Building New Knowledge and the Role of Synthesis in Innovation

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ABSTRACT
We innovate to create competitive advantage. Competitive advantage is found in new knowledge, which solves the buyer's problem. Humans create new knowledge in three ways: through Discovery – stumbling upon something that solves a problem; through Experimentation – trying different approaches to a problem until the solution is found; and through Synthesis – combining existing knowledge to create new knowledge. Today, Synthesis is the most common way we solve problems. Everyone synthesizes, but some people are extraordinarily good at it. They see the big picture, and how all the pieces fit together. Their brains have the ability to reach great mental distances to find remote metaphors which presents knowledge that turns into great solutions. Mixing your experts with people who are novice super-synthesizers can create best in class solutions and give a company a sustainable competitive advantage.

1. INTRODUCTION

One day King Henry IV, the self-made King of England, decided to impose laws banning displays of ostentation — outlawing pretentious and conspicuous shows of wealth or importance. The regulation prohibited the use of gold and jewelry as part of one's clothing. At first, this law was generally ignored, which troubled the King. A few weeks later, in a moment of inspiration, Henry enacted an amendment to the law. The amendment exempted from the prohibition, all thieves and prostitutes. The next day not a jewel or golden ornament was visible on anyone's clothing.

Creative problem solving is at the heart of innovation. Here King Henry creatively came up with a clever way to enforce his law.

In business, companies come into existence because they can solve some customer problem better than anyone else. These companies enjoy a competitive advantage. Companies go out of business because they fail to solve some customer problem better than anyone else. They've lost their competitive advantage.

Companies innovate to create competitive advantage. Of course, it is not the only way to create competitive advantage. Become a monopoly (– utilities). Influence government officials to choose your company without competitive bidding (– some companies associated with the war in Iraq). Become the low cost or high quality 'follower' (– Microsoft). Compete stupidly and appear to succeed, , then later fail (– Continental Bank.).

Companies in business for the long haul must innovate. Sooner or later, all other strategies fail to preserve the vitality of the company. Companies must solve customer problems in new and better ways than their competition, realizing that the competitive landscape changes constantly. Innovation is crucial. A. G. Lafley, CEO of Proctor and Gamble, recognized the importance of solving customer problems as the key to establishing innovation in his turn-around of that business. "The P&G leadership also made a seminal change in the psyche and working of the organization. P&G changed from a technology-push innovation model to a customer-pull one."

Innovation satisfies an unmet need in a new way. The 'new way' is based on new knowledge. It is the new knowledge that provides the competitive advantage. We are not talking about new knowledge to an individual. We are talking about new knowledge to the human race. Peter Drucker maintained that acquiring and applying knowledge will become key competitive factors. Nonaka and Takeuchi in their book *The Knowledge-Creating Company* go further, arguing that creating new knowledge will become the key to competitive advantage in the future. If the new knowledge is simply know-how, then the advantage may be short-lived. If the new knowledge can be protected, e.g. by intellectual property law, then it may be enjoyed for a longer time. But sooner or later the protection disappears, a different innovation is needed.

To survive the long haul, companies must branchiate through the jungle of competition, from innovation to innovation, product to product, structure to structure, business model to business model.

We've a plethora of definitions for innovation. For purposes of this discussion, 'innovation' means *"Creating new knowledge that solves problems and provides competitive advantage."* This definition crystallizes the discussion around two skills. First, is the ability to create new knowledge. Second is problem-solving skill. These two abilities overlap one another in people who are particularly good problem-solvers. Like many human abilities, we see variability in people's individual ability to solve problems and create new knowledge. In this article we will talk about the three methods for creating new knowledge; we will explore problem solving; and investigate the key talent of synthesis. Throughout this article, the term 'problem' means both problem and opportunity. Most people agree that in business an opportunity exists because someone has a problem needing a new or better solution. Hence, the business's opportunity is someone else's problem, and the new and better solution delivers competitive advantage.

1.1. Creating New Knowledge

Knowledge is the foundation of competitive advantage. Specifically, unique knowledge is the key asset for any company to have an edge on their competition. Unique knowledge is knowledge the competition does not have. Ideally this knowledge provides you with the path of least resistance while leaving the competition with the path of most resistance. This unique knowledge comprises: the intellectual property protected by the company's patent right; the tacit knowledge developed within the firm by its employees and used to deliver the product or service for which the company is paid; and the unique combinations of public knowledge utilized in the firm, which, while duplicable, currently are not seen in the competition. Unique knowledge is the firm's most valuable resource, which is why knowledgeable people in the right positions are the firms most prized assets. This is true whether it is the machine operator on the factory floor who knows all the quirks of the machinery; or it's the chemist who knows how to formulate the ingredients, which give the product its valuable characteristics; or it's the synthesizing manager redesigning a delivery process.

1.1.1. Discovery

Discover it the first of three methods humans use to create new knowledge. Innovation is the activity of producing new knowledge to provide competitive advantage. Sir Isaac Newton said "If I have made any valuable discoveries, it has been owing more to patient attention than to any other talent." Discovery is born of paying attention. "A Japanese monk visiting a sake brewery noticed that the brewery workers had extraordinarily soft and youthful hands. Even an elderly man with pronounced wrinkles on his face possessed the silky smooth hands of a young boy."[a] This remarkable Discovery and the work to isolate the compound responsible for this skin preservation, launched a new line of products for Proctor and Gamble. Discovery is the first of three ways we create new knowledge.

Lots of early human innovations happened due to Discovery. One day Amal is walking along the muddy bank of the Nile and sees the imprint in the mud of where one of the Nile's giant crocodiles laid. In the imprint are some crushed reeds. They are criss-crossed and matted and the mud that collected in the patterned skin of the crocodile has imprinted itself on this mat. He picks them up and notices that they're stuck together and have formed a flat surface. He think to himself, 'Hey, I could make some money selling this. But I don't want people to realize what it's made of, so I won't call it "papyrus", so what should I call it…ummm….Ah ha! I'll call it "paper"'.

Discovery is usually serendipitous as in the story of paper above. Somebody stumbles across something and then recognizes it's commercial or scientific value. Charcoal was likely discovered in this serendipitous way. The Discovery around charcoal, wasn't the finding of bits of burned wood in the bottom of a fire that had not turned to ash. No, the 'Discovery' of charcoal was that it burns much hotter that wood. So hot, in fact, that its fire can melt many metals. This is what gives charcoal its value. This was a serendipitous discovery.

