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KNOWLEDGE-BASED SYSTEM FOR SUPPORTING CREATIVITY IN PRODUCT DESIGN - FOUNDATION

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Abstract. *The current competitive industry search for better and more efficient products places high responsibility on designers to come up with different products at an increasing rate. To fulfill this demand, creativity has become an extensively studied field to improve the design team's ability to create novel and appropriate ideas. Permeating a great part of any product development, creativity and its tools are a constant need in systematic design. Although extensively investigated, few studies show creativity methods as a direct and applicable technique categorized throughout the project development. The complex and empirical nature of this expertise allows the application of artificial intelligence, such as knowledge-based systems (KBS). This computational approach serves as an expert´s opinion by emulating the human decision-making ability, aiming to help selecting the appropriate creativity tools for each phase during product development. KBS showed promising results in different areas of product design. This research presents a KBS prototype to support the selection of creativity methods. The work illustrates the prototype features, its potentialities and future challenges. Ranging from the ideation of product conceptions to alternative selection, the chosen creativity tools cover a limited scope, as suggested by the incremental approach, aiming the prototype future expansion.*

Keywords: *Creativity, Knowledge-based systems, Design, Product development*

1. INTRODUCTION

Every organization aiming to maintain its share in current competitive market requires innovation. Creation, as the first step to innovate, cannot be seen as a small part of the design process, but a philosophy inside an organization. Innovation is not restricted to next generation computers and touchscreen smartphones. Every management decision must be innovation-oriented, asserting the right resources and practices to create new products, services, methods, and processes. Organizations that fail to create often become obsolete and are not ready for market changes (Baxter, 2011).

Innovation is an unclear strategy with uncertain outcomes. Many factors define the success of a design, from user's acceptance to stakeholder's profit, and design teams must deal with a great amount of interests to deliver an adequate solution. Creativity becomes a decisive factor to explore all possibilities inside the design range and reach the best conception that fits requirements. A team with the right motivation, resources and environment can properly create and generate solutions that have higher chances to become successful (Amabile, 1997). The creation process is complex, and to enhance its efficiency is a difficult task. Modern approaches make work times more flexible, improve environment and relationship, but rarely focus on the creation process directly.

Design teams commonly use creativity techniques to explore new ideas or change perspective during product development. Many factors influence the tool choice, from organizational guidelines to team relationship. Each tool has its best application for high effectiveness, considering yet that tools can be adapted to different team's reality. This broadness shows the complexity and expertise needed for the assertion of right tools. To overcome this lack of proficiency, artificial intelligence approaches, such as knowledge-based systems (KBS), emulate the human decision-making ability, making the knowledge more available, reliable and permanent (Giarratano and Riley, 1994). By translating knowledge from a creativity expert to a computational environment, a KBS prototype can build a bridge between creativity tools and design process. Other engineering applications have been developed to show the potentialities of this approach, such as KBS for fluid power system design (Silva and Back, 2000), cogeneration power plants design (Matelli, *et al.*, 2009), sensor fault modeling (Silva, *et al.*, 2012), hermetic compressors diagnosis (Pedroso and Silva, 2014), among others.

Based on identified needs, the system correlates the requirements to the developed categories, outputting adequate creativity techniques for the team situation. In this first implementation cycle, the KBS prototype strategically is focused on the design process, from conceptual ideation to solution selection. Any design team needing creativity enhancement can benefit from this approach, bringing tools from traditional methodologies and modern agile design approaches. This work focuses on the system foundations, presenting in section 2 an introduction to individual and organizational creativity. Section 3 deals with knowledge acquisition and implementation aspects. Section 4 demonstrates the KBS prototype for a creativity techniques assertion with application example, and in the last section conclusions and future works.

