Invention

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Glossary

Invention The creation of a new device, process, composition or understanding. Novelty in invention can range from the improvement or variation of pre-existing models or ideas to a radical breakthrough that moves the boundaries of human experience. Generally four types of inventive products are distinguished. Technological invention, which refers to the conception of a new technological tool; scientific invention creates new understanding through the finding of patterns, regularities and mechanisms underlying phenomena in our world; artistic invention produces a new composition in any modality without a particular purpose or usefulness; cultural invention refers to the new habits and behaviors that appear in society that can have wide or limited spread.

Intuition The apparent ability to know things without a rational explanation for this knowledge. In the context of invention intuition may provide knowledge about the goodness of a proposed solution for a problem, a feeling of direction of where to search for a solution or the awareness of an image or other type of association that hints at the structure of a solution.

Serendipity The occurrence of a valuable or unplanned discovery, especially while looking for something entirely unrelated. This as opposed to chance findings that are useful for the problem one is actually working on.

Functional Fixedness A category or cognitive set or mental structure that manifests in rigidity or lack of flexibility in disembodying components from a given field.

Cognitive Unconscious Sometimes also called adaptive unconscious. Set of cognitive capacities that are not the result of conscious reasoning or deduction and that produces results that can’t be accounted for verbally. Examples are intuition, insight and procedural learning. A likely explanation for these capacities is the process of pattern recognition.

I. WHAT IS INVENTION?

A Definition of Invention

Invention is the creation of a new device, process, composition or understanding. Novelty in invention can vary ranging from the improvement or variation of pre-existing models to ideas that are a radical breakthrough that moves the boundaries of human experience. The importance of an invention can be assessed by taking 3 aspect into account The social impact: some invention will have little social impact, e.g. a new bottle opener, whereas others, like mass production of cars, change our live in every way. The level of an invention: an invention can occur on a system level, e.g. world wide web, or at a component level e.g. a new web browser. Inventions at a system level form the breeding ground for many other inventions. In art a new genre is an example of an invention at the system level. Finally there is the dimension of knowledge extension, which refers to the amount of knowledge that is required to get at a certain invention. To get a first useful application in nano-technology extensive research is required to get to the required "what" knowledge. Getting to new mobile phone design requires only a limited amount of "how" knowledge.

B Invention versus Discovery

It is already a longstanding discussion if creative products should be labeled as invention or as discovery A more constructivist approach to the issue will argue that all knowledge are man-made construction and thus should be considered invention. Other scholars have stressed the fact that new knowledge comes from the unveiling of inherent structure and possibilities and thus should be seen as discovery. Although the discussion is not settled in a deep philosophical sense, most authors will agree that one can distinguish "what" knowledge that is of the "discovery-type" and "how" knowledge of an "invention-type".

C Products of Invention

Generally four types of inventive products are distinguished. The first one is technological invention, which refers to the conception of a new technological tool or device. These products are often commercial in nature and often stem from a predetermined search to serve a practical purpose. Typically these inventions are patented. Scientific invention refers to the finding of patterns, regularities and mechanisms underlying phenomena in our world. Science in general is not guided by practical considerations but by the search for understanding in its widest sense. Some science may receive special funding when in areas that are expected to lead to useful inventions, (e.g. microbiology). Artistic invention has the least constraints on its products in the sense that they don't require a particular purpose or usefulness. Valued artistic invention often stems from professional activity, but unlike technological and scientific invention, is commonly produced by amateurs as well. Internet has greatly stimulated the artistic invention (e.g. photography and blogging) since it provides a cheap means for publishing. Artistic products may have great commercial value, as can be seen for example with artists such as Damien Hirst, who sold for hundreds of millions of Dollars at auctions and Abba, who for several years the biggest contributors to the Swedish GBP.

