Research Methods -III: Computing Paradigms

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Paradigm Shifts in Computing:
Drivers of Change: Moore's Law

CPU Transistor Counts 1971-2008 & Moore's Law

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Paradigm Shifts in Computing:
Drivers of Change: Universality of Computation

WORLD INTERNET USAGE AND POPULATION STATISTICS					
World Regions	**Population (2010 Est.)**	**Internet Users Dec. 31, 2000**	**Internet Users Latest Data**	**Penetration (% Population)**	**Growth 2000-2010**	**Users % of Table**
Africa	1,013,779,050	4,514,400	110,931,700	10.9 %	2,357.3 %	5.6 %
Asia	3,834,792,852	114,304,000	825,094,396	21.5 %	621.8 %	42.0 %
Europe	813,319,511	105,096,093	475,069,448	58.4 %	352.0 %	24.2 %
Middle East	212,336,924	3,284,800	63,240,946	29.8 %	1,825.3 %	3.2 %
North America	344,124,450	108,096,800	266,224,500	77.4 %	146.3 %	13.5 %
Latin America/Caribbean	592,556,972	18,068,919	204,689,836	34.5 %	1,032.8 %	10.4 %
Oceania / Australia	34,700,201	7,620,480	21,263,990	61.3 %	179.0 %	1.1 %
WORLD TOTAL	6,845,609,960	360,985,492	1,966,514,816	28.7 %	444.8 %	100.0 %

http://www.internetworldstats.com/stats.htm (site visited 28th April 2008)

Paradigm Shifts in Computing:
Drivers of Change: Social Networks

If all U.S. Internet time were condensed into one hour, how much time would be spent in the most heavily used sectors?
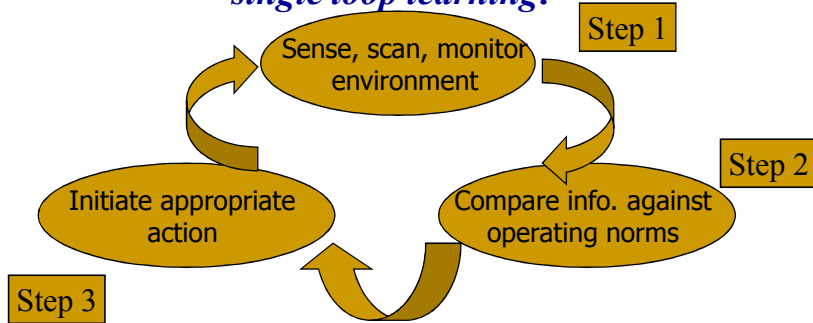
http://www.allfacebook.com/facebook-dominates-web-2010-08
(site visited 28th April 2008)

Paradigm Shifts in Computing:
Corporate Learning in the computing industry?

__Can organisations learn? Feedback and Control__
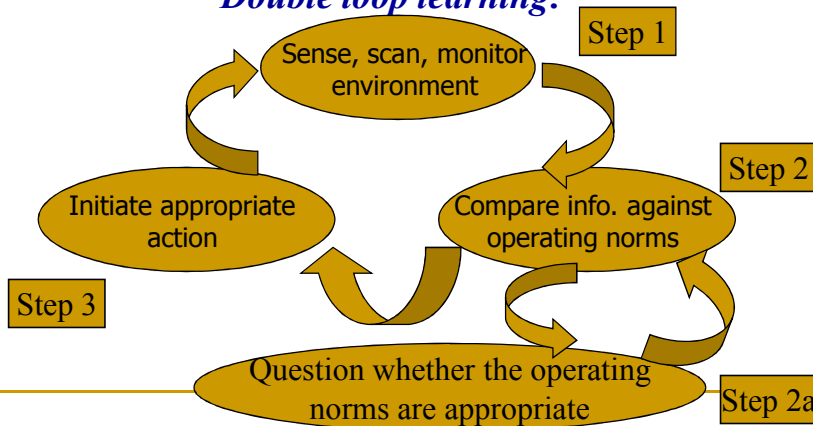
single loop learning:

Sense, scan, monitor environment — Step 1

Compare info. against operating norms — Step 2

Initiate appropriate action — Step 3

Paradigm Shifts in Computing:
Corporate Learning in the computing industry?

