

KNOWLEDGE-BASED SYSTEM FOR CATEGORIZATION AND SELECTION OF CREATIVITY SUPPORT TECHNIQUES*

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ABSTRACT

Objective: In order to maintain its market share in current competitive scenario, every design organization must enhance its creativity skills, the basis to innovate and develop adequate solutions to changing costumers' needs. A great expertise is required to reach such creativity level, a skill currently dependent on human capability. As such knowledge is subjected to availability, the development of a computational system with the capacity of selecting appropriately creativity techniques becomes relevant, emulating decision-making ability. This work aims to elucidate implemented metrics on a knowledge-based system (KBS) for asserting creativity techniques, serving as a comparison filter between typical design team's needs and the available techniques.

Design/Methodology/Approach: Creativity tools are powerful allies in building alternative mind pathways, through which a team may develop better and more suitable ideas. Each tool has appropriate use situations, covering several aspects of the design process, organization and team profile. To assert appropriately creativity techniques, the KBS requires a logic connection between factors that lead to the choice and the actual tool selection, i.e. the system output results. Such chaining was structured in a double inference process using categorization, which describes the entry scenario in terms of five categories and matches the identified values of each category with available creativity techniques

Results: The developed prototype is able to select adequate creativity techniques in design. The five categories aid in filtering techniques according to the design situation, reducing the selection spectrum and supporting the appropriate choice of tools. In its current version, the prototype selects among 24 creativity support techniques in a combination of more than 500 design scenarios. The outputs include explanations on the used inference process, learnings on how to use each tool, overall information and examples.

Keywords: creativity. product design. design thinking. knowledge-based systems.

SISTEMA ESPECIALISTA PARA CATEGORIZAÇÃO E SELEÇÃO DE TÉCNICAS DE SUPORTE À CRIATIVIDADE

RESUMO

Objetivo: Para ser capaz de se manter no mercado competitivo atual, toda organização de projeto e design deve aprimorar suas habilidades criativas, as quais são a base para inovar e desenvolver soluções adequadas às necessidades dos consumidores. Alcançar tal potencial criativo requer uma grande expertise, capacidade que atualmente depende de conhecimento humano. Estando tal proficiência sujeita à indisponibilidade, o desenvolvimento de um sistema computacional que desempenhe as capacidades de seleção de técnicas de criatividade se torna relevante, emulando a habilidade humana de tomada de decisão. Este trabalho visa elucidar as métricas implementadas no protótipo de sistema especialista (SE) para escolha de técnicas de criatividade, servindo de filtro de comparação entre necessidades de equipes de projeto típicas e as técnicas disponíveis.

Design/Methodologia/Abordagem: Técnicas de criatividade são grandes aliadas na construção de caminhos cognitivos, através dos quais é possível desenvolver soluções melhores e mais adequadas. Cada ferramenta tem sua aplicabilidade, abrangendo aspectos do processo de projeto, organização e perfil da equipe. Para selecionar técnicas adequadas, um SE requer uma conexão lógica entre os fatores que levam à escolha e a efetiva seleção das ferramentas, ou seja, os resultados de saída do sistema. Este encadeamento foi estruturado num processo de dupla inferência através de uma categorização, a qual descreve o cenário de entrada em termos de cinco categorias e corresponde os valores identificados com as técnicas de criatividade disponíveis.

Resultados: O protótipo desenvolvido é capaz de selecionar adequadamente técnicas de criatividade para projeção. As cinco categorias auxiliam na filtragem das técnicas de acordo com a situação de projeto, diminuindo o espectro de seleção e corroborando para uma escolha apropriada de ferramentas. Na versão atual, o protótipo possui 24 técnicas de apoio à criação disponíveis, criando mais de 500 combinações de cenários de projeto. Os resultados de saída incluem explicações sobre o processo de inferência utilizado, procedimentos em como usar cada ferramenta, informações gerais e exemplos.

Palavras-chave: criatividade. projeto de produtos. design thinking. sistemas especialistas.

I INTRODUCTION

Currently, design teams struggle to reach the demand placed upon them. They deal with requirements from different parts in an organization, having to consider what is technologically possible, can become a viable business model and will satisfy users' needs (Brown, 2010; Baxter, 2011). Between deadlines and interests pressure, some teams are still able to come up with creative and useful ideas to reach such goals, essential to maintain organizations on their feet in current competitive world.

To lighten this demand, creativity enhancement techniques arise as a necessity. A more diverse team, flexible working environment, and the right resources are some of the many ways with which an organization can generate a better ambience to create (Amabile, 1997). The resources are a significant factor, including time, team, funds, adequate expertise and tools to innovate. To balance short time and increasing demand for knowledge, computational approaches of artificial intelligence emerge as applicable methods. Knowledge-based systems (KBS), programs that capture empirical expertise of a specialist and translate it into a computational environment, show a potential application in heuristic knowledge for design (Knight e Kim, 1991; Müller-Wienbergen *et al.*, 2011). Although complete human creative thinking may not be possible to represent yet, the KBS approach is feasible and aid the team with the best tools for creativity boosting.

The techniques help the design team to achieve desired goals in less time. Hastening the creativity process, they serve as means to generate a larger number of different ideas, preventing the team to fall into obvious answers and, ultimately, providing a wider base to innovate (Shah *et al.*, 2003). A form of grouping or logical structure is needed for the selection of appropriate creativity tools. An adequate methodological background serves as basis to this classification, giving space between the design steps for the insertion of tools in specific situations. While methodologies give a solid basis to this categorization and implementation of creativity tools selection, the tools themselves can focus on increasing discussion, empathy, co-creation and multidisciplinary thinking during the design, important aspects in supporting individual and team creativity while increasing the chances of success of a product in the market (Brown, 2010).

Different techniques have different applicability, for singular teams and situations (King e Schlicksupp, 1999). To structure a path to a computational approach, a series of categories are essential in separating the tools and uncovering their final purpose. The selection is based on the identified design team needs, not intending to change the design process or to compel a team to use a different tool. While recommending a set of different techniques, the KBS serves as a

second opinion or an adviser in times when creativity is a vital factor or when the team reaches a creation block.