In addition to serendipitous Discovery, there is directed Discovery. Edison once sent explorers to South America and Asia on Discovery missions. They were after a specific texture of plant material that Edison thought would make the best light filaments. This was "directed Discovery". The explorers or adventurers were sent off in search of a specific thing. This notion of going out into the world to

[a]http://www.uk.pg.com/products/products/skII.html

discover new knowledge is not often used anymore. But it does happen. Landing robots on Mars, for example, is directed Discovery in the sense that we are looking for (and discovered) signs of water and are still looking for evidence of life. (Of course, as Burt Rutan of Virgin Galactic points out, NASA screwed this up because so far in its landing on Mars, they've only ever landed in the deserts. If we really want to find life on Mars, says Rutan, they should stop landing in the barren deserts and start exploring the forests instead.)

Today, Discovery plays a different kind of role in innovation. Discovery is the principal method we use to try to understand the buyer's problem. Of all the activities around innovation, this Discovery of the true nature of a buyer's problem is often sited as the most important step in successful innovation. We do this in many ways, from surveys and focus groups, to accompanying customers as they purchase and use products, to living with customers, and filming their activities for later study. All of these are Discovery. We create new knowledge about our buyers through Discovery.

1.1.2. Experimentation

The second way we create new knowledge is through experimentation. To go from discovering some charcoal in the bottom of a fire, to making it in sufficient quantities to sell, required finding a better process. This was done through Experimentation. Different solutions were tried. Some worked, some didn't. Around the world the solutions were identical in key respects, and different in others. In some places pits were dug in the earth, filled with wood, covered with earth, lighted, and allowed to burn slowly for a while, limiting the inflow of oxygen, and at the right point the air is shut off entirely. In other places a mound of wood the size of a one-story house would be constructed, covered with leaves then dirt and allowed to burn with control over the air flow to the fire. In still other place, great brick kilns were built which allowed precise control over the burn process.

All solutions controlled the timing and amount of oxygen available to the fire, which allowed the heat to build up to around 260 degrees Celsius, and allowed the air to be cut-off entirely at the end of the process. As is often the case, technology preceded science. The goal of the experiment wasn't to gain a scientific understanding of what takes place in the charcoal refinery. It was just to make lots of charcoal. The science was not known until much later.

Experimentation also taught charcoal makers not to mix soft and hardwoods, and that hardwoods make better charcoal. Also that some of the byproducts, such as turpentine also can be recovered and have value.

Sometimes Experimentation turns into Discovery. In 1928 Alexander Fleming was experimenting in search of a cure for typhoid. Like many innovative people, his approach was often more expedient than careful, and he wasn't very rigorous with proper laboratory technique. He was part technologist, part scientist. His lab was often in chaos. So when he decided to leave on a long vacation, he left things as they were, including experiments in progress. Upon his return, he found most of his culture dishes had become contaminated with a fungus and tossed them into a sink filled with disinfectant. Later in the day, when a visitor appeared Fleming pulled a culture dish that had not been submerged in the disinfectant to show the fungus. When he did, he noticed a border around the fungus where the bacteria he was culturing, seemed unable to grow.

Of course, we all know Sir Alexander Fleming discovered penicillin. Ironically, it was effective on meningitis, scarlet fever, gonorrhea, pneumonia, and diphtheria, but was not a cure for typhoid. Nevertheless, he won the Nobel Prize for Medicine in 1945. And the story provides us with a good example of Experimentation leading to Discovery.

We mentioned that Edison once sent explorers to South America and Asia on discovery missions. He also used experimentation to gain new knowledge. He even regarded failed experiments as an opportunity to create new knowledge as indicated by the following incident told by Dr. Acheson: "I once made an experiment in Edison's laboratory at Menlo Park during the latter part of 1880, and the results were not as looked for. I considered the experiment a perfect failure, and while bemoaning the results of this apparent failure Mr. Edison entered, and, after learning the facts of the case, cheerfully remarked that I should not look upon it as a failure, for he considered every experiment a success, as in all cases it cleared up the atmosphere, and even though it failed to accomplish the results sought for, it should prove a valuable lesson for guidance in future work. I believe that Mr. Edison's success as an experimenter was, to a large extent, due to this happy view of all experiments."

All of us, at one point or another, use Discovery and Experimentation to increase our knowledge. But the most common method we use today to create new knowledge is synthesis.

1.1.3. Synthesis.

In 1963, when I was a boy of 12 my father took me down to the pipeline terminus south of Sidon which is about 30 miles south of Beirut Lebanon. We'd gone there because the company my father worked for, Tapline, was about to do something no pipeline company had ever done before.

The company was eager to install a new 36 inch diameter pipeline from the shore to a berthing spot for tankers out about 2 kilometers in the Mediterranean Sea. This new line would give them over 200% more throughput than an existing 24 inch line. But constructing a 36 inch diameter pipeline under water was difficult and expensive. It's also dangerous. Oil pipelines take a great deal of pressure, and the welds, which hold the pipe together need to be flawless. Keeping a the section of pipe in place against undersea currents and over bumpy undersea terrain made under water welding difficult.

My father had solved this problem for the company in the simplest way imaginable. Build the pipeline on land, he suggested, float it out to sea over the spot where you want it to sit, and sink it. In and of itself, this was not a new idea. But it was not the company's first choice because it turns out that when you go to sink a pipeline you must replace the air with water. Water flows downhill so as a wave on the surface causes the pipe to flex, the water will go to the lowest point on that flex, and start to collect. As the water collects that portion of the pipe starts to sink which collects more water. Air can get trapped causing sections of pipe to be raised. Because of this pooling of water, the pipe can lay unevenly on the seabed. The bends created in the pipe can weaken it. The company had experience with this problem, as they'd already sunk a handful of pipelines at the Sidon Terminal. The greater diameter of a 36 inch line increased the challenge.

My father was a great problem solver, who loved challenges like this. For him, the more elegant the solution the better. Here's how he sunk this pipeline: Once the floating line was in place, the cap on the shore and was cut off and a specially prepared section of pipe was welded on. In the special section were three 36 inch diameter rubber balls filled with water. The first ball was inserted into the pipeline, followed by 15 feet of fresh water. A second ball went in after the water. Next gasoline was pumped in filling about 1000 feet of pipe. The third ball followed the gasoline, and behind that, seawater was pumped in gradually to push the three balls along with positive pressure against the leading ball. By using the balls, they were able to avoid the formation of air pockets, which create uncontrolled buoyancy problems. The gasoline, which is lighter than seawater, allowed the pipe to be gradually and evenly submerged starting from the beach, and ending at the ship berthing point. In this way the stresses in the pipe were very minor, ensuring no damage to the line, and ensuring the pipe ended up where it was intended.

When I got a bit older, and had seen my father tackle other challenges successfully, I began to wonder why he was able to solve these kinds of problems. A year or two before Tapline successfully sank the pipeline, I received a particular toy for Christmas. I'd been lobbying for a pellet gun to shoot birds, but my mother, worried I'd shoot out my eye, ended up getting me a gun that shot ping-pong balls instead. This was a disappointing gift.[b] It consisted of a clear plastic tube holding a handful of ping-pong balls and a slide pump. The pump allowed you to build up pressure, which when triggered, released the air to propel the first ping pong ball out the end of the tube. No birds were in danger from this gun. It barely propelled the ping-pong ball across our living room.

