Creativity and Complexity in Cross Functional Teams

Christopher M. Barlow
IIT - Stuart Graduate School of Business

Cross functional collaboration, when individuals attempt to integrate their diverse knowledge backgrounds into synergistic solutions, is the intersection of a complex set of factors researched in a variety of fields: psychology, management. social psychology, computer science, design, architecture, and many more. Concepts such as team, group, cohesiveness, cognitive complexity, group maturity, creativity, decision making, and many more interact and influence each other in very complex ways. Like the Blind Men and the Elephant, these different people and fields have diverse, often conflicting perspectives and insights on the process. It would seem useful if these diverse knowledge resources could be brought together in an integrated perspective on this phenomenon that would enable the different fields to build upon each other in the search for more useful knowledge.

This paper discusses some perspectives that may assist in bringing all the perspectives together into a shared discussion space that supports deliberate efforts to get more from cross functional efforts: defining creativity as insight, managing for complexity of thinking, and understanding team complexity.

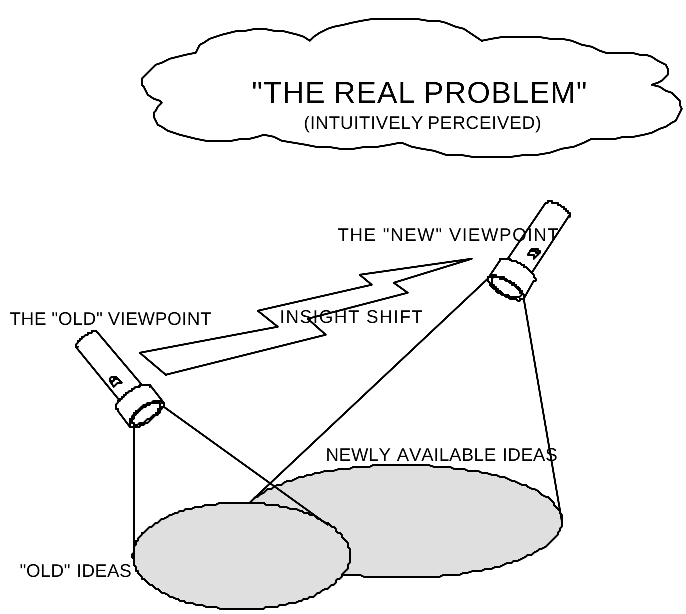
Seeing creativity as changes in the creator(s)

The outputs of successful cross functional teams certainly seem to fit the classic definition of creativity as new and different. However, so many different people and events are involved in the development and implementation of any complex solution or innovation, the classic concept of inventors getting great ideas and implementing them seems to miss much of what is happening. As an alternative, focusing the definition of creativity on the changed perspective of the creator rather than on ideas may facilitate understanding collaborative creativity.

This "shifted insight" model has its roots in that most subjective and individualistic phenomenon of all, the "AHA" or "Eureka!" experience. Throughout history, various individuals have described this reaction that a person has to getting an idea (Koestler, 1978). This intensely physical, emotional, and intellectual experience seems to mark our fundamental recognition that a profoundly advantageous change has taken place in our thinking. The image below attempts to explain this model.

1. A flashlight has been chosen for the model as an analogy for our perception of a problem. The surface below represents all the things anyone could ever do. The area of the surface illuminated by a flashlight signifies the set of ideas that fit the problem statement. If the flashlight represents a problem statement or intention like "raise the bridge" the illuminated circle contains all the various actions that might raise the bridge.

1. A second flashlight represents a new formulation of the problem, such as "increase the gap between the bridge and the water" or "get tall boats past the bridge." The surface area that its pool of light illuminates includes all the ways to accomplish that goal. In successful creativity, some of the alternatives illuminated or made obvious by this new viewpoint



are better than the best of the ideas made obvious by the old perspective. This shifted perspective can be a simple assumption about the situation or as profound as a basic paradigm of a discipline or culture.

2. The lightning bolt labeled "insight shift" represents the shift to the new definition. Although getting such an insight might take years, when it happens, it seems as fast as that lightning bolt.

3. The cloud above represents the "real" problem, the complex interaction of wants, wishes, and reality that is only approximated by our viewpoints and problem statements. Locating the second flashlight of the new viewpoint closer to that cloud represents our recognition of the closer fit of the new perspective to the total problem.

