03: **Choosing a research problem; creativity, invention, and innovation**

January 27, 2012

Announcements

- …

Sorting a topic by author

- From search results → analyze results

Results Analysis

<<Back to previous page

1,748 records. ti = syngas

Rank the records by this field:	Set display options:	Sort by:
Authors Book Series Titles Conference Titles Countries/Territories	Show the top 50 Results. Minimum record count (threshold): 2	(•) Record count ( ) Selected field

Analyze

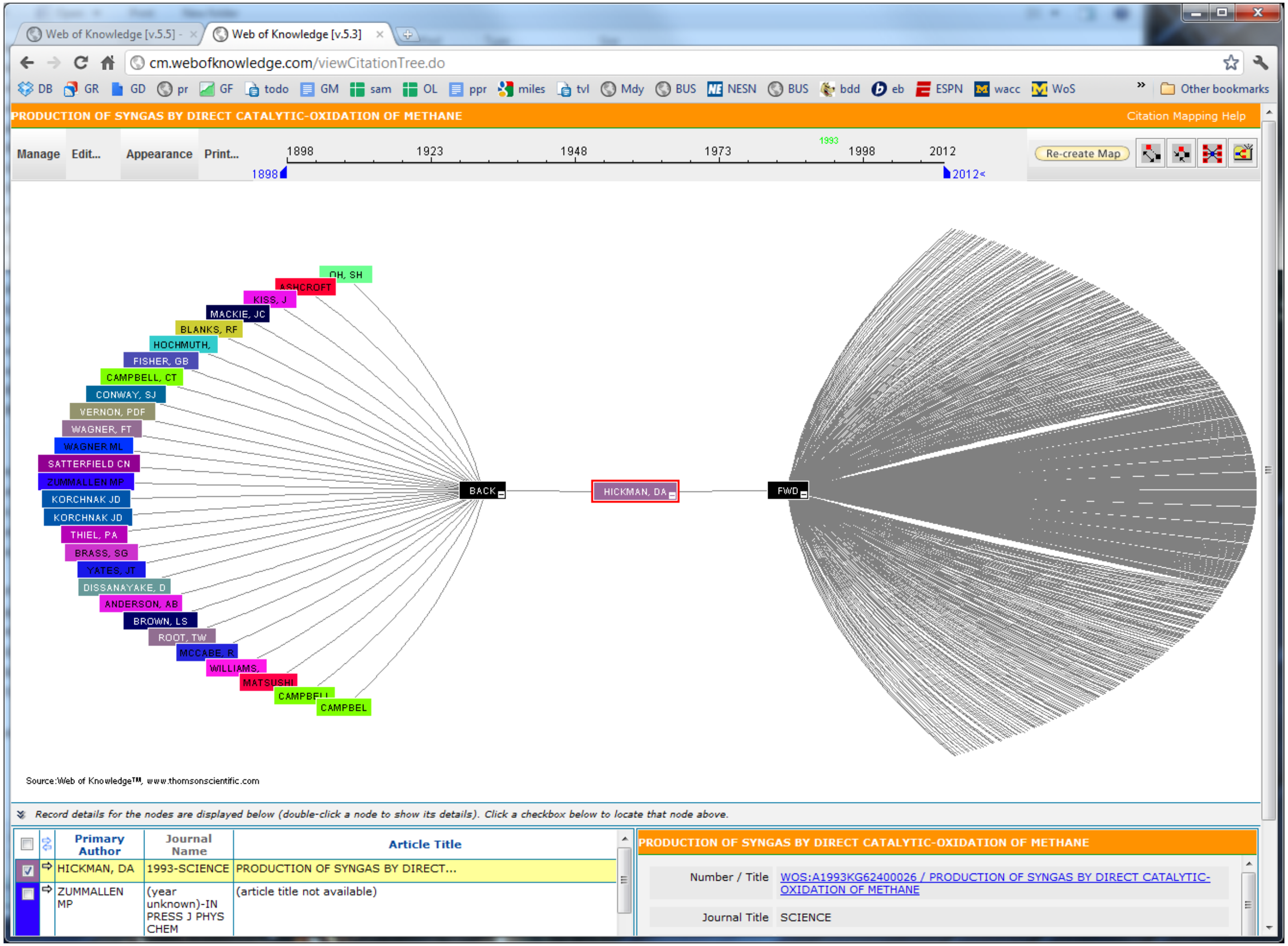
Use the checkboxes below to view the records. You can choose to view those selected records, or you can exclude them (and view the others).

View Records / Exclude Records	Field: Authors	Record Count	% of 1748	Bar Chart
☑	ANONYMOUS	43	2.460 %	I
☐	CHOUDHARY VR	30	1.716 %	I
☐	FUJIMOTO K	25	1.430 %	I
☐	YANG WS	22	1.259 %	I
☐	KNIFTON JF	21	1.201 %	I
☐	ZHENG XM	20	1.144 %	I
☐	ZHANG HB	19	1.087 %	I
☐	TSUBAKI N	18	1.030 %	I
☐	XIONG GX	18	1.030 %	I
☐	XU HY	18	1.030 %	I

Save Analysis Data to File
(•) Data rows displayed in table
( ) All data rows

Citation maps

- Click "create citation map" on the full record page for a paper
  - http://images.webofknowledge.com/WOK45/help/WOS/h_citation_map.html#CM_layout



Other lit search things

- Searches with multiple keywords
  - ts = syngas and ts = (meth* or ch4)
- Finding an author at an institution
  - au = smith j and og = univ mich
- Querying impact factors via Journal Citation Reports (web of knowledge → select a database)

Evaluating scientists

- We saw ResearcherID and Google Scholar to index times cited
- Other metrics: journal ranking, funding, etc … how are they connected?
- See http://www.scival.com/experts

Literature search assignment

Due on ctools at 2p Friday, February 3

a. Identify at least 5 journals that publish articles in your area of interest. Sign up for RSS feeds from these journals, e.g., using Google Reader.

b. Identify 5-10 keywords that represent the research theme that you will explore in this class.

c. Identify at least 3 combinations of these keywords that return a reasonable number of distinct articles in ISI Web of Science (or other suitable database). Sign up for search alerts (email or RSS feed) on these combinations. It will be helpful to look through the results of each search to see if the contents are highly relevant, and iterate on the keywords/syntax chosen.

d. Start a library using Endnote Web, Mendeley, or another platform. Based on the results from (c) or other searches that you find to be more effective, add the following to your library:
   1. 3 seminal (= relatively old, highly cited) papers.
   2. 2 recent (within 5 years) review papers.
   3. 5 very recent (0-2 years) papers which are highly relevant to your research topic.

e. **Submit a Word document including**
   1. A summary (<0.5 page) of the anticipated theme of your Ph.D. research (or other topic discussed with John). This may be identical to your "research summary" assignment, or it may be revised as you wish. The theme should align well what you are searching for this assignment.
   2. A screenshot of your RSS reader listing the journal feeds. It's ok if some of the feeds don't have new items yet, as long as the journal name is
   3. The list of 5 journals from (a), along with the impact factor of each journal (as found in the ISI citation index), and a 1-2 sentence summary of why you chose each journal.
   4. Your list of keywords.
   5. Your search terms (combinations of keywords), in the advanced search syntax of Web of Science. State the number of articles that each search returned.
   6. Citations for the papers from (d), separated by category as listed in (d), and formatted using the "Nature" reference format. If you are having trouble (or prefer not to) install the Endnote plugin, enter the references using you preferred method (e.g., the Word footnote or endnote feature), in a consistent and complete format of your choice.

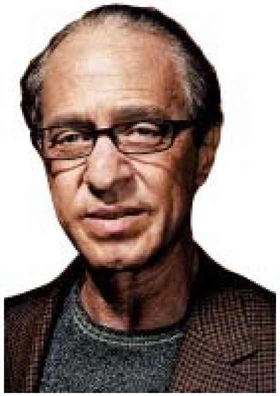
<u>Note:</u> if you have a different preferred way to search (e.g., database) and cite literature (e.g., way to import references into document software), you are welcome to use this process as long as you mention it in your submission, and fulfill all the requirements listed above.