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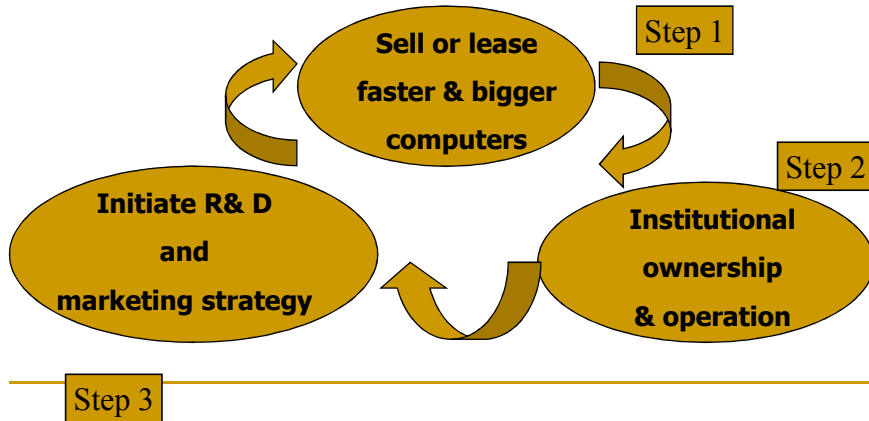
Double loop learning:

Sense, scan, monitor environment — Step 1

Compare info. against operating norms — Step 2

Initiate appropriate action — Step 3

Question whether the operating norms are appropriate — Step 2a
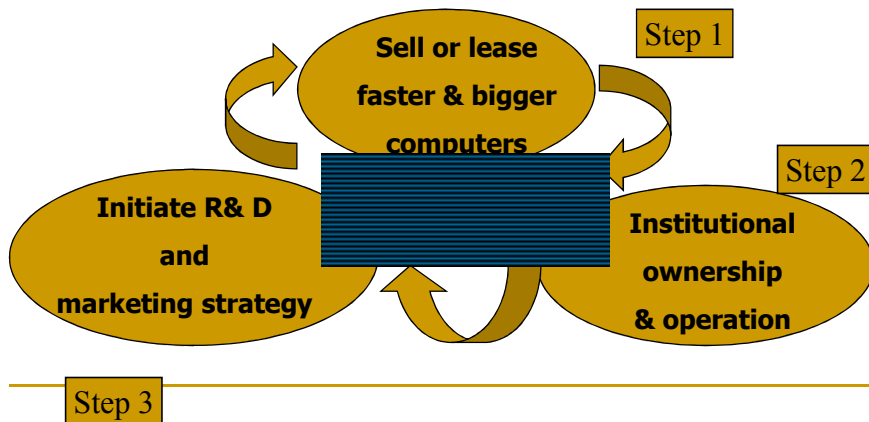
Paradigm Shifts in Computing:
Corporate Learning in the computing industry?

Can organisations learn? Feedback and Control
Single loop learning in computing industry

Sell or lease faster & bigger computers

Step 1

Initiate R& D and marketing strategy

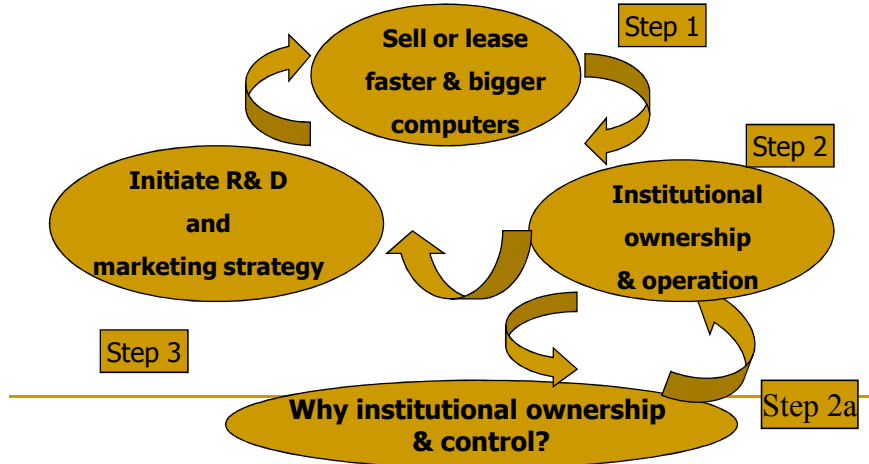**Institutional ownership & operation**

Step 2

Step 3

Paradigm Shifts in Computing:
Corporate Learning in the computing industry?