2. CREATIVITY

Ancient Greek philosophy attributed creativity to the gift of a god or associated it to an involuntary madness frenzy. They conceived this ability as the will of a higher entity, which infused its power into the mind of chosen people. Recent research projects show that this vision, although still sometimes perpetuated, is false and creativity is a much more trivial and humanly skill (Amabile, 1997; Mostert, 2007). Experts divide the creation process in five stages (Baxter, 2011):

- **Inspiration:** focus on a specific problem, triggering the creative process;
- **Preparation:** knowledge acquisition to ground creation. It is considered the rational stage of creativity;
- **Incubation:** distancing from the problem for the mind to ideate unconsciously. It is the irrational stage of creativity, which may be time-consuming;
- **Illumination:** known as the "eureka" moment, the mind successfully creates connections that fit the problem;
- **Verification:** proofing of the solutions adequacy to the original problem, serving as a reality filter.

The understanding and formalization of the creative pattern allowed researchers to focus on enhancing organizational creativity by different approaches, which, when combined, potentiates the capabilities of a design team to come up with more innovative products. Innovation is deeply connected to a creative team. While creativity helps to diverge and come up with different ideas and unusual combinations, innovation serves as a filter, bringing the ideas to a feasible reality (Amabile, 1997).

According to Amabile (1997), creativity in the individual sphere is a result of the combination between three factors: expertise, creative skill, and intrinsic task motivation. To explore the individual skills, an organizational environment should be adequate in three components, according the same author: organizational motivation to innovate, resources, and management practices, to match adequate personal to each task, create feasible goals and support the design team. To enhance creativity, organizations try to offer a better working environment, more resources, multidisciplinary teams, flexible schedules and many other approaches that help the creation and innovation processes. Unfortunately, most approaches do not efficiently affect the weak link of the creation process: the incubation stage (Mostert, 2007). Being the phase when mind correlations occur, this step may be slow, and creative ideas can require a long time to develop involuntarily. To accelerate the connections and reduce the time demand, creativity tools arise as a viable alternative.

As a scarce asset in current competitive industry, time is an expensive resource and its reduction is essential. Creativity tools serve as means for the team to balance time reduction and ability to develop novel and appropriate products, shortening the incubation stage and overcoming creativity blocks. The great number of existing creativity tools demands a certain level of expertise from the design team to properly choose and utilize them. Each tools has its usefulness and peculiarities, demanding knowledge from the team and an expert to facilitate creativity sessions. This person would know when to use each tool and which are the most adequate for the team and design situation. This assertion is facilitated by the understanding and employment of design methodologies, coherent structures of the design process that help the team to focus and control the complex development of any competitive product

3. KNOWLEDGE ACQUISITION

Design requirements are the foundation of the work, divided in three aspects for KBS stage of knowledge acquisition. Product development gives bases to the assertion of the tools, presenting the design situation to the system. Organizational guidelines encompass the market alignment and information about the intentions of the design. Design team describes the dynamics of the team, influencing the technique selection depending on relationship between members and work environment.

A design team wishing to develop any competitive product in current market should base itself on design methodology. Its structure serves as verification and control method, encompassing all design process phases, while helping the team with deadlines and design requirements. Extensive planning of design, product and methods of verification before the development increase in three times the chances of product success (Baxter, 2011). Those guidelines are explicit when based on a structured methodology, making the team responsible of framing the methodology according to its design reality.

3.1 Design Methodologies

Based on the Integrated Product Development Process (PRODIP – p*rocesso de desenvolvimento integrado de produtos*), six phases cover design process and planning, as represented in Fig. 1. Macro phase of design planning sets the design process foundation, specifying needs and delineating the development structure. Designs should be aligned with the organizational strategies (viability), current market (desirability), and available resources (practicability) (Brown, 2010). Focus on any of these criteria is dependent on organizational strategy, but directing the development guidelines on the market may increase in five times the chance of product success (Baxter, 2011). Product planning uses those criteria to outline a space of possible designs, subsequently choosing the most adequate problem to be addressed, alike the inspiration step of creativity. Design planning sub phase organizes guidelines, milestones, team, and many other facets that are fundamental to a structured approach.