Cultural invention refers to the new habits and behaviors that appear in society. They can be of limited influence such as punk or gothic sub-cultures, or as widespread as environmentalism. They can be short-lived or mark an entire époque like the Renaissance or the Enlightenment. The distinction between these different inventive products is not absolute and they greatly influence each other. Science and technology are increasingly synergistic, often scientific invention lead to technological applications, and technological invention such as instruments, open up new areas for scientific inquiry. Artistic invention may inspire scientific invention; design synthesizes technological and artistic invention and several inventors were also artists.Technological invention such as internet or television can have a profound impact in the habits of our culture, and in turn culture can determine if certain artistic or scientific directions are promoted or hindered .

D Invention as a Process

Many instances are known where decisive insight was reached in a single moment. Poincarré's insight in a mathematical problem he was working on, when getting on the bus, Archimedes eureka sitting in the bath and Kekulés revealing snake dream which set him to the idea of a circular structure of benzene, are examples of such insight. These insights seem to occur in idle moments that have been caricaturized as the 3B's: the bed, the bath and the bus. How important these insight may be, the invention can be reduced to such a single moment. A long period of problem seeking, experimentation, searching, and many failures precede such insight and often more than one insightful breakthrough is needed. A lot of persistence is needed before such crucial understanding is turned into a fully worked out theory, useful product or artistic realization. Darwin worked on his original idea for 30 years before he published it. An initial idea has to be developed, made into a prototype, tested and improved before getting to a marketable product. Invention is thus the result of a long and complex process. Creators take around 10 years before they come to their first major invention. Characteristics such as persistence and passion amongst others, are required to bring this process to end in successful invention. These different emphases on insight versus process is called the sudden-gradual controversy

II. FACTORS INFLUENCING INVENTION

A Role of Personality

Some inventors have been very productive (e.g. Edison) while other people seem to lack completely this capacity. This asymmetric distribution of production has led to the assumption that there is a special talent underlying the creative capacity. Successful inventors are shown to possess a number of personality characteristics that seem to favor invention such as: passion, optimism, nonconformity, tolerance for ambiguity and a tendency to embrace failure as a learning experience. Especially important seem persistence and the capacity to delay gratification since most inventions take many years to reach a useful, marketable, or publishable form. On the other hand it has been argued that creative invention is at the reach of everyone and several studies have shown a normal distribution of creative production and number of patented inventions. This controversy is called the special-ordinary discussion and lasts till today.

B Role of Context

Invention is a highly purposeful but purposes vary depending on context. Invention may be driven by a specific need, like for instance searching a solution for a engine that breaks down repeatedly. But it can also stem from a general search for understanding as in fundamental science. Artistic invention may be solely for the pleasure of discovering and creating. Economically this aspect is called demand-pull where inventors respond to demands that exist in the marketplace. Other inventions are supply-push, the invention is unforeseen and creates a market for itself, e.g. post-its. Still others are invented before there is any use, like the parachute that was invented before there were planes. Inventors working in an entrepreneurial context are required to produce profitable inventions, whereas inventors who work in a university setting are less so. Also the epoch we live in influences invention; DaVinci designed war engines, and recently the ecological danger of economical progress has liberated funds for environmental studies. Thus social context influences what is fashionable, acceptable and desirable in scientific and technological invention and may be in a lesser degree in artistic invention. Finally the team context and other resources are important factors in determining the outcome of invention .

C The Role of Knowledge

All novelty is created through cognitive processes that build on existing knowledge. Something new may be invented through analogy, combination or abstracting, but it always depends on existing knowledge. Effective inventors build on the knowledge that has accumulated over centuries, making inventions possible that were unthinkable before. It is possible to invent, in the sense of creating novelty, with a limited knowledge base, but the result will simply be poor and with little use. As much as invention depends on knowledge it also requires stepping over existing boundaries, and abandon or challenging what is known. People have a natural tendency to look at problems in a habitual way and to become trapped in this conservative view, which is called functional fixedness. It is necessary to take a new approach, think outside the existing knowledge; something often referred to as lateral or divergent thinking.