The structure of this model has several implications:

1. The strength of the AHA or Eureka experience is directly related to its fit to the perceiver's image of the problem, not the general quality of the idea. The better the fit of the perceiver's knowledge to the breadth of issues involved, the more relevant the AHA response. For example, if we are having a casual conversation with a new acquaintance, and we mention a problem we are facing, that person may get a great AHA reaction to an idea about what we should do, an idea that proves the acquaintance really does not understand the problem. On the other hand, if their comment or idea triggers a shift in our perception to a point that better fits our perception of the problem and makes obvious some new and useful alternatives, our AHA reaction is relevant, especially since we are the ones to act on the new perception.

1. Our AHA response to someone else's idea or suggestion, an "Appreciative AHA", is a measure of the value of that idea or perspective as to the problem as we see it. It is entirely possible for a non-expert to trigger such a response in an expert, a relevant AHA which indicates the potential of an idea, but the general relevance of the response depends on the breadth of understanding of the perceiver. In a cross functional team, each participant from a different discipline sees a different set of benefits and problems in each idea.

2. It is important to note that the problem as perceived, the context of our AHA reaction, includes our values and wishes as well as our knowledge and experiences. So, for example, if there is a person at work that has really irritated you, and a new perspective or idea occurs to you which not only seems to fit the problem, but also really punishes your opponent, your AHA will have more energy. The same is true of your good wishes for others. So if you hate or disrespect customers, the ideas that really light your fire will be those that punish the customers.

3. Satisficing is another important aspect of this creative process. Simon (1946) used the term to describe our tendency to decide to accept less than optimum solutions because the improvement to optimum was not worth the effort to gather and analyze additional data. One of the things which happens to a person who participates in an AHA experience is that their expectations and perceptions of the situation change. We often talk of the "Not Invented Here" syndrome because it seems that organizations and departments refuse to accept ideas developed by outsiders, but would accept it if they developed it themselves. Note that after you shift to the new perception the new ideas seem obvious, but if you are still back at the old perspective, the new ideas are ridiculous. A good example of this phenomenon would be planning a family vacation. If you sat down, gathered all relevant data, and effectively planned the absolutely best possible vacation for your family given the conditions, they would all complain and be dissatisfied, because your plan is pretty poor in their individual perspectives. On the other hand, if they had been in on the planning, the process would have had an effect on their understanding and expectations, and they would have shifted to a perspective in which your plan is quite good.

In summary, the insight model of creativity seems to open up several ways to more effectively research the roles of knowledge background, beliefs, intentions, and other mental processes in an individual's creativity and their reactions to the creativity of others. This may lay the basis for more effective analysis of the dynamics of collaborative teams and organizations.

Including the Requisite Knowledge

It seems obvious that well trained engineers will develop good designs, and therefore any design errors would seem to result from a lack of engineering expertise, but there are too many cases where this explanation simply does not fit. Let's look at some better-known examples of design "errors." It may be wrong to label these examples as errors, because in many cases, the design was pure genius, given the problem they were focusing on. Its just that other parts of the situation they did not understand prevented complete success, or parts of the situation they did understand changed, and the design become a problem.

Most technology lovers are familiar with the "**QWERTY"** keyboard, standard on English language computers because it was standard on electric typewriters, because it was standard on manual typewriters as a way to slow down the better typists so they wouldn't jam the keys. This was a great creative solution to their biggest problem at that time. It is hard to sell typewriters if your customers spend a lot of time unjamming the keys. As an additional feature for the salesmen, the designers even shifted a few keys so that the word "typewriter" could be typed very fast alternating between two fingers just on the top line so salesmen could make typing look easy and fast. That idea, so useful then, is wasting an incredible amount of time around the planet as we try to type words on a keyboard designed to slow us down.

Petroski (1994) tells of the marvelous Britannia Tubular Bridge built in 1850 over the Menai Strait on the Northwest coast of Wales to carry passengers to the port for a Dublin bound ferry. A wrought iron tube with the train running on the inside, it was a technological marvel of design and construction, a work of true engineering genius. Only after construction was it discovered that the bridge was unusable. Imagine a black, wrought iron tube sitting in the hot sun of a summer day, with more sunlight reflected off the water. Imagine the temperature inside as this wonderful solar collector stores heat. Now, take a wood-fired engine pulling a trainload of passengers through this tube with no ventilation. Imagine the heat, the smoke, the sparks flying from the engine. It could easily be described as hell on earth. Examination of the design notes and specifications shows not a single bit of discussion focused on the realities of passenger trains, only wind loads and ocean storms and spans. It was a remarkable solution to the problem as understood, but missed one of the most important parts of the problem.