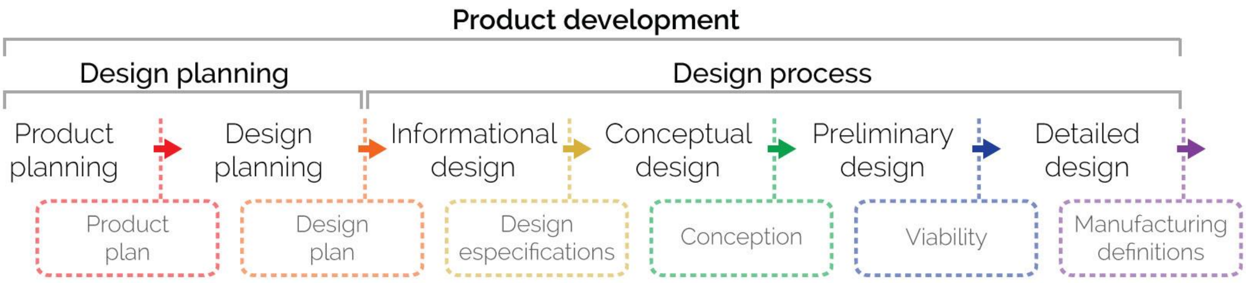

Figure 1. PRODIP (Back, *et al.*, 2008).

Design process, based on design planning, can focus on developing the most adequate product to fulfill the requirements. State of the art searches and establishment of design specification are the core of informational design, similar to the preparation stage of creativity. Like the incubation and illumination steps, the team uses this information during the conceptual design to diverge and come up with many possible conceptions for the problem, along with posterior preliminary convergence to feasible solutions. Preliminary design confirms conception adequacy and refines it, verifying the viability of the ideas as the last stage of creation. Detailed design focuses on preparing the solution to further implementation and detailing it in terms of technical drawings and manufacturing definitions (Back, *et al.*, 2008).

The parallel of creation process and design methodology shows the proximity of both structures, and presents correlations to identify the creativity needs in each design step. Two moments of intense creation are identified during product development. Design planning requires divergence of ideas to choose the most adequate problem, converging with the defined criteria, while design process focuses on diverging conceptions and converging into feasible solutions. Double Diamond approach specifies the development in terms of creativity (Design Council, 2015), as shown in Fig. 2.

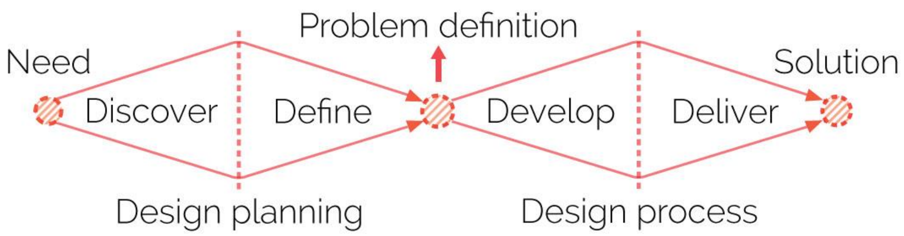

Figure 2. Double Diamond (Design Council, 2015).

The four design steps focus on creativity during design. Discover stage uses a need as a catalyzer of divergence to generate a great quantity of design possibilities, while the define step uses the organizational criteria to converge the possibilities into a feasible and adequate problem. Develop focuses on exploring the defined problem in terms of conceptions divergence, leaving the convergence to a feasible and appropriate solution to deliver (Design Council, 2015). Each phase has adequate creativity tools that help to accelerate the process and keep design alignment to the original need. Adequate balance among these steps is also important, neither hasting into the first idea nor creating infinitely.

It is important to notice that the present work uses creativity process in a broad spectrum. It focuses not only in creation of ideas, but also in convergence for innovation. The chosen tools, as described later, encompass those facets of each diamond, using different stimuli to diverge in develop step, analysis and synthesis to converge in deliver step. In current development stage, a focus on design process is given, leaving design planning for future studies.