It turns out that it amused my father more than me. One night after supper, my father picked up this toy and began experimenting. He held one hand over the open end and allowed changes in pressure in the tube to move the ping-pong balls along. Thinking back on watching my father sitting on the couch, playing with the ping pong balls in the tube, I wondered if his mind later used that as a metaphor for his pipeline solution. Years later, when I asked, he didn't remember how he came up with the pipeline idea, but thought it was very possible that in the back of his mind the fact that the ping-pong balls held a pocket of pressure in the tube may have lead to the pipeline solution.

Synthesis occurs when we combine existing knowledge to create new knowledge. Returning to our charcoal example we use synthesis to create knowledge which solves another problem in making charcoal. At the end of the process, when charcoal is recovered from the refinery kiln, there is always a collection of small bits and pieces of charcoal left over. This material is too small to sell. But charcoal manufacturers did not want to waste it either. By combining existing knowledge to form new knowledge, a solution was found. The existing knowledge was that charcoal is a natural fiber material just like wood. Its fiber creates surfaces such that within a single gram of charcoal there is a surface

[b] An image of this toy is at: http://www.burpgun.com/

area estimated at 200–300 square meters. The other knowledge came from the paper industry which had discovered that natural starches serve as a good binding agent for natural wood fibers. By mixing a starch and charcoal slurry and forming these into balls and letting them dry out, one could create a lump of charcoal. This is how briquettes of charcoal are made. It allowed the manufacturers of charcoal to recover this waste and sell it as a product.

Synthesis includes analysis. Analysis is the agent which brings forward the existing knowledge, synthesis combines that knowledge with other resident knowledge to form new knowledge, or different knowledge. One could argue that analysis by itself is a source of new knowledge. I would call it discovery. But in this case, it is not worth disagreeing over the point. If you are more comfortable thinking analysis creates new knowledge distinct from discovery, it is a legitimate point of view. The point of the discussion is innovation, and for this purpose I am including the analysis piece into synthesis, because synthesis is where the solution to a problem is created.

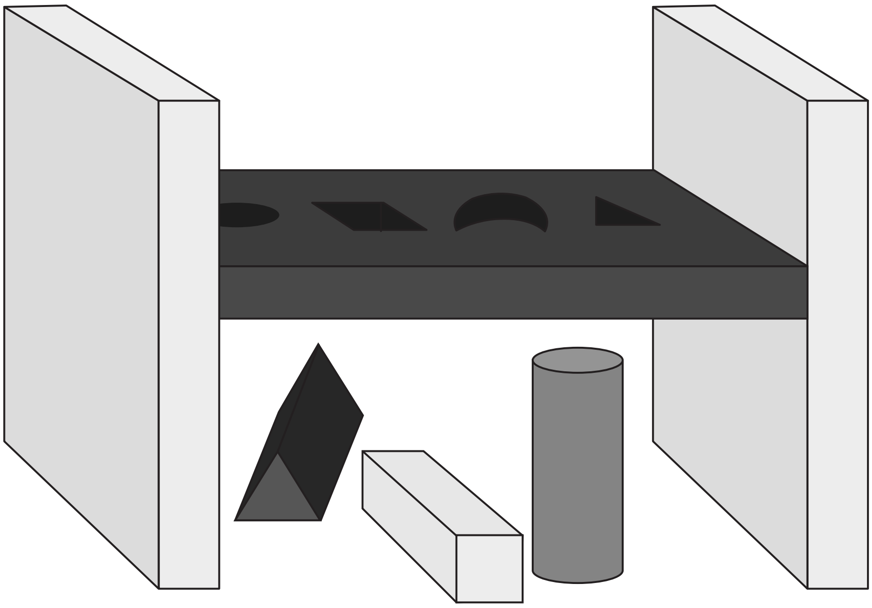

Figure 1. Child's block and platform toy.

Perhaps the most interesting is that we all synthesize, and we do a lot of it. For example:

If you give this toy, to a baby who has never seen it before, the baby will likely do a bit of discovery first. The child will pick up the blocks and look at the colors, discover the taste of each, test the hardness with some banging and throwing, etc.,. If you show the child that a block will fit into one of the holes, then the child will begin experimenting. The round block will be tried in the square hole, the triangle in the round hole, and so on until through a process of trial and error, the child will get all the blocks into the right holes. This is Experimentation at work.

If you give the same toy to an adult, even one who has never seen the toy before, then the adult will be able to tell you which block goes in which hole without employing the heuristic approach the baby uses. The adult doesn't need to taste the blocks, or be concerned with the colors, or know how far a block will travel when thrown. Nor is the adult going to need to try the square block in the round hole. No trial and error is needed. Without consciously thinking about it, the adult's brain uses prior knowledge about shapes of blocks and shapes of holes to quickly realize the square-ended block goes in the square hole. The adult synthesizes the solution instantly. When my father came up with water filled balls to control air pockets when sinking a pipeline, he used synthesis. It is the most common method we use today to innovate solutions in business. We have three primary methods of innovation described: Discovery, Experimentation, and Synthesis. While we've talked about them discreetly, it is usually the case that new knowledge is the result of combining two of the three, or all three, toward the same solution. That is, we use some synthesis to set up efficient experiments, or we find some discovery in performing experiments as Alexander Fleming did. Just as the imaginary infant in the discussion of the blocks above used discovery, experimentation, and finally synthesis to solve the problem, we often use all three tools to come to a workable result.

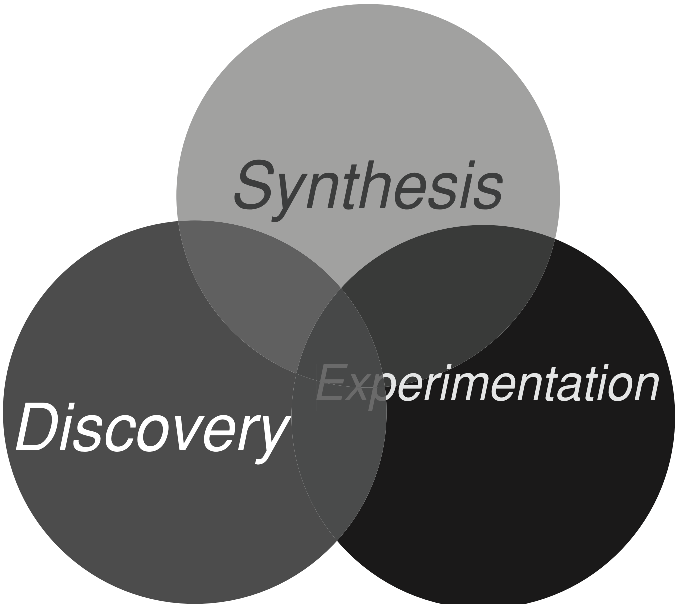

Figure 2. Overlap of methods for creating knowledge.

