Exploring Invention Capability

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Abstract: Research on invention has focused on business invention and little work has been conducted on the process and capability required for the individual inventor or the capabilities required for an advice to be considered an invention. This paper synthesises the results of an empirical survey of ten inventor case studies with current research on invention and recent capability affordance research to develop an integrated capability process model of human capabilities for invention and specific capabilities of an invented device. We identify eight necessary human effectivities required for individual invention capability and six functional key activities using these effectivities, to deliver the functional capability of invention. We also identified key differences between invention and general problem solving processes. Results suggest that inventive step capability relies on a unique application of principles that relate to a new combination of affordance chain with a new mechanism and or space time (affordance) path representing the novel way the device works, in conjunction with defined critical affordance operating factors that are the subject of the patent claims.

1 INTRODUCTION

Invention concerns the creation of new or novel technology (Arthur, 2007) by an act of insight that yields new structures of prior knowledge and experience (Ruttan et al., 1959). As Arthur (2007) asserts "a technology is a means to fulfil a purpose through some effect" and relates to structured objects and their architecture as well as the process of know-how and sequence of activities to do something. Most invention research focuses on strategy and process conditions for company based group invention (Giuri et al., 2007). It suggests invention ability is widespread and invention is driven by market opportunities. A third of European inventions are created by independent inventors (Scherer, 1982) motivated by personal satisfaction, and prestige (Giuri et al., 2007). But, there is a lack of research to explain the process of invention for the individual inventor, what capabilities are required and what activities relate to the unique characteristics of the invented device. This leads to our research question: what is the capability of invention? We explore this from both the agent and device perspective; a) *what are the abilities and process required of the inventor as agent (invention process capability)* and b) *what specific capabilities make an advice an invention?*

1.1 Capability

Capability research has traditionally used Grant's definition of a firm's ability to produce a discrete productive task repeatedly (Grant, 1991) and higher level organisational dynamic capabilities (Winter, 2003), rather than functional capabilities. To answer our research questions, we propose functional capabilities need to be defined in terms of agent actions on resources. Business capability can be defined as "*the potential for action to achieve a goal G via an action/series of actions in a process P resulting from the interaction of 2 or more resources, in a transformation that produces business value for a customer*". (Michell, 2011). Capabilities for agents acting on objects can be modelled using Gibson's affordance theory where affordances are; "the property that the environment or physical system offered the animal to enable a possible useful transformation for the benefit of the animal" (Gibson, 1979). Affordances refer to descriptions of (verb-noun) object abilities such as "a cup affords drinking" or an invention such as a thermometer affords temperature measurement. Human affordance, the ability of an animal or agent to complement the object affordance, is termed effectivity (Greeno, 1994). For example "can fish", or "knows how to fish" etc.

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Effectivities refer to human abilities, functional skills and knowledge (Michell, 2013). The Wright brothers effectivity of know-how about flight enabled them to invent the first flying aircraft. Our earlier papers showed how capability can be modelled as a process of object affordances and human effectivities of the agents involved (See Michell, 2014). So the capability of invention depends on the process of human activities and effectivities and the invented device affordance that meets novel invention criteria. To model invention capability we must investigate a) Invention behaviour –what effectivities - skills and knowledge are involved? b) The invention process - what activities are involved? c) Invention device development - what constitutes an invented device?

This paper proposes an integrated model of invention capability using findings from primary research on invention behaviour and blending it with models of invention using the capability affordance model. Section 2 explores the characteristics of an invented device. Section 3 explains the pilot survey and the resulting effectivities or human capability traits of invention. Section 4 explores the current work on invention process and problem solving and proposes an integrated model based on this data. Section 5 investigates affordance and organisational capability models and how these can be used to understand invention device capability and contribute to the integrated invention capability model Section 6 Concludes with further work.

2 INVENTION CHARACTERISTICS

2.1 Device Capabilities

The newness of an invention relates to the idea/model for how something is done before it is known or used by others (Pressman 2014). Patent requirements for legal acceptance and classification of new technology refers to a new "inventive step" within the novel idea. Inventive step relates to a specific ‘concept’ that is not obvious to those skilled in their knowledge of existing technology in the domain (Cohen and Levinthal, 1990).