D The Role of Chance

Several instances are known where inventions where made by chance. The inventor was looking for something completely different but then discovered something unexpected, a phenomenon called serendipity; a famous example is the 3m post-it, an unexpected application of a failed product. Also errors can lead to invention. The metallic color of plastic resulting from accidentally adding a thousands times too high amount of catalyst led to the idea of exploring its metal-like properties, leading to a Nobel prize winning invention of electrically conductive and light emitting plastic. Invention normally comes from planned activity, an inventor has a problem in mind that he wants to solve and he consciously uses a number of strategies to find a solution. Often inventors consciously expose themselves to unfamiliar perspectives or areas to be inspired by the unexpected. Other times chance has an important hand in the process, as in the well known example of Pasteur's discovery of penicillin. But it can seldom be attributed entirely to luck, because chance favors the prepared mind, as Pasteur remarked himself. Many people may have seen the same phenomenon before, but didn't recognize its potential.

III. COGNITIVE PROCESSES IN INVENTION

A Conscious Processes

In invention various conscious steps can be identified. A first step is setting the objective or problem. In technological invention the inventor usually searches for a solution of an existing problem: how can I achieve X, or how can this be better, lighter or faster. In artistic and scientific invention this phase is rater one of problem finding such as: how can I express Y or understand Z. Sometimes the major invention is in the finding of the problem itself, when discerning a problem or possibility that wasn't noticed before and that may have a very simple solution. One might think of paperclips or toilet paper, where rather the application is the invention than the product itself. The inventor will then search for existing solutions and subsequently start generating his own ideas. The heuristics described further on refer predominantly to this phase. Not all ideas are useful or executable and some are better that other so that after this the inventor selects from his ideas on that are good ideas along certain criteria of goodness. In science these will be such as testability or parsimoniousness, in art originality and cost, in technological inventions manufacturing aspects and profitability. Since no idea is ready first time around in the final phase the inventor has to fine-tune his ideas shaping it into a useful final product.

B Creative Cognitive Operations

One of the defining characteristics of invention is that implies the creation of something new. In principle there are 4 cognitive operations that can be identified that create novelty. Application is the adaptive use of existing knowledge. Something already invented is adapted or variations are introduced to better to fit it to the necessities of the current context. A brilliant defense of a lawyer might be an example of such an invention; no new legal concepts are introduced, but the existing ones are used creatively to fit the case. The second creative operation is analogy, which is the transposition of a conceptual structure from one habitual context to another innovative context. Many examples can be found in chemistry and physics whenever a model is used, e.g. the planetary model of the atom. In art, the importance of analogy can be found in the styles like Impressionism or Surrealism that spread to other art forms. The third operation is combination: the merging of two or more concepts into one new idea. This operation is also referred to as synthesis. Combination is especially relevant for technological invention, since many inventions are the result of bringing together existing elements in a useful and practical manner; think for instance about the manufacture of a car. In artistic invention combination can be seen when artists, incorporating aspects of others' work into their own artistic styles. Finally the most radical novelty is created through abstraction. Abstraction is the invention of any structure or pattern that describes the relation between a number of different instances of a certain phenomenon. For instance young children primarily use abstraction to organize the concrete external world into interiorized mental concepts. Repeated exposure to objects leads to more abstract notions such as color, weight or number. Abstraction is most prominent in scientific invention. A good example is Einstein's relativity theory. In his theory the relation between time and space is redefined into a new higher abstraction in which time and space are part of the same entity.