The real point of the discussion is to zoom in on Synthesis. That is because it has become the primary method today for developing new knowledge. Historically, Discover may have played the most significant role in ancient history, but that's no longer the case. Synthesis has become the dominant method of creating new knowledge. And because Synthesis depends upon pre-existing knowledge, and the Internet provides efficient access to knowledge, we will continue to see Synthesis dominate the innovation landscape. But knowledge isn't the only factor affecting the quantity or quality of Synthesis. Thus, it is valuable to understand how it works and who is good at it.

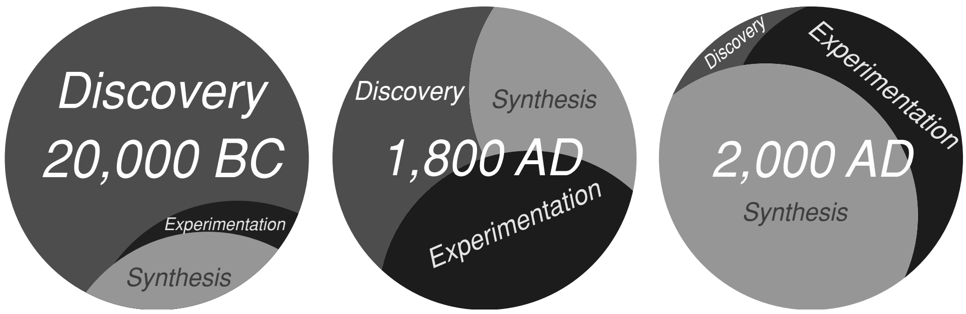

Figure 3. Change over time in use of methods for creating knowledge.

2. SYNTHESIS AND INNOVATION

Today, Synthesis is the most common way we innovate, that is *create new knowledge that solves problems and provides competitive advantage.* It is also the most common way we solve problems even where no competitive advantage is needed.

When adults are faced with solving a problem we fairly quickly make a choice on the most efficient approach. Some problems we tackle with a trial and error approach, while others we tackle with synthesis. We rarely tackle a problem by setting out on a directed discovery mission – e.g. looking for light bulb filament material in the Amazon forest as one of Edison's engineers did.

If you have a problem for which it is believed that no knowledge exists that's applicable to solving the problem, then you are left with trial and error. For example, there are symmetric key encryption

[c]This assumes that the keys are housed securely, etc.,. The CIA maintains that it is easier to break into the computer that holds the plain-text document than to try to decrypt the document once it's been encrypted.

[d]Crash course on cryptography: Security aspects of cryptographic systems: http://www.iusmentis.com/technology/encryption/crashcourse/security

methods for which cryptographers believe there is no known way to discover the key, other than through brute force[c]. Brute force means trying every possible key until you find the right one. Because we lack knowledge of some trick to discover the key, or it is mathematically impossible, this trial and error method is the only one that will work. The security of a key is based on the key length, the longer the key, the more tries are required to break it. To break a 128 bit key, you could need a few more than 340,282,366,920,938,463,463,374,607,431 billion tries. It's a lot of tries. If every second you could do 340,282,366,920,938,463,463,374,607,431 tries, you'd need just over 31 years to try every possible key[d].

People interested in such things have worked on methods to build computers specifically designed to perform a lot of tries quickly. It is conceivable of course, that someday a whiz kid will discover a mathematical flaw, something that was not previously realized, to short-stop this trial and error process. But for now, we are left with only a trial and error process.

In other cases, when first faced with a problem to solve, it is not always immediately apparent that we already have the knowledge needed to synthesize a solution. In those cases, the most efficient approach is to start with trial and error. During the trial and error process, we might see opportunities to apply knowledge, which allows us to synthesize the solution.

For example: If you want to devise a strategy to ensure you never lose at tic-tac-toe (noughts and crosses) whether you go first (the player using X's) or second (using O's), then you are likely to pull out a sheet of paper and start putting X's and O's in the 3 by 3 tic-tac-toe board. Fairly quickly you will come up with a foolproof strategy. This approach starts with trial and error. If the game were played like football, right to the end irrespective of the impossibility of the other team winning, there would be 362,000+ possible games. But the game ends when one player gets three in a row. This leaves just over 255,000 games. However, you do not need to go through the more than 255,000 possible games to develop a foolproof strategy.

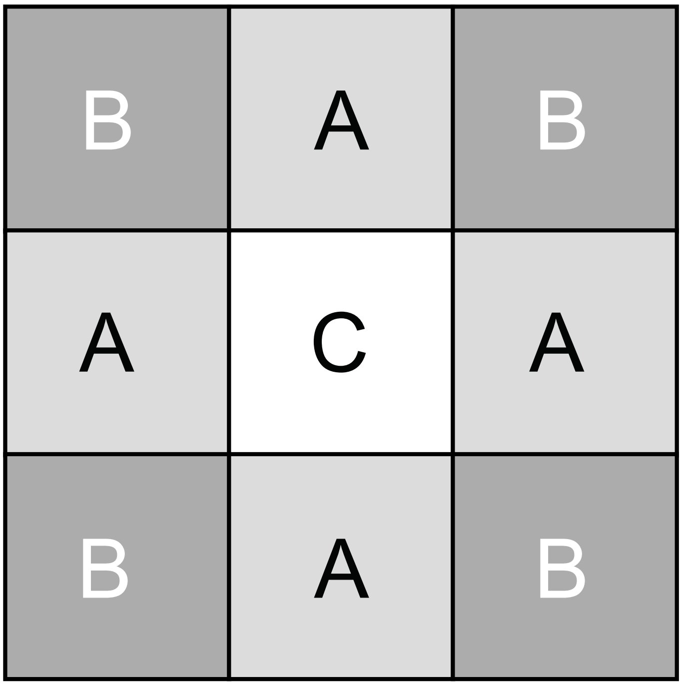

Figure 4. Tic-tac-toe board.

That is because the trial and error approach either creates knowledge or knowledge becomes apparent, and you use that knowledge to synthesize shortcuts. For instance, if you are playing "Xs", then you move first. Suppose you decide your first move is to place your "X" mark in one of the middle-border squares (those marked with an "A"), you may realize that the game board is symmetrical. It makes no difference which "A" square you start with, the game that follows will be the same. That is, there aren't four different games because there are four "A" squares, each "A" square is equivalent to the other three at the beginning of the game. The same is true if you started in the corner ("B"). You really only have three choices for your first move, any "A", any "B" or "C", not nine. Now you've cut the number of possible games by two-thirds and only have 85,000 possible games left.