Can organisations learn? Feedback and Control
Double loop learning in computing industry

Step 1

Sell or lease faster & bigger computers

Step 2

Institutional ownership & operation

Initiate R& D and marketing strategy

Step 3

Why institutional ownership & control?

Step 2a

Paradigm Shifts in Computing:
Corporate Learning in the computing industry?

Can organisations learn? Feedback and Control
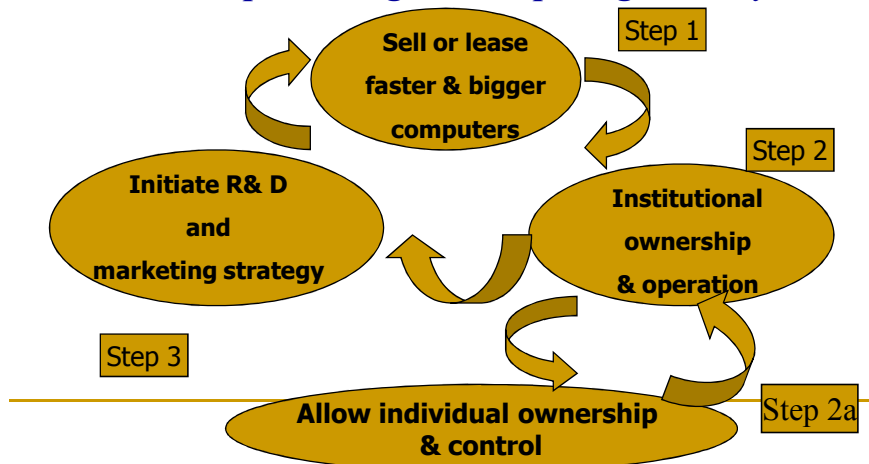### *Double loop learning: In computing industry*

Step 1

Sell or lease faster & bigger computers

Step 2

Institutional ownership & operation

Initiate R& D and marketing strategy

Step 3

Allow individual ownership & control

Step 2a

Paradigm Shifts in Computing:
Corporate Learning in the computing industry?

Can organisations learn? Feedback and Control
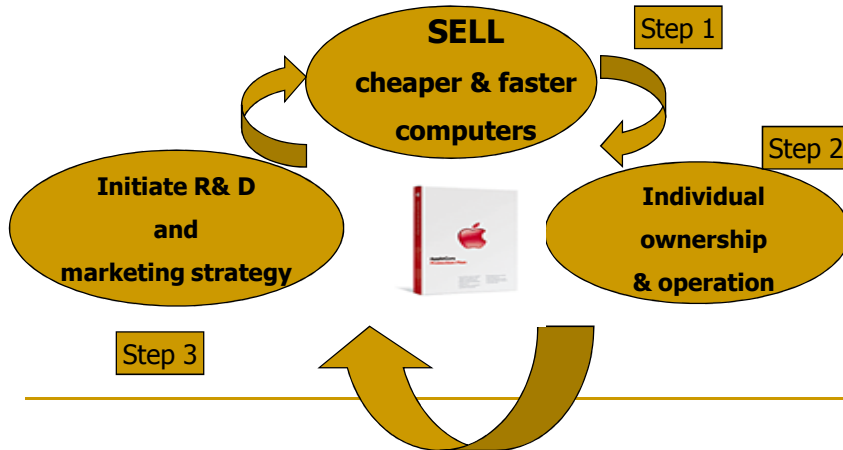### *Double loop learning in computing industry*

SELL

cheaper & faster

computers

Step 1

Step 2

Initiate R& D

and

marketing strategy

Individual

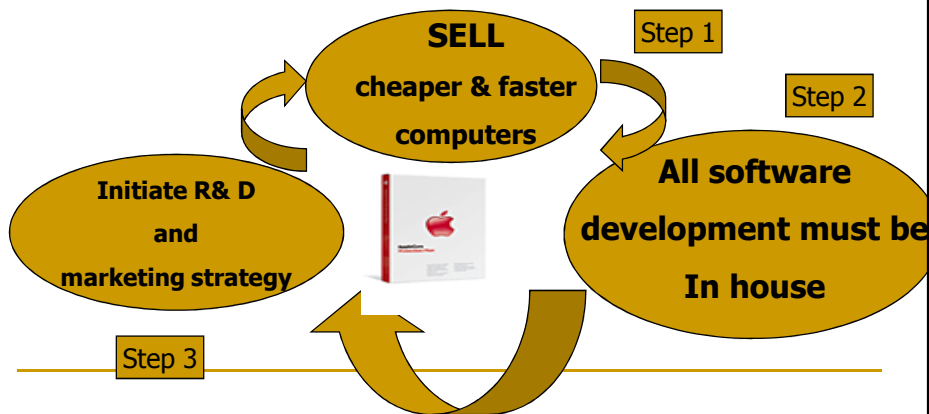**ownership**

& operation

Step 3

Paradigm Shifts in Computing:
Corporate Learning in the computing industry?