C Cognitive Unconscious

Although the effort to invent comes from a conscious determination, inventors report that many of their most important breakthroughs seem to come from processes that happen outside awareness. After conscious effort to solve the problem it is helpful to put the problem aside to permit a process called incubation, after which insight can pop up in consciousness. In the last two decades research has identified and demonstrated the importance of a number unconscious cognitive processes, which are relevant for invention. Patterns in complex data are detected unconsciously and cause procedural learning: subjects are able to decide correctly on a task without being able to give a verbal account of why or how they did it. On several complex tasks conscious reasoning has been shown to worsen peoples decisions. Similarly asking people to give a verbal account worsened their capacity of problem solving. This interference of verbal accounts or conscious reasoning occurs especially in so-called insight problems and not on analytical problems. This makes unconscious processing especially relevant for invention, a process characterized by the occurrence of insights and lateral thinking.

D Intuition

The most elusive of cognitive processes that are important for invention is intuition. Many inventors report to be guided by hunches and inspirations that they can't account for but that were absolutely essential to get to the final invention. There isn't a clear theory for the workings of intuition, but the most likely candidate is a process of unconscious pattern recognition. Some people seem to be more intuitive or rely more on intuition then others, in general. However, intuition is also related to experience and expertise since experts develop a capacity for intuitive insight in their field over time. Certainly three different types of intuition can be distinguished. The first is evaluative intuition. It tells us to trust people and solutions or not. The inventor knows that he is "on track" or that "it doesn't feel right" or "something is missing". A good example is mathematical intuition that predicts if a proof or solution can be arrived at through a certain method. A second type is directional intuition. It informs the inventor where to look for solutions. It can take the form of "the problem must be in the…" or "I should look at the…". In working on the relativity theory Einstein started to investigate the notion of simultaneity, as if he knew that this notion would provide information about a solution for this problem. The wobbling movement of a soup plate fascinated the physicist Feynman, but only much later discovered that it was analogous to the atomic spin problem he was working on. Finally there is the metaphorical intuition. In this type of intuition solutions come in analogical or symbolic form. The inventor spontaneously gets certain images, memories, poems, words or even kinetic sensations that hint metaphorically at a new way of looking at the issue he is working on. Kekule's dream of a snake that led him to hypothesize a circular structure for benzene is a famous example of this type of intuition.

IV. HEURISTICS IN INVENTION

There are a number of strategies or heuristics that inventors use to get at ideas and novelty for invention. They don't guarantee success but often lead to (partial) insights that are helpful to arrive at solutions for the inventive problem they are working on

A Subgoaling

Subgoaling refers to the breaking up of a problem into nearly independent parts that can be solved separately. This subgoaling can highly facilitate complex inventive tasks. For instance the Wright brothers were able to achieve their flying machine by working separately on the problems of lift, control and power. Partitioning a problem into parts is also important form the perspective of collaboration since it permits that invention can be speeded up and improved by the division of labour.

B Variable and Feature Extraction

When trying to get at a scientific understanding of some phenomenon, a good strategy is to identify the entities that vary. These variables often provide vital clues to get to invention. The inventor can now study these variables, and their covariance with other factors may be manipulated. Especially studying extreme values of variables can provide important insights for scientific invention. The correlate in technological invention is feature extraction. Features that may be identified are for example size, materials, and functions. This identification subsequently facilitates and systematizes operations such as elimination, adding on, combination, rearrangement and scaling of these features. One might for instance think about the variations one could apply to the features of a chair such as number of legs, back support, adaptation possibilities in tilt and height rotations, materials, arm support. Another example of this heuristic is morphological analysis, where a system which is too complex to fully quantify is broken down into parts, simpified by dropping the trivial components and then only the vital parts are used. Creating desired models or scenarios is done by only taking the contributions of the simplified system into account.

C Analogizing

Searching for analogies has proven to be a fruitful strategy for invention. In order to do so inventors may read on purpose outside their field to find ideas. Other phenomena can function as metaphors for invention. Alexander Bell took inspiration from the curved spiral from in the human ear to invent his first telephone design. The concept of homeostasis was imported directly from chemical theory into family therapy. Analogy is different from similarity. Similarity refers to directly observable characteristics as form or color, analogy to the abstract underlying structure. There is nothing similar between a musical instrumental and an atom. Yet the idea of musical intervals and harmonics served as an analogy for the quantum mechanic atom model.