Today’s topics

- Choosing a research problem: the process and why it’s very very very very important
- Perspectives on creativity, invention, and innovation

"A successful person [researcher] isn't necessarily better than her less successful peers at solving problems, her pattern-recognition facilities have just learned what problems are worth solving"

-Ray Kurzweil



Why is problem choice so important?

- Once you choose a problem you spend lots of time working on your choice!
- If you are *personally* interested in your problem, it will be easier to overcome the rough patches (failures).
- If you have a good perspective on your field (both forest AND trees), your choice will be more robust to disturbances that happen as your work progresses.

There are multiple voices… [Alon]

- “one is a loud voice of the interests of those around us, in conferences, department, etc… the other says ‘this is interesting to me’ ”
- “when one can achieve self-expression in science, work becomes revitalizing, and laden with personal meaning”

Factors to consider when choosing a problem

- Feasibility: “whether a problem is hard or easy, in units such as the expected time to complete a project”. [Alon]
  - Problems are always harder than they “look”.
- Importance: how important is the topic within the research community and beyond?
  - Who will care?
  - What will others do when they see your work?
  - How long will the answer be relevant and important? (longevity)
- Interest: both internal and external…
  - “distance from the known shores …the amount by which [the problem will] increase verifiable knowledge” [Alon]
  - do you have a **passion** for the topic?
- Competence: why are you qualified? Do you have an advantage (secret weapon)?

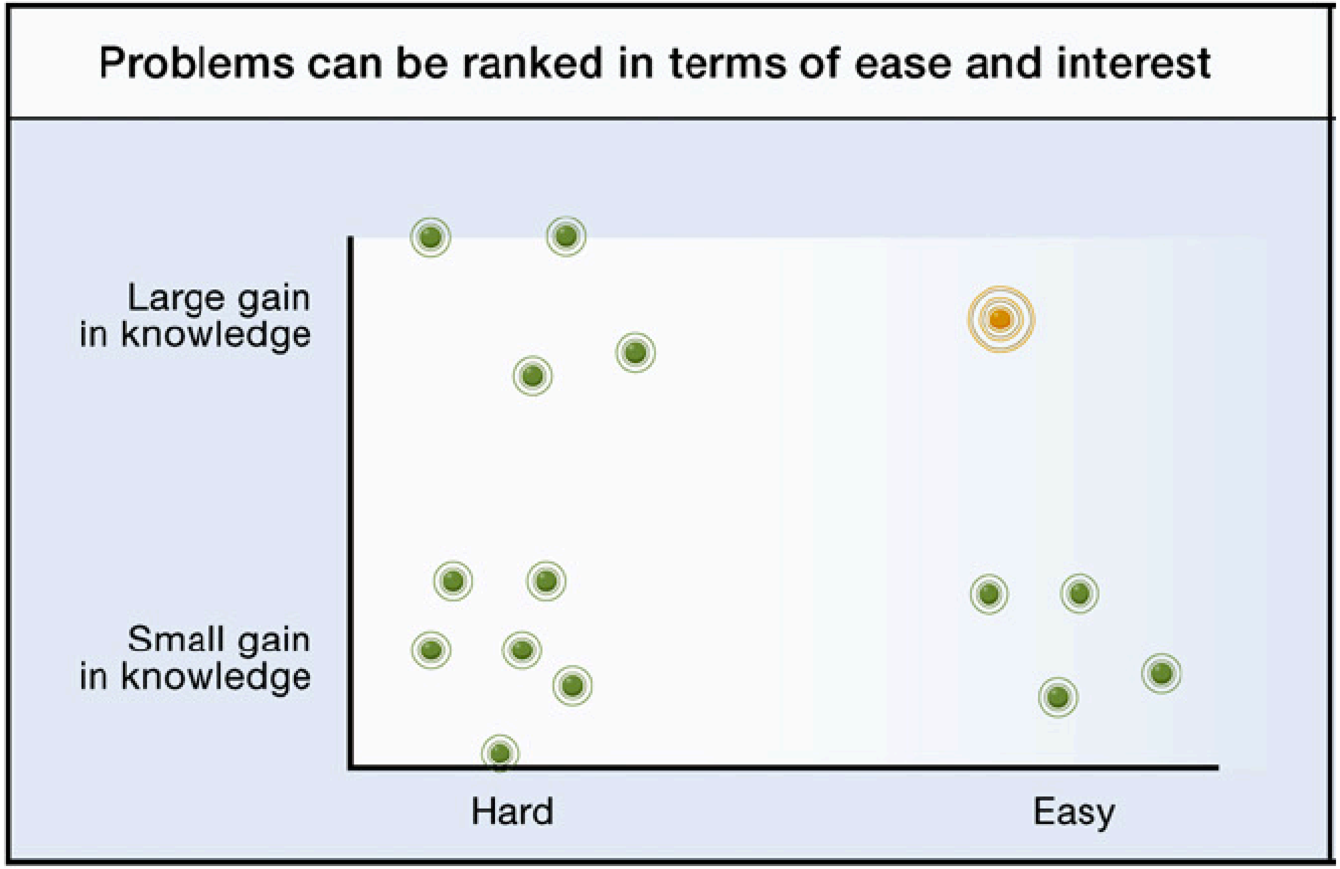
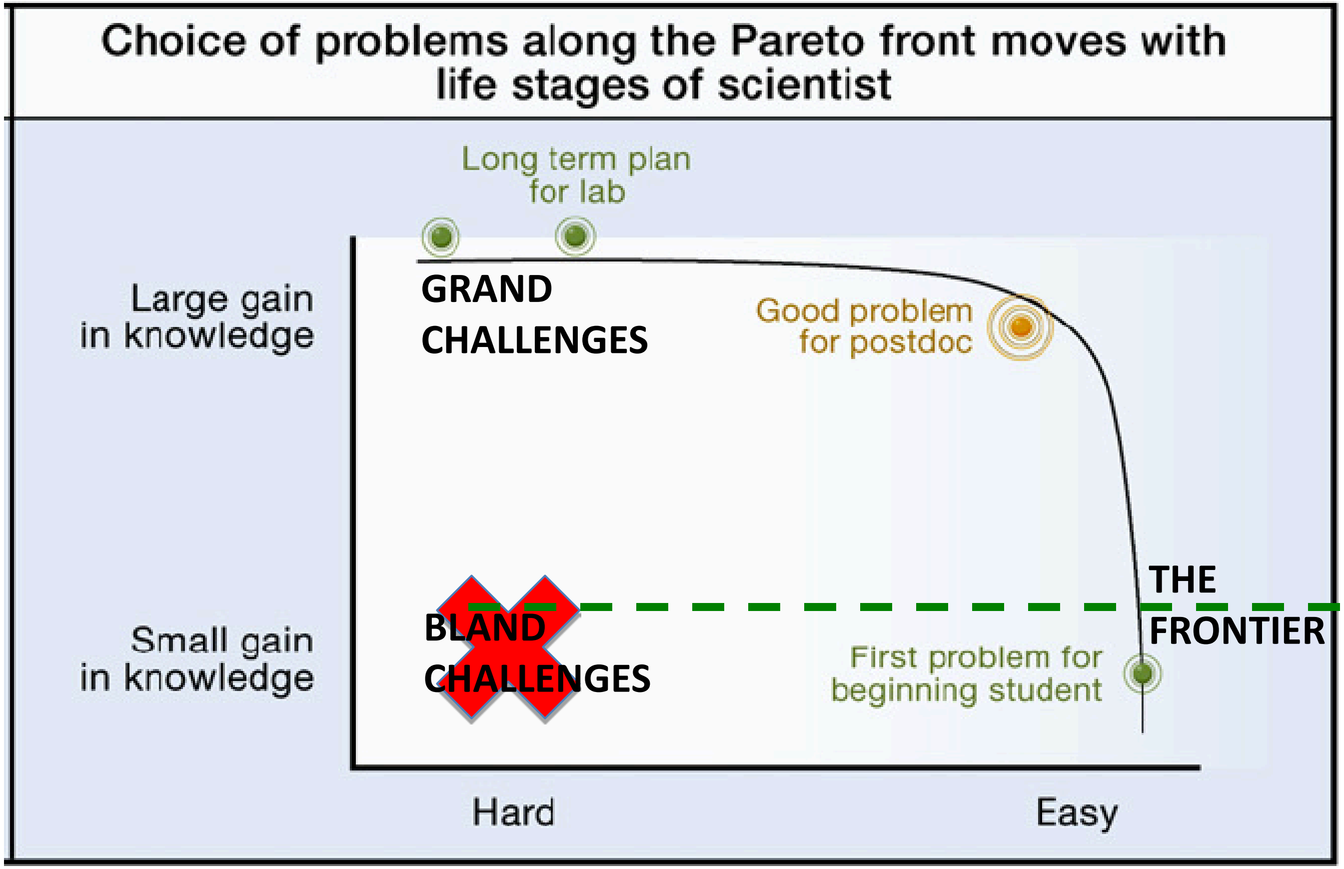