One great solution to this problem, where possible, is to select designers who have all the knowledge relevant to the problem, or to train designers in the missing knowledge. In the early 1950's at General Electric, management began to realize they had problems in the design of kitchen appliances for the consumers. For example, they noticed that to the well-educated electrical engineers they had hired to design electric ranges and cooking stoves, a superior design was one which most efficiently converted electricity to heat, which was not the concern highest in the consumer's mind. Therefore, they hired a chef to come in and teach the engineers to cook on those ranges. After this experience, they began to make improvements to design that actually helped the homemaker. Of course, it never occurred to them to hire some housewives to be designers. Moreover, if you have ever owned one of those General Electric ranges from the late 50's and early 60's, it is obvious that the engineers never had to clean a stove, especially after several years of use.

The Bureaucratic Solution

The more common approach to complex design is the bureaucratic organization in which managers coordinate the work of multiple specialists on various parts of the design. One of the most common attitudes in these organizations is "You do your job, and I'll do mine." The assumption is made that somehow if all the parts are done right, they will fit together into an effective whole. A great deal of our civilization's economic success has come from dividing complex tasks into simpler ones which could be done by less talented people. Adam Smith (1776) tells the story of pin making, where dividing the work formerly done by master craftsmen into simple steps done by people with far less training allowed a quantum leap in productivity. The sciences and engineering have accomplished a great deal by dividing things up so that some people worry about the electrical nature, others about the mechanical nature, others about the electronic nature, others about the chemical nature, etc.

This is often seen as being the equivalent of the old military strategy "divide and conquer." It was discovered long ago that a smaller army could beat a bigger army if it could divide the larger army into separate smaller elements that could be outnumbered by the smaller army, until the larger army was completely destroyed. There is only one flaw to this logic. The "enemy" (the design problem) is not actually divided, but the designers are. We have divided ourselves in a way that can easily lead to defeat. The key to our success is our capacity to integrate and synergize the various aspects.

Multiple Stakeholders, Multiple Perspectives: Putting the Pieces Together

One of the best descriptions for the problem of complete design is the old story in which blind men encountered different parts of an elephant, then argued about the true nature of the elephant. It is interesting to note that each blind man is fairly right about the nature or the part they encounter, yet wrong in their total perception. Each has had a powerful AHA experience that fits the part they know of the elephant. Until they can let go of their conclusions, share their information, and experiment with different perspectives and models, they cannot understand the elephant.

A great example of dealing with this issue was the original design project for the Ford Taurus. Lew Veraldi, leading the project, mapped out every organization and type of individual who had an interest in the final design of the car, whether repair shop mechanics, legislative bodies, or production workers. Each of these "stakeholder" groups was approached and a list of their "demands" was created. Each demand was dealt with, although often in a way quite different from the suggestion. For example, assembly workers demanded that they get rid of plastic bumpers and return to steel. Instead of accepting the idea, which would have caused real problems in their fuel efficiency, they asked why. It turned out that the original implementation of plastic bumpers had endcaps to go around the corners of the car, which were almost impossible to align with the bumper. To solve the real problem more completely, they found that they could mold plastic bumpers that would go around the corners, thus keeping the weight down, eliminating the alignment problems, and improving the appearance. They went through all the requests of all the stakeholders and dealt with them in a similar fashion. The resulting design won many awards and captured a very large market share.

Modern reality: the boss can't do it

This integration of elements is supposed to be the role of bureaucratic organizations. In a well-designed bureaucracy, each person has a boss. Bosses are responsible for checking the quality of subordinate's work and coordinating their work schedules. The boss is also responsible for breaking up the department's work into sub-components that can be worked on independently by the available subordinates, then for combining those sub-components into a smooth, complete design.

This process may have worked to a certain extent in the past, but today, there are several problems. First, in most fields, the technological world is changing so fast that the subordinate, with more recent training, often has more knowledge about the technology than the boss does. Most JAVA programmers cannot turn to their C^{++} trained bosses for detailed help, or for a competent design review.

If the boss is supposed to integrate the bits and pieces developed by subordinates from different specialties, the boss needs to have a strategic understanding of each of those fields. There are few bosses who can do this integration alone as well as their team members can by interacting about the various goals, dynamics, and interfaces. A boss who must check every detail personally limits his or her department to the things that the boss can understand in detail. This can be quite dysfunctional.

Peter Drucker in many of his writings points out that the modern boss is more like an orchestra conductor. Conductors cannot play the instruments better than the orchestra members. Their value lies in their ability to bring the players together into a great performance. In the same way, a modern manager succeeds by guiding an "orchestra" of diverse experts in a process that outputs the beautiful music of a realistic and economic design.

In other words, the complexity of modern problems cannot be managed by merging individual efforts. It requires people of the diverse backgrounds and levels to work together, which requires lots of meetings and team efforts.

