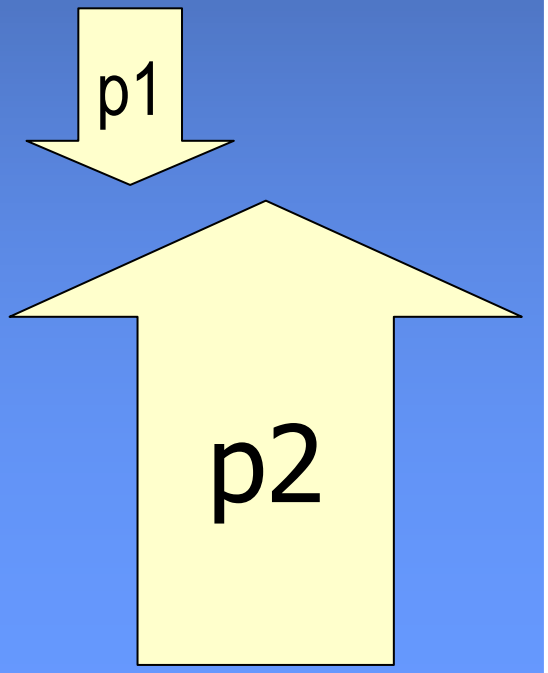


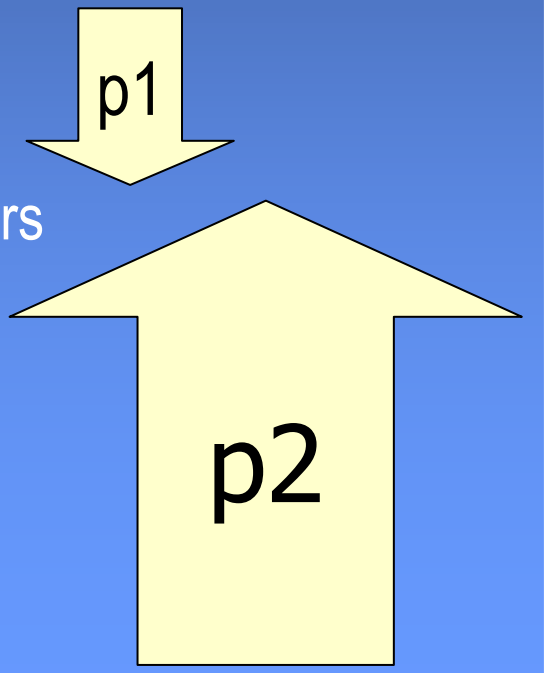
Results

Constraints on successfully employing knowledge to best adapt is mediated by

- organizational design
- use of knowledge technologies

Organizations need to balance

- fast and slow (less likely to conform to org code) learners
- less about management per se, more about cultivation



Relating This to Research at OII

Managing Knowledge in Turbulent Environments

Relating This to Research at OII

Global Trends 2015 Report

"The networked global economy will be driven by rapid and largely unrestricted flows of information, ideas…"

Relating This to Research at OII

Global Trends 2015 Report

"Less and less control over flows of information, technology, diseases, migrants, arms, and financial transactions..."

Relating This to Research at OII

Global Trends 2015 Report

"Effective governance will increasingly be determined by the ability and agility… to exploit increased information flows, new technologies..."

Relating This to Research at OII

Increasing fragmentation leads to knowledge gaps

- with bioterrorism response = more 90 different U.S. agencies involved
- with national security = 16 different U.S. intel agencies, spending $43+ billion
- with energy and environmental security = problems of a global scale

How can our government and business organizations "connect the dots" better?