Figure 1. The Feasibility-Interest Diagram for Choosing a Project

Two axes for choosing scientific problems: feasibility and interest.

Alon, *Molecular Cell* 35, 2009.



Alon, *Molecular Cell* 35, 2009.

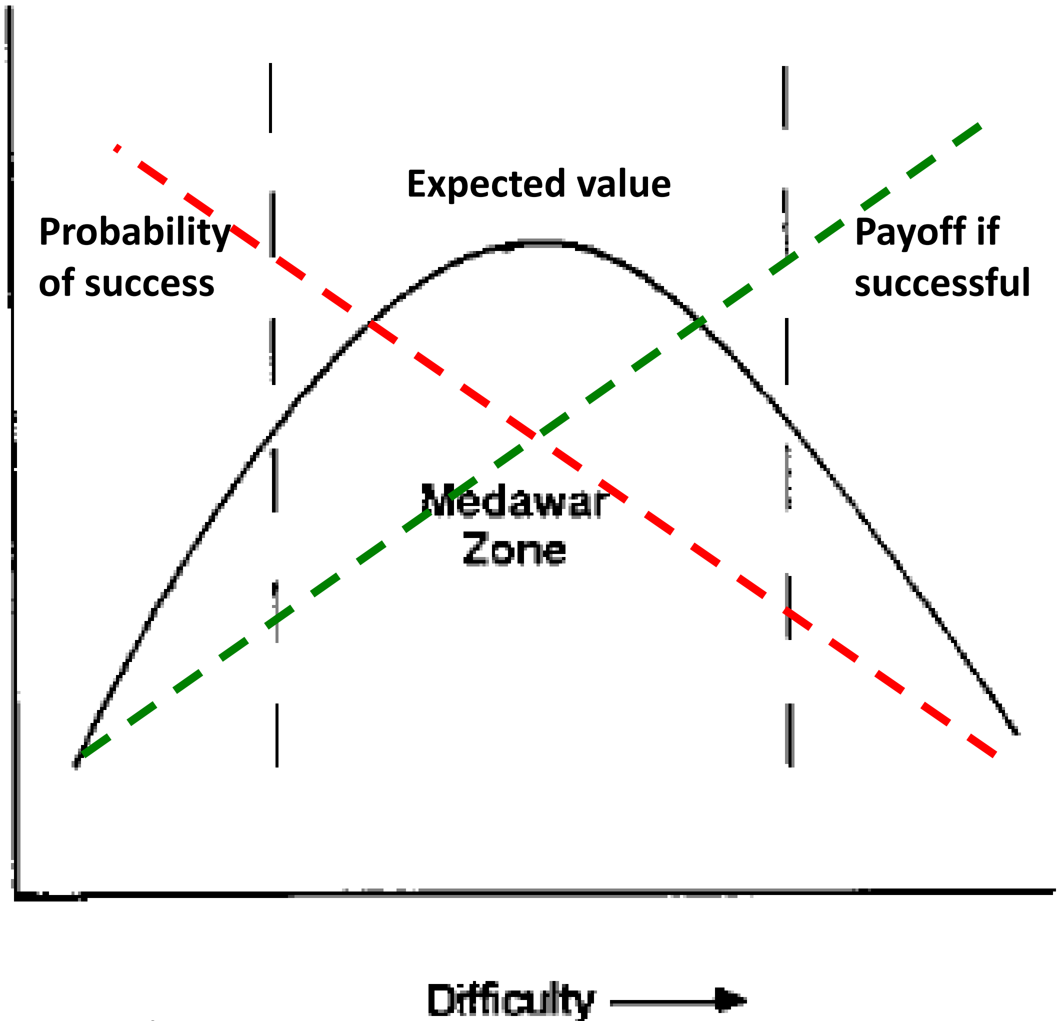


Figure 1. Relationship between degree of difficulty and payoff from solving a problem. Solving problems that are too easy does not advance science, whereas those that are too difficult may be impossible for other scientists to understand, i.e., they are premature. The Medawar zone refers to Peter Medawar's (1967) reference to science as "the art of the soluble."

Pasteur’s quadrant

- ***Where do you fit?***

Applied and Basic research

Quest for fundamental understanding?	**Yes**	Pure basic research (**Bohr**)	Use-inspired basic research (**Pasteur**)
	No	--	Pure applied research (**Edison**)
		No	**Yes**
		Considerations of use?	

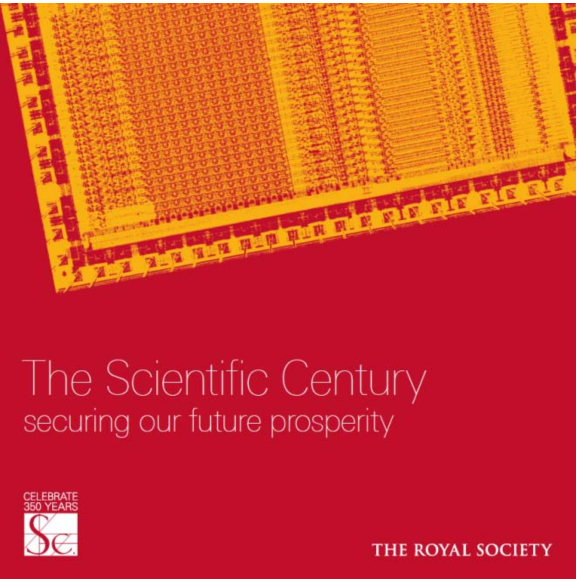
The result is three distinct classes of research:

1. Pure basic research (exemplified by the work of Niels Bohr, early 20th century atomic physicist).
2. Pure applied research (exemplified by the work of Thomas Edison, inventor).
3. Use-inspired basic research (described here as "Pasteur's Quadrant").

Donald E. Stokes, Pasteur's Quadrant - Basic Science and Technological Innovation, Brookings Institution Press, 1997.