Nonaka and Takeuchi (1995) in discussing the "Knowledge Creating Company" discuss several other cases of team design such as the Canon personal copier, bread making machines, and automobiles. Interestingly, in a time when middle managers are being eliminated, Nonaka argues that only middle managers are equipped to lead and manage the collaboration among functional departments which is the knowledge creating engine of organizations. Unfortunately, many of these managers are promoted engineers who have only been trained to act as individual designers and have little preparation for the kinds of leadership and management necessary to make team collaboration across disciplines effective.

Two issues make this team work complex. First, while individual professionals and disciplines are capable of working with very complex concepts, an new kind of complexity comes into play, in which the truths of different perspectives conflict with each other. Second, people not only bring diverse knowledge sets, they differ in cognitive style, cultural backgrounds, personality, and values in ways that can quickly destroy all hopes of collaboration. This is probably the basis of the story of the Tower of Babel, a massive building project which was abandoned because people could not understand what each other was saying.

Deliberate attempts to more effectively bring knowledge together must succeed in dealing with, and even taking advantage of, these complexities of knowledge and of teams.

Teams: Both Organizations and Groups

A great deal of work has been done on the dynamics of groups and teams, but there are some interesting additional issues that emerge or become more important in these knowledge creating teams. One special dynamic of cross functional teams that has to do with trust.

If a team project is assigned to a single discipline group, such as an MBA finance class or a VRML Coding group, each team member can be expected to have the ability to check the work of other team members in great detail. The issues of trust affecting group performance center around levels of effort and reliability of commitments.

One critical difference in knowledge creating collaborative projects is that every member brings knowledge and processes that cannot be checked in detail by other team members. The marketer can't really check the engineering calculations and the engineer is rarely equipped to check the allocation decisions of the accountant. This reality strongly affects team performance and the earning of this different kind of trust from each other is a critical team dynamic, one that requires time and process.

Another obvious assumption about teams may need to be questioned: the idea that the work of teams is the sum of the work of its members. Nonaka (1995) describes product development team processes and makes an interesting analogy, based on the idea of hypertext, the mechanism underlying the world wide web. A "normal" page contains what it contains, pictures, words, tables of numbers, etc.. A "hypertext" page links to an entire spectrum of knowledge and resources, such as other pages, databases. computer programs, web cameras, even audio connections to experts.

Nonaka points out that members of collaborative teams are links to their home departments and disciplines, not just independent experts. Researchers on matrix organizations and project teams often think of the members as limited to using their individual capacities, when it is their access to resources and ability to blend those inputs with others that defines their usefulness to the team. Seeing team members as portals to resources would seem to trigger significant shifts in the design of support systems and in the research into these teams.

As these new factors emerge in understanding these collaborative teams, it becomes clear that they are taking on more of the nature of an organization, and various organizational dynamics begin to become relevant.

Complexity of problems and thinking

One factor which certainly affects the dynamics of creative productivity and the relevance of research in this area is the complexity of the problems being solved. Complexity is itself a complex issue.

Most are familiar with the distinction of structured vs. ill structured problems. There seems to be a natural progression from having the answer available in memory to being able to follow an algorithm to get the answer. Most people have memorized the answer to multiplying 7 times 8, but have to use an algorithm to multiply 52 times 86. Problems for which we can identify and apply a successful algorithm are considered "well structured". Of course, algorithms can be quite complex. Calculating the optimum dimensions for a 12 ounce aluminum beverage can is computationally complex, but well structured. There is a process to get an answer and you can check it when you are done.

Problems for which there is no clear algorithm are considered ill-structured. Two natural sources of this lack of clear structure are non-congruent values of the stakeholders and non-congruent dynamics of the subsystems, often referred to as "sub-optimization". In a company where everyone is working on the same goal of maximizing profits, different departments have different optimization strategies, which often conflict. Marketing effectiveness is best served by a production system that can deliver a "one of a kind" product by tomorrow morning, and a finance system that gives the customer 12 months to pay. Manufacturing efficiency is best served by receiving orders six months in advance and then making the same version continuously for three months. Accounting is most successful when cash is received before the sale is accepted, so they can purchase the raw materials well in advance for production. Finding the best positioning on manufacturing flexibility and credit flexibility is an extremely complex task. Ability to memorize theories and findings in finance, production, and marketing do not predict an ability to integrate these strategically.