D Exhaustive Search

A crude but sometimes successful strategy to get at invention is exhaustive search. It is questionable if this deserves to be qualified as a heuristic but has certainly proven its worth. Edison tested hundreds of different materials to get at suitable one to sera as a glowing filament for the light bulb. Pharmaceutical companies roam the forest in search for new plant species to test for medicinal power.

E. Combining

Purposeful combination has led to important inventions. It may be done on a feature level like combining different functions in a cell phone, or making existing products with new materials. For instance plastic and sophisticated polymers have been combined into products previously constructed with traditional materials such as metal, wood or glass. But also concepts and principles can be combined into new ones. For instance paleontologist Steven Gould brought together the ideas of chance statistics with evolutionary theory to get to a deeper understanding of the development of life on earth. Picasso deliberately tried to incorporate primitive art in modern painting and sculpture. Two specific techniques based on this principle are homospatial thinking: imagining two or more discrete entities occupying the same space and janusian thinking: conceiving two or more opposite or antithetical ideas, images, or concepts simultaneously. Finally there is the phenomenon of synesthesia the interfusion of perceptual modalities such as color with sound or taste with form, which inspired especially poets in their artwork.

F. Modeling

4 different types of models may be distinguished that are instrumental in invention: a physical model which displays the physical characteristics of a real object; a functional model capturing the essential operations of an object or mechanism; a theoretical model embodying the basic concepts governing the operation of some process; and finally the imaginary model to display aspects features of something we can’t observe directly. All models are abstractions in some way of another, which help to understand, predict or manipulate certain aspects of reality. Probably the most famous invention that came from a physical model was Crick and Watson’s discovery of the double helix structure of DNA. Another instance are Gaudi’s inverted models with strings to determine the required force of his architectural inventions. Chemistry and physics are replete with functional models that predict or describe phenomena correctly, without having a complete understanding of the phenomenon.

G Imaging

Imagining is prominent in every invention and has been equated by some authors to thinking itself. Visualizing structures or objects, fixed or in movement helps to get a deeper understanding of the workings of things, can inspire new ideas and is a tool for testing certain aspects of inventions. The inventor may imagine how his new invention may look like, its form, its color, how it will be used, how it moves. A famous example of imaging are Einstein's thought experiments in which imagined traveling in trains, spaceships and on a photon, which helped getting to the invention of relativity theory. But imagining does not only refer to the visual but also to other modalities such as the auditory and kinesthetic and in rarer cases even taste and olfactory modalities. Apart from the visual modality, especially the kinesthetic seems important. This body or kinesthetic thinking is common in choreographers and sculptors. The sculpture Henry Moore says in order to create he needs a deep feeling of the statue on a physical level, to feel the statue from within. But also in less obvious areas such as engineering and science, kinesthetic imagining has been reported crucial. Several scientists that work on particles such as molecules, chemical reactions or atom interaction reported gaining insight by imagining physically being these particles. Cyril Smith working on metal alloys reports that he creates a feeling of how he would behave as an alloy, how brittle, hard or conductive he would feel in a truly sensual way. Many engineers are known to imagine buildings or bridges from within, detecting design flaws from a proprieties and muscular sense of their structure.