But you are not going to go through all those possible games to come up with a strategy. That's because your objective is to never lose. If you are the player who goes first, you can build a strategy around always starting in the same place every time, say the very center square ("C"). You've reduced the possible games by two-thirds again, to 28,000. That leaves the opponent with 8 squares to choose from. But the grid is symmetrical. So every "A" square is the same as every other "A", and likewise every "B" square is identical to every other "B" square. Thus, the opponent has 2 possible moves, not eight. That further reduces the play to 7,000 games.

Without going through the complete strategy development, you can see that using knowledge about possible moves and the geometry of the board, you are able to synthesize shortcuts to the solution. We do this automatically in our brains.

Our brains have the automatic ability to see some solutions with a mental snap. It is the moment of insight which magically seems to pop into our brains. If you are a native English speaker you may experience that snap with the following. Apologies to those of you who are less familiar with English. Compound Remote Associate Problems, or CRAP, are being used for fascinating brain research by Mark Jung-Beeman at Northwestern University. He and Edward Bowden have compiled a list of these puzzles based on how quickly people 'get' them. The puzzles are word association puzzles. For example: What word is associated with each of these three words: man/stop/wrist? The answer is 'watch', as in 'watchman', 'stopwatch', and 'wrist watch'. Try these 4, each with a different answer:

cottage/swiss/cake

rocking/wheel/high

cream/skate/water

show/life/row

Chances are, with at least one of these, you experienced a brain snap, where the answer ('cheese', 'chair', 'ice', 'boat') just popped into your head. It's a little weird because it's as if your brain does something which you really don't control or understand. That is why we say our mind seems to automatically find the solution. Neuroscientists like Beeman have done very interesting work in trying to understand what is taking place in the brain when we have these brain snaps, or when we take a bit longer to solve a puzzle. You may find with the following puzzles, that you feel more like you are in control of the process. Most of us don't get these easily, if at all. If you get even one, you're doing better than I did.

reading/service/stick

shadow/chart/drop

land/hand/house

cast/side/jump

Here you may have found yourself doing a great deal more manual labor, going step by step through the catalogue in you mental dictionary of all the words that are associated with each of the words in the four puzzles. You are trying to force the synthesis through this knowledge review. The answers are 'lip', 'eye', 'farm', and 'broad'.

There are other problems where we have the knowledge to synthesize the answer, but trial and error appears to be a more efficient process. For example consider the following popular puzzle:

You must place the numbers 1–9 in a 3 by 3 grid such that the three numbers in any straight line, add (horizontally, vertically, or diagonally) to 15.

Almost all of us would tackle this problem using the trial and error method. That is because, it is not immediately obvious that the synthesis approach would work, and clearly, trial and error will work. But you could have chosen to solve this puzzle without using trial and error. Synthesis, in this case, is more challenging than trial and error. If you like a challenge, this is a good one.

Still other problems do not lend themselves to a trial and error approach. For these, we must use our ability to synthesize. The following simple puzzle is easier to solve using synthesis, mostly because few of us have two sandglasses that would allow us to perform trial and error. Even if you have a three minute timer, you're unlikely to have a 7 minute timer. Moreover, the construct of the puzzle suggests that we really only get one try, otherwise, the 8 minutes are gone.

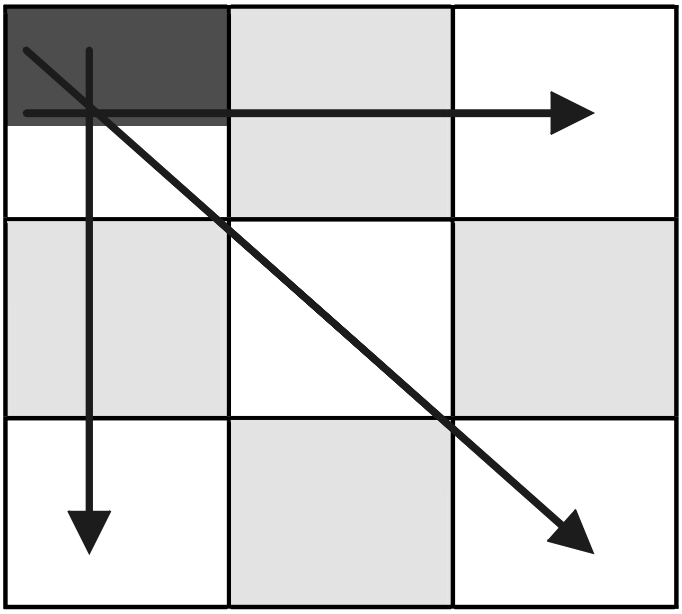

Figure 5. Sums to 15 geometry.

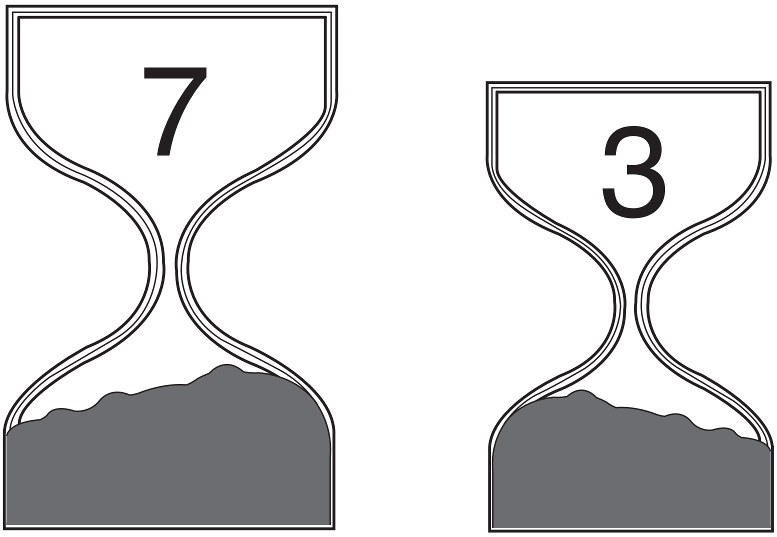

Figure 6. Hour-glass timers.

You need to measure 8 minutes. You have two sand timers, one for 7 minutes, and the other for 3 minutes.

How can you measure 8 minutes using these two sand timers?

Solving this puzzle uses simple mathematics. Mathematical thinking is almost always synthesis even though it's almost never innovative.

So, why is synthesis important and useful to solve business problems? First, it is often the only way to approach a problem. It is hard to imagine how Tapline could have developed experiments in underwater pipeline installation to 'find' the balls solution without having the idea in the first place. Second, even when there are alternatives, synthesis is almost always a cheaper approach. Companies that rely heavily upon trial and error solutions, such as a pharmaceutical company searching for a new

[e]From repeated calculations in physics, he knew the logarithm of 10 to the base e was 2.3026, thus he knew e to the power of 2.3026 is 10. Of course he also new e to the power of 1 is 2.718283…. Thus, e to the power of 3.3 was e to the power of 2.3 times e to the power of one, or 10 times 2.718... or 27.18 which was a little high because of the .0026 and he corrected for it thus his answer 27.11.