The term wicked problems was coined to designate those ill-structured problems that are further complicated by goal and values conflicts among the stakeholders, such as who is going to get what share of the company profits. These can sometimes be reduced by relating decisions to ultimate goals on which the different parties agree, or by inventing detailed concrete solutions which leave all parties equally (dis)satisfied. Both of these strategies can benefit from participatory creative efforts, but even after the best rationality and creativity, goal conflict can remain. For example, when couples go shopping for a house, their preferences often conflict. This is the zone of negotiation, whether it is family members working out inheritance issues or union-management negotiations about who gets to take home the greatest part of the profits of their joint work. Even here, the effort of attempting problem solving together may transform the perspectives of the participants, opening up new zones of possible solutions.

"Cognitive Complexity"

The term "cognitive complexity" is used in psychology for the ability to process information which is not well defined and internally consistent, such as the knowledge relevant to ill structured problems.. It is generally worth the effort to attempt to transform an “ill structured” problem to one or more “well structured” problems, but with even the most competent and diligent effort, there seem to be residual “irreconcilable differences”.

Successful organizations balance an ability to focus experts on well structured problems and sub-problems with an ability to take on ill-structured and complex problems and convert them into well structured sub-components that the organization can handle. In fact, Jaques (1996) proposes that each level in an organization must handle a particular level of problem complexity, and managers must be selected not only for relevant knowledge, but for their ability to think at that level of complexity. Various organizational tasks should be assigned to levels by the same complexity dimension.

After discovering he could explain the perception of fairness in pay with the time horizon of the work (the further to the future you were expected to look, the more you should get paid), he noticed distinct differences in cognitive processing between different organizational levels. The kinds of thinking required at each level are qualitatively different from each other. His current version of the first four levels of a well designed organization as doing the following kinds of work:

- **Declarative.** Take direct action, following a linear path, paying attention to feedback, and using pre-learned coping mechanisms to handle problems
- **Cumulative.** As one takes action**,** it is necessary to reflect on events and accumulate data to perceive and solve problems.
- **Serial.** In addition to direct action and data accumulation, it is necessary to understand a complex plan of multiple elements and alternate pathways to the goal.
- **Parallel**. Multiple, simultaneous, and interacting goals require a pattern of disparate adjustments which optimize the total system.

In this model, the cognitive complexity of the manager needs to encompass the cognitive complexity of the problem. Excelling at one level does not imply effectiveness at the higher level, nor does functioning at one level imply competence at lower levels. In sports, the best player is often the worst coach, and many coaches were mediocre players. In the modern world, the speed of changes in technology and procedures in different areas often result in the managers of a higher level of thinking complexity lacking the more current knowledge of the problem and possibilities which are available in lower levels of the organization.

One major task of any manager in this model is to design work for subordinates which is of a level of complexity to match their abilities, which they process and develop sub-tasks of their subordinates’ level of thinking complexity. It may be that these cognitively complex, ill structured, and often wicked problems are addressed by cross functional teams as a way to bring together the relevant areas of knowledge in a conversation of adequate cognitive complexity.

Increasing Complexity of Interaction

One critical question is whether it is possible, effective, and efficient to have team interactions among people operating at multiple levels of complexity. In a group setting, it would seem that the interaction complexity must be limited to the lowest capacity present in the group. However, many facilitation techniques seem to help people of different cognitive levels to work together and/or help people function at a higher level of capacity, allowing those of lower levels of cognitive capacity to effectively contribute their unique explicit and tacit knowledge in interactions of higher complexity

The first issue is whether you assume that a person’s cognitive capacity is fixed at a certain level. Jaques (1996) finds a fairly fixed trajectory of development over years that prepares an individual to rise to higher levels in an organization until reaching some plateau of maximum capacity.

However, there is some evidence that the same person at the same time can vary in their ability to handle complexity depending on their way of thinking about the problem. Gier Kaufmann (1980) investigated the usefulness of visual images in the solution of concrete problems. He took problems and puzzles which had already been assessed for their difficulty and presented then in different ways. He took easy, moderately difficult, and difficult problems and presented them to different people as: word problems requiring word answers; picture problems requiring sketched answers; or actually putting the subjects in the physical situation described in the problem.

The most difficult problems were only solved by people working in a physical version of the problem. The easy problems were solved quite effectively when given as word problems, and presenting them as pictures or real world situations just slowed down the solution.

Problems of moderate difficulty were difficult to solve as word problems, but generally well solved as picture problems, with little advantage from putting the subjects in the real world.

Therefore, word focused thinking is effective only for the easiest of problems. With more difficult problems, there is an advantage to drawing pictures to understand and solve the problem. And for the most difficult problems, it seems that you need to just jump into the situation and muddle around until you get it solved.