The prototype development was based on literature review, combining creativity, design methodology and artificial intelligence, while using the last as a bridge between design team and creativity techniques. This paper focuses on describing the selection metrics used in the prototype, addressing five categories used to filter the techniques. By firstly presenting a theoretical background, the work foundation is the introduction and justification of the classification system. The development shows the KBS approach as a relevant and powerful instrument in overcoming creativity blockages and generating more innovative products.

The paper is organized in the following structure. Section 2 presents issues covered by knowledge acquisition and applied to develop the KBS prototype. The following section explains the categorization used to represent the key information used as framework. Section 4 brings a brief presentation of the prototype system, and the final section deals with conclusions and future studies.

2 KNOWLEDGE ACQUISITION

2.1 CREATIVITY

Although usually associated with masterminds of arts and technology such Mozart, Leonardo da Vinci, and Steve Jobs, creativity is a much more trivial ability, seen in everyday life. Considered as complex and individual, modern researchers see creativity as an inherent talent, learnable and exploitable by any human being with the right motivation (Amabile, 1997; Souza, 2001; Mostert, 2007).

Regardless of the stimulus, creativity tends to follow a structured pattern. The initial inspiration sets tone of what will be created, properly focusing the task. Contrary to popular belief, the second step presents a deep search and understanding of the task, being a rational stage in creation. The acquired knowledge then must be incubated in order to create non-trivial connections of ideas between different knowledge and situations, which will lead to possible answers. Allowing the right amount of time, the 'eureka' moment may culminate in solutions, which should be afterwards analyzed and validated (Baxter, 2011).

The fore-mentioned incubation time is the weak link in the creativity chain (Mostert, 2007). Time resource is scarce in current competitive world and must be shortened to maintain productivity. Without adequate creativity tools, a capable team may reach a creativity block, requiring weeks or months to develop the ideas into creative and real solutions, as do musicians

and writers (Mostert, 2007). In order to abbreviate time requirements in creation, the use of creativity tools arises as a process catalyzer, giving the team different routes to find possible solutions (King e Schlicksupp, 1999).

According to Amabile (Amabile, 1997) and the Component Theory of Individual Creativity, the stimulus to create in an organizational environment is attained by the intersection of three factors:

- **Expertise:** includes the factual memory, technical knowledge and special skill in the working domain. The expertise level is directly linked to the number of creative ideas;
- **Creative skills:** determined by the individual personality. Although seemingly innate, this factor can be developed by use of adequate techniques to improve cognitive flexibility and intellectual independence, such as creativity tools;
- **Intrinsic task motivation:** related to a deep interest, curiosity and involvement in the work. Even with the greatest potential available through expertise and creative skills, a lack of motivation lowers the efficiency of the creative thinking. It is the difference between what “can be done” and what “will be done”.

Unfortunately, creativity by itself may be useless in design. Referring to the psychoanalysts’ theory (Aranda, 2009), creativity (pushed by the unconscious mind or id) without a sense of reality is arbitrary and unreal, requiring a process of structured thinking. This organized process (pushed by the reality principle or ego) serves as a filter of reality, originating a useful and tangible creativity known as innovation.

Innovation, as said, acts as a reality check to the creative mind, allowing the conception of not only novel, but also appropriate products (Amabile, 1997; Aranda, 2009). The sole divergence of ideas is useless, even though the number of ideas generated through creative thinking is essential to innovate. Out of ten ideas of new products, only three will be developed, less than two released to consumers, and only one will originate a lucrative business (Baxter, 2011).

The organizational environment has a deep impact on the individual or team creativity. Innovation-oriented organizations understand creativity as a first step in the development of novelty, allocating resources, adapting management practices and focusing the organizational motivation to innovate. The Component Theory of Organizational Creativity and Innovation (Amabile, 1997) presents these three factors as follows:

- **Organization motivation to innovate:** the commitment to innovate must permeate the guidelines of the organization through risk-orientation, sense of pride in the members and their capabilities, and offensive strategy towards the future;

- **Resources:** although scarce in the current competitiveness, the organization must guarantee the right amount of time, materials, knowledge and funds, as well as a capable team;
- **Management practices:** the ability to match people and tasks is fundamental to any product development, both in skills and interests. Adequate project goals, planning, feedback and support are also necessary.

The right environment, motivation and personnel potentiate creation and innovation. Other barriers during the product development may also interfere in the process such as incorrect definition of the task, functional attachment, overspecialization, rejection of ideas from non-specialists, fear of criticism and early judgment (Back *et al.*, 2008). An organization can prevent a great portion of these problems with a systematization of the design process, possible with the usage of adequate methodologies to delimitate de work and keep the team aligned with the guidelines of the design and the organization.

2.2 DESIGN METHODOLOGY

A design team can only fulfill the demand for innovative products at the current rate requested by the market with the aid of design methodologies. A systematic approach not only reduces the project total time, but also enhances the quality of the product (Souza, 2001; Baxter, 2011), and boosts creativity.