Achieving novelty requires an excellent understanding of principles (Williams, 1990), as Arthur (2007) asserts "a novel invention technology must use a new or different base principle to achieve a specific purpose". A principle is a generic explanation of the causal conditions necessary to reproduce some observed natural happening or phenomenon. It describes generally how the invention works and is independent of specific structure and means. For example a set of objects a, interact in situation b producing an effect c resulting from their specific interaction properties. An example phenomenon is mercury expands and contracts according to ambient temperature. The related principle is the height of a column of mercury exposed to the air corresponds to the air temperature. The effect relates to the end state produced as a result of the phenomena acting on an initial state ie the column height rises/falls. Principles explain the how an observed phenomena is harnessed to produce the desired beneficial effect (Arthur, 2007). Arthur’s definition of invention "the exploitation of some effect as envisaged through some principle of use" identifies that an invention typically uses a natural effect or result of a natural law through some principle". However, for invention the general principle must be harnessed in a specific arrangement in what Arthur (2007) calls a "working concept", ie how exactly the principle could be applied in practice and be made to cause the desired effect. It refers to how the invention works via generic structures and the generic process sequence of its operation. The process of inventing involves the investigation and testing of a range of possible concepts and component variables, until the right generic combination is identified (Arthur, 2007). In a thermometer the working concept involves the use mercury (ie a high co-efficient of expansion) in a container such that its change of height is easily visible and measurable. Experiments and trials suggest the need for a sealed evacuated tube and what size and shape and how to calibrate it.

The invention concept needs to be organised in a specific physical structural arrangement, ie an architectural system of components,that are proven to produce the specific desired effect. The architecture will cover the spatial arrangements, volumes, part relationships, materials and physical properties and any critical numerical factors that are needed for the invention to work within the specified range of the need or requirement. Harnessing the principle requires development of a technology ie the system of components in a specific architecture form as a device or machine configured for a specific purpose. For a thermometer the device architecture is rudimentary; a known volume of mercury is constrained in a sealed transparent evacuated cylinder, whose height at a known temperature is measured and recorded for different temperatures on a scale beside the cylinder.

Hence an invented device concerns a new specific architectural arrangement of components that interact under some new principle that governs the component interaction to produce a desired effect that achieves some specific purpose. This may be an arrangement of physical parts or of people and technology. Arthur's work (figure 1) proposed the knowledge artefacts sequence necessary for invention. However, what are the specific human capabilities (effectivities) and actions required for invention?

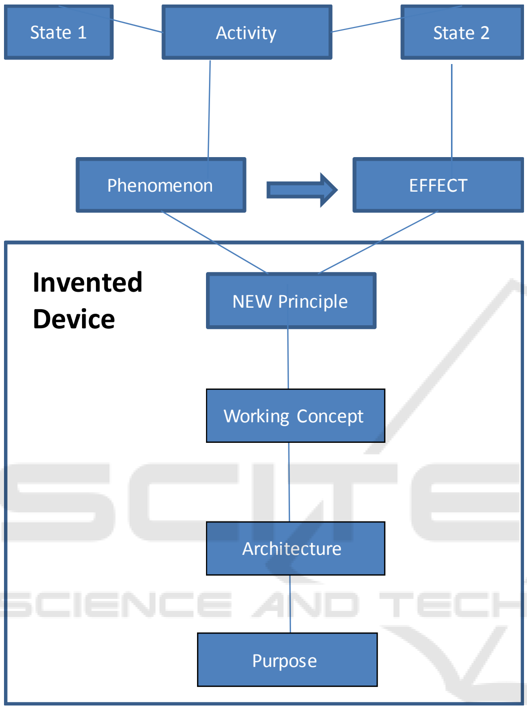


Figure 1: Characteristics of an invented device (adapted from Arthur).

2.2 Pilot Survey

A pilot survey was conducted to investigate invention behaviour factors. A sample of seven independent inventors was selected from contacts with the British patent office, qualified by the fact that they had all patented devices in the international patent classification sector of human necessities ie basic devices. These devices included, a sash clamp frame for installing windows, a garden leaf grabber, a non-slip builders bucket for roofers, a wind up generator used in a radio, card readers and displacement sensors and a " Squeezeopen" easily removable lid.

Invention advisors; a patent agent, patent PR agent and a patent advisor were also interviewed. A semi structured questionnaire (Cummins & Gullone, 2000) was based on a literature survey of invention processes and included 90 questions on; the personal factors affecting invention, the steps of the inventive process and the impact of information and knowledge. The questions used a 7 point Likert scale of agreement/disagreement levels (Cummins & Gullone, 2000).