3.2 Organization guidelines

To identify a need and define the problem, an organization should know its capabilities and guidelines. Needs can be found in the market with users (through interviews, observation, questionnaires), and in internal survey and development of new technologies, but the organization should be sensitive to different paths. One central guideline to define a design is its innovation focus. An organization that wants to explore new markets or find applicability of new technologies tends to focus its design in radical innovation (Baxter, 2011). This vanguard approach is more aggressive and riskier, but usually it is more profitable and can even remodel a whole industry (Henderson and Clark, 1990). Defensive strategies, which follow leading companies, also require creativity, focusing on incremental innovation (Baxter, 2011). This tactic uses known products as basis to upgrade potentialities and acquire market differentiation, being less profitable but safer (Henderson and Clark, 1990). A third approach is intermediate and, though not using new technologies, it can change products markets. Architectural innovation seeks to reconfigure the product, aiming new markets or new functionalities for the existing technology (Henderson and Clark, 1990).

To elucidate the concept, an easy example is a room air fan (Henderson and Clark, 1990). Considering ceiling electric fan as current technology, improvements in the blades design characterize an incremental innovation, while a change to air conditioner involves a radical innovation. A floor fan, on the other hand, would change the whole interaction between components keeping the core technology, hence architectural innovation. With the current competitive market, any organization that gives too much emphasis on incremental innovation is faded to be overshadowed by new and agile companies (Back, *et al.*, 2008) (Brown, 2010). To focus only on radical innovation is also expensive and uncertain, considering that a successful radical innovation usually opens ways to incremental or architectural innovation.

3.3 Design team

Management practices have deep impact on the design team capabilities, and to match different people to specific product developments is a challenge. While multidisciplinary teams are more likely to fully explore design possibilities (Back, *et al.*, 2008; Baxter, 2011), personality traits and personal issues interfere in communication and relationship among members. Some teams with great potential may not achieve success due to introverted behavior or unwillingness to share information and ideas. To overcome such barriers, many teams decide to disassemble the project and give responsibility of each part to a specialist. This approach is ineffective due to the lack of information exchange, which may reveal other solutions, and increase on design time, due to communication delay and design mismatch (Back, *et al.*, 2008).

Innovative ideas take time to develop, and occasional or informal conversations among few team members helps to develop concepts that are still unformed, even without formal meetings with the whole team (Amabile, *et al.*, 2002). For that casual exchange to take place, the team should spend time together, especially in a common design space. By having a team space, all the chaotic creational ideas are upheld, and schemes, drawings, prototypes, and post-it have a safe place to be. A trusting and safety environment also helps team interactions, generating more discussion and hastening the design process while keeping the team motivated (Mostert, 2007). Team relationship is a deciding factor on the adequate creativity technique. It is ineffective for the facilitator to give an introverted group tools that explores discussion, and it is unproductive to instigate individual design when the team is able grow quickly on each other's ideas (Mostert, 2007).

According to team behavior, creativity tools can also be divided into verbal or symbolical techniques, each with its characteristics and applicability. Symbolical tools are helpful for retaining the knowledge developed into a palpable form. Being by schemes, drawings or mock-ups, information can be virtually stored or even maintained in white-boards and walls with post-it. The accompaniment of these tools on a daily basis helps to focus the team on the design reality, giving a common view of the process (Brown, 2010). Naturally, symbolic approaches may be enhanced by verbal discussions. Every scheme and draw requires an amount of discussion to develop the initial concept. Verbal tools have the advantage of being quicker and the development of ideas more intense, while notes or recordings can easily retain the knowledge.

The expertise needed to effectively use a technique can be translated to its difficulty of application, commonly used categorization method used in literature (DIEGM, 2005; Curedale, 2013; IDEO, 2015). While low difficulty techniques are quick to learn and use, they are more beneficial for teams that converge too prematurely to solutions, or that need hurried ideas due to a tight chronogram, especially for the lower knowledge need. The high difficulty ones tend to be slower, because of the information and experience needed in its development. To obtain all the specificities of those techniques is time consuming and requires a deep knowledge from team and facilitator. Some tools can be versatile and learnable through repeatable using, requiring attention, but not deepening.