Can organisations learn? Feedback and Control
Single loop learning: Apple's contribution

SELL

cheaper & faster

computers

Step 1

Step 2

Initiate R& D

and

marketing strategy

All software

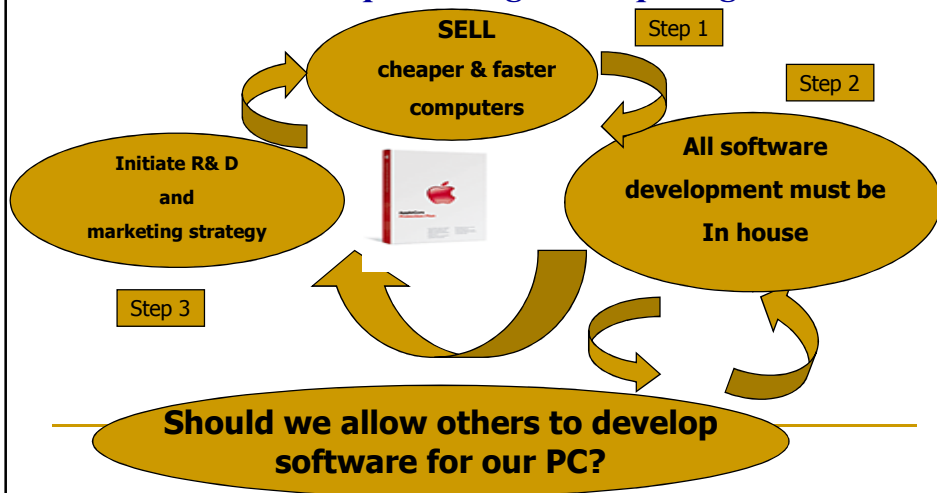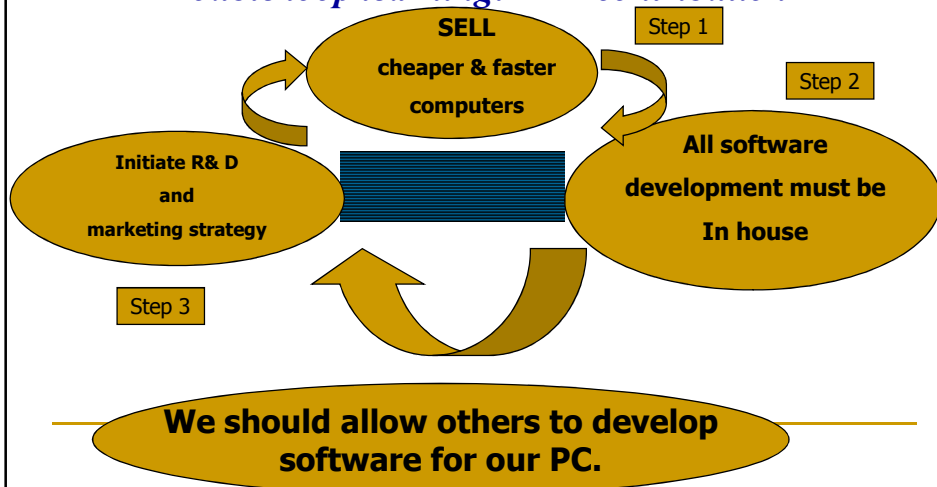**development must be**

In house

Step 3

Paradigm Shifts in Computing:
Corporate Learning in the computing industry?

Can organisations learn? Feedback and Control
Double loop learning in computing

SELL cheaper & faster computers

Step 1

Step 2

All software development must be In house

Initiate R& D and marketing strategy

Step 3

Should we allow others to develop software for our PC?

Paradigm Shifts in Computing:
Corporate Learning in the computing industry?

Can organisations learn? Feedback and Control
Double loop learning: IBM contribution

SELL cheaper & faster computers

Step 1

Step 2

All software development must be In house

Initiate R& D and marketing strategy

Step 3

We should allow others to develop software for our PC.

