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Opportunities for Applying Science to the Art of Research: A Workshop Review

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Sandia National Laboratories hosted, in the summer of 2013, a workshop on the "Art & Science of Science & Technology." The workshop brought together distinguished **practitioners of the art of research (physical scientists)** and **experts in the emerging science of research (social scientists)**. The two communities engaged in a broad-based discussion; here we summarize some of the insights that emerged during the workshop and post-workshop reflections.

Foundational assumptions (hypotheses) that emerged from the workshop:

1. ***Divergent (idea generation) and convergent (idea selection) thinking are the fundamental processes underlying research.***
2. ***The quality, quantity, and interactivity of divergent and convergent thinking are directly correlated with research impact.***
3. ***Divergent and convergent thinking occur, but can be inhibited, at all levels of the research ecosystem.***

Overarching science questions:

1. ***How can we measure divergent and convergent thinking?***
2. ***How is (or isn't) divergent and convergent thinking correlated with research impact?***
3. ***What are the mechanisms by which divergent and convergent thinking are inhibited, and are there dis-inhibitory interventions?***

DIVERGENT THINKING
Generate new ideas, largely through the recombination of pre-existing ideas[a]

[a]WB Arthur, "The nature of technology: what it is and how it evolves" (Simon & Schuster, 2009)

Examples of Divergent-Thinking Inhibitory Mechanisms	Possible Dis-Inhibitory Interventions	Level in Research Ecosystem	Examples of Convergent-Thinking Inhibitory Mechanisms	Possible Dis-Inhibitory Interventions
CULTURE OF PERFORMANCE[1] *An institutional culture in which people are hired and rewarded for immediate performance and problems are too rigid, hence for choosing safer problems that don't require deep learning or divergent thinking in either the problem or solution spaces.* *[1]CS Dweck, EL Leggett, "A social-cognitive approach to motivation and personality," Psychological Review 95, 256 (1988).*	**RE-BALANCE TOWARDS A CULTURE OF LEARNING[1]** *Learn how to measure when an individual or a team is choosing too-safe problems, and thus how to re-balance institutional culture towards one in which people are hired and rewarded for choosing optimally challenging problems.*	**Institution**	**CULTURE OF CONSENSUS[5]** *An institutional culture in which people are hired and rewarded for consensus and intellectual harmony.* *[5]IL Janis, "Groupthink: the desperate drive for consensus at any cost," Classics of Organization Theory 6, 185 (1971).*	**RE-BALANCE TOWARDS A CULTURE OF TRUTH** *Learn how to measure when consensus is artificial (e.g., achieved without rigorous intellectual debate), and thus how to rebalance institutional culture towards one in which people are hired and rewarded for seeking truth even at the cost of intellectual disharmony.*
OVER-RELIANCE ON STRONG LINKS[2] *Over-reliance of a team on idea-flow to and from individuals who are strongly rather than weakly linked to the team's social network, and who therefore only know what the team already knows.* *[2]MS Granovetter, "The strength of weak ties," American J of Sociology 78, 1360 (1973).*	**EXPLOIT WEAK LINKS[2]** *Learn how to engineer idea-flow to and from individuals who are weakly linked to the team's social network, and who therefore know what the team doesn't already know and can contribute out-of-the-team's-box thinking.*	**Team**	**IMPERMEABLE TEAMS[6]** *Teams whose membership is overly fixed [e.g., because of existential (loss of funding) or social (loss of friendship) fears], and hence are not real-time optimized for the expertise set necessary to rigorously test and select ideas.* *[6]CP Alderfer, "The Practice of Organizational Diagnosis: Theory and Methods" (Oxford, 2010).*	**PERMEABLE COLLABORATIONS** *Learn how to measure the degree to which teams are impermeable, and thus how to re-balance towards collaborations which are permeable and can be real-time optimized.*
IDEA FIXATION[3] *An inability to break free from ideas that preoccupy the mind and hold attention.* *[3]J Linsey, I Tseng, K Fu, J Cagan, K Wood, C Schunn, "A study of design fixation, its mitigation and perception in engineering design faculty," J Mechanical Design 132, 041003 (2010).*	**ENGINEER IDEA EXPOSURE** *Learn how to expose researchers to ideas that are an optimal analogic distance[4] away from their center of gravity: far enough to catalyze shifts in perspective, but not so far that conceptual and language gaps are too difficult to bridge.* *[4]K Fu, J. Chan, CD Schunn, J Cagan, K Kotovsky, "Expert representation of design repository space: A comparison to and validation of algorithmic output," Design Studies 34(6), 729-762 (2013).*	**Individual**	**SLOPPY THINKING[7]** *Errors of logic and analysis in the testing and selecting of ideas.* *[7]RS Nickerson, "Confirmation bias: a ubiquitous phenomenon in many guises," Review of General Psychology 2(2), 175-220 (1998).*	**RESEARCH NARRATIVES** *Learn how to make more disciplined use of research narratives (storylines which knit together background, hypothesis, methodology, analysis, findings and implications) as tools for logical thinking.*

Table and categories are a work in progress.

CONVERGENT THINKING[b]
Select the best of the new ideas, largely through logic and analysis

[b]A Cropley, "In praise of convergent thinking," Creativity Research Journal 18(3), 391 (2006).