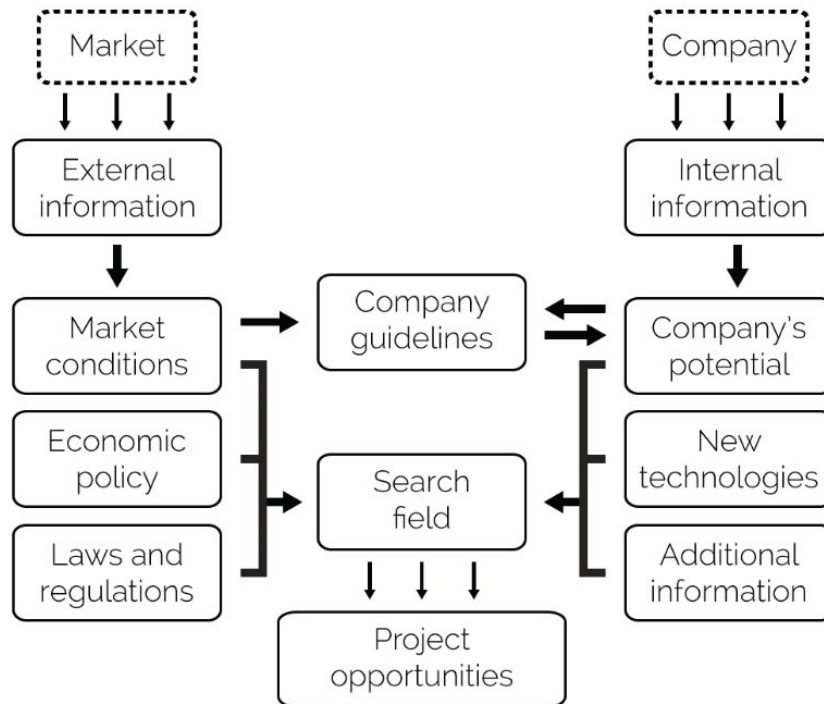
The increasingly complex needs from consumers and stakeholders force teams to work with conflicting requirements. While consumers seek innovative, inexpensive, and good quality products, the executives focus on profit and high-return investments (Baxter, 2011). This conflict calls for a trade-off, making the team choose which design aspects are more relevant to ensure its market success. This volume of decision-making and detailing is solvable through a systematic design methodology, which ensures the adequate attention to all the aspects of the product design with a series of chained steps.

The detection of a need is the main trigger to innovation. Although many successful products may have arisen from a technological development, the users' need must always be satisfied. Focusing the development guidelines on the market may increase in five times the chance of success of a product (Baxter, 2011). Figure 1 presents a structure of product design planning. The combined information of market and company broadens the search field for unfulfilled needs, detecting more adequate design opportunities.

Extensive planning of design, product and methods of verification before the beginning of development may increase in three times the chances of product success (Baxter, 2011). The premise is to set appropriate guidelines and to detect possible flaws, correcting or minimizing

them with the lowest possible costs of time and resources. It is cheaper to detect a mistake before it happens than to correct it afterwards (Baxter, 2011).

Figure 1 - Product planning activities.



Source: (Back *et al.*, 2008).

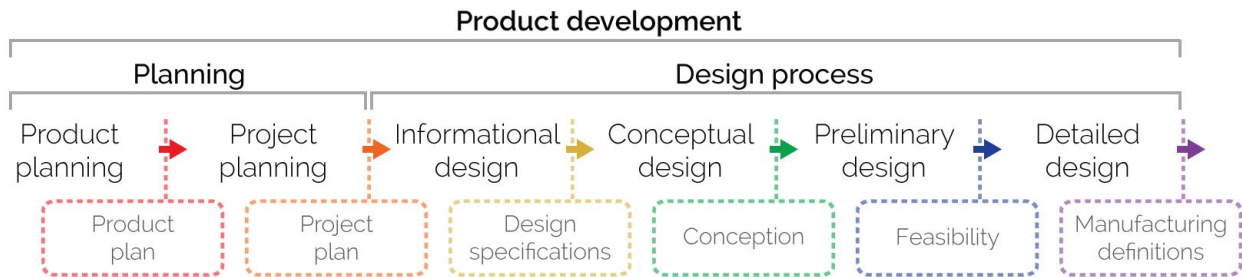
Several methodologies with different approaches have been developed. The right delimitation of the methodology is a determinant factor for the design success, being broader and more structured methodologies usually required in large designs with larger teams, number of components, expertise and development time; while more flexible methodologies tend to be more appropriate to small design processes and teams. Figure 2 presents the used delimitation of the product development process, focusing in the design regions requiring creativity and innovation.

The process follows the classic steps:

- **Product planning:** finding a suitable problem or need to address;
- **Design planning:** organizing guidelines, deadlines, team, among others;
- **Informational design:** based on state of art and definition of specifications;
- **Conceptual design:** comes up with adequate conceptions;
- **Preliminary design:** analyzes and refines the concepts through the use of models;

• **Detailed design:** specifies the design in terms of technical drawings and manufacturing definitions.

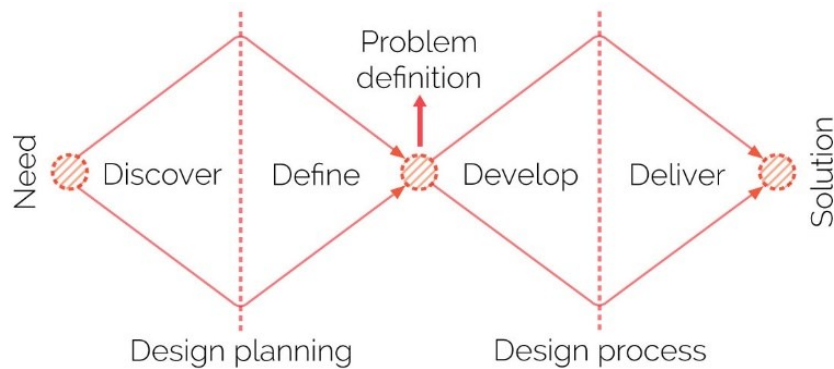
Figure 2 - Product development methodology.



Source: (Back *et al.*, 2008).

It can be seen throughout the process two phases of divergence and convergence of ideas. The first focuses on finding the adequate need and delimiting the project (product and design planning), while the second focuses on a conceptual solution for this need (informational, conceptual and preliminary design). The sequence resembles the double diamond methodology developed by Design Council (Figure 3) (Design Council, 2015).

Figure 3 - Double Diamond methodology.



Source: Adapted from (Design Council, 2015).

This chain starts with a need, which triggers a large number of design possibilities. This starts the first divergence phase named discover, in which potential problems are unveiled. Techniques such as Observation, Questionnaires, and Interviews delimit the design space, triggering problem causes and focusing the project on the users' needs. With a sufficient number of problems, the phase of convergence, known as define, initiates. This phase targets the problem selection to be dealt with during the product development, focusing on the basic need.

Defined the problem, the develop phase, or the second divergence, starts elaborating creative ideas of products, which must be adequate to the problematic and, consequently, the need. The last step of the process, named deliver, focuses on finding the most appropriate solution in the generated field, reaching an innovative consensus considering the team, stakeholders, and, naturally, fulfillment of the basic need.