Table 1: Pilot Survey Invention Traits (effectivities).

		Level of importance to invention: 1 not important, 7 very important												
	FACTORS	IF1	IF2	PA1	IN1	IN2	IN3	IN4	IN5	IN6	IN7		median	mode
1	Creativity	6	6	6	6	5	7	7	7	7	7		6.5	7
2	Curiosity	6	6	6	6	7	7	6	7	7	7		**6.5**	**6**
3	Childhood exp.	6	6	6	7	7	7	7	6	2	7		**6.5**	**7**
4	Deprivation	6	6	7	6	7	2	6	2	4	6		**6**	**6**
5	Imagination	7	7	7	2	6	7	6	7	6	7		**7**	**7**
6	Inspiration	6	6	6	6	7	7	2	7	6	7		**6**	**6**
7	Expertise	1	6	5	2	3	4	4	5	6	5		**4.5**	**5**
8	Self drive/motivation	7	6	6	6	7	7	6	6	7	7		**6.5**	**7**
	KNOWLEDGE TYPES													
KH	know how	6	6	6	7	7	7	6	6	7	5		**6**	**6**
KY	know why	5	6	7	6	4	5	6	6	3	5		**5.5**	**6**
KW	know what	6	6	6	5	7	6	6	6	6	4		**6**	**6**

3 INVENTION EFFECTIVITIES

3.1 Human Traits

Survey results identified the importance of 16 invention skills and 3 knowledge capabilities. The subset of capability factors are shown in table 1.

Curiosity, the ability and motivation to want to know more, was quoted by most respondents as vital to problem perception and the process of identifying that the need is not currently met or not met well that helps motivate the invention process. Self-motivation was seen as a driver to move the inventor to explore the problem. The ability to deduce an implication from a set of facts, an experience or the act of reasoning, is a sub process of problem solving (Aamodt, 1991). Answers to open questions, suggested inference was important to the invention step, to conceive and consolidate a final working design by connecting the principles and concepts to a working architecture arrangement of a prototype.

Respondents also identified inspiration in driving curiosity into action, to understand and solve the problem in a new way. For example "it is the inspiration of an event that led many inventors". The builders bucket was inspired by the problem of buckets of water and mortar falling off roofs. An inventor was inspired to search for an easy opening jar cap solution for his arthritic grandmother as none were available. Hence a need coupled to a gap in the available devices to meet the need is a key driver or invention.

Expertise or existing knowledge in the area was not felt to be so important with respondents suggesting "expertise can constrain creativity and thought processes necessary for invention". However, knowledge of engineering and problem solving subjects was felt to help by a number of respondents. This is supported by Cohen's absorptive capacity principle suggesting prior problem solving knowledge and experience better enable the acquisition of new problem solving capabilities (Cohen and Levinthal, 1990). But a careful balance is needed between what Arthur calls "knowledge of functionalities" ie the principles of how things work and problem solving, and a creative mind open to new concept combinations.

Respondents felt imagination to be critically important, relating this to an ability "to see their ideas in 3D in their mind", that helped them create and identify solution options. Mental models or the ability to create often a dynamic model of ideas and mechanical/electrical action representations are important to the ability to invent (Ash et al., 2001). Equally important is the inventor's ability to evaluate and categorise experiences and concepts, through the use of reference frames or mental data structures which links to attributes and values (Ash et al., 2001). Unsurprisingly, creativity was seen to be vital to an inventor's ability "you cannot solve an inventive problem without being creative". Creativity, "the ability to think what no one else has thought on seeing the same event", (Swann et al., 2005) is vital in the solution exploration stage. Patent agents felt creativity is necessary to work around existing inventions and produce the inventive step.

3.2 Knowledge for Invention

The capability to invent is heavily dependent on the inventor knowledge base and the ability to learn, assimilate and apply new knowledge (Büyükdamgacı, 2003). There are three primary know ledge types Know how, why and what.