It is important to notice that creativity sessions do not always give the big idea or the ready optimal solution. The sessions help to generate different mind pathways, to which the team members can later progress in their works. Many meetings may be necessary to develop a ready product, but creativity sessions help the team not to fall into obvious conclusions and elevate each other's work. A facilitator is also important to conduct the session (Baxter, 2011). While any team member can fulfill the role, experience and knowledge about the group and its environment is indispensable. The function can be facilitated with the help of artificial intelligence software. While only a person can perform the function of moderating the session, the assertion of adequate tools and its way of use are condensable into a computational environment such as a Knowledge-Based System, working as a consulting engine and help the process facilitation.

4. KNOWLEDGE-BASED SYSTEMS

Expertise is a rare and expensive asset in current market. With the need for deepening in a subject, many organizations find themselves at short of an expert, either due to costs of hiring other employee or lack of professionals with the needed skills. Even when an expert is part of the organization, many obstacles may exist between him/her and the problem that requires the expertise, like overload with other designs, quitting, or being currently unavailable. A knowledge-based system (KBS) is a computational approach that emulates the decision-making ability of the expert. After adequate implementation, this system can act as an advisor, with the advantages of being always available even with multiple requirements, reliable, and permanent (Giarratano and Riley, 1994). The system does not replace an expert, rather it helps in situations of doubt, or when quick decisions should be made accurately.

KBS is a field branched of artificial intelligence, which can be defined as the study of how to make computers do things that, at the moment, humans do better (Rich and Knight, 1994). The systems focus on capturing heuristic knowledge, usually coming from combined knowledge or acquired experience of an expert, and then translating it in a synthetized output that not only presents the solution for the given situation, but also explains the chaining of thought behind the decisions.

Five stages structure the development of a KBS (Waterman, 1986). Viability study defines the adequacy of the problematic for a computational approach and frames the problem's scope. Second stage of knowledge acquisition is the main contact between the Knowledge Engineer (KE), who develops the system, and the Human Expert (HE), i.e. the main knowledge source. Although the presence of a HE is important, KE can also acquire knowledge in literature or other means. Once knowledge is acquired, KE starts the representation step, in which the gathered information is translated to the computational framework. The implementation stage starts with the coding and putting the developed structure in the computational environment. Last phase of verification and validation encompasses the debugging, performance and outputs correlation of the system. Validation is especially crucial for defining if the knowledge is properly represented, requiring testing with experts and non-experts. Usually, this development process takes place in incremental cycles. The first cycle structures the program basis, while further developments improve and refine the KBS. The flow of knowledge of a KBS development process is shown in Fig. 3.

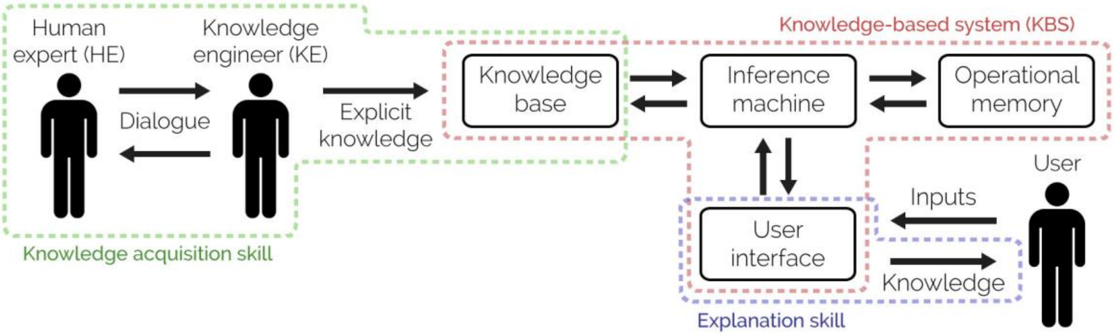

Figura 3. Knowledge-based system knowledge flow and use representation.