Paradigm Shifts in Computing:
Corporate Learning in the computing industry?

Can organisations learn? Feedback and Control
Double loop learning:

Double-loop learning is like a thermostat which can ask the question: Why have you set my operating norms as X^oC for hot and Y_oC for cold? Although the thermostat questions it still goes on controlling the environment

Step 1

Sense, scan, monitor environment

Step 2

Initiate appropriate action

Compare info. against operating norms

Step 3

Question whether the operating norms are appropriate

Step 2a

Paradigm Shifts in Computing:
What is paradigm shift anyway?

A research paradigm (Kuhn 1970) was defined originally by Kuhn to 'suggest that some accepted example of actual scientific practice - examples which include law, theory, application and instrumentation together - provide models from which spring particular coherent traditions of scientific research' (1970: 10).

American philosopher and sociologist of science; held chairs at Princeton and MIT. Born 1922, died 1996

KUHN, T. S.(1970).*The Structure of Scientific Revolutions*. Chicago: Chicago Univ. Press.

Paradigm Shifts in Computing:
What is paradigm shift anyway?

Normal Science: science that is considered standard or normative; science that works within the prevailing paradigms of its time and uses generally accepted methods (*OED*);

"'Normal science' means research firmly based upon one or more past scientific achievements [...] that some particular scientific community acknowledges for a time as supplying the foundation for its further practice." (Kuhn 1970:10)

Revolutionary Period (Science?)

American philosopher and sociologist of science; held chairs at Princeton and MIT. Born 1922, died 1996

KUHN, T. S.(1970).*The Structure of Scientific Revolutions*. Chicago: Chicago Univ. Press.

Paradigm Shifts in Computing:
What is paradigm shift anyway?

Kuhn's attempt to revolutionise the philosophy of science by predicating a structure of scientific revolutions follows a research tradition that was *operationalised* by, amongst others, Ludwik Fleck. Fleck, a neo-Kantian scientist, attempted to argue that the *genesis and development of a scientific fact* (Fleck 1935/1979) involved 'thought styles' and 'thought collectives' that show sociological conditioning as vital to the consolidation of scientific facts.

Paradigm Shifts in Computing:
What is paradigm shift anyway?

The term thought collective ('Denkkolektiv') is defined as 'a community of persons mutually exchanging ideas or maintaining intellectual interaction and [....... the thought collective] also provides the special "carrier" for the historical development of any field of thought, as well as for the given stock of knowledge and level of culture' (Fleck 1979:39). A thought style ('Denkstil') 'is a definitive constraint on thought and even more; it is the entirety of intellectual preparedness or readiness for one particular way of seeing and acting and no other [...] scientific facts [depend] upon thought style' (Fleck 1979:64).

FLECK, L. (1979/1935). *Genesis and Development of a Scientific Fact*. Chicago and London: The University of Chicago Press. (Originally published in 1935 as *Entstehung und Entwicklung einer wissenschaftlichen Tatsache: Einführung in die Lehre vom Denkstil und Denkollektiv*. Basel (Switzerland): Benno Schwabe & Co.

Paradigm Shifts in Computing:
What is paradigm shift anyway?

Fleck was aware of the developments in the atomic theory of matter (c. 1900-30) and commented that 'the concepts of the elements and of the atom can thus be constructed from historical factors as well from those of the thought collective. Such concepts are derived from the collective imagination.' (1979:83).

Paradigm Shifts in Computing:
What is paradigm shift anyway?

Kuhn notes that although he is not certain what effect Fleck has had on him, he acknowledges that 'Fleck's text helped me to realise that the problems which concerned me had a fundamentally sociological dimension' (Kuhn 1979:viii).

KUHN, T. S. (1979). 'Foreword' to Fleck (1979/1935). pp vii-xi.

Paradigm Shifts in Computing:
What is paradigm shift anyway?

Kuhn's position has shifted over the last quarter century and this has led him to argue that conceptual and linguistic change during scientific revolutions are amongst the key changes. During the last 10 years Kuhn has brought terms like *lexicon* and *lexical structure* into what has otherwise been an historical and sociological analysis of how science works and develops. Every scientific theory, according to Kuhn (1991), has its idiosyncratic structured taxonomic lexicon organised within a particular network whose links comprise structural relationships such as that between genus and species.

KUHN, T.S. (1991). 'The Road since *Structure*'. In (Eds.) A. Fine, M. Forbes and L. Wessels. *PSA 1990*, Vol. 2. East Lansing: Philosophy of Science Association.