Know how relates to procedural knowledge based on learning by doing ie practice and feedback or first-hand experiences applying facts from experience. Know how is cumulative and dependent on the path of prior experience gained (Arthur 95, Levitt and March 1988). For example the Wright brothers were able to use their bicycle know how to develop and test the wright flyer mechanics and create flying know how from their tests (Weber, 2006). Know how relates to the "doing, using, interacting" (DUI) mode of learning and innovation (Jensen et al., 2007). Know how is critical in the solution and prototype investigation stage of invention to assemble and try out possible concept architectures and test how well they meet the need. Know how was identified as most important by almost all respondents. This is to be expected as low technical complexity inventions are often created by trial and error know how (Dutton & Thomas 1985).

In contrast, Know why knowledge is based on understanding of principles and theories. It is the process of knowing through analysis or primary experience or second-hand information to identify causal rules about why something behaves as it does in terms of logic, natural laws etc (Garud, 1997). Know why is cumulative, depends on prior knowledge and the 'bi-association' of new knowledge from different areas to develop new theories and knowledge (Garud and Nayar 1997). Know why was seen as less important than know how. Using know why for modelling is referred to as science, technology, innovation or STI model of knowledge management (Garud, 1997). It enables inventors to use models to calculate more precisely how a principle can be converted into a prototype concept that is more likely to produce the desired effect. For example, the Wright brothers used weight and lift calculations to determine the required engine power (Weber, 2006). Know why can minimise the number of prototypes and experiments and avoid missing the inventive step that meets the need. This is critical as many inventors take years to search and try out invention prototypes in an effort to discover the application of a new working principle. Know why replaces the serendipity/chance of the lone inventor who otherwise relies on know how to try prototypes with different variables and to adjust them to a solution. Patent advisors suggested know why was less important at the discovery stage of invention, but know why relates more to defining claims of the inventive step, possibly because know how trial and error is easier and low cost within the invention category analysed and know why, in terms of inventive step, definition can be established via the patent agent.

Know what is based on declarative knowledge) and is generated by learning by using (Rosenberg 1982). Know what was felt to relate to 'expertise' in known facts which was seen to be moderately important, but less critical than know how.

In summary survey respondents suggested the invention process begins with inquiry or curiosity as to why a problem exists. Then inspiration fosters a drive to solve a problem is based on a problem experience often connected to a driver eg personal or family need for solution that makes the problem important. This is followed by imagination and creative ways to solve the problem that prompts serious investigation activity to experiment and test potential prototypes against the need. Respondents suggested the inventive step is characterised by a moment of inference or insight to see a potential solution among possible variations in tested prototypes that depended on an ability to synthesise knowledge. The final steps involve evaluation and interpretation of the inventions importance, value and why it works, codified into a patent. The results can be interpreted as the sequence of effectivities required for invention, but not the activities. For this we used insight from process model research.

4 INVENTION PROCESS ACTIVITIES

4.1 Process Review

Invention is seen as a needed problem solving process using "a problem description, a goal and a knowledge base as input and derives a solution that satisfies the goal" (Büyükdamgacı, 2003). The widely used information processing model for problem solving identifies 3 steps; perceiving the problem in the "task environment", converting this into a problem space or mental model of the observed problem and then a solution space of possible solutions based on the knowledge and memory of the problem solver. These process steps are heavily influenced by the prior experience of the inventor.

Inventing is also a creative process. Isaksen & Trefinger's 60 year old creative problem solving methodology (Treffinger et al., 2008) identifies three key creative stages. Firstly understanding the challenge involves identifying problem solving opportunities, gathering appropriate data about the problem and importantly framing and identifying the right problem. Identifying the right problem is key to reducing the invention search space and hence increasing the chance of finding the application of the right principle in a working concept (Weber, 2006). The second stage focuses on generating solution ideas. The final stage, developing criteria for and selecting and testing solutions and techniques for building acceptance of the proposed solution (Isaksen and Treffinger, 2004). Their process highlights the need to clearly identify and define the problem. This is emphasised by the Wright brothers division of the problems of flight into lift, power and finally control with the focus on 'how' to warp the wing (Weber, 2006). It also identifies a critical balance between thinking creatively and a further effectivity – evaluation and judgement of solutions.

Usher outlines 4 steps for invention. Perception of the problem that relates to an unsatisfactory method of meeting a need, followed by setting the stage to gather data regarding the problem and possible solutions, followed by an act of insight (confirmed by respondents) and critical revision to the final solution (Ruttan, 1959).