In case a Human Expert (HE) is not available, a KBS serves as storage and bridge for information consulting. Through conversations with HE, the KE is able to translate the knowledge into a knowledge base. This module inside a KBS is the explicit representation of the knowledge, which can be accessed by the user through an interface. By inputting the problem situation, the system uses its inference machine to correlate operational memory and knowledge base, ultimately outputting the needed knowledge. Explanation skill is an important aspect, due to the KBS requirement to explain the knowledge chaining.

4.1 Implementation

In the current research, to classify the outputs and create the correlation possibilities, five categories were developed based on literature review. It is not the intention of the system to decide how the design should be done or to oblige a team to use a certain approach, rather it offers support in current conditions with possible tools to overcome creativity blocks or to enhance creativity in general. The first category to narrow the techniques possibilities is the Design Step. The aimed information is if the team needs to diverge and develop further the ideas or to converge and focus on the conceptions already at hand. Although being an iterative process during design, the used double diamond methodology divides it in two stages for design process: develop and deliver. Tools such as TRIZ (DIEGM, 2005) help develop ideas, while Pugh Matrix (Back, *et al.*, 2008) focus on refining them. Based on a strategic decision, this work only encompasses the second diamond of the methodology (design process).

Every organization wishing to maintain its consumers must have a balance of innovation focus. New products are important, but maintaining old users is also vital. Three attributes arise from this strategic positioning of the organization or design. Incremental innovation focuses on improving existing products, with tools as SCAMPER (DIEGM, 2005). Radical aims to create completely new products fitting new technologies or new market niches, with tools as Biomimetic (King and Schlicksupp, 1999. Architectural innovation emphasizes upgrading products and putting them into new uses, using tools from both approaches such as Functional Tree (Baxter, 2011). The relationship of a team is decisive in the tool assertion, categorizing two groups of interactive or dissociated teams. Interactive teams tend to create together and use techniques that chain ideas easily as the Mind Map (DIEGM, 2005). Dissociated groups with introverted members or personal issues benefits from structured tools as Morphologic Matrix (Back, *et al.*, 2008), which require less discussion.

Linked to the relationship, the execution method is defined by the surroundings of the team. Teams with an individual design space and/or virtual sharing of information tend to have more space to develop further the tools with the course of the design, tending to symbolic tools as Functional Tree. The information gathered in those tools can be easily uploaded and shared, or remain in walls or whiteboards. Teams with contact only on periodical meetings, but with good relationship, can rely on verbal tools that focus on discussion, as Brainstorming (DIEGM, 2005) (Back, *et al.*, 2008) (Brown, 2010).

Not always having an expert available, and considering the extent of existing creativity techniques (IDEO, 2015), the team must sometimes resort on unknown tools to overcome creativity blocks, which require time to learn and even so has no guarantee of success. The difficulty of use last category is connected to the team multidisciplinary composition and its relationship. Low difficulty techniques, like SCAMPER, converge quicker to solutions and can be iterated continuously, generating the alternative pathways that help non-multidisciplinary teams to diverge. The high difficulty tools usually require more structure and have a longer time of learning and use. Traditional methodologies that have a chaining of tools, as Morphologic and Pugh Matrix, follow systematizations that harden the use of the tools, but enhance the outputs. Moderate difficulty tools, like Brainstorming, are more flexible, being commonly learnable through use (IDEO, 2015).

In the presented prototype, these characteristics are addressed by the initial questionnaire to define the team necessities. To ask directly the user for such information would be ineffective, minding that the teams can have different backgrounds and may not use the same design structure as this work. General questions about the team, design and organization are more adequate to delineate the requirements and then correlate each with the structured categories. Even teams with no knowledge of incremental, architectural and radical innovation can answer simple questions as “Is the design based on existing products?” whose answer defines if the innovation focus is incremental/architectural (yes) or radical (no). Further questions would define all the categories and deliver adequate tools.