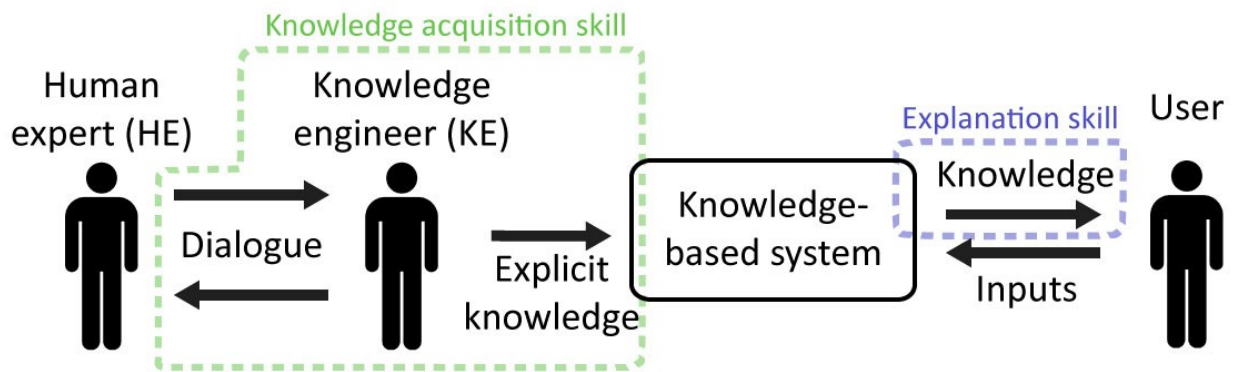
As said, the emphasis in the market and the users increases the chances of a product success. The Double Diamond division helps focusing on the final consumer, compatible with the human-centered design or the design thinking (Brown, 2010; Ideo, 2011; 2015). Even commonly applied in service design, the approach can be used for product development, offering space to different creativity tools in each step. Naturally, it is difficult to delineate the phases during the product development, and many variables influence on the right tools selection. The sorting must take into account each team's behavior, expertise, and specific needs of the situation.

To implement this sorting into an applicable tool for a design team, a computational approach such as a KBS is being developed. This approach can compress the theoretical classification into a presentable and useful guide in the assertion the right creativity tools. For this application, the second diamond was prioritized, because it is considered the main step for product conception. The prototype system serves as a bridge between the expertise for creativity tools selection and application, and the design team.

2.3 KNOWLEDGE-BASED SYSTEMS

Artificial intelligence can be defined as the study of how to make computer do things which, at the moment, people do better (Rich *et al.*, 2009). The idea of making a computer rationalize as a human being in a given situation, contrary to a science fiction movie, does not imply on a substitution of the human thinking ability, but serves as a supporting tool to time reduction, permanence enhancement, and raise in reliability or availability (Silva, 1999).

Study fields branched out of the concept of artificial intelligence include areas such as neural networks, chatterbots, robotics and knowledge-based systems (KBS). The KBS approach captures the required information of an expert into a direct and readily applicable tool. This implementation emulates the decision-making ability of the expert in the pertinent field using inferences to correlate the needs of the user with the base of knowledge available in the system (Giarratano e Riley, 2005). As shown in Figure 4, a knowledge engineer acquires knowledge from the human experts and then implements it in the program, which, in turn, intermediates the represented knowledge and the program user. The intention of the system is to act as a bridge for the knowledge to pass from expert to user (Giarratano e Riley, 2005).

Figure 4 - Knowledge-based system development and key-players.

Source: Authors (2015).

According to the traditional structure (Waterman, 1986), a KBS development starts with a viability study, where it is confirmed if the problem can be solved through a KBS. A knowledge acquisition step, considered the process bottleneck (Waterman, 1986), gathers the required information to develop the system, followed by the knowledge representation, where the gathered information is formalized via different techniques. Implementation, fourth step, translates the knowledge to the computational environment and the last phase of verification and validation evidences that the system is adequate. Every step must have the same weight on the development to assure a balance in the program. Further cycles of development are commonly used to increase and improve the system, following an incremental approach.

Since the first commercial implementations in the 60's and 70's, like MYCIN and Dendral, the development of KBS has grown in technology, applicability and esteem among researchers (Nordlander, 2001). The CODA system (Concurrent Design Advisor), published in 1991, shows the usage of a knowledge-based system in product design, aiming to enhance the efficiency and quality of design. The automation of many routine tasks allowed the achievement of the goals. The system also contains a creativity support system (CSS), helping the users to come up with creative solutions to complex problems (Knight e Kim, 1991). The system does not present different tools or applicability for the team to create, but focus on the exhibition of a variety of random stimuli, trying to deviate the team from obvious answers. The CODA system focus on design with a limited and chained set of creativity tools (quality function deployment), which are traditionally used as part of the design process in engineering.

Hewlett Packard (HP) developed an online advice system (CAST/BW), a KBS that provides quick and accurate hardware sizing, network configuration, and usage recommendations (Nordlander, 2001). Other notable applications include the KBS for hydraulic system design

(Silva, 1998), fluid power system design (Silva e Back, 2000), design of natural gas cogeneration plants (Matelli, 2008), sensor fault modeling (Silva *et al.*, 2012), cogeneration power plants design (Silva *et al.*, 2014), hermetic compressors diagnosis (Pedroso e Silva, 2014), among others.

A KBS requires some form of logical configuration to generate adequate outcomes. Although creative thinking is essentially complex and inherent of the human being, the assertion of adequate creativity tools follows a much more structured pattern. The classification of the tools into five categories, being the last step in the knowledge acquisition process, is the chore of the implementation. The adequate theoretical structuring of the knowledge facilitates the subsequent steps of the KBS development, not included in this work.

3 CATEGORIZATION

The heuristic and particular nature of creativity opens space to the development of the KBS prototype not intending to implement a creative thinking in the program, but to advise the team with a variety of appropriate creativity tools. The complexity of creativity, especially for design purposes, hamper the use of an AI technique for the whole creation process. A program hardly has the ability to come up with new and appropriate ideas with the same capacity as humans with the current technology (Minsky, 1982).