M

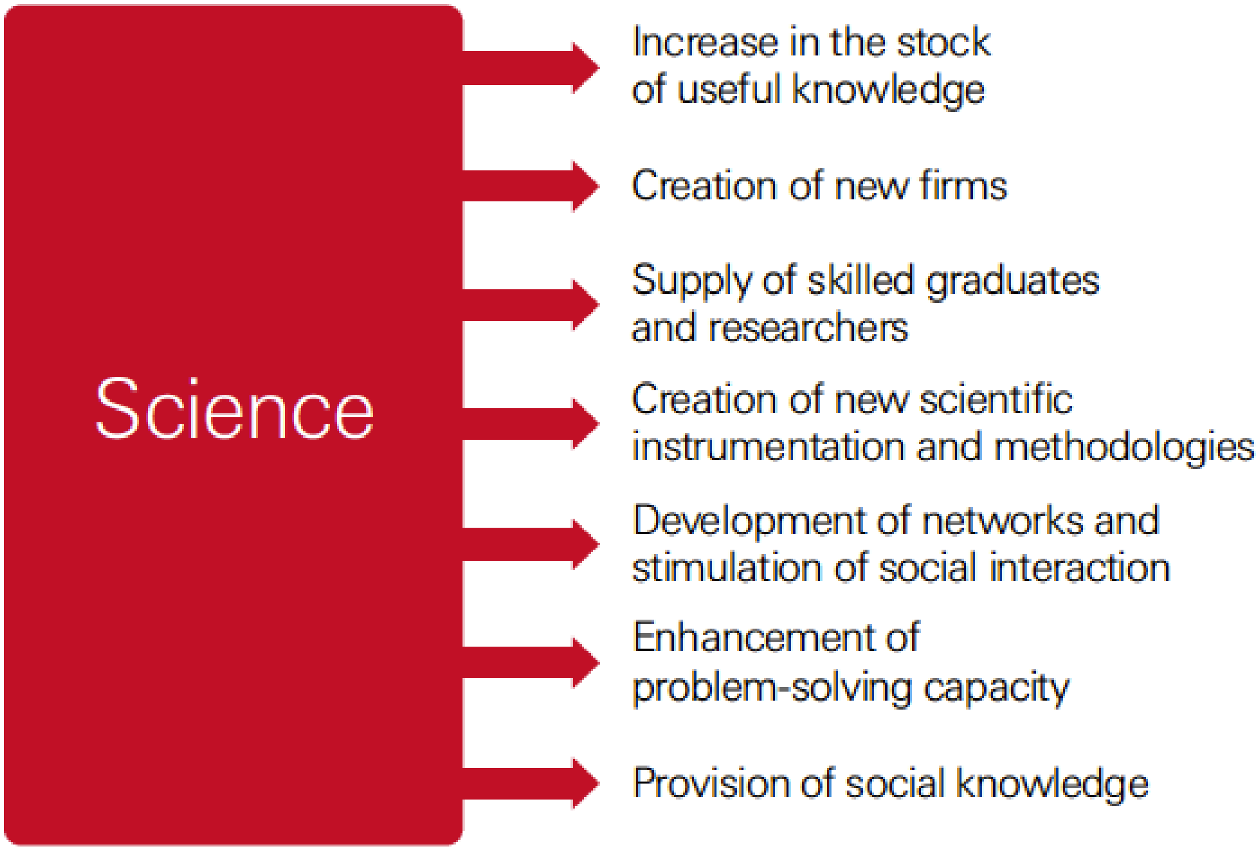
Figure 1.8 How UK academics classify their own work[42]
Pure basic research
(Bohr's Quadrant)
User-inspired basic research
(Pasteur's Quadrant)
39.4
36.2
39.4
34.4
32.2
26.3
24
6.9
8.2
31.9
34.5
21.7
Yes
Quest for fundamental understanding?
Pure applied research
(Edison's Quadrant)
26.2
31.5
34.4
44.1
58.6
70.1
No
No
Yes
Considerations of use?

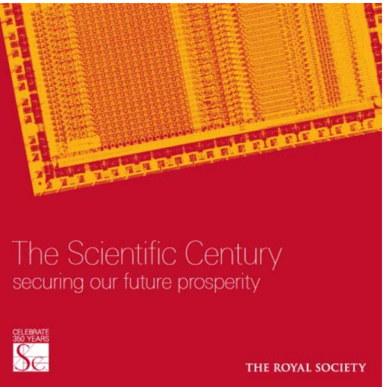


The Scientific Century
securing our future prosperity
CELEBRATE
350 YEARS
THE ROYAL SOCIETY

Consider the potential impact of both the process and the product (results)

Figure 1.5 **How science has an impact**[22]





Where we are now: identifying the frontier

"I skate where the puck is going to be, not where it has been"

-Wayne Gretzky

"The Great One"

Identifying the frontier

- New observations or findings that need explanation.
- New opportunities provided by instruments, methods of study, or theoretical frameworks.
- Converging lines of research (interdisciplinary) that combine to provide new opportunities.
- Important problems identified by leaders (heroes) in the field.

- ***Does your work fit one or more of these categories?***

"Good research is done with a shovel, not with tweezers… you should find an area where you can get a lot out of it fast."

-Roger Needham

Famous British computer scientist

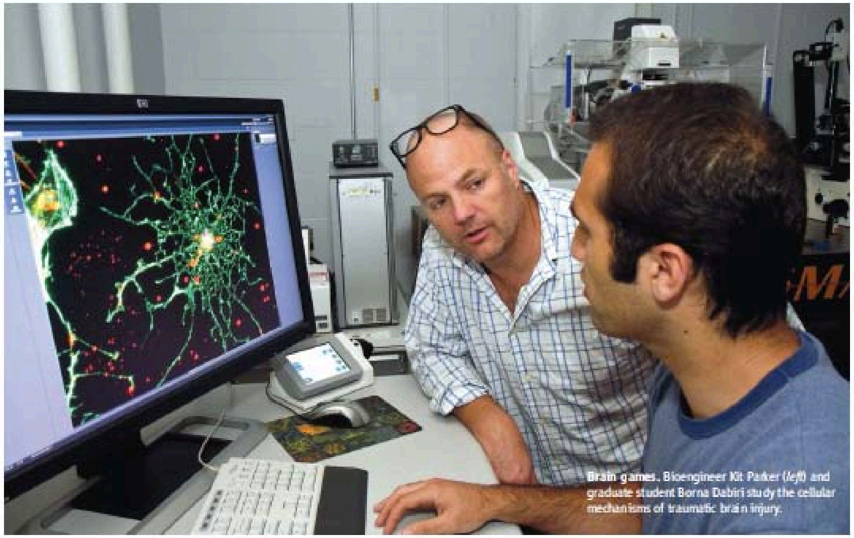
George Whitesides' perspective

- http://pubs.acs.org/page/publish-research/episode-1.html
- see "How do you choose your areas.."

Unique competence

- What is it that makes you better able to address your question than others?
- Don’t say…
  - “I am smarter than others.” (rarely true!)
  - “I will work longer, harder, faster.” (someone will be more efficent ☺)
- What is your “secret weapon”?

Inspiration and information go hand-in-hand



Brain games. Bioengineer Kit Parker (*left*) and graduate student Borna Dabiri study the cellular mechanisms of traumatic brain injury.

PROFILE: KIT PARKER

Engineering a New Line of Attack On a Signature War Injury

By jolting neurons in the lab, an Army officer and bioengineer hopes to gain ground on traumatic brain injury

When hijacked planes slammed into the World Trade Center towers in 2001, Kevin Kit Parker knew he had to do something. He'd always had a patriotic streak, and years earlier, while a graduate student in applied physics at Vanderbilt University in Nashville, Tennessee, Parker had enrolled in the Army Reserve Officers' Training Corps (ROTC). By the time of the attacks, he was a postdoctoral fellow, working on cardiac electrophysiology at Johns Hopkins University in Baltimore, Maryland, and in the middle of hunting for his first faculty position. He felt certain the country would soon be going to war, and despite having several job interviews on his calendar, he transferred to a unit he knew would be deployed. "I wanted to get in the game," he says.

While waiting to deploy, Parker accepted a job at Harvard University. With considerable trepidation, he asked the dean who'd just hired him for an immediate leave of absence to go to Afghanistan. It was a very unusual request, says then-dean Venkatesh Narayanamurti. Few, if any, Harvard professors have taken combat leave since World War II. But Narayanamurti admired Parker's dedication to national service. "I knew right away I would support him," he says.