4.2 Knowledge-Based System Prototype Development

Creativity tools assertion is suitable for the KBS approach for being part of a heuristic knowledge acquired intrinsically by the design teams (associational knowledge) (Gonzalez and Dankel, 1993). This work has its bases in literature and dialogues with engineers and designers. The categorization was established five groupings, each with attributes that help sorting the tools: design step **(**develop and deliver), innovation focus **(**incremental, architectural and radical), team relationship (interactive and dissociated), execution method (verbal and symbolic) and difficulty of use (easy, moderate and hard).

Those five categories are defined with an initial questionnaire of eight questions. They range from organizational factors to team relationship, allowing 336 input combinations, of which 258 are positive (outputting at least one creativity technique) when verified. Twelve techniques were chosen for the first cycle of implementation, being commonly used creativity tools with literature representation. Each consulting session outputs an explanation of the correlation, along with one or more tools description, situations of use, step-by-step, example, tips and similar tools. Table 1 presents the connection between tools and categories. The computational environment was CLIPS (Giarratano and Riley, 1994) being a commonly used KBS shell. Knowledge was represented in COOL module (CLIPS Object-Oriented Language), allowing the appliance of fundamental properties such as inheritance, abstraction and assembly relationship. Verification of the first cycle of implementation demonstrated the prototype potential, and the systems remains in stage of validation with experts and non-experts, and second cycle of implementation (refining of code and expansion of system).

Table 1 – Tools-categories correlation.

Tool name	Design Step	Innovation focus	Team relationship	Execution method	Difficulty of use
Analogies and associations	Develop	R	Interactive	Verbal	Moderate
Functional tree	Develop	I A	Dissociated	Symbolic	Moderate
Biomimetic	Develop	R	Interactive & Dissociated	Verbal	Hard
Brainstorming	Develop & Deliver	I A R	Interactive	Verbal	Moderate
Brainwriting	Develop	A R	Dissociated	Symbolic	Easy
Mind map	Develop	I A R	Interactive	Symbolic	Easy
Pugh matrix	Deliver	I A R	Dissociated	Symbolic	Hard
Morphologic matrix	Develop & Deliver	I A	Dissociated	Symbolic	Hard
Prototyping	Deliver	A R	Interactive	Symbolic	Moderate
SCAMPER	Develop	I A	Interactive & Dissociated	Verbal & Symbolic	Easy
TRIZ	Develop	I A	Dissociated	Symbolic	Hard
Voting	Deliver	I A R	Interactive & Dissociated	Verbal	Easy

I – incremental / A – architectural / R – radical

The presented correlations are based on literature review (Henderson and Clark, 1990; King and Schlicksupp, 1999; DIEGM, 2005; Back, *et al.*, 2008; Brown, 2010; Baxter, 2011; Curedale, 2013; IDEO, 2015; Design Council, 2015).

4.3 Application example

In order to demonstrate this research potential, in this section, we present a hypothetical scenario based on a situation documented in Baxter (2011). The reference presents a case from Psion, now part of Motorola, an English company specialized in design and manufacture of handheld computers for commercial and industrial applications. After a failure to maintain its market share with the obsolescence of the pocket computer Psion Organizer 2, and growth of competitors, the company needed to release a new product urgently. The last design, laptop MC400, was a huge market failure that caused a crisis in the company, and triggered the design of a new generation hardware, known as Psion 3.

With the opportunity and design specifications well delineated, the team focused on the conceptual design, deciding for a QWERTY keyboard (not common at the time) with an articulation between keyboard and screen. The design halted with the battery-positioning problem, when designers needed to find room in a compact structure for two AA batteries. In that typical creativity blockage situation, the team could benefit by using the KBS prototype, which could impulse the creativity process and reduce design time.