[f]Perhaps a better word here is 'consciously connected' since the brain 'obviously' made the connection we are just not conscious of what the connection was.

drug, are constantly looking for ways to shortcut the number of trials they need to perform, or for ways to run the trials faster, and cheaper. In the case of drug researchers, if they had better knowledge of chemical properties and interactions with illnesses and the human body, they could use more mental synthesis and less experimentation to find effective drugs.

It is useful to understand we have at least two types of synthesis, which apply to problem solving. One is an analytic approach to problem solving. This is really the type of synthesis applicable to the puzzles above. With the analytic approach, the synthesizer sees patterns in the problem and reconfigures them logically to derive a solution. The element of synthesis in this process is the ability to pick out the relevant patterns, which leads to the analytic solution. For example, in the sand-glass-timer puzzle, a good synthesizer probably did not even consider that the imaginary timers were made of glass; that the glass is transparent; that the imaginary sand grains are of a certain size; that when they fall from to the bottom they might form a cone initially; that if you took the timers to the moon, they would have to be recalibrated to different timers and the puzzle may be unsolvable; etc... These ideas are not relevant in coming to a logical solution.

Nobel Prize winning physicist Richard Feynman was extraordinarily good at figuring out what knowledge was useful to solving a problem. In the book "*Surely You're Joking Mr. Feynman*", he tells a story about how 'lucky' he was one day when his friends at Princeton challenged him to solve for *e* to some power. He had started the challenge by saying it was easy to do, you just have to sum a series. It was a big series, not really something Feynman could do in his head really fast. But they said 'ok, what's *e* to the 3.3?' Almost instantly he says '27.11'.

Feynman wants to stop, feeling incredibly lucky that they gave him one he happened to be able to do quickly because he broke it into mathematical parts, which he already knew.[e] They then said '*e* to the 3?' Feynman couldn't believe his luck, '20.085' he says. He tells them that's enough for one day. But then one of them says '*e* to the 1.4?' 'It's 4.05,' says Feynman. In his book he explains how he solved each of these using different tricks. None of them were solved in the same way. But he didn't know the answers in advance. That is, he hadn't memorized that *e* to the 3 is 20.085. He figured it out by employing some mathematical characteristics he knew well. He refused to do anymore because he was certain he had just been extremely lucky with their choices.

Feynman wasn't really as lucky as the thought. He had an uncanny mental ability to see patterns in problems that made them simpler to solve. His brain could make great fast leaps that let him discover these shortcuts.

The other kind of synthesis is what Frans Johansson calls "flash in the sky serendipity". It is similar to that moment of inspiration we talked about with the Compound Remote Associate Problems, but different in one key way. In the Compound Remote Associate Problems the solution is always obviously connected to the 'problem-words' since they are all compound words. In the "flash in the sky serendipity" the knowledge used to solve the problem is not a property of the problem or in some other way obviously[f] connected. It is often express as a metaphor from some distant field. The memory pattern formed in acquiring the knowledge of the ping pong ball burp gun possibly coming back to mind and matching up with the mental patterns represented in the problem of sinking a pipeline - is an example of this. Often, however, the source of inspiration is less traceable and the innovator is at a loss to describe where the idea came from.

Mark Jung-Beeson, who we mentioned earlier, teamed up with John Kounios, a neuroscientist at Drexel University to monitor what goes on in the brain when we have these moments of insight. Those of you who follow the notions of what the right and left brains do, will not be surprised that there is a correlation between the moment of insight and a spike in activity in the right hemisphere. The researchers believe cells in the right side of the brain are active within a broader landscape than cells on the left side. They make more distant and unprecedented connections. The connections are unprecedented at least on a conscious level. Work at MIT's Picower Institute with rats provide an intriguing insight into how patterns are formed in the brain during learning. They have been looking directly at the memory forming mechanics by studying living rats – using technology which allows them to monitor the synaptic activity in the rats' brains. Sleep plays a key role in how rats construct and retain success patterns. In a maze, the rats run and then stop for a few moments, run and stop, run and stop, etc. When they stop their brains fire the same sequence of hippocampal cells that fired when they were running but very rapidly, and in reverse order. Also the sequence represents the entire track, not just the sequence of patterns between stops. Later when the rat goes to sleep, during slow-wave sleep the sequence is again observed as played back very rapidly, in proper order, but skipping the stop points. Finally, in REM sleep the patterns appear again, in proper sequence and in near real time. The brain is using replay while awake and replay while asleep to organize the synaptic patterns to create a memory pattern. Experiential evidence also suggests that human brains function similarly during ‘stop’ and sleep periods. People often find they do their best problem solving while doing things like showering (a mental ‘stop’ cycle). And waking up after a nap having solved a problem apparently while asleep. It makes sense that our brains are working on pattern processing during those periods, just as rats do.

However, it is possible that much more is going on. That is, the connections that Jung-Beeman sees as unprecedented may turn out to be sort of ‘pre-recorded’. It is possible that in the background, as knowledge is acquired, it is broken apart into its characteristics that will later allow the brain to search across the knowledge bank for that kind of characteristic. For example, in the case of the ping pong ball burp gun, when my father processed his analysis of the burp gun, his brain may have stored things like *‘a ball which is almost the size of the diameter of a tube will act as a one way valve as a fluid substance is pressed against one side of the ball when it is in the tube’. ‘Leakage can only go one way’.* Also, *‘the ball can be propelled along when the pressure on the one side of the ball is sufficiently greater than the pressure on the other side of the ball’.* Thus when my father looked at the pipeline process, his brain went looking for a way to stop one fluid substance (air) from leaking into another fluid substance (water). In his brain he may have had many references to leakage, but when the concept of pipe (tube) was added, the brain could offer up the ball-in-the-tube memory. No doubt I did not process the ping pong ball burp gun in the same way. As a young boy my mind was not yet prepared to analyze the properties of the balls and the tube the way my fathers mind was prepared. More likely, I processed the gun as inadequate in helping me solve the bird population issues I was trying to address. Likewise, my mother probably processed it as a much safer toy than an air rifle. This is all speculation. We do not yet know how this works in the brain, it just does.

How we process incoming information is an indicator of our problem solving abilities. Good synthesizers have the ability to take incoming information, knead it, turn it around, look at it from top to bottom, and absorb something fundamental, as they process it into knowledge.