By fall 2002, Parker was leading a team that patrolled a 900-square-kilometer swath between Kandahar and the Pakistan border, providing aid to villagers and searching for Taliban and Al Qaeda fighters. He finally started his job at Harvard in the summer of 2003, then deployed again in 2008, putting postdocs in charge of running the lab in his absence. His deployments caused Parker to reconsider the focus of his research and to establish a project on a signature injury of the wars in Iraq and Afghanistan: traumatic brain injury (TBI). He has been back to Afghanistan twice more as part of a panel of experts convened to assess how the military handles TBI and combat stress.

The Pentagon estimates that more than 200,000 U.S. troops have experienced TBIs in the recent conflicts, mostly from roadside bombs and other improvised explosive devices (IEDs). The long-term effects of these brain injuries won't be known for decades, but there are already worrisome hints that TBI may compound the effects of combat stress and predispose veterans to the type of early-onset dementia seen in football players with a history of head injuries (*Science*, 29 July 2011, pp. 514 and 517). Despite the urgency of the problem, frustratingly little is known about the mechanisms by which an explosive blast injures the brain, Parker says. "I kept seeing guys get hit, and I thought, all right, I'll take a look at this and see if I can get a better angle on the problem."

Mission shift

On a recent morning, Parker's students and postdocs mill about a conference room before their weekly lab meeting. They pour coffee and set out a plate of jalapeño bagels for Parker, who likes to goad others into eating spicy food. He arrives a few minutes late, wearing torn jeans and a red Harvard baseball cap with the bill folded into a sharp crease. A commanding presence at just under 6'6" (2 meters), Parker has a booming voice that bears more than a trace of his upbringing in west Tennessee. He launches into a list of lab business he's scribbled on a whiteboard. Some Italian researchers have asked about collaborating; so has a team from Merck, the pharmaceutical giant. And Parker has just returned from a molecular medicine conference in Korea. "Y'all make some damn fine fried chicken over there," he says to one of his Korean-born postdocs. "Hyungsuk, do you make that stuff at home?" When he shakes his head no, Parker pretends to be heartbroken. A second later, he's back to his list.

When Parker first arrived at Harvard, his main academic interest was the physical forces that determine how cells and tissues build themselves. His lab did cardiac tissue engineering, and that's still the focus for about two-thirds of his group. At the lab meeting, postdoc Anna Grosberg presents a computational tool she's developed for quantifying the alignment of sarcomeres, the protein fibers that make up muscle cells. How the fibers line up affects how a muscle contracts, and Parker thinks the tool could be useful for clinical pathologists or companies interested in engineering cardiac tissue for drug screens or therapies. In quick asides, he quizzes David Coon, who handles industry relations and intellectual property issues for the lab, about the commercialization prospects, and asks Sean Sheehy, a grad student with a computer science background, how hard it would be to incorporate Grosberg's metric into a graphical software package. When Sheehy says it's doable, Parker jokingly tells him: "This is your project now, baby!"

Ideas and projects spring up freely in the lab. A cotton-candy machine inspired a new way for making nanofiber scaffolds on which to grow cells (and a 2010 paper in *Nano Letters*). Back in his office, Parker shows off a movie on his computer of a more recent project: an artificial jellyfish. Cut from a polymer sheet coated with rat heart muscle cells, its form lacks the organic curves of the real thing, but the ghostly flap of tissue pulses across the screen with surprisingly lifelike motion.

Parker sees his fledgling TBI research project as a moral obligation. He saw IED explosions firsthand in Afghanistan, and he has buddies who've suffered the consequences. When Colonel Geoffrey Ling, the program manager who oversees TBI research at the Defense Advanced Research Projects Agency (DARPA), asked Parker in 2006 if he'd ever thought about studying TBI, he demurred at first. "I said, 'There have to be better people than me; I'm not a brain guy,'" Parker says. But as he started reading the scientific literature, he was struck by how little was known about what happens at the cellular level in a TBI.

In the thick of it. Parker, here searching for IEDs in Afghanistan, has changed the course of his research after two tours of duty.

Concussion on a chip

One prevalent idea has been that a blast wave or physical blow to the head tears the membranes of neurons, allowing positive ions to rush in and overexcite neurons to the point of killing them. Based on his experience with tissue engineering, Parker suspected something else might be going on instead, or in addition. He was surprised to see nothing in the research literature about integrins, proteins in the membrane of all cells that connect a cell's internal protein skeleton to the scaffold of proteins outside the cell, the so-called extracellular matrix. Parker reasoned that the force of a blast could propagate through this network of proteins, interfering with integrins and the many cell-signaling pathways they interact with.

The first challenge was figuring out how to go about studying TBI in the lab. Researchers have studied TBI by issuing blows to the heads of rats, pigs, and other animals, but it's not clear how well those experiments replicate what the human brain experiences in a car crash or explosive blast. Moreover, Parker says, "if I start blowing up goats at Harvard, I'm not going to last long." As an alternative, his lab has devised an arsenal of devices that can subject cultured neurons or slices of brain tissue to carefully calibrated forces. "We need to think of ways to replicate this on the bench top so you can mainstream the science," Parker says.

Their early work supports the idea that integrins may play a role in TBI. In one study, graduate student Matthew Hemphill and others put cultured rat neurons on a stretchy, square sheet of silicone that could be given a short tug by a high-precision motor. These tugs subjected the neurons to forces that the researchers estimated would be similar to those generated inside the head of a soldier exposed to an IED blast. Within a few minutes, microscopic swellings appeared on the spindly axons and dendrites that send and receive messages from neighboring neurons. Axonal injury is a hallmark of TBI, and a diffusion tensor imaging study by a different group published 2 June 2011 in *The New England Journal of Medicine* found evidence of axon damage in U.S. soldiers who suffered TBIs in Iraq. Additional experiments with the cultured rat neurons implicated a particular integrin signaling pathway in this damage. Treating the neurons with a drug that inhibits a component of this pathway called Rho-kinase reduced damage to neurons after a simulated blast, the researchers reported in *PLoS ONE* in July 2011.

In another study, published 2 August 2011 in the *Proceedings of the National Academy of Sciences*, a team led by then-postdoc Patrick Alford used the same setup to investigate the effects of a simulated blast on blood vessels. In this case, the researchers used rat muscle cells from the lining of blood vessels. When subjected to a sudden stretch, these cells flipped a genetic switch that made them more likely to contract and promoted their proliferation. Both effects would tend to clamp down on blood vessels,

CREDIT: JON CHASE/HARVARD STAFF PHOTOGRAPHER

CREDIT: KIT PARKER

Downloaded from www.sciencemag.org on January 5, 2012

Consider how much freedom you will have vs. time

Creativity?

What is creativity?