…top-down strategies are insufficient…

Relating This to Research at OII

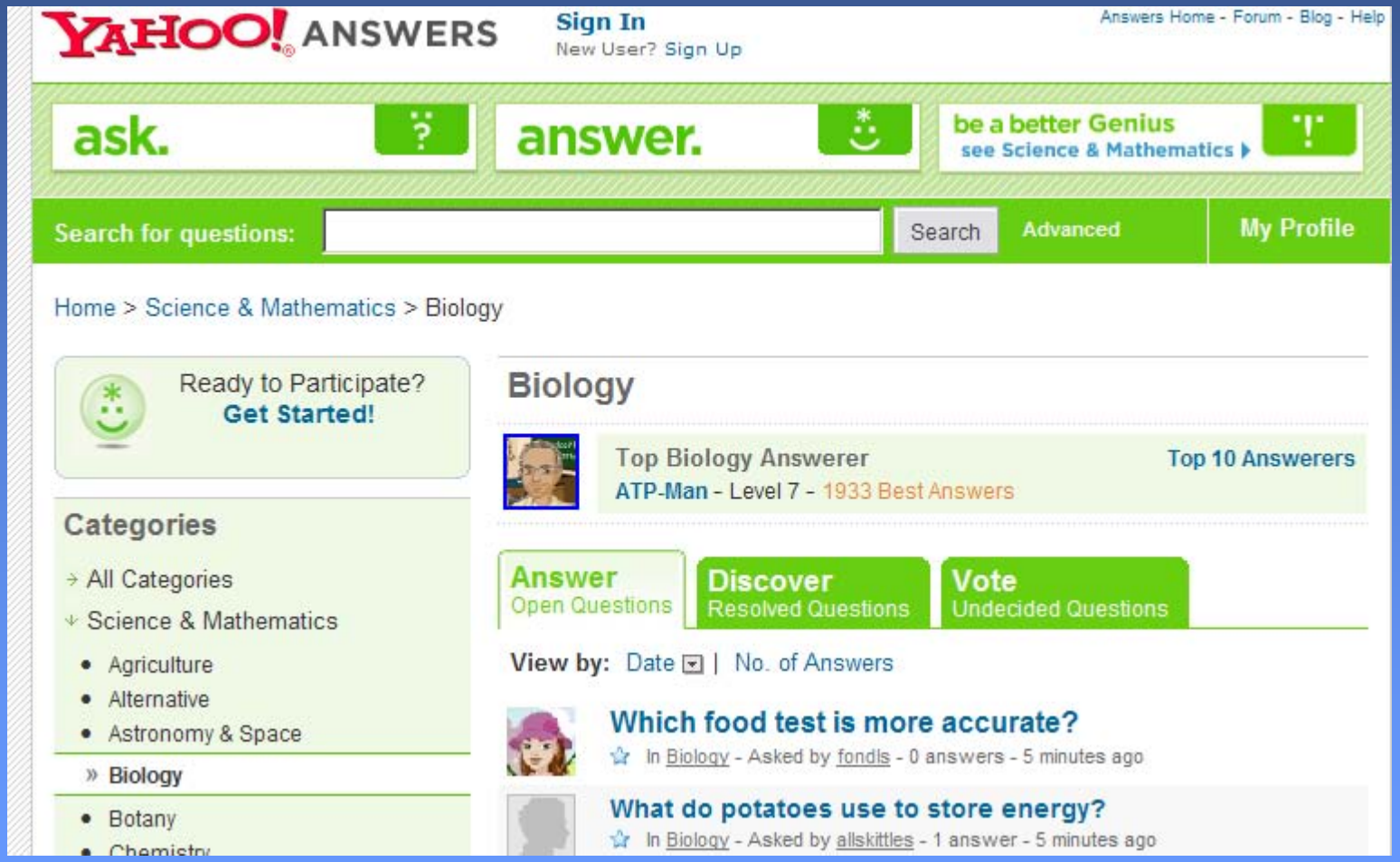
Pioneering bottom-up tools are already present

- reputation systems, prediction markets
- collective intelligence systems, attention economies
- open source collaborations, problem solving forums

Distributed problem-solving networks and knowledge ecosystems to improve intra- and inter-organizational responsiveness