People who are strong synthesizers certainly can easily solve puzzles such as the examples here. The single most valuable skill in finding solutions, is the ability to completely and correctly define the problem. This is a skill useful in both synthesizing through the logical analysis method, and synthesizing via the “flash in the sky serendipity”. It may be that it is not so much a ‘flash’ as a process. The process may be the same whether we are conscious of it while doing analysis, or when our brain seems to do it on its own. Occassionally we experience this whenwe wake from a nap with a brilliant solution or when we’re soaking in the tub and have that ‘Eureka!’ experinece.

Supersynthesizers have the ability and inclination to see the problem from different angles. As a young physicist, Feynman was nominated to the Manhattan project because of his legendary problem-solving/synthesis ability. Oppenheimer did not use the word “synthesis”, he just knew from stories in the physics community that Richard Feynman had a great mind for problem-solving. True to his reputation, Feynman proved his problem-solving skill right from the start. The first place he was sent was to the University of Chicago where Enrico Fermi led the team building the first nuclear reactor. The scientist there had heard this wiz-kid was coming, and on his first day they presented him with a mathematical problem that had been vexing the team there for more than a month. He looked at it for a few moments and then showed them the solution. It was a great example of seeing the problem from a completely different angle. He showed them that it wasn’t really one problem at all, but two. When he laid out the two problems, all the mathematicians in the room could easily see the solution. Often precisely redefining the problem, exposes the solution.

For example, take the puzzle below.

Puzzle: This figure is made up of matchsticks laid out to form these five squares. Reposition two (and only two) matches to form four equal squares each with the same size and shape as the individual original five squares. You may not overlap one match on top of the other.

Most of us would tackle this by first looking for a solution. We ask ourselves – “Where might we be able to remove a match or two matches that would eliminate a box?” Then, we’d figure out where to use those matches such that we end up with four boxes. We might do a lot of mental trial-and-error, and with enough persistence, either solve the puzzle or go crazy. If you are interested in doing this on your own, stop reading here and come back when you’re crazy.

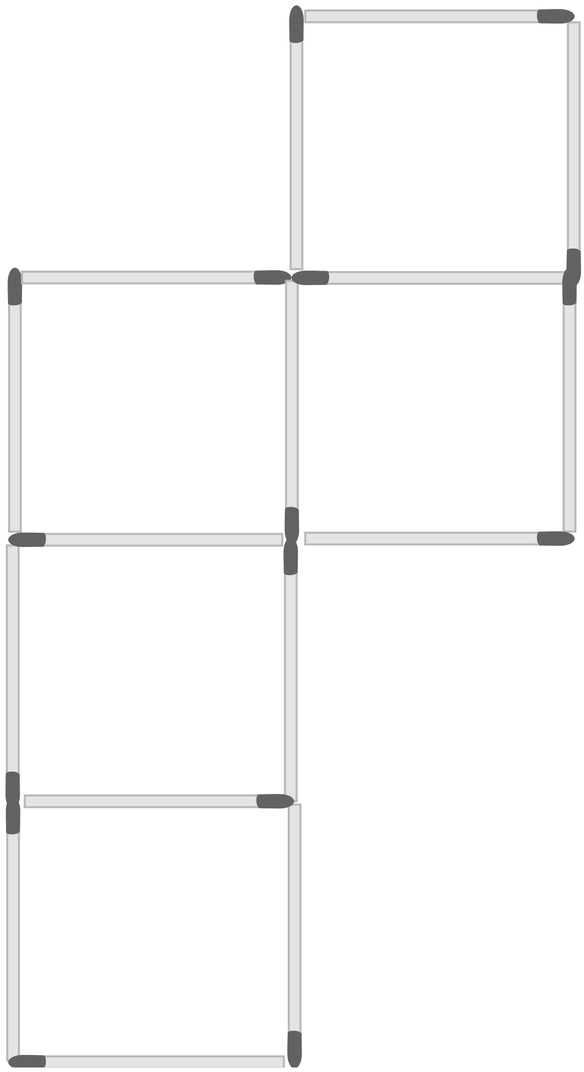

Figure 7. Match-stick boxes problem.

But a super synthesizer sees patterns in problems differently from the rest of us. Instead of looking for a solution, a supersynthesizer might look at the problem and see if there is a different point of view. Instead of saying "I'll start by picking up two matches" the supersynthesizer may say something like this. "I have to place two matches here such that they will each be a side to a box. I cannot place these two matches were a match exists already, because I would either be overlaying a match or just putting a match back where it was. Thus, I need to find a new spot where I can place two matches and form a box that is not already formed."

This divides the problem into two separate steps, and in reverse order of the way most of us would attempt a solution. By taking this approach, the synthesize quickly sees that there are only two places where a new box can be formed with two matches: at the top just to the left of the top box (marked 'A"), and to the right of the second box just below the first box in the right column (marked 'F').

Or the synthesizer might say "I have 16 matches," (how many of us would have even thought to count the matches), "and I need to make four boxes. Each box has four sides, 4X4=16, therefore, no squares can share a match on a side because then you'd only be using 15 matches. If they touch at all, they can only touch at corners. This means that you cannot use the two matches to form a box at 'A'. It currently shares a side with both 'C' and 'B' which would need to be eliminated. While you could eliminate box C by just removing one match, (the left vertical match in 'C' leaving boxes 'A', 'D' and 'E') you cannot do the same with box 'B'. To eliminate 'B' you would need to remove both the top-

[g]See Stanford University's Robert Sutton in his book "Weird Ideas That Work".

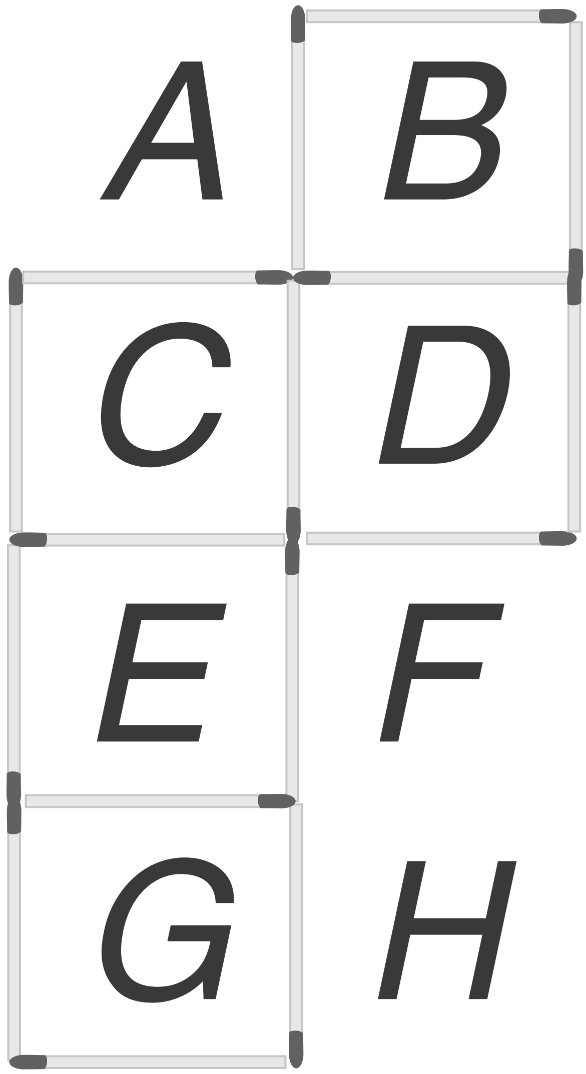

Figure 8. Match-stick boxes problem (enumerated).

most match and the right vertical match, which would still leave box "C" intact.