H Shifting Representations

Successful inventors are characterized by using a rich variety of representations to look at the problem at hand. They may draw charts, maps and diagrams or use computer simulations; problems can be represented using colors, numbers, symbols or mathematical equations. For instance the graphic representation of the elements in a 2 dimensional grid by Mendelejev was a crucial step in revealing patterns in the underlying characteristics of the different atoms. Most importantly inventors shift representations swiftly to detect unnoticed possibilities, regularity and analogies. Similarly it helps to break free of fixed and conservative ways of thinking about the inventive problem one is working on. Shifts may be made from physical models , functional or theoretical models. Inventors may also consciously try to shift perceptional modality, for instance from visual to kinesthetic or from kinesthetic to auditory. Imagining other perceptional modalities, e.g. what sound would molecules make? , can open up new ways of understanding the issue. Dimensional thinking refers to shifts in scale, and dimension. The inventor can move from 2 to 3 dimensional representations and vice versa and in some cases even higher dimensions. For instance in understanding the structure of proteins both second and third dimensions have been instrumental in understandings mechanisms of protein folding. In art the effort of representing 3 dimensions simultaneously into the 2 dimensional surface led to cubism. Finally in scaling looking at objects from short and long distances can help to discover new properties or even regularities and was the case in discovering fractal patterns in studying geographical maps at different scales.

I Experimenting
Experimenting is an important tool in gathering new knowledge about phenomena. Certain aspects of reality may be manipulated in order to understand their causal influence. The simple question of "what if", put into practice may generate ideas and open possibilities and is the basis for trial and error learning.Variations of existing concepts and products may be tried out to get to better, faster, simpler o cheaper products. No invention is ready when it is devised for the first time. It needs to be tested, improved and perfected to reach its final form. Numerous plane prototypes crashed in experiments before a properly flying one was invented. Experimenting can also be done in a mental way by thought experiments. Observing can be considered an experiment without manipulation. Observation of natural phenomena with or without the aid of instruments can be inspirations for invention. Novelist Somerset Maugham said that it is essential for a writer to study men. The mind has to be trained to observe to detect the relevant clues from natural occurring phenomena.

J Playing
Play is not only important for the infant to train and discover its capacities, but it is a creative force during our lifetime. The pleasure and curiosity that are inherent to playing, motivate and inspire us to think outside the box. We experiment new things just for fun and to see what happens. Playing is a heuristic for invention since it leads the player to the unexpected. It may cause serendipitous or chance invention and lead to observations that may be instrumental in finding the way to invention. For some inventors such as Richard Feynman and Alexander Calder, play was a way of life. The mental modality of play is daydreaming.

K Blockbusting
Many authors have argued that invention requires divergent or lateral thinking, to break free from conventional and habitual ways of thinking. People have a natural tendency to look at problems in a fixed way and to become trapped in a conservative view. Blockbusting is a conscious strategy to identify and overcome this functional fixedness. Key blocks are perceptional, emotional, cultural and intellectual blocks. A typical perceptional block is stereotyping, where one can only look at something in a preconceived way. Emotional blocks can be founding the fear of failure or risk taking, and intolerance for insecurity. Intellectual blocks occur when one is too fixated on one's specialty, one type of solution or not wanting to abandon certain dogmas or assumptions. Einstein had such a block when rejecting quantum mechanics for esthetic reasons. Cultural blocks can cause that the inventor doesn't consider solutions that are not currently fashionable or politically incorrect. Many of the afore mentioned heuristics, in one way or another, circumvent this type of blocks. Thus the inventor may analyze explicitly what limits he has put on the type of representation, materials, size, perceptional modality, modeling etc…

V. COLLABORATION IN INVENTION

A Advantages of Collaboration

Although there exists a common idea of the inventor as the lone genius, and although there have been some, most inventions are done in collaboration. It is true that any idea has to rise from one mind for the first time, but collaboration is important in many ways. It offers a critical perspective, fosters spotting problems and opportunities and can promote divergent thinking. Both understanding the ideas of others as well as the effort to explain one's ideas to others, are useful instruments to sharpen and progress in one's own ideas. The dialogue between Picasso and Braque brought about cubism. In addition, collaboration can greatly increase inventive potential through the division of labour. Think for instance about the teams of the Manhattan Project that worked on the atom bomb.