Creativity enhancement, on the other hand, is feasible and necessary to the current industry. Not only does it affect the quantity and quality of ideas generation, but it also reduces the time consumption of such tasks. A boost on creative thinking can be achieved by different stimuli or the insertion of people with different backgrounds on the design team (Mostert, 2007; Müller-Wienbergen *et al.*, 2011). Nevertheless, a team with the right conditions and environment can still not be able to come up with novel ideas due to a lack of communication or systematization of the process. A rightly asserted creativity tool will create the adequate scenario for idea generation depending on the team and design situation, enhancing the design process efficiency.

In order to correctly assert a creativity tool, the team needs to consult an expert. This person has the means and knowledge to induce creative thinking in the team through counseling, ambience, tool selection and group moderation. Although literature shows an extensive number of creativity tools (Ideo, 2011; Curedale, 2013; Ideo, 2015), the timing of the usage and the right choosing demand an experience from the moderator. This heuristic knowledge serves as a connector between creativity and the design process.

Unfortunately, the required person may not be present at the required time, or the experience empirically acquired may become unavailable. Even though a trustworthy employee is indispensable, a computational system such as a KBS may come at handy in some situations.

While a person can retire, quit, be unavailable or be unreliable with mood swings, the knowledge transcribed into a software is steadier, broader, becomes available at all times in parallel situations, and, above all, is permanent (Giarratano e Riley, 2005). Once the software is developed, a knowledge engineer can expand it, combining others specialties and regularly updating the content. The KBS would work with the same capacities of the expert inside the implementation range, but it would be, by its nature, faster (Giarratano e Riley, 2005). The human factor would still be decisive for verification and validation of the program, due to the lack of common sense of any software (Waterman, 1986).

The KBS approach requires a categorization of the tools for their posterior selection. For the developing prototype, a set of five categories is defined based on empirical knowledge and literature. The categories aim to create the required computational environment in the tool selection, bringing aspects form methodologies, team relationship and design situation. This initial classification narrows the number of adequate tools based the team needs, selecting the more appropriate tools to overcome the difficulties.

3.1 DESIGN STEP

The systematization of the creativity techniques expertise for implementation has its basis on the categorization of the design process and its inherent needs. The mentioned design methodologies present a foundation for creativity inside the design process, showing where it is necessary. The first acknowledgeable division, noticed on the double diamond scheme (Figure 3), is between design planning and design process. The foremost division aims to focus the task and creating the problem space. It defines how to approach the users' needs, which are relevant to the problem and, at the same time, are an economically and technically viable project (Brown, 2010). This demands a deep consciousness of the organization of its place in the market, alignment to the company's guidelines, knowledge of target public's desires and applicable technical advancements.

The second part of the Double Diamond consists in the conception of solutions. Based on drawn opportunity, the team searches for a product that meets the needs of users, organization and stakeholders in the best possible configurations, aiming yet a differentiation to other competitors' products. The intention is to concretize the problem obtained on the first part of the process into a tangible product or service. State of the art technology is not always necessary, but technological progress is a font of inspiration to better satisfy needs or create a market niche (Baxter, 2011).

The same methodology presents a derived grouping. Each diamond contains a two-step structure, one for divergence of ideas, and the other for convergence. Consistent with the creativity-innovation duality, this approach sees two different categories for design tools: the first is divergence, seeking to broaden the capabilities field, targeting quantity of ideas over quality (Amabile, 1997). Lateral thinking (Aranda, 2009) is fundamental in this step, and tools often use discussion and stimuli images or words for associations. The second step is convergence, pursuing analysis and synthesis of the process, narrowing ideas created during divergence into a feasible and viable reality (Amabile, 1997). Vertical thinking (Aranda, 2009) dictates this more rational step, and the tools tend to filter and combine concepts to optimize solutions. This categorization is not so visible during design process, but aids the selection of the tool according to the situation.

Unifying design planning and process with divergent-convergent duality, the four steps of the diamond appear as the first classification of creativity tools for the KBS. The discover step seeks to organize the project agenda. The team should define the project space, which problems will be addressed, which are intrinsic needs in each problem, and in which ways the design will help to overcome those needs. Forms of Observation, Questionnaires, Interviews, Canvas, and SWOT Matrix are fundamental tools in this step, creating a sense of empathy between team and market, and establishing the organization place. The define step narrows the large amount of information gathered in the previous phase, establishing the project. By analyzing and synthesizing the information, this step helps in the establishment of milestones, task-responsibility, alignment between design and organization guidelines, and definition of the problem and public. Tools such as Work Breakdown Structure, Personas, and Journey Maps help the team focus not only in the original need, but also in empathy with costumers, and market nuances.

The second divergence, starting the design process, is the develop step. Here, the team must come up with several ideas, which can solve the original need. By considering all the previous developments, they have the foundation to create with any tools at hand, such as Brainstorm, SCAMPER, Analogies and Associations, and many others. This large divergence is rewarded in the last step of deliver. To converge the ideas into a feasible, desirable and viable product, a great number of ideas come at hand. Models, Prototyping, Pugh Matrixes, and even Voting, are available tools in delivering a feasible product. This convergence, taking into account every decision taken before and using the reference decisions of target market and design guidelines from the define step, presents the most adequate product for the need that the team could generate, increasing design chances of success.

3.2 INNOVATION FOCUS

Organizations with different guidelines tend to differ also in the focus given to innovation. In correlation to a product, innovation have been categorized in two:

- **Incremental:** partial improvements and optimizations of the product aiming to keep the organizations portfolio (Brown, 2010; Forés e Camisón, 2015);
- **Radical:** usually grounded on technological progress or unexplored market niches, being able to remodel a whole industry (Brown, 2010; Forés e Camisón, 2015).

This traditional categorization does not account for cases such as Xerox in mid-1970s. Even though Xerox has invented the core technology for plain-paper copiers, the insertion of much smaller and more reliable competitor products claimed almost half of their market. It took eight years for the company to regain stability and accompany the new trend. Even with the same core technology, the architectural alterations and the different market targeted by the competitors changed the whole conception of the product (Henderson e Clark, 1990). This example stays in between the two traditional innovations, not properly fitting any category. An intermediate class of architectural innovation is used for such cases with no changes in the core technology, but the design seeking a reconfiguration of the system.