Exploring a problem and separating it into problem exploration and solution exploration stages is critical for technical problem oriented engineering (POE) problem solving methods (Hall and Rapanotti, 2009). Whilst TRIZ, the theory of innovative problem solving developed to help inventors identify combinations of parameters for a new ie inventive solution, emphasises the need to synthesise and evaluate the newness and feasibility of the solution (Barry et al., 2010).

4.2 Proposed Invention Process

Integrating these process activities with the effectivities and Arthur's model yields the proposed process necessary for the capability to invent, with the required human effectivities defined as per the process in our earlier papers (see table 2).

4.2.1 Invention Need Identification

Survey respondents suggested invention begins with "think (ing) of a problem" However as we have seen the problem that leads to an invention has a specific need to do something differently. This involves establishing that the current way of doing things does not meet current need as evidenced by survey respondents. Critically unlike normal problem solving, for invention there must be no immediately obvious alternative means of solving the problem.

4.2.2 Problem Definition

For efficient invention clarity is required about the correct problem to solve (the "goal" of POE) and the invention requirements or need (cf Isakson's problem framing). This is illustrated by the Wright brothers clear definition of lift, power and control problems and requirements which allowed them to focus their resource costly efforts more productively than rivals. Similarly, the jet engine inventors Whittle and Von

Ohain were both able to express an informal need in a set of defined technical problem requirements that optimally directed their inventive search (Arthur, 2007).

4.2.3 Problem Exploration

However, most inventions involve the evolutionary recombination of existing technologies (Fleming and Sorenson, 2001), or principles. So a novel invented solution requires an understanding of existing solutions and what does and does not work (know how). Most inventors see the need to explore and fully understand the problem, its cause and the factors involved ie as in Isaksen's "stage setting". For example respondents suggested "I immerse myself in a challenge and learn as much as I can about it". Clearly identifying the importance of problem-context understanding.

4.2.4 Unique Solution Exploration

The move to a solution involves searching for possible new architectural arrangements of principles that meet the defined requirements. Unlike traditional problem solving, this is not any, or a well tried solution, but one that uses existing principles and concepts differently in a new way. Narrowing down ideas can involve trial and error experiments by taking a principle and trying it out in concept form until a working concept is developed that meets the invention needs (Arthur, 2007). All respondents confirmed the importance of "building a prototype and developing and testing the concepts".

4.2.5 Invention Synthesis & Evaluation

Filtering ideas into a working concept is also critical. A respondent suggested "inventors have an uncanny ability to generate ideas and narrow down the best idea from them" and others that their process involves; "filtering the ideas and (then to) prototype the best idea, refine it and patent it", suggesting synthesis and evaluation as advocated in Bloom's learning taxonomy (Starr, 2008) are key inventive skills or functionalities. It is in the combination of trying and inspecting combinations of principles that many respondents suggested the "Eureka moment" of the elusive inventive step was hidden. Respondents described the "flash of inspiration that enables inventors to see a solution to a problem". This relates to the inference and reasoning task of identifying how known principles could be integrated into a concept, able to meet the problem need (Cohen and Levinthal, 1990). Thus we propose the inference and synthesis combined with evaluation, using invention domain knowledge delivers the inventive step.

4.2.6 Invention Design

What Arthur refers to as a working concept needs to be refined to a robust solution that reliably meets the requirement parameters. This involves identifying and optimising the parts/components of the invention architecture to meet the desired need. A respondent suggested "in my process; I refine it (the invention) and patent it". Refining is an engineering design activity that requires careful and detailed specification and testing of all parts of the invention and their physical properties and behaviours to meet the requirement tolerances. It is also necessary to identify the inventive step claims necessary to patent the design as a new application of principles and concepts to meet a specific set of uses.

5 INVENTION AS NOVEL DEVICE CAPABILITY

5.1 The Capability Affordance Model

We now turn to objective b): what specific capabilities makes a device a new invention, or what is device invention capability. Our previous papers used affordance theory to model device capability and we apply this to identify invented device capabilities. The capability-affordance model at the action or atomic level is based on the concept that the capability of an agent or device can be decomposed into an affordance cause and effect mechanism operating through a topological path "*The affordance mechanism is the cause and effect energy transformation at the interface between the two or more interacting resources and its properties that enable the transformation*" (Michell, 2014). The causal path relates to the space-time path of how the agent, the device and it components change and move as energy transfer propagates through the connecting objects. The capability of a device to perform a specific action is then a combination of an energy mechanism (either within the device or supplied by an external agent) acting through a path defined by the structure and architecture of the device. The path may be a series of linked affordances or an affordance chain (Michell, 2014). The affordance chain identifies the individual interactions or actions between object interfaces as they interact. The critical affordance factors (CAF) quantify the range of values over which the device will deliver the capability and is a generalisation of Warren's work (Warren, 1984).