Paradigm Shifts in Computing:
What is paradigm shift anyway?

A lexicon is defined to be the 'module in which members of a speech community store the community's kind-terms' (Kuhn 1993:325). The scientific lexicon is the essential precursor for the formulation of scientific problems and their solutions, the description of nature and the order within it: significant changes in the lexicons of scientific theories indicate whether or not a 'revolution' has taken place within a subject specialism.

KUHN, T.S. (1993). 'Afterwords'. In (Ed.) P. Horwich. *World Changes: Thomas Kuhn and the Nature of Science.* Cambridge (Mass., USA): The MIT Press. pp 311-341.

Paradigm Shifts in Computing:
What is paradigm shift anyway?

Kuhn's 20 senses of the term paradigm. (Masterman, 1970: 61-65).

Orientation	Possible interpretations of the proposition: A paradigm is
Metaphysical	a successful metaphysical speculation (Kuhn 1970:2)
	a set of beliefs (*ibid*:4)
	a myth (*ibid*:17)
	a standard (*ibid*:102)
	a map (*ibid*:108)
	a new way of seeing things (*ibid*:117-121)
	an organising principle governing perception (*ibid*:120)
	something which determines a large area of reality (*ibid*:128)
Sociological	a universally recognised scientific achievement (*ibid*:x)
	a concrete scientific achievement (*ibid*:2)
	(like) an accepted judicial decision (*ibid*:23)
	(like) a set of political institutions (*ibid*:91)
Constructural or Artefactual	(like) a textbook (*ibid*:10)
	(like) an analogy (*ibid*:14)
	a universally recognised scientific achievement (*ibid*:21)
	a grammatical paradigm (*ibid*:23)
	a conceptual and instrumental tools (*ibid*:37, 76)
	a device or type of instrumentation (*ibid*:59, 60)
	(like) a gestalt figure (*ibid*:63)
	an anomalous pack (*ibid*:85)

MASTERMAN, M. (1970) 'The Nature of a Paradigm'. In (Eds.) I. Lakatos and A. Musgrave. *Criticism and the Growth of Knowledge: Proceedings of the International Colloquium on the Philosophy of Science, London 1965 (Vol. 4).* Cambridge: Cambridge Univ. Press. pp 59-89.

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Paradigm Shifts in Computing:
What is paradigm shift anyway?

	Realist-Naturalist	Constructivist-Interpretivist
Ontology	Objectivist (reality exists independent of or external to the researcher)	Intersubjectivist (*social* realities are constructed and learned through collective, experience-based, phenomenological-hermeneutic processes)
Epistemology	Positivist (the world is knowable through the application of human reason; knowledge is achieved through direct observation via sense data)	Experiential, interpretive (both knowers and knowns are situated; perception and sensemaking are intertwined)
	Knowledge takes the form of universal principles that are generalizable	Knowledge is context-specific
Methodology	Representational, universalist; 'the scientific method'	Contextualized, reflexive, interpreted; embodied, expressive
Method of perceiving	Sense data (sight, touch, etc.)	Sensing (seeing, touching, etc.) + sense*making*
Implications for studying organizations/ organizing	Organizations are objects external to the researcher, who can perceive them through direct observation; it is possible to make valid and reliable observations that will meet the demands of scientific rigor according to the canons of 'the scientific method'	Organizing arises in interactions among internal and external stakeholders and their perceptions of these interactions, and from their efforts to make and communicate meaning or to thwart such communication; it is possible to make trustworthy observations and to render them in ways that meet the evaluative standards of interpretive science

Mary Jo Hatch and Dvora Yanow (2008) Methodology by Metaphor: Ways of Seeing in Painting and Research. *Organization Studies*. Vol. 29 (No. 01), pp 23–44

Paradigm Shifts in Computing:
Corporate Learning in the computing industry?

Paradigm shifts in computing can be observed in three major and inter-related developments in computing:

Three C's:

(C1). Software emerges as a **C**ommodity;
(C2). **C**ollaborative software development becomes the norm, perhaps;
(C3). **C**ustomising software to your needs.

Paradigm Shifts in Computing:
Corporate Learning in the computing industry?

Paradigm shifts in computing can be observed in inter-related developments in computing:

Commodity and Software: Software standards were almost non-existent up until late 1970's; programming languages used to conform to certain international standards. The current situation, where two major standards, HTTP and mail exchange protocols (SMTP) allow a degree of inter-operability across application platforms that could not have been forseen by the original pioneers.