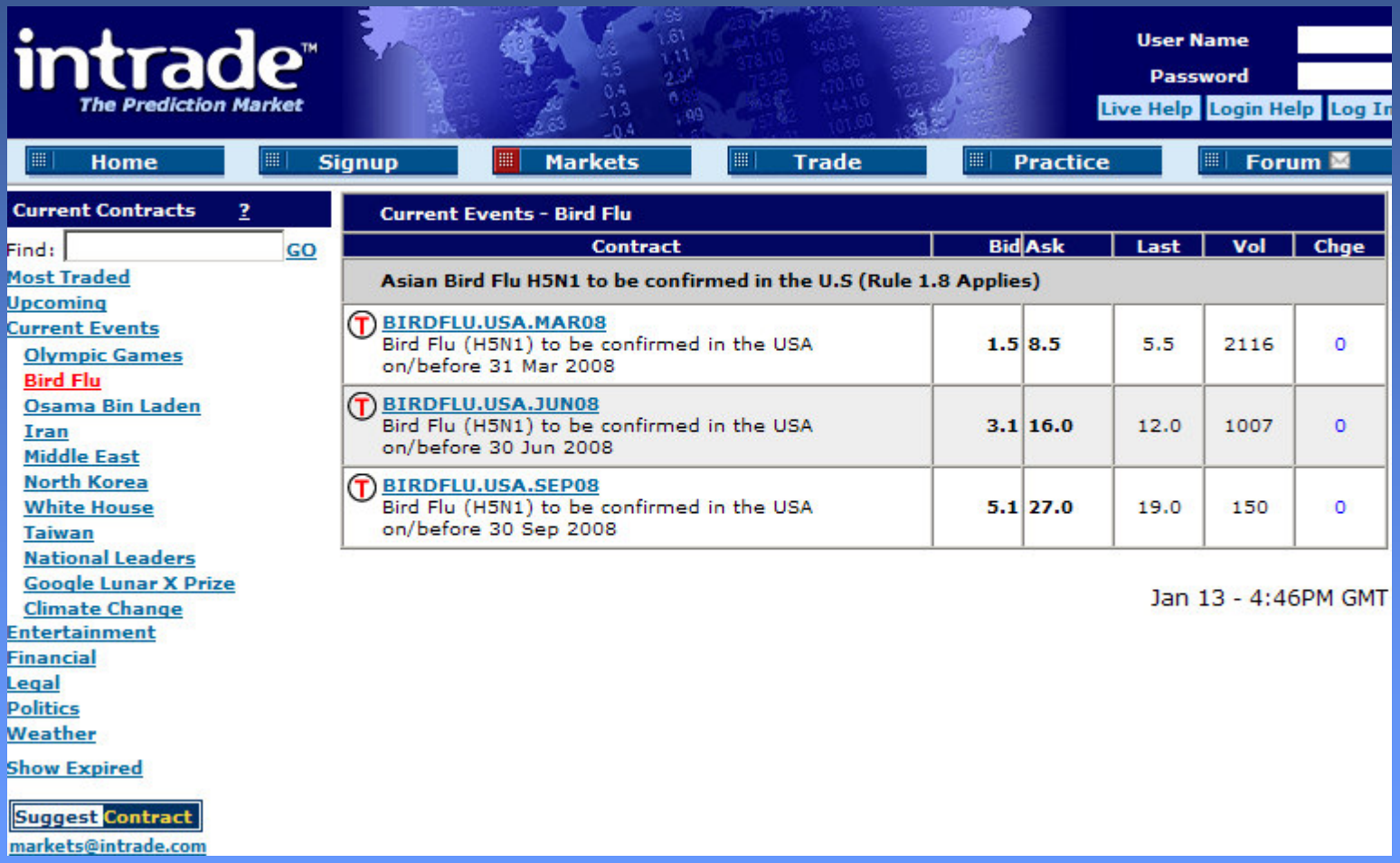
Knowledge Ecosystems In Action

Reputation Systems: Y! Answers, Digg.com



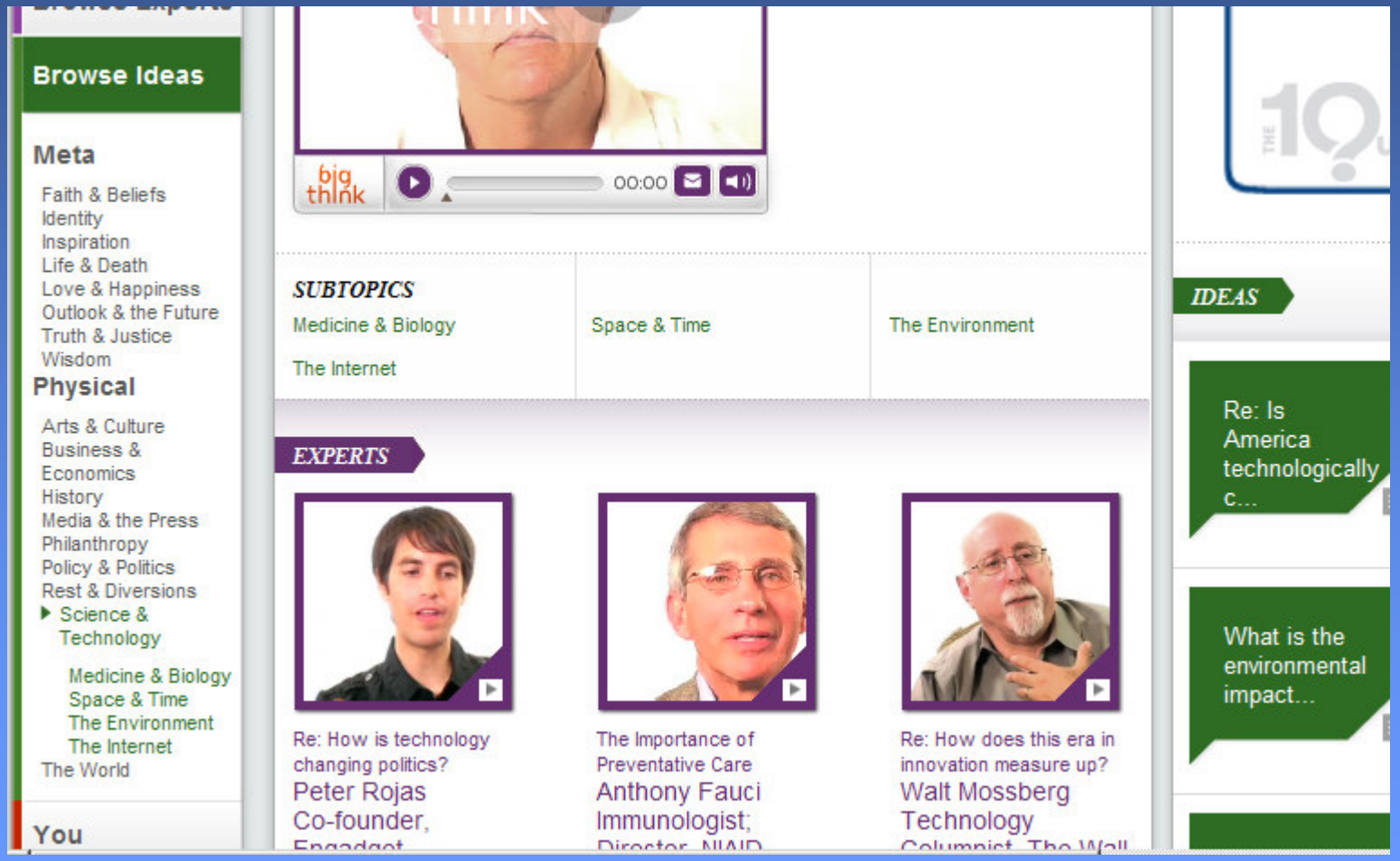
Knowledge Ecosystems In Action

Prediction Markets: intrade, Foresight Exchange



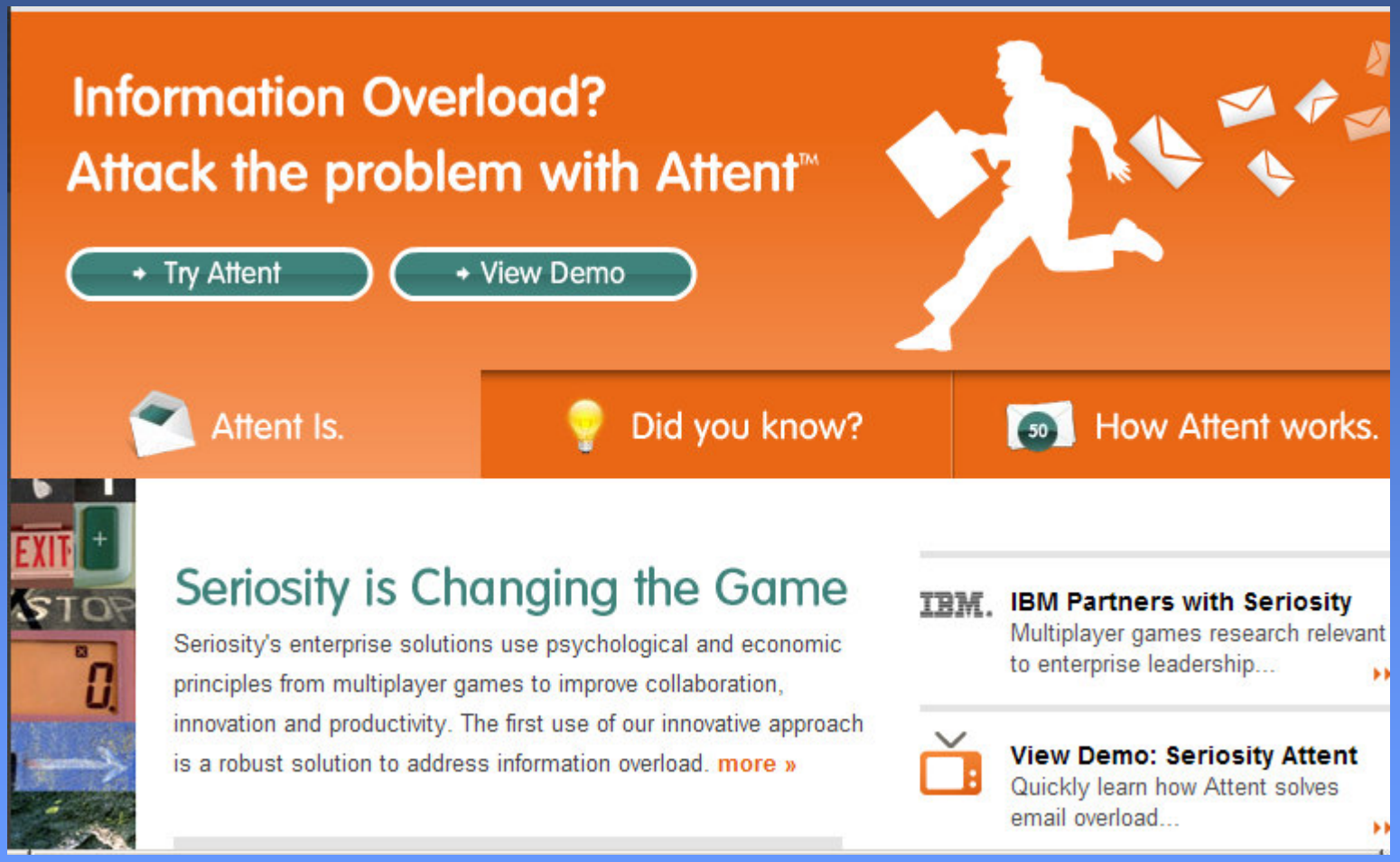
Knowledge Ecosystems In Action