Google define: creativity Search Advanced Search Preferences

Web

Related phrases: creativity techniques creativity movement total creativity creativity magazine creativity and mental illness creativity alliance threshold of creativity adobe creativity sweet creativity technique creativity demons

Definitions of **creativity** on the Web:

- the ability to create
  wordnetweb.princeton.edu/perl/webwn
- → Creativity is a mental process involving the discovery of new ideas or concepts, or new associations of the existing ideas or concepts, fueled by the process of either conscious or unconscious insight.
  en.wikipedia.org/wiki/Creativity
- Creativity is a website, formerly a monthly magazine, covering all things creative in advertising and design. ...
  en.wikipedia.org/wiki/Creativity_(magazine)
- creative - promoting construction or creation; "creative work"
  wordnetweb.princeton.edu/perl/webwn
- creatively - in a creative manner; "she solved the problem creatively"
  wordnetweb.princeton.edu/perl/webwn
- Creative was released in November 2008 as the third single from Leon Jackson's debut albm Right Now. To promote the track Jackson appeared on the official BBC Children in Need 2008 show performing the song as a "exclusive" as this was the first time Jackson had performed the track. ...
  en.wikipedia.org/wiki/Creative_(song)
- Generates and/or recognises how best practice and imaginative ideas can be applied to different situations.
  www.ucas.ac.uk/seps/glossary
- → the capacity to produce something which is both unique and useful.
  www.tuition.com.hk/psychology/c.htm
- → The production of previously non-existent information. All new items of information are based on preceding ones, and they are "new" because they restructure the preceding items and/or insert foreign informational elements ("noises") into them.
  www.european-photography.com/labor/lab_vf_glo_e.shtml
- Jessica Fleck, The Richard Stockton College of New Jersey, USA
  www.elsevierdirect.com/brochures/consciousness/content.html
- → The ability to think imaginatively and originally
  www.sqa.org.uk/sqa/files_ccc/SVQ%20Credit%20Rating%20SSBs%20Appendix%205%20v1.0.doc
- → is the ability to produce something new, to generate unique approaches and solutions to issues or problems or opportunities.
  aaahq.org/aecc/intent/glossary.htm

A creative insight, then, is a sudden, unexpected recognition of concepts or facts in a new relation not previously seen (*19*, *20*). Such creative insights often follow conceptual reorganization or a new, non-obvious restructuring of a problem situation (*3*, *21*). The mechanism whereby two ideas are blended (*22*) or convoluted (*20*) by insight-like mechanisms into a third novel idea by a process termed "conceptual integration" (*23*) is an area of active research.

DeHaan, *Science* 334:1499, 2011

Creativity is our trump card

"The key to maintaining a socioeconomically sustainable world will lie in our creative ability. Creativity is and will continue to be the one differentiator of the human from the machine."

Prof. Jim Gimzewski, UCLA

"A recent IBM poll of 1500 CEOs identified creativity as the number-one leadership competency of the future."

Dyer, Gregersen, and Christensen
The Innovator's DNA

Creativity can be a matter of behavior

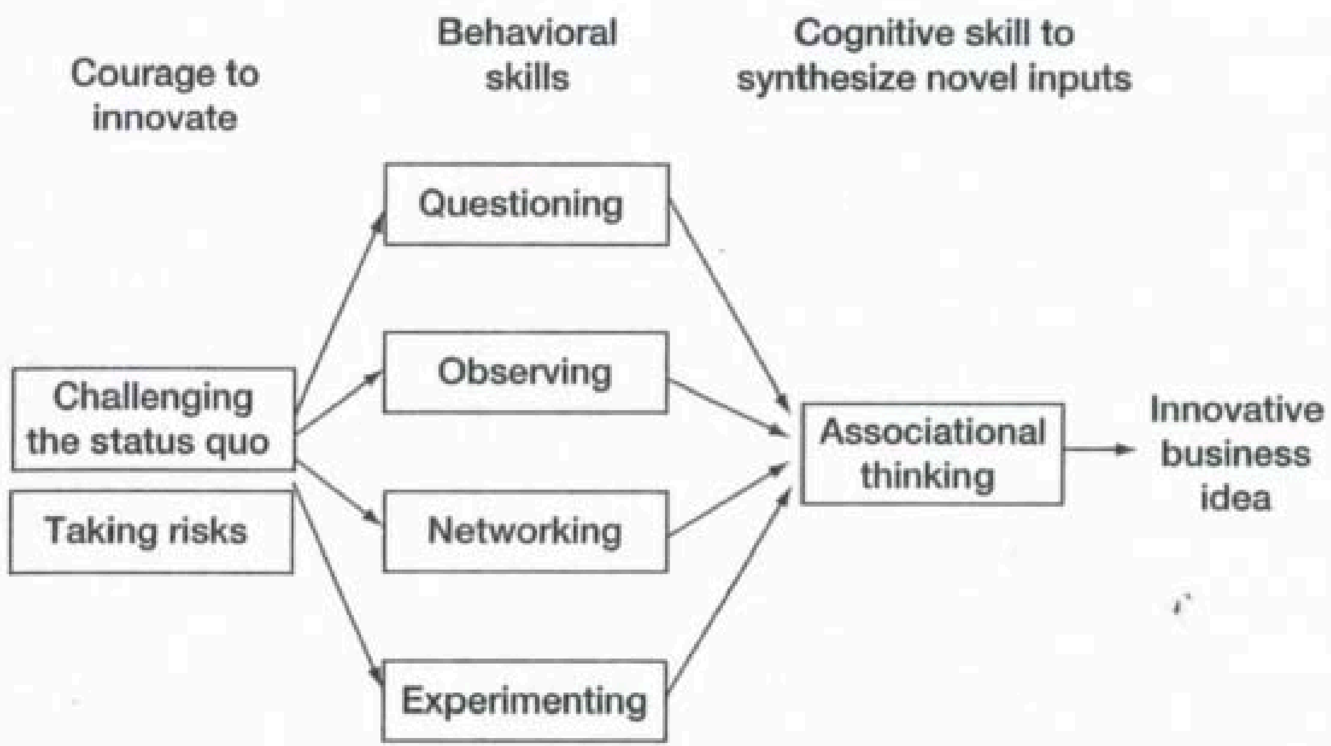
thinking" or "associating"). But to think different, innovators had to "act different." All were questioners, frequently asking questions that punctured the status quo. Some observed the world with intensity beyond the ordinary. Others networked with the most diverse people on the face of the earth. Still others placed experimentation at the center of their innovative activity. When engaged in consistently, these actions—questioning, observing, networking, and experimenting—triggered associational thinking to deliver new businesses, products, services, and/or processes. Most of us think creativity is an entirely cognitive skill; it all happens in the brain. A critical insight from our research is that *one's ability to generate innovative ideas is not merely a function of the mind, but also a function of behaviors*. This is good news for us all because it means that *if we change our behaviors, we can improve our creative impact*.

Dyer, Gregersen, and Christensen, <u>The Innovator's DNA</u>

http://tech.mit.edu/V129/N47/obamavisit.html

FIGURE 1-1

The innovator's DNA model for generating innovative ideas



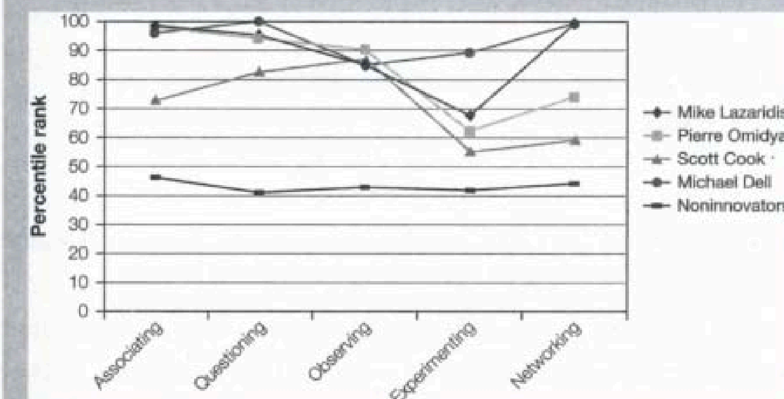
Dyer, Gregersen, and Christensen, The Innovator's DNA

Discovery Skill Strengths Differ for Disruptive Innovators

To understand that innovative entrepreneurs develop and use different skills, look at figure 1-2. It shows the percentile rank scores on each of the five discovery skills for four well-known founders and innovators: Pierre Omidyar (eBay), Michael Dell (Dell), Michael Lazaridis (Research In Motion), and Scott Cook (Intuit). The percentile rank indicates the percentage of over five thousand executives and innovators in our database who scored lower on that particular skill. A particular skill is measured by the frequency and intensity with which these individuals engage in activities that compose the skill.