This seems to indicate that the same person can solve more difficult problems by using different ways to approach the problem. If a person is assessed for their cognitive complexity from their word focused thinking, we do not have a true measure of what they could do with the help of images and models.

Using External Models

The ability to perceive, create, and manipulate images in the mind has long been associated with effective and complex creativity, but it may be that the use of sketches and physical models can compensate for lack of this talent, while opening the process up to team members and other collaborators.

Spatial visualization is the ability to picture a physical item in one's mind and to infer what it would look like if transformed in different ways. You may have taken tests in which you were asked to pick out which drawing could be a rotated version of another drawing.

Many great inventors and artists report picturing their creations in detail before producing them, and early researchers found correlations between this ability and performance on standardized tests of creativity. The quest for deliberate increases in the complexity of thinking performance leads to the question: can people deliberately choose methods that allow them to perform at higher levels of complexity? There is a hint in some research about testing for the ability.

One effective test for spatial visualization is the solving of anagrams, those scrambled combinations of letters which can be rearranged to form known words. The better your spatial visualization ability, the faster you can solve these problems. Gavurin (1967) did some methodological research on anagrams to determine if there were any problems with allowing test subjects to manipulate the materials. He discovered that when the anagrams were presented with each letter on a separate piece of cardboard which could be moved around on the table, spatial visualization ability no longer affected the speed of solving the problem. As a test developer, he learned that if you want to effectively measure this talent, you must not allow the subject to use any external materials which can be manipulated. On the other hand, this research also means that allowing people to move the letters around externally allows those low in spatial visualization to perform as well as those who excelled in it. This is a good thing for deliberate creativity.

Mathematics as an Analogy to Problem Solving

This advantage to using external representation for creativity and problem solving seems to be the same as in mathematics, where most of us can solve far more difficult problems on paper than we can in our heads.

The table below explores in more detail an analogy between creativity and arithmetic. If I want to multiply two numbers, there are several possibilities. I might know the answer already, although most people have only memorized the answers for multiplying pairs of single digit numbers. A few might be able to calculate the answer unconsciously, but this ability is labeled “idiot savant” because it is usually accomplished by severe defects in other cognitive areas. This is what the movie “Rainman” was about.

Some have practiced "mental arithmetic" and have learned tricks to handle problems of three, four, or more digits in their minds. Most of us could take paper and pencil to work these problems out, with our ability limited by our patience, carefulness, and the size of the sheet of paper. Of course, most folks would simply use a calculator.

Level	**Arithmetic**	**Creativity**
Remembered or Known	Memorized multiplication tables	Knowledge
Unconscious process	"Idiot Savant"	Intuition and Incubation
Conscious, internal process	"Mental arithmetic"	Thinking about a problem, possibly following a process
External model	Paper and pencil, graphing	Journaling, doodling, writing, PERT charting
External and Social	Group problem solving with chalkboard	Group problem solving with paper, models, facilitated process
External processor	Calculator	?

Applying this same structure to problem solving, we note that sometimes we already have an answer as part of our knowledge. Getting these previously known answers from others is one of the dynamics of brainstorming sessions.

Other times an answer seems to arise from our subconscious with no indication of where it came from. We label this process intuition, and we use the term incubation to label the process of doing something else while waiting for the answer to emerge.

We also have a certain level of ability to solve problems in our minds, but most of do better with paper or some other medium for listing and/or sketching our ideas.

Just as with arithmetic, various techniques enable us to handle more complex and extensive problems, both in our heads and on paper. Part of the function of external models may be to hold for reference more information than we can hold in our heads at one time. When we use paper and pencil to multiply large numbers, we carefully write down the intermediate steps and basically solve lots of little single digit problems with those answers we memorized as children. The writing helps us keep track of our progress and remember our sub-answers.

Shared Images Operating at Multiple Levels

Drawing pictures and manipulating models seems to be very valuable to those working alone, but there also seem to be several advantages for team collaborations. Keeping notes of ideas and facts and work in progress in front of a problem solving group on flip chart sheets around the room seem to help them handle more complexity.

Blueprints of building or product designs give us a similar capability of looking together at various details in the context of the whole. Charts such as flow charts and PERT charts can represent complex interactions in a form which allows groups to both see the whole interaction and to focus on simpler details and relationships.

The architect and planner Alexander (1964), noted that while there seem to be a limited number of people who can invent new structural patterns, there are many more who can effectively evaluate those structures, their details, and their implications. So external models may permit people of higher cognitive complexity to present and manipulate their complex structural ideas while permitting those who operate at lower cognitive complexity to check their implications against their knowledge and values.