B Types of Collaboration

Studies show that several types of collaborations can emerge. In distributive collaboration, collaboration does not go beyond the exchange of information and experience by partners who have a shared interest in a topic. Common examples are email, newsgroups or meetings. Complementary collaboration is found in the work environment and derives from a role definition and division of labour. Finally integrated collaboration is often long-term and develops a more intimate and lasting exchange of ideas. This latter collaboration has the most potential for generating new ideas required for invention.

C Roles in Collaboration

Within the collaboration process many roles can be found amongst whch the following are the most important. Visionary roles: people with the courage and imagination to search out new problems and challenges and step out of the obvious. Often these visionaries also possess charisma to motivate others to assist in realizing their dream. Quite opposite is the organized and rational management role that includes planning, setting deadlines, allocation of resources and maintaining relations with funding and supervising institutional structures. Peer roles represent the horizontal relation of working together on a common issue, the exchange of ideas, critical analysis of each other's work and generation of new solutions. Leadership roles mediate between task and team, and form a communicative factor. A specific role is the bridge role that is important when collaboration occurs at the interface between groups that have different institutional cultures. Group collaboration seems to last about 10 years after which members go on solo careers or regroup. E.g. the Beatles

VI. CONCLUSIONS

A. Invention as Indefinable

Largely due to its unconscious aspects, our understanding is still full with gaps.
A number of creative cognitive operations such as application, combination, analogy and abstraction are known, but it may be debatable if a inventive product should be understood as the result of for instance an analogy operation or rather a combination operation, or if several operations were involved. We understand important characteristics of the process and heuristics that can be helpful, but many times it is difficult to understand what heuristics or processes have contributed to a particular invention. It is clear that some strategies such as imagination, janusion and homospatial thinking may stimulate hidden process of lateral thinking, but the process remains essentially hidden. Another gap in understanding is that from a number of ideas, inventors somehow consider only the most useful ideas, suggesting that there are some selection criteria at work of which little is known. Successful inventors are probably well aware of an underlying required structure they use to sieve out ideas

B. Complementarity in Invention

When describing invention a number of factors appear that are complementary or dialectic in nature. Invention can be seen as a conscious process trying to solve a problem or trying to understand a phenomenon, experimenting solutions and heuristics to get at a satisfying solution. But inventors report that their most important breakthroughs seem to occur outside conscious awareness and intuitive inspiration and feel for direction are essential. Invention creates a new product or understanding but is always based on structures of old knowledge. Invention is a, often long, gradual process but with sudden jumps of insight. It requires hard work and effort as well as letting go and idleness to allow for incubation to help new ideas to come up. Ideas can only come up for the first time in one person, but the collaboration and human interaction is vital in promoting invention. On the one hand the inventor has to work purposeful and directed towards a product, on the other hand periods of undirected play and distraction can promote chance findings. Invention seems to result from a special giftedness in some, yet is also an ordinary capacity we all posses.

C Invention Can Be Learned

Like any other human activity invention can be learned and optimized. Everybody can invent and practice makes perfect. Inventors can work hard on acquiring knowledge and skills that will enrich their base on which to build new solutions. Applying heuristics help to liberate the inventor from the conventional paths and get innovative and creative ideas. Well-rehearsed knowledge and skills will disappear into unconsciousness, operating on an automatic level freeing attention for new tasks and focus. Questions and conscious effort function as motivators that somehow set the cognitive unconscious at work. An inventor has to learn how to switch productively between conscious effort and allowing time to allow for unconscious processes that require incubation. He can become more sensitive to and listen for intuitive insights. Thus a cyclic process of conscious problem finding, followed by listening for intuitive inspiration, critically working out these ideas and asking new questions can be optimized. Pattern recognition skills can be applied to the mental process itself creating meta-knowledge of the inventive process. The experienced inventor can understand something of how the interplay of all these factors can be more productive and learn over time to use all these mental tools more effectively. Various authors argue that teaching should not only teach existing knowledge but specifically stimulate inventive skills.

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