Thus, the new square has to be at 'F'." Or say "Since I cannot form a square at 'H' with only two matches, I cannot take one or two matches from the bottom box ('G') without leaving a match just hanging out. 'G' must remain. The same is true of the top box ('B') if you use two matches from 'B' to form the new box other than box 'A' which we have already ruled out you will leave one match from 'B' just hanging out. 'B' must remain. And thinking that through: "Thus, if the only place the boxes can touch is at the corners and I already know that I must have boxes 'B', 'G', and 'F', then 'C' must be the other box. I must be left with boxes at 'B', 'C', 'F', and 'G'. Therefore, I must eliminate boxes 'D' and 'E'. In each case I need three of their matches for other boxes, thus I must take the non-used match, the outer match in boxes 'D' and 'E' which eliminates the boxes and gives me the matches to form 'F'.

By looking at the problem from a different perspective we analyze and synthesize it differently. This makes the solution easier to get to if you didn't get a flash of insight that solved the problem for you, or you couldn't get it by trial and error.

In a business context, the obvious solution often isn't apparent until someone comes along and redefines the problem. Of course we can easily image that a suggestion like "Let's don't think about moving two matches, rather, let's start by adding two matches…" In a business meeting this approach might get a response something like "look, we're trying to solve a problem here which is <u>exactly about moving</u> two matches, it's not about adding matches. Just stay out of the way if you don't have something useful to add."

3. SYNTHESIS TALENT AND INNOVATION

Synthesis is a human talent. And like most talents, some people are better at it than others. In the case of synthesis, I don't know whether or not it's an innate talent; or one that can be improved with practice; or perhaps, like playing a musical instrument, it's some mix of the two. I have been asked if someone can be taught to be a great synthesizer. I don't know the answer to that question. But it seems that the crucial element in becoming extraordinarily good at anything is either some natural gift, or a deep enduring passion. Thus, perhaps you could study the techniques used to analyze and synthesize, but without a great passion for problem solving, you may not reach that level of superior talent. You're unlikely to put that much energy into the activity. Perhaps a good litmus test is this. As you were reading up to this point, did you stop at the match-stick puzzle and solve it before you read on? Did you find a way to solve the sum to 15 puzzle using synthesis rather than trial-and-error? If your answer was "Yes", then you probably have the passion.

The other ingredient, which makes for a great synthesizer is broad knowledge. The patterns that pop into our brains as solutions to problems are patterns created as our brains store knowledge and experience. The more breadth to the patterns, the more likely our brains are to find a matching pattern. Synthesizers like Feynman drew from broad knowledge. In the case of Feynman, it is said that had he been interested in publishing his non-physics work, he could easily have won an additional Nobel Prize or two in other fields of study. He had deep curiosity about many things, which he pursued, and this knowledge provide the framework of patterns which his mind could use so fruitfully.

In 25 years building and leading innovation and problem-solving teams all over the world with people from all sorts of cultural and educational backgrounds, its become obvious that the most successful teams not only include experts in the business problem, but also a couple of synthesizing, knowledgeable novices. The value of knowledgeable novices in problem solving has been written about elsewhere.g Fundamentally, experts who've been close to a problem for a long time lose the ability to see alternatives. They fail to recognize great ideas when they are first presented. You need a novice to bring fresh perspective. But the selection of the novice is important because the right novice can raise the quality of solutions by great leaps. To find super-synthesizing, knowledgeable novices, I use a three step process. First, if asked, good problem solvers will self-identify. A short employee survey will identify people who think they are good problem solvers. Next, I use a tool which allows the problem solver to demonstrate his or her synthesis ability. Finally, a short interview to assess their level of curiosity and the breadth of knowledge. People who fit the bill can be as young as 25 years old. Experience is a good source of knowledge, but in this context the breadth of knowledge is most important and experience alone is often a little narrow.

The value of the right novice can be extraordinary. On one systems redesign team included a young gentleman as the novice super-synthesizer. He was quiet for the first two days of brainstorming and then presented an idea. His idea leveraged the two days of work done by the experts and changed the business model. This was well beyond the scope of the assigned task and it took a few weeks to convince the chairman of our company that this new model might work. It did. Upon implementation, with a tiny investment in systems and training it delivered $2 billion in incremental sales in the first year alone.

In another instance a super-synthesizing novice help a team design a revolutionary customer service support system. After it was implemented, a senior manager from the leading competitor called up to jealously report that the system was by far the best in the industry.

3. CONCLUSIONS

We innovate to create competitive advantage. Competitive advantage is found in new knowledge which solves the buyer's problem. Humans create new knowledge in three ways: through Discovery – stumbling upon something that solves a problem; through Experimentation – trying different approaches to a problem until the solution is found; and through Synthesis – combining existing knowledge to create new knowledge. Today, Synthesis is the most common way we solve problems. Everyone synthesizes, but some people are extraordinarily good at it. They see the big picture, and how all the pieces fit together. Their brains have the ability to reach great mental distances to find remote metaphors which presents knowledge that turns into great solutions. Mixing your experts with people who are novice super-synthesizers can create best in class solutions and give a company a sustainable competitive advantage.

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BILL BURNETT

More than 25 years of experience in the financial services industry. Bill is a proven leader with a track record of building and leading innovation teams at both the global and local level; delivering ingenious performance improvements in Product, Customer Service, Operations, Network Infrastructure, Systems Functionality, and Policy Management; Bill's special talent is his ability to recognize and leverage hidden inventiveness of knowledgably internal employees. Bill has traveled to, and worked with businesses and across many cultures in over 65 countries.

Bill's keen analyzing and synthesizing skills, along with the capacities of 'big picture' conceptualizing, and independent thinking, are the foundations for his ability to find opportunities, solve problems and deliver high ROI profits. Subscribing to the Japanese proverb "None of us are as smart as all of us." Bill's outstanding delivery lies in his understanding that the workings of a well constructed team will always surpass individual inventiveness. But, that, in the end, it is an individual who comes up with the breakthrough idea. And the team must include individuals capable of breakthrough ideas