Collective Intelligence Systems: bigthink, Sermo



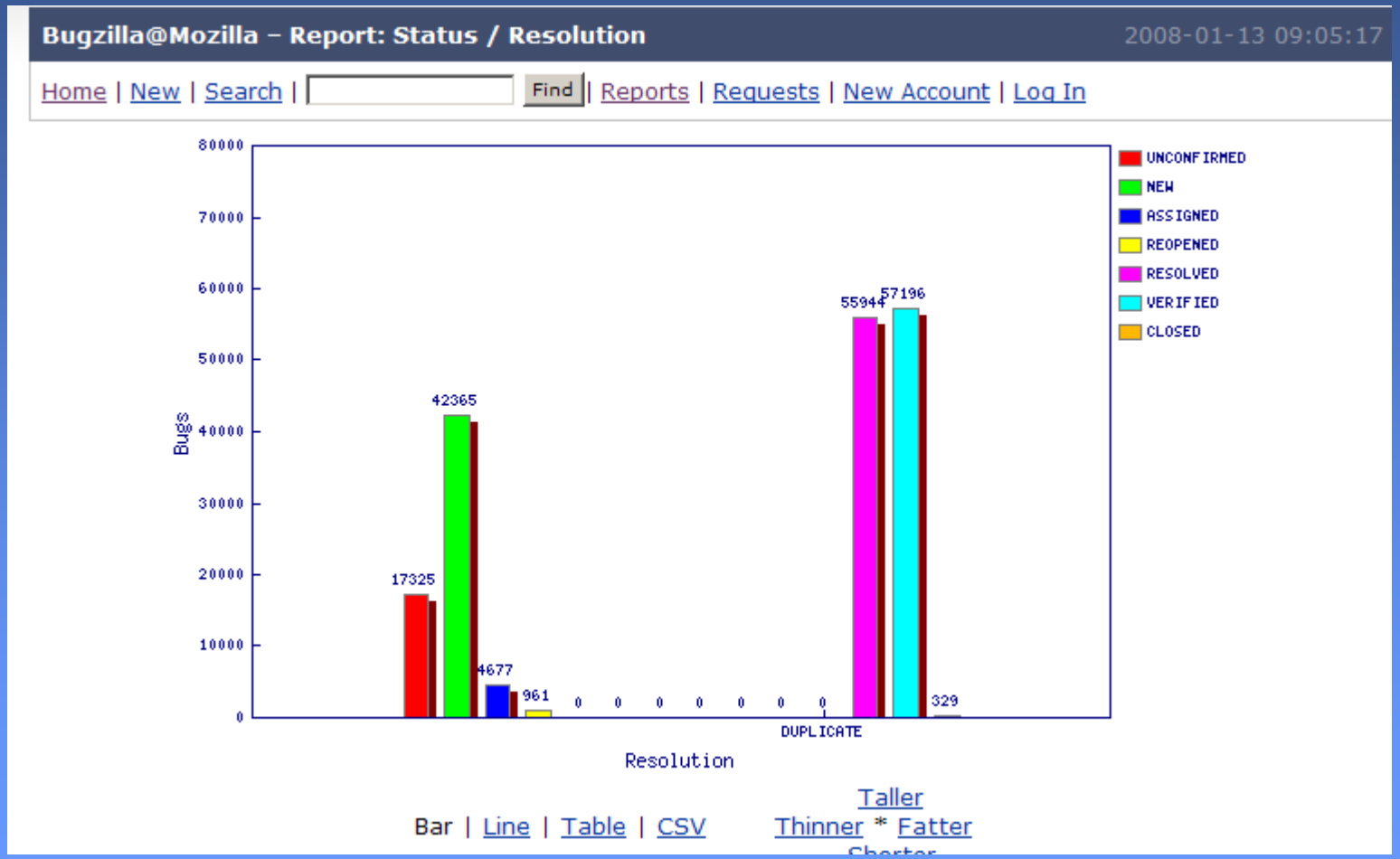
Knowledge Ecosystems In Action

Attention Economies: Seriosity



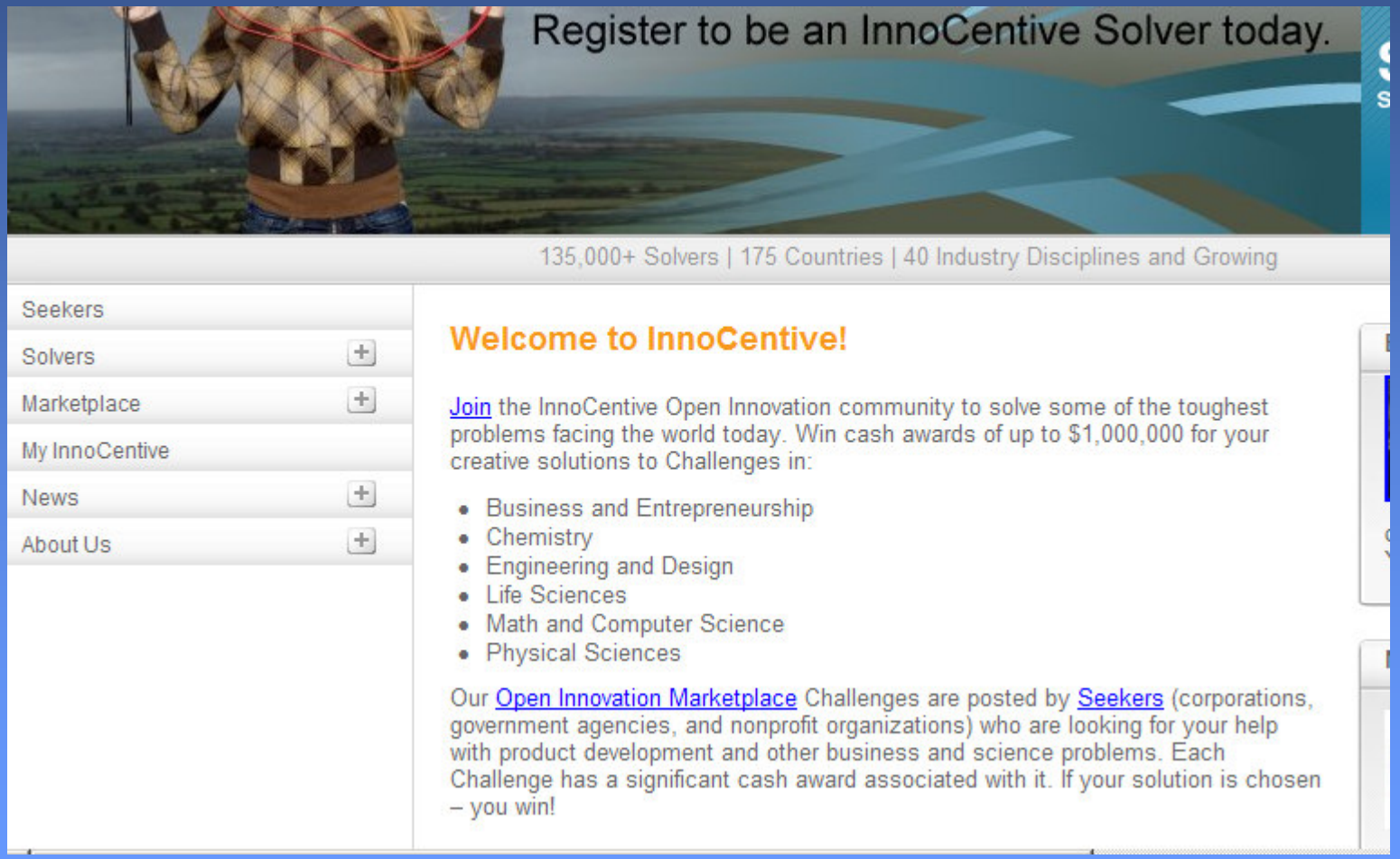
Knowledge Ecosystems In Action

Open Source Collaborations: Bugzilla, Wikipedia



Knowledge Ecosystems In Action

Problem Solving Forums: InnoCentive, SourceForge



Towards the Future

Consider how our organizations can best leverage technologies, stimuli, and processes to improve

- public health preparedness and outbreak response
- national security and counter-terrorism efforts
- global energy and environmental security
- improved inter-agency collaborations
- strategic intelligence and foresight efforts

Towards the Future

Additional references:

- Heckscher, C. and Adler, P. The Firm as a Collaborative Community: Reconstructing Trust in the Knowledge Economy, Oxford, UK: Oxford University Press, 2006.
- Kerr, R., Wolfe, T., Donegan, R., and Pappas, A. “A Holistic Vision for the Analytic Unit,” Studies in Intelligence (50:2), 2006, pp. 47-55.
- Majchrzak, A., Jarvenpaa, S., Hollingshead, A. “Coordinating Expertise Among Emergent Groups Responding to Disasters,” Organization Science (18:1), 2007, pp. 147-161.

questions? (dbray@bus.emory.edu)