Paradigm Shifts in Computing:
Corporate Learning in the computing industry?

Paradigm shifts in computing can be observed in three major and inter-related developments in computing:

O'Riley has argued that 'Software commoditization has been driven by standards, in particular by the rise of communications-oriented systems such as the Internet, which depend on shared protocols, and define the interfaces and datatypes shared between cooperating components rather than the internals of those components. Such systems necessarily consist of replaceable parts. A web server such as Apache or Microsoft's IIS, or browsers such as Internet Explorer, Netscape Navigator, or Mozilla, are all easily swappable, because in order to function, they must implement the HTTP protocol and the HTML data format. Sendmail can be replaced by Exim or Postfix or Microsoft Exchange because all must support email exchange protocols such as SMTP, POP and IMAP. Microsoft Outlook can easily be replaced by Eudora, or Pine, or Mozilla mail, or a web mail client such as Yahoo! Mail for the same reason.'

http://www.oreillynet.com/pub/a/oreilly/tim/articles/paradigmshift_0504.html

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Paradigm Shifts in Computing:
Corporate Learning in the computing industry?

Paradigm shifts in computing can be observed in three major and inter-related developments in computing:

Collaboration and software development: Bulletin boards, e-mails, meeting platforms have facilitated the development of complex software systems – in turn the complex systems have facilitated communications amongst the developers.

http://www.oreillynet.com/pub/a/oreilly/tim/articles/paradigmshift_0504.html

Paradigm Shifts in Computing:
Catch-up in newly emerging economies?

A technological paradigm is described as a "pattern of solutions to selected technological problems, based on selected principles derived from natural sciences and on selected material technologies'

New paradigms represent discontinuities in trajectories of progress which were defined within earlier paradigms.

Wu, Xiaobo and Zhang, W. (2010). 'Seizing the opportunity of paradigm shifts: Catch-up of Chinese ICT firms. ' International Journal of Innovation Management. Vol. 14, No. 1 ,pp. 57–91

Paradigm Shifts in Computing:
Catch-up in newly emerging economies?

Drivers of change:

      Evolutionary changes in ICT

      Market inspired changes in ICT

Wu, Xiaobo and Zhang, W. (2010). 'Seizing the opportunity of paradigm shifts: Catch-up of Chinese ICT firms. ' *Int. Journal of Innovation Management*. Vol. 14, No. 1 ,pp. 57–91

Paradigm Shifts in Computing:
Network Science?

ICT has helped to create n-e-t-w-o-r-k-s

The world is networked: Large complex networked systems include urban transportation systems, electric power markets and grids, the Internet, wired and wireless communication,

Networks sustain life on Earth: Infrastructure networks are utilized to distribute energy, information, water, goods, and people.

Networks appear organic: Such infrastructure networks are continuously growing more complex, on one hand handling increasingly more and variety of demands, and on the other hand due to their inherent and increasingly more complex interdependence.

Paradigm Shifts in Computing:
Network Science?

Network science has brought together researchers from many areas including mathematics, physics, biology, computer science, sociology, epidemiology, and others. Many researchers have demonstrated that most social, biological, and technological networks display substantial nontrivial features, with patterns of connection between their elements that are neither purely regular nor purely random.

Paradigm Shifts in Computing:
Network Science?

"Future integration of information and communication systems with the critical infrastructures to create dynamic, interactive, smart, and self-healing new mega-infrastructure" (Kocarev & In 2010).

See a presentation by Jennifer Chayes, MD, Microsoft UK for more details: http://journal.webscience.org/407/1/Age_of_Networks_-WebSci2010.pdf

Ljupco Kocarev & Visarath In,(2010). 'Network Science: A New Paradigm Shift. ' *IEEE Network.* Vol. 24, No. 6 ,pp. 6-9.

Paradigm Shifts in Computing:
Web Science?

The World-Wide Web is an artefact and the artefact is used extensively. The artefact in itself is a complex assemblage of hardware, communications and software systems. Some computer scientists argue that the artefact in itself is never studied systematically:

The Web Science aims to redress this: to build a platform where the web can be '…studied and understood as a phenomenon and also something to be engineered for future growth and capabilities' (Hendler et al 2008; 63).