This reconfiguration is the basis of this form of innovation, not implying that all the components must be left untouched. Changes on the size or shape of components often impel architectural innovation, allowing better interactions among parts. The defining point is to keep the original core design concept behind each component. As usual, the boundary of the categories may become indistinct in some situations. To elucidate the concept, an easy example is a room air fan. Being current technology a ceiling electrical fan, improvements on the blades design or the motor characterize an incremental innovation, while a change to air conditioner or acclimatization systems implies in radical innovation. A portable or floor fan, on the other hand, would change the whole interaction between components keeping the core technology, hence architectural innovation (Henderson e Clark, 1990).

The impacts on the creativity tools are observable in the form of stimulus provided. Tools that focus on the existing components or new associations between them, such as SCAMPER or TRIZ, tend to be more adequate to incremental innovation, while tools that focus on seeking new inspiration from associations, discussions or even in the nature, as Analogies and Associations or Biomimetic, tend to have a more radical effect. The architectural category is a middle point between the two, merging adequate tools from each extreme, for instance Mind Map, Morphological Matrix, and Functional Tree.

3.3 TEAM RELATIONSHIP

To improve creativity on a team, we must address a series of variables. As presented in both Component Theories (Amabile, 1997), individual creativity is a correlation of expertise, creative skill and intrinsic motivation of the task, meaning that a creative person must learn and be personally motivated in order to create. Organizational innovation, on the other hand, builds itself on resources, management practices and organizational motivation to innovate, meaning that an organization as a whole must be innovation-focused, permeating from its goals and guidelines to its employees.

For creativity tools applications, a focus on the creativity skill factor reveals the learnability of creative thinking. Although favorable by specific personality traits, techniques to improve cognitive flexibility and intellectual independence are essential to explore properly each individual potential (Amabile, 1997). As said, creativity is a learnable ability and can be propelled by the use of the right creativity tools. In terms of organization, right resources and management practices play a significant role on the creativity tools assertion. Intellectual resources for creativity and information on the techniques are essential in innovation. No competitive creation comes out of the simple mind of a person in a small period. The team must focus, search, discuss and correlate in order to be creative. Any team that lack, for instance, communication among the members must come with alternative ways to debate the ideas. For that, the right assertion of creativity tools comes at hand. Team composition is also fundamental. Different specialties are important to generate discussion, but the background and mind of each individual play a central role in innovation (Mostert, 2007). Even a multidisciplinary team with similar mentalities will be handicapped of the necessary perspectives.

A division between interactive and dissociated groups helps asserting right creativity tools. While the first uses of discussions and integrative tools to create a mentality together, the second needs a more structured or individual technique to overcome problems of communication. The lack of cohesion of the group can come from different reasons. Introverted people mingled with extroverted people tend to become shunned during discussions. A tool that gives equal voice to different members of the team, as Brainwriting, would allow even the most introverted member to share his/her thoughts and contribute to creation. Personal disagreements between members are also harmful for the project. This factor inhibits members from accepting others ideas or co-create. The systematization of the process, with tools like Morphological Matrix or Pugh Matrix, would allow a better flow of ideas. Another factor in team interactivity is the language used by each participant. Members from engineering and marketing or design may use different terms

and have different thoughts chaining, which would hinder the fluidity of creation. Tools of better visualization, as varieties of Prototyping, help to create a universal image of the design.

3.4 EXECUTION METHOD

The execution of the tool is another determinant factor. Some tools, as Brainstorming, have a verbal intention to debate and create the ideas together. This discussion is important to the development, using comparison and co-evolution of ideas to generate more creative solutions (Toh e Miller, 2015). Others have a more written or illustrative perspective, as Brainwriting, allowing the team to individually create and still merge ideas. Without discussion, the sharing of ideas should base itself on other methods, such as a creativity technique. This division is challenging, even that in more verbal tools, some form of symbolism needs to be used, while the symbolic tools should also lean on discussions, which would enhance the team creative ability.

The developed separation focuses on aspects such as team availability, meetings and interaction between the members. Teams whose constant contact is impeded by distance or time have difficulties in maintaining long and recurrent discussions, which would benefit creativity. By sharing the same space (as in a team room), a team can create schemes or prototypes which would better inform other members of the progress of the design. While reports can be massive and not communicate properly the ideas, white boards, post-its, pictures and simple models are very effective in creating a general design idea when the creation is not conjunct.

A virtual space may become handy in situations of limited contact. Pictures and schemes are easily uploaded, and can be shared simultaneously with the whole group, each member following the design progress. This virtual network and integrated space are essential to preserve information in teams with high turnover. The design progress is more easily understandable in symbolic form and new team members become aware in less time of the whole process. Yet in the team factor, bad interaction, especially with personal quarrels, or the presence of introverted members interfere on discussions, which are primarily verbal.

3.5 DIFFICULTY OF USE

A creativity expert will not be always available, leaving to the team the responsibility to moderate its own sessions. As a common form of categorization (Ideo, 2011; 2015), this considers the expertise required to learn and apply tools as of great influence on tool selection. A difficult technique, as Pugh Matrix, not only requires a longer learning curve to understand, but also has a more intricate utilization form, needing more discussion and deepening on the design

process. The positive aspect is the better quality of outcomes, although, because of its difficulty, the tool also tends to generate more quarrels between group members over the usage.

Low difficulty tools are easily learnable, usable and overall quicker. These tools, as SCAMPER, are ready to use and require no expertise. This easiness also tends to create more predictable and superficial outcomes, being more adequate when there is a time shortage or a constant need to restart the chain of thought. The moderate difficulty tools, as Brainstorming, are intermediate, usually requiring more attention than the easy ones, but not a deepening as the difficult ones. These tools are learnable through repeatable usage and are more versatile.