FIGURE 1-2

High-profile innovators' discovery skills profile



As you can see, the pattern for each innovative entrepreneur is different. For example, Omidyar is much more likely to acquire his ideas through questioning (ninety-fifty percentile) and

Dyer, Gregersen, and Christensen, The Innovator's DNA

A creative process: Ideo product design

What did you notice?

"Focused chaos."

"Enlightened trial and error succeeds over the planning of the lone genius."

Everyone is equal.

List as many uses as you can for a plastic bottle

SCIENCE EDUCATION

Teaching Creative Science Thinking

Students' creative insights can be nurtured by promoting peer-peer learning and increasing associative thinking.

Robert L. DeHaan

Scientists frequently encounter ill-structured problems that can have multiple paths to multiple solutions (*1*). To approach such problems, "higher-order" mental operations such as analysis, synthesis, and abstraction are key. But, in addition, creative thinking—the most complex and abstract of the higher-order cognitive skills according to Bloom's taxonomy of learning skil… lem… pect… the i… or p… criti… belo… mor… how… crea… soni…

I… we… tant… ture… sing… Not… also… is li… cog… 77 u… by 5… the… den… (*11*)… four… soni… problems (*12*).

An extensive literature is replete with instructional strategies to help students be more creative (*13*). Creativity is a complex, multicomponent construct and, therefore, is not easy to define or assess, especially in the context of science (*13*, *14*). Nonetheless, there is evidence that the cognitive operations that are required for creativity can be taught and that the instructional strategies that work best are relatively simple modifications of the active learning instruction that is most effective for teaching abstraction and problem-solving (*15*).

Frameworks for Creativity

Creativity has been defined within two different theoretical frameworks. In one, a novel idea or solution to a problem occurs in the mind of an individual as a creative insight …

… ing (*17*). Associative thinking increases the probability of accessing weakly associated ideas (*18*).

A creative insight, then, is a sudden, unexpected recognition of concepts or facts in a new relation not previously seen (*19*, *20*). Such creative insights often follow conceptual reorganization or a new, non-obvious restructuring of a problem situation (*3*, *21*). The mechanism whereby two ideas are blended (*22*) or convoluted (*20*) by insight-like mechanisms into a third novel idea by a process termed "conceptual integration" (*23*) is an area of active research.

… decompose and rearrange components in different contexts, striving to increase the range of associations they apply (*25*).

Associative thinking has been used as a proxy to test for creativity (*15*), and there are

RUBRIC* FOR RESPONSES TO THE CHALLENGE: "LIST AS MANY USES AS YOU CAN FOR A PLASTIC BOTTLE"

Criteria	3 points	2 points	1 point	0 points
Fluency	20 or more relevant responses	10–19 relevant responses	1–9 relevant responses	No relevant responses
Flexibility	14 or more different categories	6–13 different categories	2–5 different categories	All responses in the same category.
Originality	At least one response that is unique or common to no more than 10% of the population.	One or more responses that are novel; common to no more than 19% of the population.	One or more responses that are slightly novel; common to 20–49% of the population.	Responses common to 50% of the population; no novel responses.

* This rubric is expanded from the originality scoring checklist in (*13*).

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* This rubric is expanded from the originality scoring checklist in (13).

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Creativity favors the prepared mind

It is not possible deliberately to create ideas or to control their creation. When a difficulty stimulates the mind, suggested solutions just automatically spring into the consciousness. The variety and quality of the suggestions are functions of how well prepared our mind is by past experience and education pertinent to the particular problem. What we can do deliberately is to prepare our minds in this way, voluntarily direct our thoughts to a certain problem, hold attention on that problem and appraise the various suggestions thrown up by the subconscious mind. The intellectual element in thinking is, Dewey says, what we do with the suggestions after they arise.

Other things being equal, the greater our store of knowledge, the more likely it is that significant combinations will be thrown up. Furthermore, original combinations are more likely to come into being if there is available a breadth of knowledge extending into related or even distant branches of knowledge. As Dr. E. L. Taylor says:

> "New associations and fresh ideas are more likely to come out of a varied store of memories and experience than out of a collection that is all of one kind." [90]

Beveridge, The Art of Scientific Investigation

Good ideas often come at quiet times

(*d*) Most people find intuitions are more likely to come during a period of apparent idleness and temporary abandonment of the problem following periods of intensive work. Light occupations requiring no mental effort, such as walking in the country, bathing, shaving, travelling to and from work, are said by some to be when intuitions most often appear, probably because under these circumstances there is freedom from distraction or interruption and the conscious mind is not so occupied as to suppress anything interesting arising in the subconscious. Others find lying in bed most favourable and some people deliberately go over the problem before going to sleep and others before rising in the morning. Some find that music has a helpful influence but it is notable that only very few consider that they get any assistance from tobacco, coffee or alcohol. A hopeful attitude of mind may help.

Beveridge, The Art of Scientific Investigation

Traits/methods of creativity

→ Always ask **questions**

- What? Why? Where? How?

→ **Explain your idea to others, talk with experts**

- What do they ask about?

Systematic variation

- Consider all permutations of an idea

Reversal and reciprocity

- Start with the end goal and work backwards
- Take your current idea and do the opposite

Slocum.

Ideas are everywhere??

It was the dinosaur-bone story all over again. You sent a proper search team into territory where people had been looking for a hundred years, and, lo and behold, there's a T. rex tooth the size of a banana. Ideas weren't precious. They were everywhere, which suggested that maybe the extraordinary process that we thought was necessary for invention—genius, obsession, serendipity, epiphany—wasn't necessary at all.

run the show. Good ideas are out there for anyone with the wit and the will to find them, which is how a group of people can sit down to dinner, put their minds to it, and end up with eight single-spaced pages of ideas.

Malcolm Gladwell, "In the air"

Multiples

"There were four independent discoveries of sunspots, all in 1611; namely, by Galileo in Italy, Scheiner in Germany, Fabricius in Holland and Harriott in England," Ogburn and Thomas note, and they continue:

The law of the conservation of energy, so significant in science and philosophy, was formulated four times independently in 1847, by Joule, Thomson, Colding and Helmholz. They had been anticipated by Robert Mayer in 1842. There seem to have been at least six different inventors of the thermometer and no less than nine claimants of the invention of the telescope. Typewriting machines were invented simultaneously in England and in America by several individuals in these countries. The steamboat is claimed as the "exclusive" discovery of Fulton, Jouffroy, Rumsey, Stevens and Symmington.

For Ogburn and Thomas, the sheer number of multiples could mean only one thing: scientific discoveries must, in some sense, be inevitable. They must be in the air, products of the intellectual climate of a specific time and place. It should not surprise us, then, that calculus was invented by two people at the same moment in history. Pascal and

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

Malcolm Gladwell, "In the air"

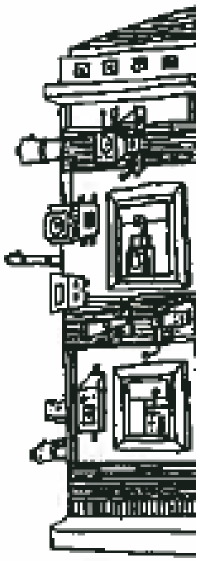
discoverer." There are just too many people with an equal shot at those ideas floating out there in the ether. We think we're pinning medals on heroes. In fact, we're pinning tails on donkeys.

Malcolm Gladwell, "In the air"

If multiples are inevitable, what makes a genius?