Deliberate Improvement of Collaborative Success

One way to look at a collaborative design process is as a way to increase the probability of "relevant AHA's" by making sure that every part of the "elephant" is included in the discussion. After selecting the participants needed to understand and represent the breadth of relevant issues, it is necessary for them to interact effectively, allowing each participant to affect the discussion with their knowledge and be affected by the discussion, reformulating their own perspective on the problem. Because each participant has different perspectives and goals, as well as a history of conflict and interaction, creative conversation is often difficult, beyond the skills of most managers. Since most have been trained in rational decision-making with well-structured problems, they think that all problems are like that. Classic decision making starts with clear consensus about the problem, the facts, and the criteria. But real design problems are ill-structured, with constraints and criteria in so many conflicting domains that a clear decision is impossible. Moreover, most are actually of the type called "wicked": even when we clearly understand the problem, the players disagree about the ultimate goals and values. Even when the most successful, complex, diverse team has designed and accepted a course of action, there remain strong disagreements about the goals, facts, and criteria. The trick is to work together in relative disagreement, seeking out all the clarifications and simplifications possible, but accepting that consensual clarity is impossible.

Barlow (2000) measured the impact of some techniques seemed to have make very strong contribution to these multi-perspective design efforts. In this analysis, ideas are seen as more creative when they involve more disciplines or require so much of a shift in the problem definition that the problem must be re-explained to management. One surprise of the research was that ideas which are more creative in this sense are **more** likely to be accepted by the organization, leading to the possible conclusion that many ideas are rejected simply because they are not creative enough.

In this study, the most effective technique for guiding team interaction was a strategy that involves separating the benefits and effects from the attributes and methods, then considering the costs of attributes and methods used to provide the benefits and effects desired by the customers. This strategy is often referred to in systems design as "black box" thinking, and is called "function analysis" in the field of Value Engineering (Miles, 1971; Mudge, 1971; Fowler, 1990). Even more powerful is a technique where a team analyzes the cost for each increment of benefit the customer is buying, as well as the price the customer is willing and able to pay for that increment. (Snodgrass and Kasi, 1986)

A second technique that strongly related to creative team success was the use of the decision criteria matrix in which each alternative is evaluated against each criterion. Although both of these techniques would be seen by many as too confining and analytical to allow creativity, they seemed to lead to a deeper, more complex understanding of the situation, allowing more complexly creative ideas to emerge.

Further research will be needed to evaluate the ability of various methods to increase complexity of understanding without reducing team creativity.

Educating for Collaboration

This shifted insight model helps understand the conflicts between creativity and education. For years, people have complained that education suppresses creativity, and have struggled to bring more creativity into the educational process. In fact, Simonton (1985) discovered a negative relationship between advanced education and eminence in famous people in history (1650-1850). In this insight model, educational programs normally take as their major task to teach students to know the right flashlights, and how to work within the constraints of a particular flashlight. When deliberate creativity is guided by the "out of the box" philosophy, it is very difficult to distinguish between someone who is being creative by "shifting flashlights" and someone who has not absorbed the knowledge.

Another view of education is also possible in the insight model, that of developing the ability to discover new perspectives and to judge when a perspective might be more valid or provide an advantage for thinking., what might be called "better box thinking".

This seems to involve development in more complex and strategic thinking, developing a sense of how to measure the relative fit of different models to the problem, and an extensive building of the "cloud" of knowledge and experience against which they can test the perspectives. So it is important to train engineers and designers not only how to meet specifications, but also how to improve specifications. In addition, of course, they need broader perspectives and experiences to make their shifted insights more relevant.

An interesting validation of this point is the work of Charles Darwin, who spent much of his life thinking about and developing the perspective we call evolution. Darwin was a bright, well educated and well read man, but he was also someone with intensive hands-on experience with the variations among species from his work gathering data about birds on the Galapagos Islands and developing classifications of other species.

Others, whose background was limited to discussing the writings of the field, had no grounding to go beyond classification to the dynamics of evolution. This may be the "creativity killer" of educational programs. As we teach students intensively to understand a certain perspective, we generally only expose them to problems that can be solved in that perspective. It would generally be considered unfair to ask a student studying electronic circuit board layout to discuss issues of chemistry or mechanics.

I am reminded of a colleague who spoke of the marketing course he taught to MBA students in Rio de Janeiro. One in-class assignment was to break up into teams and develop a creative marketing campaign to sell the local telephone book across Europe. Any team that came back with a plan failed the exercise. Those who pointed out it was a stupid idea got full credit. This "specification hypnosis" is a legacy from all our educational systems, because very few teachers are in a position to put such questions into their testing. This unquestioning attitude is especially damaging to the best students.