The difficulty of usage category is linked to the time available to create. Harder tools require more time to generate adequate outcomes. It is important for the team to have enough time to create, but never lose focus on the tasks and goals ahead. Based on the principle that a larger amount of ideas culminates in better innovative solutions, the team must focus all the spare time in the chronogram to divergent thinking. Although convergence is essential to innovate, a bigger picture to associate and filter will generate a more adequate project outcome (Baxter, 2011).

At the beginning of a product development, it is indispensable the construction of a chronogram. This simple tool will help to keep the design and team at the right pace, motivating it to reach deadlines with a compatible work. Too tight chronograms will raise the team stress levels, undermining creativity to reach impracticable goals (Amabile *et al.*, 2002). A chronogram with a loose timeframe can incite the team to leave everything to the last minute, especially when the work is repetitious (Amabile *et al.*, 2002), also discouraging creative ideas.

3.6 CORRELATIONS

The combination of the five categories helps the linkage between team need and creativity tool. This correlation is dependable on the present design situation, corresponding needs to most appropriate tool. Naturally, the team could search through a database with the correspondent characteristics to come with the appropriate tool, but such method would require more time, knowledge, and would not make explicit to the team the reasons behind the selection. Each tool has its singular range of action, which non-experts may wrongly identify.

To create a satisfactory outcome, information about the team in general is required. How is the progress of the design; which is the environment; how is the relationship and communication between team members; among other questions help to define the current situation of the team. Those simple facts are fundamental to the right tools selection and will lead to a plausible explanation for the tool selection.

The identified aspects (user’s inputs to the KBS prototype questionnaire) influence collectively the values for each category, meaning that a variety of factors combination lead to a set of specific output. For instance, in a direct correlation, a team that bases the design on existing products is not aiming for radical innovation, staying between incremental and architectural. For the same situation, if the team pursues new functionalities or a new market for the same product, the category of architectural innovation and its tools become more adequate. This information flow generates a combination of factors for each category, leading to suitable techniques.

4 PROTOTYPE

The prototyping aims to confirm the applicability of a KBS in creativity tools assertion. The five above-mentioned categories help to divide the chosen tools in correlated groups, which were the basis of emulation to generate the outcome. The implementation used CLIPS as an inference engine, a shell system to build KBS.

The first cycle of implementation included twelve creativity and innovation tools, restricted to the second diamond of the Double Diamond methodology. The categorization is established as shown in Table 1, along with the twelve tools. Used literature review for the construction of the table includes (Henderson e Clark, 1990; King e Schlicksupp, 1999; Diegm, 2005; Back *et al.*, 2008; Brown, 2010; Baxter, 2011; Ideo, 2011; Curedale, 2013; Ideo, 2015).

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	Moderate
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 & Symbolic	Easy

Key: I – incremental / A – architectural / R – radical

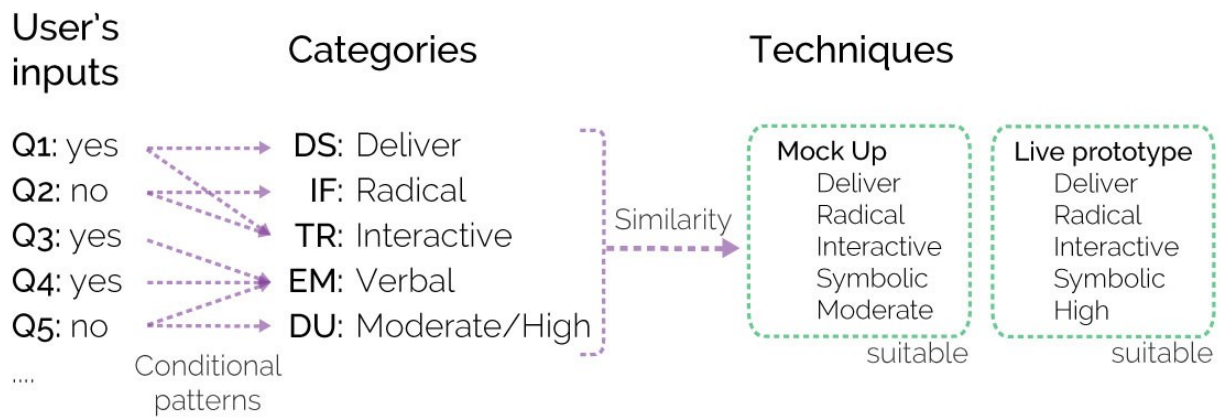
Source: Authors (2015).

The tool selection does not intend to assert how the design should be done, or interfere in the development process. The aim is to support the team and boost creativity according to the situation. Even though some team configuration may be preferable for radical innovation, if the design purpose is to improve a simple product part, the system will offer an incremental innovation tool. Naturally, each team may find other tools more adequate to the execution, especially since the application of tools is adaptable to different situations. The system tries and encompasses some of the dualities and singular applications, but the team must always decide the most adequate method. It is also possible for the system to deliver more than one output depending on the prerequisites and the implemented tools, leaving options to choose a more adequate tool.

The KBS prototype is useful in any design step in which the team needs a creativity boost, for instance in concepts generation or selection. Although many teams have commonly used methods developed empirically, the program intends to offer a confirmation or second opinion. Many blockages on creative thinking can be overcome by a change in perspective, which is facilitated using different creativity tools. Many of the asserted techniques are also usable as a support instrument, assisting the use of other tools.

An initial questionnaire of eight questions gathers the necessary information for the selection. For means of verification, every output combination was checked, generating 336 possible arrangements, out of which 269 are positive, meaning that at least one of the twelve creativity techniques is adequate. The questionnaire leads to the described categorization, which then correlates adequate techniques to fulfill the identified needs. By using rules and object-oriented modeling, along with forward chaining reasoning, the system identifies combinations of user's inputs and responds with values to each category. These values serve as inference base to select adequate techniques.

Each output of the system presents an explanation on the assertion, clarifying for the user the reasons behind the correlation. The connections between values of the categories and techniques are created by similarity, having each technique a set of parameters that are directly crosschecked with the identified category values. Techniques that match at least one of the corresponded values in every category are selected and displayed. The parameters used in defining the values for each technique were based on literature and empirical experience. Each technique also has a description, usage situations, step-by-step of use, examples, tips, and related tools, informing the team of the best ways to adequate the tools to the team reality. As a work-in-progress, the development of the KBS stands on the second cycle of implementation, in phase of validation with creativity and design process experts.