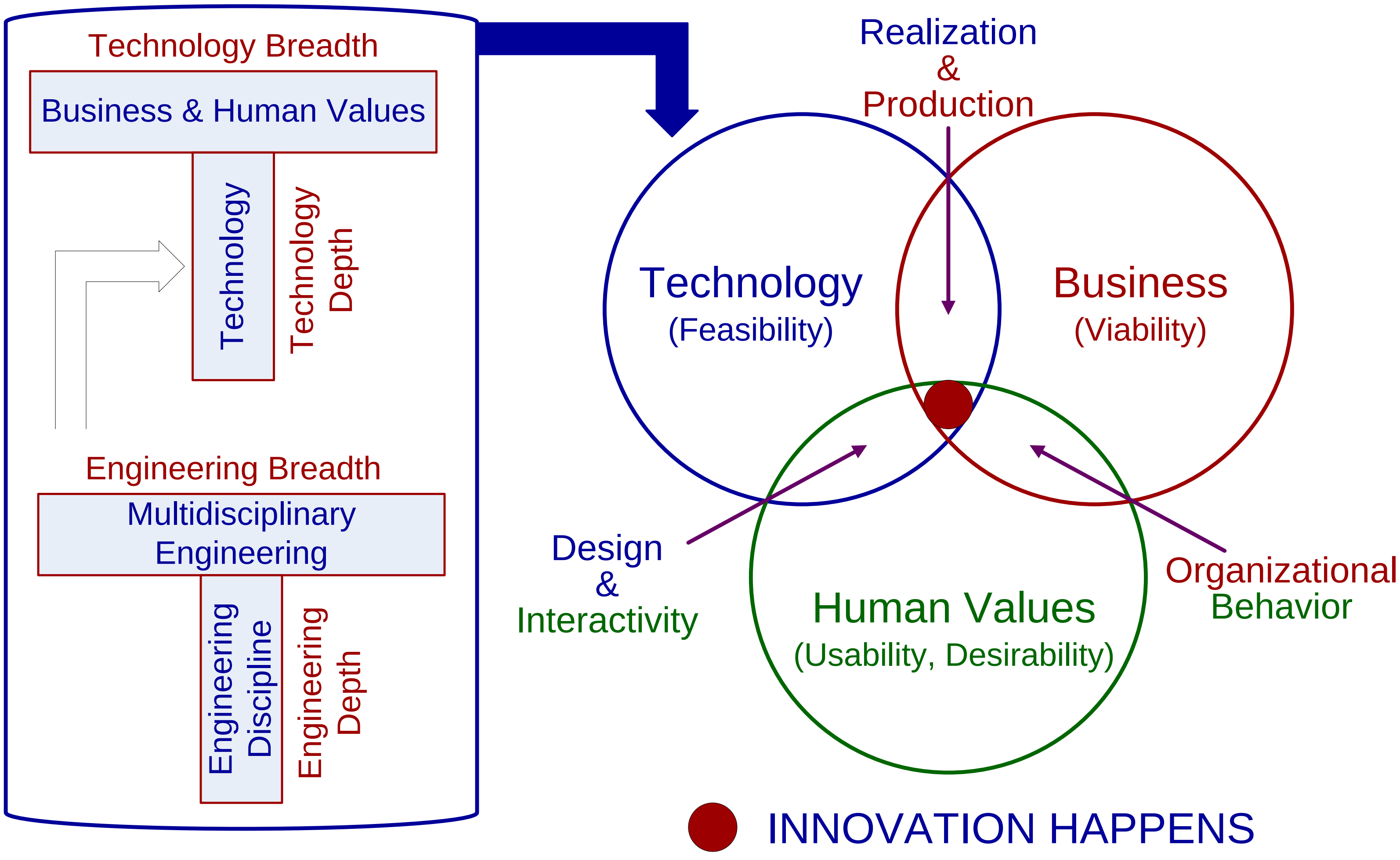
the genius must be wrong. A scientific genius is not a person who does what no one else can do; he or she is someone who does what it takes many others to do. The genius is not a unique source of insight; he is merely an efficient source of insight. "Consider the case of Kelvin, by way of illustration," Merton writes, summarizing work he had done with his Columbia colleague Elinor Barber:

After examining some 400 of his 661 scientific communications and addresses . . . Dr. Elinor Barber and I find him testifying to at least 32 multiple discoveries in which he eventually found that his independent discoveries had also been made by others. These 32 multiples involved an aggregate of 30 other scientists, some, like Stokes, Green, Helmholtz, Cavendish, Clausius, Poincaré, Rayleigh, themselves men of undeniable genius, others, like Hankel, Pfaff, Homer Lane, Varley and Lamé, being men of talent, no doubt, but still not of the highest order. . . . For the hypothesis that each of these discoveries was destined to find expression, even if the genius of Kelvin had not obtained, there is the best of traditional proof: each was in fact made by others. Yet Kelvin's stature as a genius remains undiminished. For it required a considerable number of others to duplicate these 32 discoveries which Kelvin himself made.



What are the differences between *creativity*, *invention,* and *innovation*?

Innovation happens at the intersection between technical and non-technical disciplines



The Ideo shopping cart prototype

The product

at a market in Rio de Janiero, Brazil, July 2007

at a market in Rio de Janiero, Brazil, July 2007

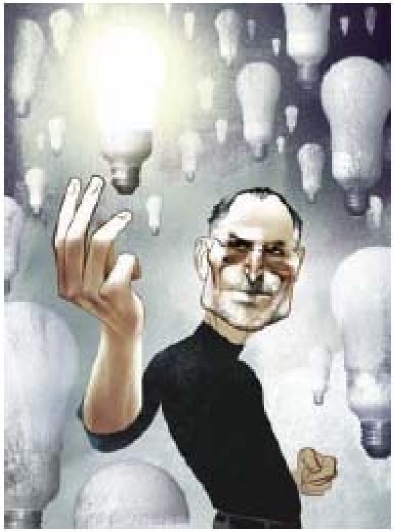
THE NEW YORKER

ANNALS OF TECHNOLOGY

THE TWEAKER

The real genius of Steve Jobs.

BY MALCOLM GLADWELL



Jobs's sensibility was more editorial than inventive. "I'll know it when I see it," he said.

Was Steve Jobs a Samuel Crompton or was he a Richard Roberts? In the eulogies that followed Jobs's death, last month, he was repeatedly referred to as a large-scale visionary and inventor. But Isaacson's biography suggests that he was much more of a tweaker. He borrowed the characteristic features of the Macintosh—the mouse and the icons on the screen—from the engineers at Xerox PARC, after his famous visit there, in 1979. The first portable digital music players came out in 1996. Apple introduced the iPod, in 2001, because Jobs looked at the existing music players on the market and concluded that they "truly sucked." Smart phones started coming out in the nineteen-nineties. Jobs introduced the iPhone in 2007, more than a decade later, because, Isaacson writes, "he had noticed something odd about the cell phones on the market: They all stank, just like portable music players used to." The idea for the iPad came from an engineer at Microsoft, who was married to a friend of the Jobs family, and who invited Jobs to his fiftieth-birthday party. As Jobs tells Isaacson:

http://www.newyorker.com/reporting/2011/11/14/111114fa_fact_gladwell

Conclusion: we seek *wisdom*

(Beveridge calls it "scientific taste")

Taste can perhaps best be described as a sense of beauty or aesthetic sensibility, and it may be reliable or not, depending on the individual. Anyone who has it simply feels in his mind that a particular line of work is of interest for its own sake and worth following, perhaps without knowing why. How reliable one's feelings are can be determined only by the results. The concept of scientific taste may be explained in another way by saying that the person who possesses the flair for choosing profitable lines of investigation is able to see further whither the work is leading than are other people, because he has the habit of using his imagination to look far ahead instead of restricting his thinking to established knowledge and the immediate problem. He may not be able to state explicitly his reasons or envisage any particular hypothesis, for he may see only vague hints that it leads towards one or another of several crucial questions.

Beveridge, The Art of Scientific Investigation

Homework

- Literature survey (submit via ctools, due 2pm Friday)
- Readings for lecture 4 (on ctools)
  - 2 chapters from Getting Things Done by David Allen
  - Surowiecki, "Later: what we can learn from procrastination", http://www.newyorker.com/arts/critics/books/2010/10/11/101011crbo_books_surowiecki