In the thermometer example the mechanism that makes the device work is an affordance chain of heat transfer from the atmospheric surroundings through the glass tube to the mercury which is channelled by the path constraints of the evacuated thermometer tube that forces the mercury according to its physical expansion properties to rise up the graduated cylinder when the ambient temperature increases. Hence a sealed evacuated mercury containing cylinder 'affords' measuring temperature changes. The CAF for the thermometer would include a max/min temp range for accurate measurement and failure ie temperatures beyond which the glass will break or materials or the required properties fail.

5.2 Capability Mechanism

The capability affordance model relates to Arthur's model of invention. For example, the leaf grabber invention uses a principle of the lever, with a working concept of opposed arms with large rake jaws. However, to qualify as a new invention the specific way the architecture works or dynamically causes the desired effect must be different. Ie what Arthur calls the principle ('an effect in action'). The principle refers to the chain of interactions or affordance chain that relates to a cause-effect. It can be decomposed using the CAM model to the causal mechanism and path. Where affordance relates to a property or function of the object that satisfies a need. Most of the chosen inventions eg bucket, grabber have short affordance chains ie energy derives from a human agent to a single action. Although the sash clamp has many interacting affordance chain components, it is too complex to illustrate here. For the leaf grabber invention the affordance mechanism involves human energy forcing the arms together through a constrained path (dictated by the invention architecture) as the jaws rotate about their pivot to trap the leaf waste. The squeezeopen cap mechanism also requires a human energy (mechanism) to deform it to enable it to be removed.

However some inventions rely on a new specific mechanism as well as a unique path. For example the crank powered generator connected to a rechargeable battery is the basis of the patent claim in the electric current generator (Baylis 2001) and defines a new general principle for a clockwork DC power mechanism architecture. It uses an affordance chain of human energy being transferred to the clockwork mechanism which is then released and moderated via an electronic controller to power a device eg radio.

5.3 CAM Interpretation: Path

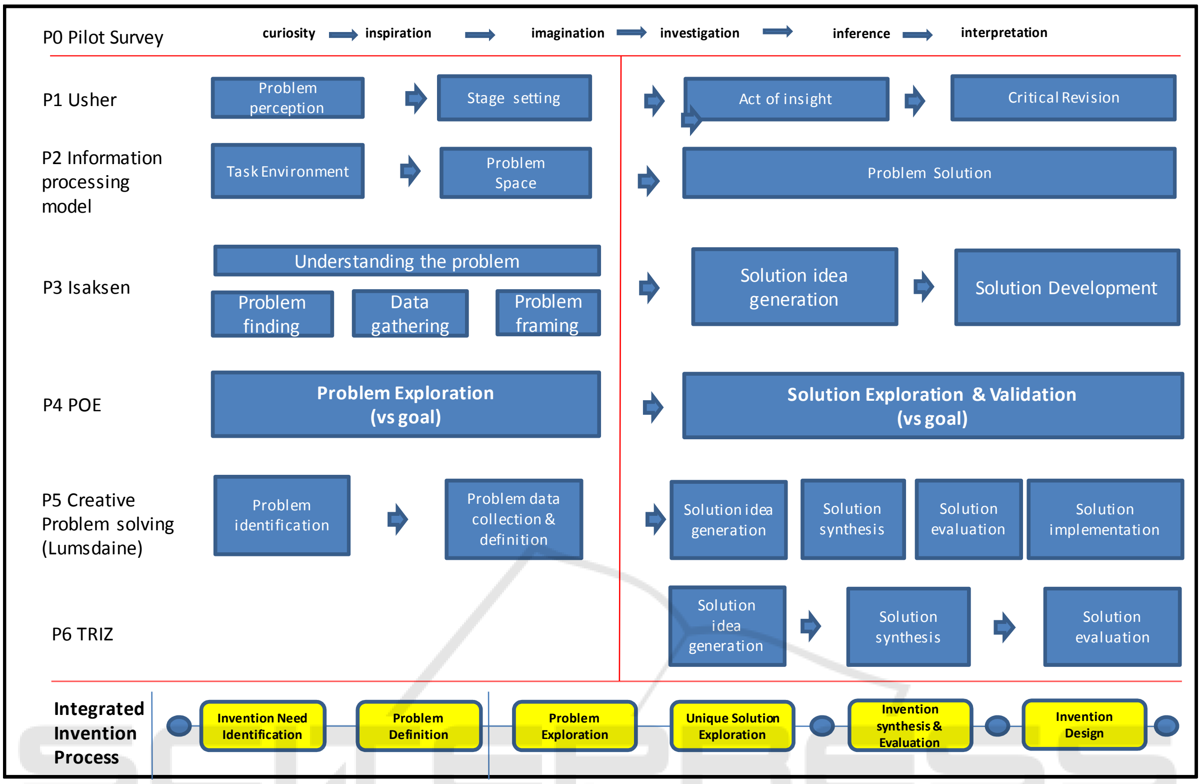
For invented novel devices, the path, ie space time way the device works, must be different from existing devices ie "the topology of (component) interactions is unique" (Williams, 1990). This relates to the affordance path topology and suggests for an invented device the specific path followed by the device components as they deliver the capability to meet the need of the invention must be new. Specific path topology is seen in the squeezeopen cap, where the path affordance is based on an affordance chain mechanism of human force that deforms a specific type of plastic cap such that it slips easily over the specifically designed (path constraints) rim and can be removed with minimum force. The patent claim directly illustrates this path affordance by legally describing the specific space time path followed to remove the lid and its relation to specific architecture. For example "claim 3, in which the side wall of the lid has a bead portion for sliding over the formation during the initial separating movement of the lid from the body portion" (Sheahan M. 1999). Five of the inventions surveyed relied on similar unique path topology and device structure. For example the leaf grabber uses opposed leavers – a well-known standard mechanism of magnifying force, but the critical affordance factors are the shape and arrangement of the jaws and their length provide a way of working or path that is deemed to be unique.

