COMP 516
Research Methods in Computer Science

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Lecture 2: What is ‘Research’?

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What Is ‘Research’?

Research and experimental development (R&D) (Frascati Manual 2002)

“Creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications.”

What Is ‘Research’?

Basic research (Frascati Manual 2002)

“Experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view.”

Applied research (Frascati Manual 2002)

“It is also original investigation undertaken in order to acquire new knowledge. It is, however, directed primarily towards a specific practical aim or objective.”

Experimental development (Frascati Manual 2002)

Systematic work, drawing on existing knowledge gained from research and/or practical experience, which is directed to producing new materials, products or devices, to installing new processes, systems and services, or to improving substantially those already produced or installed.

What Is ‘Research’?

Research (a maxim)

”Copying from one source is plagiarism, copying from several sources is research”.

Gain

Research (HEFCE): Original investigation undertaken in order to gain knowledge and understanding

Contribution

Research is supposed to add to the world’s body of knowledge and understanding (in contrast to adding to the researcher’s knowledge and understanding)

Epistemology

- What is knowledge?
- How is knowledge acquired?
- To what extent is it possible for a given subject or entity to be known?

Knowledge: A Hierarchy

Knowledge is a particular level in a hierarchy:

1. Data
2. Information
3. Knowledge
4. [Wisdom]

Knowledge: Data and Information

Datum/Data

- statements accepted at face value (a ‘given’) and presented as numbers, characters, images, or sounds.
- a large class of practically important statements are measurements or observations of variables, objects, or events.
- in a computing context, in a form which can be assessed, stored, processed, and transmitted by a computer.

Knowledge: Data and Information

Information

- Data on its own has no meaning, only when interpreted by some kind of data processing system does it take on meaning and becomes information

Example:
The human genome project has determined the sequence of the 3 billion chemical base pairs that make up human DNA
$\rightsquigarrow$ identifying base pairs produces data
$\rightsquigarrow$ information would tell us what they encode!
$\rightsquigarrow$ knowledge would tell us what they do!
$\rightsquigarrow$ wisdom would tell us what part of this knowledge is important to what we do!
In analogy to OSI model of networking: Physical layer, Data link layer, Presentation layer, Application layer

Knowledge: Alternative Definitions (1)

Knowledge (Dawson 2005)

- higher level understanding of things
- represents our understanding of the ‘why’ instead of the mere ‘what’
- interpretation of information in the form of rules, patterns, decisions, models, ideas, etc.

In natural sciences, understanding ‘why’ is too ambitious most of time; understanding ‘how’ is usually what we aim for

In other areas, understanding ‘why’ is trivial, understanding ‘how’ is challenging

Knowledge: Alternative Definitions (2)

Knowledge (Davenport et al. 1998)

- a fluid mix of framed experience, contextual information, values and expert insight that provides a framework for evaluating and incorporating new experiences and information.
- information combined with experience, context, interpretation, and reflection
- high-value form of information, ready to apply to decisions and actions

Second point similar to last point in the previous definition

Last point seems to imply that knowledge has to be useful
(is astrophysics useful?)

Knowledge: Alternative Definitions (3)

Knowledge (http://en.wikipedia.org/wiki/Knowledge)

- awareness and understanding of facts, truths or information gained as experience or learning (a posteriori), or through deductive reasoning (a priori)
- appreciation of the possession of interconnected details which, in isolation, are of lesser value
- both knowledge and information consist of true statements, but knowledge is information that has a purpose or use (information plus intentionality)

Knowledge: A Hierarchy

Datum/Data

- statements accepted at face value (a 'given') and presented as numbers, characters, images, or sounds.
- a large class of practically important statements are measurements or observations of variables, objects, or events.

Information

- Data interpreted by a data processing system (giving meaning)

Knowledge (Dawson 2005)

- higher level understanding of things
- represents our understanding of the 'why' instead of the mere 'what'
- interpretation of information in the form of rules, patterns, decisions, models, ideas, etc.

Knowledge and Theories: Definition

Scientific knowledge is often organised into theories.