Hendler J, Shadbolt N, Hall W, Berners-Lee T, Weitzner, D (2008) Web science: an interdisciplinary approach to understanding the web. *Comm. of the ACM* Vol. 51 (7): pp 60- 69

Paradigm Shifts in Computing:
Web Science?

This paradigm shift in computing in itself is the innovation and integration of a range of technologies:

The usage of WWW is facilitated by the methods, techniques and software for *information retrieval* in particular, and for *information science* in general, during a forty year period spanning 1960-1995

'The innovations of the 1990s [..] provide the crucial algorithms underlying modern search and are fundamental to Web use.' (Hendler et al 2008:62).

Hendler J, Shadbolt N, Hall W, Berners-Lee T, Weitzner, D (2008) Web science: an interdisciplinary approach to understanding the web. *Comm. of the ACM* Vol. 51 (7): pp 60- 69

Paradigm Shifts in Computing:
Web Science?

This paradigm shift in computing in itself is the innovation and integration of a range of technologies:

New resources (such as Hadoop, lucene.apache.org/hadoop/, an open-source software framework that supports data-intensive distributed applications on large clusters of commodity computers) make it possible for students to explore these algorithms and experiment with large scale Web-programming practices like MapReduce parallelism [...] in a way not previously accessible beyond a few top universities. ' (Hendler et al 2008:62).

Hendler J, Shadbolt N, Hall W, Berners-Lee T, Weitzner, D (2008) Web science: an interdisciplinary approach to understanding the web. *Comm. of the ACM* Vol. 51 (7): pp 60- 69
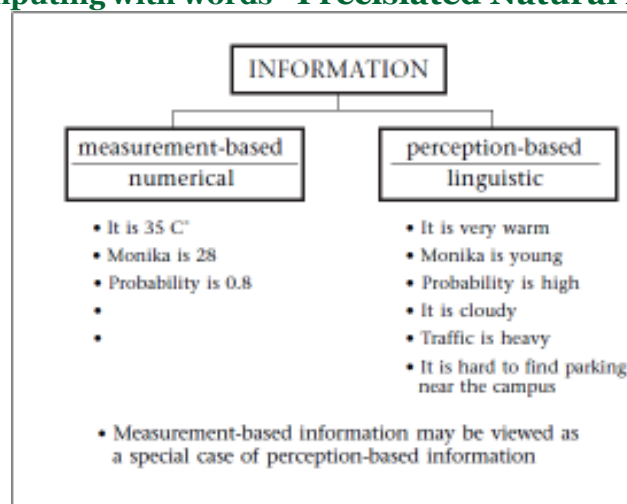
Paradigm Shifts in Computing:
Web Science?

The technology motivated changes:

What are the fundamental theoretical properties of social machines, and what kinds of algorithms are needed to create them?;

What underlying architectural principles are needed to guide the design and efficient engineering of new Web infrastructure components for this social software?;

Paradigm Shifts in Computing:
Web Science?

The Market/User Driven Changes:

How can we extend the current Web infrastructure to provide mechanisms that make the social properties of information-sharing explicit and guarantee that the use of this information conforms to relevant social-policy expectations?; and

How do cultural differences affect the development and use of social mechanisms on the Web? As the Web is indeed worldwide, the properties desired by one culture may be seen as counterproductive by others. Can Web infrastructure help bridge cultural divides and/or increase cross-cultural understanding?

Paradigm Shifts in Computing:
Computing with words?

Zadeh has argued that "moving from computation with numbers to computation with words has the potential for evolving into a basic paradigm shift—a paradigm shift which would open the door to a wide-ranging enlargement of the role of natural languages in scientific theories.

Lotfi Zadeh (2009). "Computing With Words and Perceptions—A Paradigm Shift". *Proc. 2010 Int. Conf. On Information Reuse and Integration .* pp viii - x

Paradigm Shifts in Computing:
Computing with words - Precisiated Natural Language ?

Lotfi Zadeh (2004). 'Precisiated Natural Language (PNL)'. *AI Magazine* **Vol 25 (3), pp 74-92**

Paradigm Shifts in Computing:
Computing with words?

How can a natural language be precisiated— precisiated in the sense of making it possible to treat propositions drawn from a natural language as objects of computation?

Paradigm Shifts in Computing:
Computing with words??

Computing with Words (Zadeh 2009) is a system of computation which adds to traditional systems of computation two important capabilities: (a) the capability to precisiate the meaning of words and propositions drawn from natural language; and (b) the capability to reason and compute with precisiated words and propositions.