5.4 Critical Affordance Factors

Critical affordance factors relate to device parameter values and limits for which the capability is possible. These factors relate to both mechanisms, ie forces and to path dimensions, eg size of components. They also relate to the physical properties of the materials that ensure specific mechanism and path behaviour. For the squeezeopen cap example, the path relates to the architecture dimensions of the deformable cap interacting with a specially designed lip, under a specific amount of force, otherwise the cap would not work as intended. The invention claim specifies the specific cap material that has the properties to deform the right amount (based on specific affordance parameters) under an old persons' hand pressure, given the designed geometry between the cap and jar. The leaf grabber depends on the arms and size of the jaws being a specific size etc. See figure 3.

Hence any invention must and does include clear specification relating to any new path and/or the energy transfer mechanism and the specific (capability affordance) factors and their range values

Table 2: Processes Related to Invention.



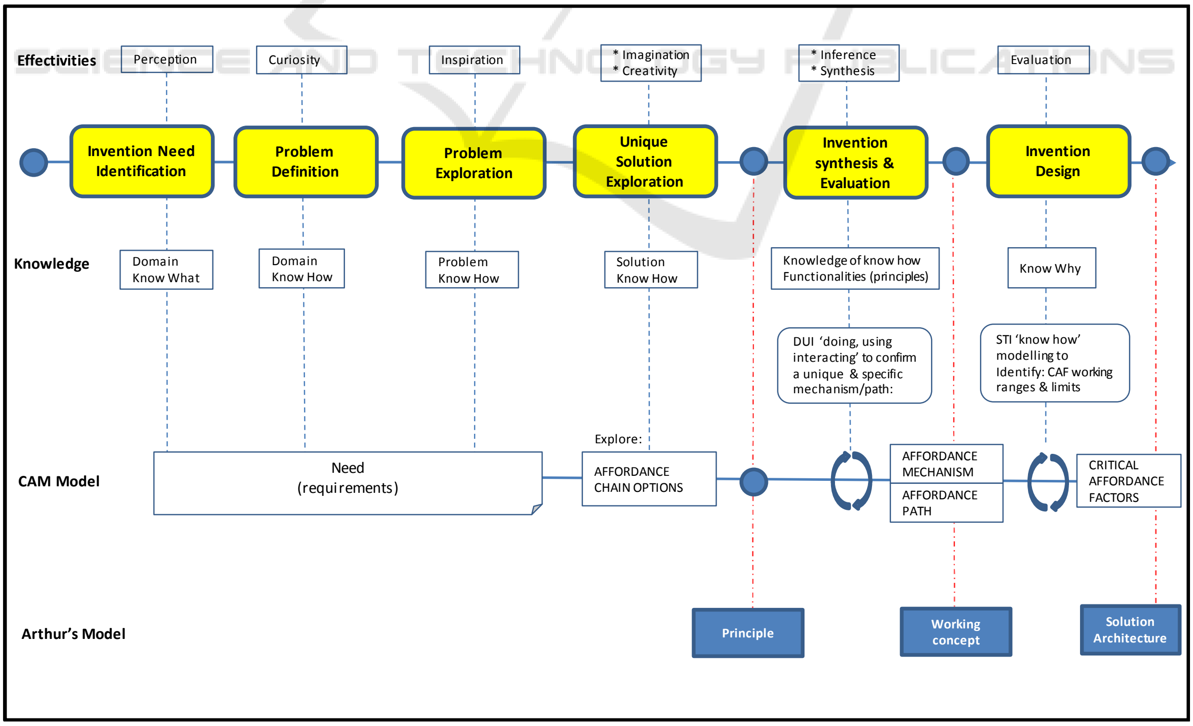


Figure 2: The Invention Capability Process.

over which the invention will work and hence legally what must is protected by the patent.

In terms of invention process, a knowledge of Arthur's principles, or causal mechanisms and various architectures and paths that inventions operate in is gained and used in the solution exploration invention activity.

The solution exploration stage is where the inventor explores the possible principles that could be used to meet the need. Where the principles are affordance chain compositions. For example Whittle's exploration of combinations of power unit mechanisms in different affordance chains such as "rockets, turbines driving propellers or rotating nozzles, fans powered by piston engines etc" to invent a new aircraft power plant, the jet (Arthur, 2007).

The development of a prototype, in the invention synthesis and evaluation stage, relates to testing of different architectures to identify the working concept. Prototype testing involves empirically trying various mechanisms and path variations to identify a different way to existing solutions. Finding a new working concept embodies the inventive step which defines a new and previously undiscovered specific mechanism and a working path/architecture that delivers this need.