Inside the categories, it can be seen that the team did not have a good number of conceptions to the deliver step, needing shortly to come up with new ideas in the develop stage. The design followed the Psion Organizer 2, but the team wanted to reinvent the product, which falls over architectural innovation. We assume that the team had a good interaction and had an exclusive design space, but no virtual connection. The development was limited to work hours, which, when added to the interactive relationship, reveals a preference to symbolic execution. This is based on the team having a visual identity of the product in the design room, using communal schemes and representations to explore ideas cooperatively every daily. The time shortage and need for quick answers compelled the team to use a technique with low difficulty, which are usually quicker. These characteristics, when inputted in the KBS prototype, correlate with two tools: SCAMPER and Mind Map. The team would choose one and quickly arrange a creativity session to develop solutions. On the real scenario, the design team came up with innovative ideas after stressful development. As shown in Fig. 4, an idealized Mind Map with possible solutions would quickly reveal opportunities, having a structured arrangement of ideas. Considering as central idea the articulated screen and batteries insertion, the team would deliberate over the items connection, developing chaining of ideas and reaching new conceptions. The company ultimately opted by conception F, which made the Psion Series 3 a commercial success selling over 1.5 million units worldwide (Litchfield, 1998)

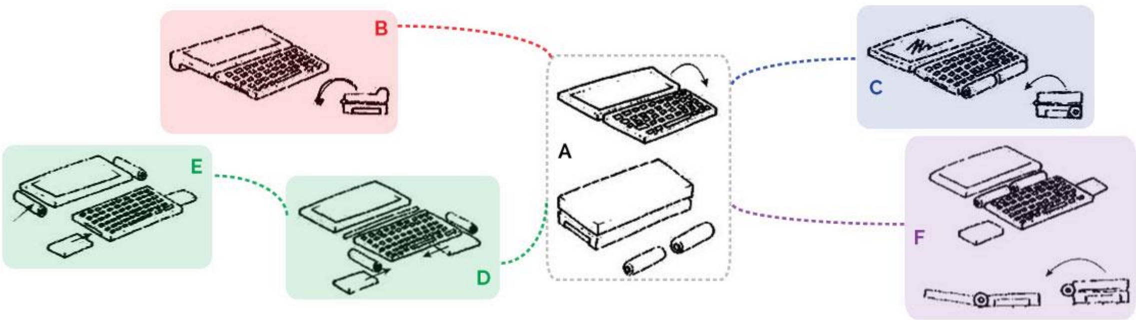

Figure 4. Psion series 3 idealized mind map (Baxter, 2011).

5. CONCLUSIONS AND FUTURE WORKS

As demands grow for new products with increasing functionality, creativity becomes a key asset to design teams. To satisfy the needs of customers and stakeholders, the teams must innovate at an increasingly rate. It is vital for an organization willing to maintain its space in current competitive market to adjust its guidelines to the changing scenario. Creativity and innovation must not be seen as a design requisite, but as asset that permeates the whole institution. To enhance creativity, many methods have shown success, but it is hardly seen a structured computational method to diminish creativity time and still deliver satisfactory products (Müller-Wienbergen, *et al.*, 2011). The creativity enhancement KBS approach aims to reduce the ideas incubation time, delivering for the design team adequate techniques according to current design stage and team configuration.

To classify creativity tools, categories based on literature grounds the development. Five categories arose as fundamental in the assertion, encompassing aspects of team, organization and design situation. Even with the study field complexity, the assertion correlates the needs and tools accordingly, giving the team new ways to create. By using the system, the team has access to the background knowledge for each tool, learning why the tool is adequate and how to use it through step-by-step, tips and examples.

The KBS prototype showed the potential to assert creativity tools. General questions can delineate the team situation and correlate with the five categories: Design Step, Innovation Focus, Team Relationship, Execution Method and Difficulty of Use, the prototype suggests which tools are adequate to the scenario and output not only the right tools, but also the underlining reasons and how the chosen techniques should be used. The employment of the KBS can enhance team's productivity and allow creating better solutions in shorter time, serving as creativity advisor.

Further studies will expand the creativity tools knowledge base, and include the first diamond of the Double Diamond methodology, encompassing the whole design process that requires actively creativity. A balance between traditional and modern methods will help the system to deliver tools for any team wishing to enhance creativity during design. Validation with experts and non-experts are a constant need to refine and deliver an adequate system to any product development team, regardless of the background.

6. AKNOWLEDGEMENTS

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