Figure 5 – Schematic correlation between user's inputs, categories and techniques.

DS: Design step / IF: Innovation focus / TR: Team relationship EM: Execution method / DU: Difficulty of use

Source: Authors (2015).

4.1 APPLICATION EXAMPLE

As potential scenario for the application of the proposed KBS prototype, we consider the example of the multinational frog Design Inc. that challenged its 1600 employees of 15 locations around the world to an internal competition to develop the future of energy industry. One team of designers and engineers aimed to create a product to harness the greatest amount of power with the smallest environmental footprint (frog Design, 2011).

Through research and discussion, the team associated low impact and energy efficiency with Darrieus wind turbine. Consisting of hard curved airfoil blades on a vertical shaft, the system can use winds from different directions, is smaller compared to other wind turbines, and has quicker wind speed recovery, with lesser influence over its trajectory. The concept, despite its disadvantages for large-scale energy generation, is adaptable for small and compact wind turbine, aiming mobile and electronic devices charging. With no reference for a Darrieus turbine in small-scale with flexible blades, the team aimed to translate the large-scale concept into a portable product.

Considering that this team had access to the KBS prototype, we envision a potential application the next step in the product development. It is considered that the team aims to create an innovative product, unlike the state-of-art technology. By having an appropriate space, the ideation can take place primarily in meetings and conversations among team members, aided by virtual form of communication. The team has also good relationship among members embracing different expertise. The tight competition chronogram pushes the team to converge into a solution quickly, while they already considered the generated concept adequate. This

scenario sets the team configuration and design situation to answer the questionnaire as shown in Table 2.

Table 2 - Input questionnaire.

Questionnaire	Answers
1. Is the design based on existing products?	No
1. Is the number of generated ideas sufficient for the team?	Yes
1. Is there available time for posterior tasks according to the chronogram?	No
1. Is the team multidisciplinary?	Yes
1. Does the team have an exclusive physical ambience (e.g. room)?	Yes
1. Does the team have virtual connection for design purposes?	Yes
1. Does the team have periodical meetings (daily or weekly rate)?	Yes
1. Does the team have a good relationship between members?	Yes

Source: Authors (2015).

With the answers, the KBS correlates needs, using inferences to combine the inputted information with category values. In this particular case, the attributed values for each category and user’s inputs that led to each value are presented in Table 3.

Table 3 – Correspondence between categories values and user’s inputs

Category	Value	Used answers during inference
Design step	Deliver	2 / 3
Innovation focus	Radical	1
Team relationship	Interactive	5 / 6 / 7 / 8
Execution method	Verbal / Symbolic	5 / 6 / 7 / 8
Difficulty of use	Moderate / High	2 / 3 / 4 / 5 / 6 / 7 / 8

Source: Authors (2015).

The KBS prototype then led to two creativity techniques, providing an explanation for the reasoning behind each assertion. For instance, the “Prototyping” technique explanation presented is “The assertion of Prototyping is based on its applicability in deliver stages of development, helping the team to converge the available conceptions into feasible solutions. The team’s interactive nature gives way to building the ideas together, which is made easier with a technique such as this. It is suitable to radical innovation approach for basing itself on new markets and/or technologies. By having symbolic execution, this technique is based on sketches, prototypes and diagrams. For being of moderate use difficulty, this technique requires knowledge

and attention, but can be learned through use”. Additional information and technique description is presented with a HTML. The results of the KBS befitted the real case study, in which the team made engineering prototypes to envision the real functionalities and capabilities of the wind turbine, honing the design efficiency and style. The final design product was the Revolver™, a small and portable wind turbine with four flexible silicon blades, which generates enough energy for charging laptops and mobiles in any time of the day and location with minimal impact (frog Design, 2011).

The design was awarded with the BraunPrize in 2012, a prize for beautiful and intuitive product design. It was also winner of the German Federal Ecodesign Award in 2013. As presented above, we include this example as potential application of the KBS prototype and expect to attract interested users to investigate the system functionalities.

5 CONCLUSIONS AND FUTURE STUDIES

Creativity is an essential ability for the current competitive world, being the first step in the innovation process. The capacity to come up with different ideas that are useful and fulfill costumers’ needs is the basis of any organization that aims to stay in business. Even with shorter time for design and users increasingly more demanding, it depends on the design team to work with all the interests and still be able to satisfy the stakeholders. The use of design methodologies creates the needed systematization for creative thinking. Chronograms, milestones, team selection and definition of task responsibility consolidate the design process, consolidating the design structure and helping to reach better and quicker solutions (Back *et al.*, 2008; Baxter, 2011). The user-centered design, focusing the design on the final user, is also a relevant addition, since a market orientation and attention to users’ needs increases the chances of a successful product or service (Brown, 2010; Baxter, 2011). This approach presents a series of correlations and techniques for creativity boosting, especially for co-creation, empathy with users and multidisciplinary teams.

The paper presents a KBS prototype the concentrates theoretical categorization development on design methodologies. The current system progressed into the second implementation cycle using the similar implementation approach, which contains 24 techniques and more than 500 entry scenarios to characterize the design team profile. With this prototype, the expert knowledge become permanently available and reliable, although requiring a certain degree of human interaction in terms of critical sense for utilization. Five categories were the foundation of the project:

- Design step

- Innovation focus
- Team relationship
- Execution method
- Difficulty of use

The team needs are translated using a double inference process from questionnaire to categories, then from categories to techniques.

Promising results with the prototype present opportunities to further developments. Validation tryouts with experts in creativity and design, as well as non-expert designers, will allow an optimization of questionnaire, correlations and techniques to be implemented, specially taking into account the number of existing tools and different background of designers. Inside the double diamond approach, the first diamond will be implemented and encompass the whole creation process of the methodology, from detection of the need to selection of the solution. A refinement on questionnaire, tools description and explanation also will increase the system overall utility and usability.

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