The final invention design stage; solution architecture involves establishing the optimum arrangement of components for the invention. This includes exploring and identifying the limitations to its workings, ie establishing and quantifying critical affordance factors ie the range of values relating to the way the device operates. This involves critical dimensions, characteristic values and physical properties needed. For many inventions formal requirements are often only produced, to qualify the legal patent limitations, after thorough testing of the prototype to understand its working limitations at which the critical affordance factor values are exceeded.

6 DISCUSSION & CONCLUSIONS

Based on empirical findings and analysis of theory we reason that a) 8 necessary human capabilities or effectivities are required for individual invention capability. We also propose 6 key activities that require these effectivities and are components of the functional capability of invention. We have identified different types of knowledge at each stage and key differences between invention and general problem solving processes at the need identification, solution synthesis and solution design stage. We have shown b) what specific capabilities makes a device a new invention. We observed that inventive step capability relies on a unique application of principles that relates to a new use of mechanism and or space time (affordance) paths representing the new way the device works, in conjunction with specific and defined critical affordance operating factors that enable the invention to meet the invention need in a given operation envelope and that these are used to legally specify the inventive step.

Complete details of questions and examples have been limited by space. The research is also limited by only studying ten invention cases. To reduce bias we are currently working on a larger sample and statistical approach to corroborate and evaluate the relationship between the human traits (effectivities) and process activities necessary for invention capability. We are also evaluating mechanism and path characteristics of other devices to provide further evidence for the capability affordance model.

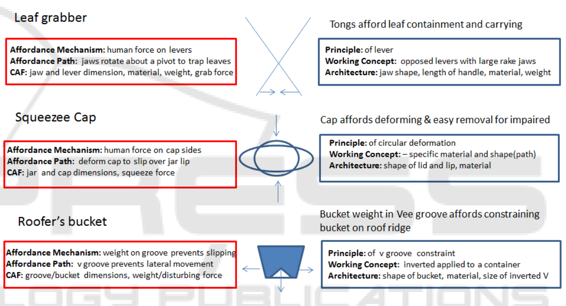


Figure 3: Example Inventions – Mechanism, Path and Affordance Factors.

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