Theory (http://en.wikipedia.org/wiki/Theories)

- a logically self-consistent model or framework describing the behaviour of a certain natural or social phenomenon, thus either originating from observable facts or supported by them
- formulated, developed, and evaluated according to the scientific method

Knowledge and Theories: Criteria

Theory (http://en.wikipedia.org/wiki/Theories)

A body of (descriptions of) knowledge is usually only called a theory once it has a firm empirical basis, that is, it

1. is consistent with pre-existing theory to the extent that the pre-existing theory was experimentally verified, though it will often show pre-existing theory to be wrong in an exact sense
2. is supported by many strands of evidence rather than a single foundation, ensuring that it's probably a good approximation if not totally correct
3. makes (testable) predictions that might someday be used to disprove the theory, and
4. has survived many critical real world tests that could have proven it false,
5. is a/the best known explanation, in the sense of Occam's Razor, of the infinite variety of alternative explanations for the same data.

Knowledge and Theories: Facts versus Theories

'This (e.g. evolution) is only a theory not a fact'

Fact

1. a truth (statement conforming to reality)
   or
2. data supported by a scientific experiment

- Status of a 'truth' is by and large unachievable
- A theory is formulated, developed, and evaluated according to the scientific method

  Given enough experimental support a theory can be (a scientific) fact

Investigation

- Scientists use observations and reasoning to propose explanations for natural phenomena in the form of hypotheses
- Predictions from these hypotheses are tested by experiment and further technologies developed
- Any hypothesis which is cogent enough to make predictions can then be tested reproducibly in this way
- Once established that a hypothesis is sound, it becomes a theory
- Sometimes scientific development takes place differently with a theory first being developed on the basis of its logic and principles

Research and Originality (1)

Research (HEFCE): Original investigation undertaken in order to gain knowledge and understanding

Originality

Doing something that has not been done before

Dawson (2005):
There is no point in repeating the work of others and discovering or producing what is already known

Only true for what is truly known (i.e. very little)

- Theories make predictions, which need to be tested
- Those performing the tests are neither infallible nor trustworthy
- Tests need to be repeated and results replicated

(In)Fallibility

Cold fusion (`http://en.wikipedia.org/wiki/Cold_fusion`)

- Cold fusion: Nuclear fusion reaction that occurs well below the temperature required for thermonuclear reactions, that is, near ambient temperature instead of millions of degrees Celsius
- First reported to have been achieved by Pons (University of Utah) and Fleischmann (University of Southampton) in 1989
- Scientists tried to replicate results shortly after initial announcement
- Teams at Texas A&M University and the Georgia Institute of Technology first confirmed the results, but then withdraw those claims due to lack of evidence
- Vast majority of experiments failed

(Un)Trustworthiness

Jan Hendrik Schön

(http://en.wikipedia.org/wiki/Jan_Hendrik_Schon)

- Researcher at Bell Labs working in the field of condensed matter physics and nanotechnology
- In 2001, he was listed as an author on an average of one research paper every eight days
- Claimed to have produced a transistor on the molecular scale
- Published (and peer reviewed) papers were suspected to contain duplicated and anomalous data
- Dismissed after an investigation found 24 cases of misconduct
- Science withdrew 8 and Nature 7 papers co-authored by Schön

Research and Originality (2)

Areas of originality (Cryer 1996)

- Exploring the unknown
  Investigate a field that no one has investigated before
- Exploring the unanticipated
  Obtaining unexpected results and investigating new directions in an already existing field
- The use of data
  Interpret data in new ways
- Tools, techniques, procedures, and methods
  Apply new tools/techniques to alternative problems
  Try procedures/methods in new contexts

What Is ‘Research’?

In summary, what are the three key aspects of research?

What is ‘Research’?

http://en.wikipedia.org/wiki/Research

Systematic investigation to establish facts

Higher Education Funding Council for England

Original investigation to gain knowledge and understanding

Sharp et al. (2002)

Seeking through methodical process to add to one’s own body of knowledge and to that of others, by the discovery of non-trivial facts and insights

What Is ‘Research’? (Summary)

Wikipedia	HEFCE	Sharp
active, diligent, and systematic process of inquiry	investigation	methodical process
discover, interpret, or revise		discovery
	gain	add
facts, events, behaviours, or theories	knowledge and understanding	knowledge / non-trivial facts and insights