What is supremely ironic is that the more successful a person is as a student, the more likely they will encounter these problems of applying their knowledge.. When highly successful students take a test, they rarely make an error. Consequently, they have had the consistent experience that every time they feel good about an idea, the idea is right. Of course, the point they missed was that the tests they took were deliberately designed to be single domain problems with correct answers. Unfortunately, the real world is full of messy, multiple domain problems with no single clear answer. With such real world problems, the poorer students have a definite advantage. Throughout their academic career, whenever they felt good about an answer, they were wrong about 35% of the time. So they never trust their own judgment and instincts, they check with other people to make sure they understand the full problem and its possible solutions. This is frowned on in the academic systems because it makes grading of individuals impossible, but is a great engine of success and error avoidance in the real world. The ability to choose and question the right people is an essential success skill for engineers and designers. To combine the multiple perspectives and disciplines needed for total design, organizations are formed to manage the design/knowledge creation work, combining individual activities into a single product or service. Unfortunately, the bits and pieces of designs do not assemble as easily and cleanly as engine parts. Fortunately, designers are people and can learn to make adjustments to their contributions until the whole thing goes together.

Conclusion

Deliberate success in collaboration is about bringing together the right knowledge into an interaction of adequate complexity and creativity. The phenomena may be sufficiently complex to require more insight than is currently available in research on creativity, teamwork, and complexity of thinking. Shifting the ways that we look at some of these issues may open up new and more useful possibilities.

References and Interesting Resources

1. Alexander, C. (1964) Notes on the Synthesis of Form. Cambridge, MA: Harvard Univ Press.

2. Barlow, Christopher M.. (2000) Deliberate Insight in Team Creativity. Journal of Creative Behavior, Vol 34 Number 2, pp 101-117.

3. Basadur, Min; Runco, Mark A.; and Vega, Luis. (2000) Understanding how creative thinking skills, attitudes, and behaviors work together: a causal process model. Journal of Creative Behavior, Vol 34 Number 2, pp 77-100.

4. Edidin, P. (1988) The OOPS Factor. Omni, 10(5), 31.

5. Fjermestad, Jerry and Hiltz, Starr Roxanne (1999) An Assessment of Group Support Systems Experimental Research: Methodology and Results. Journal of Management Information Systems Winter 1998-99, Vol 15, No 3, pp 7-149.

6. Fowler, T.C. (1990) Value Analysis in Design. New York: Von Nostrand Reinhold.

7. Gavurin, E. I. 1967. "Anagram Solving and Spatial Aptitude", Journal of Psychology, 65, 65-68.

8. Gruber, Howard E. (1981) Darwin on Man (2nd Edition). Chicago: University of Chicago Press.

9. Jaques, Elliott. (1996) Requisite Organization, Revised Second Edition. Arlington, VA: Cason Hall & Co.

10. Kaufmann, G. (1980) Imagery, Language, and Cognition. New York: Columbia University Press.

11. Kirton, M. (1994). Adaptors and innovators: styles of creativity and problem solving. New York: Routledge

12. Koestler, A. (1978). Janus, New York, Random House.

13. Lobert, Beata M., Massetti, Brenda, Mockler, Robert J. and Dologite, Dorothy G. (1995) Towards a Managerial Model of Creativity in Information Systems. Proceedings of the 28th Annual Hawaii International Conference on System Sciences, Washington: IEEE Computer Society Press. pp 556-565.

14. Miles, L. D. (1971). Techniques of Value Engineering and Analysis (2nd rev.). New York: McGraw Hill.

15. Mudge, A. E. (1971). Value Engineering. New York: McGraw Hill.

16. Nonaka, I. and Takeuchi, H. (1995) The Knowledge Creating Company. Oxford University Press.

17. Petroski, H. (1994) Design Paradigms, New York, Cambridge University Press.

18. Rhodes, M.(1961) An analysis of creativity. Phi Delta Kappan, 42, 305-310.

19. Simon, H. (1946) "The Proverbs of Administration", Public Administration Review, 6 (Winter, 1946): 53-67.

20. Smith, A. (1776) The Wealth of Nations.

21. Snodgrass, T. J. and Kasi, M. (1986). Function Analysis: The Stepping Stones to Good Value. Madison, Wisconsin: University of Wisconsin.

22. Woodman, R. W., Sawyer, J.E. and Griffin, R. W. (1993). Toward a theory of organizational creativity. The Academy of Management Review. 18:2, pp 293-321.