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Corresponding Author: Dr. Daniele Bacciotti,

Corresponding Author's Institution:

First Author: Daniele Bacciotti

Order of Authors: Daniele Bacciotti; Yuri Borgianni, Contract Researcher; Federico Rotini, Assistant Professor

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An original design approach for stimulating the ideation of new product features

Daniele Bacciotti[1,2,*], Yuri Borgianni[3], Federico Rotini[1]

[1]Università degli Studi di Firenze – Dipartimento di Ingegneria Industriale, Via Santa Marta, 3, 50139 Florence (Italy)
[2]Politecnico di Milano – Dipartimento di Meccanica, Via La Masa, 1, 20156 Milan (Italy)
[3]Free University of Bolzano/Bozen – Faculty of Science and Technology, Piazza Università, 5, 39100 Bolzano (Italy)

[*]Corresponding author
Email: daniele.bacciotti@unifi.it

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1. Introduction
The paper illustrates a method and a computer application supporting the ideation of new product attributes. The contribution described in the present manuscript can be seen as the result of treasuring a bundle of stimuli, which have, more or less recently, affected the authors' background and visions. These hints arise from both the literature, with a particular reference to contributions within engineering design, and the interpretation of the needs that emerge by cooperating with industrial partners in various research projects. More precisely, the stimuli stand in grounded assumptions with reference to innovation in industrial contexts, which will be subsequently explained:

- the declared relevance of innovation in the 21st century industry [1], which results in an increasing importance of design activities with a special emphasis on those initial New Product Development (NPD) tasks, such as Product Planning, that participate to the definition of the business opportunities to be exploited;
- the claimed need of fine-tuning formal methods supporting the above design activities;
- the focus on individuals' creativity to achieve new products and services offering greater value for customers;
- the expected growing participation of computers in the creative phases of innovation activities;
- the need of building computer-based applications tailored to aid initial design phases.

The goal of product innovation gradually shifts from technologies for achieving superior performances to user-centred approaches aimed at including unprecedented sources of value for perspective customers. In this sense, the scope of engineering design is expanding towards the initial NPD phases, more focused on the definition of requirements to be fulfilled [2]. This trend is far from being surprising, if the claimed impact is considered of early design stages, the so-called Fuzzy Front End (FFE), in terms of the success chances of new artefacts [3] and the determination of upcoming product development costs [4, 5]. Consequently, the models used to describe design processes tend to encompass user needs and requirements, besides traditionally comprising functions, components, interactions and physical principles [6]. Within the FFE, a particular attention is then paid to Product Planning, whose scope is, among the others, identifying and analysing users' needs and translating them into design objectives.
The need of systematically aiding the early design phases has been frequently declared (e.g. [7]), but formal methods are considered still inadequate to the purpose [8, 9]. The literature shows that big corporations have introduced best practices for an adequate management of the FFE, but they still require introducing formal instruments for enhancing idea generation [10, 11]. By insightfully surveying existing techniques devoted to support Product Planning, it emerges that they face the dichotomy between, on the one hand, disruptiveness of generated ideas and, on the other hand, predictability of market results and feasibility of new products with the available company resources [12].
Similarly, it is possible to assess that strictly demand-pull approaches substantially limit the capability of exploration of designers, bringing to the development of poor-valued and scarcely innovative products [13]. The stimulation of creative thinking is conversely seen as a prerequisite for allowing the generation of breakthrough ideas (e.g. [14]). Nevertheless, unconstrained stimuli can give rise to bizarre ideas, which are often characterized by noticeably limited utility for customers [15] and, therefore, are not viable to correctly address NPD cycles. In this sense, the objective of the research is attempting to build a roadmap for systematically investigating the possible sources of value for customers and the circumstances in which they can emerge. The present proposal provides stimuli to conduct the

exploration of said sources and circumstances. An original method has been fine-tuned, intended to leverage these guided stimuli to improve designers' ideation processes.
The following Sections (4.2 more in particular) will lay bare the large number of concepts potentially identifying new sources of customer value. In this perspective, the introduction of computerized tools results critical to support the management of a considerable quantity of stimuli. This aspect is consistent with the predicted increase of ICT involvement in NPD activities [16] and innovation projects aiming at engendering major value for customers [17]. However, the role of computers in initial product development phases has been fundamentally limited to a design partnership supporting communication between multiple parties and data management. This circumscribed contribution contrasts with the extensive development of CAD/CAE systems supporting the Back End of design cycles. To this regard, it is deemed that the goal of reducing new products' time-to-market has pushed the evolution of computer tools capable to shorten design processes by quickening those activities that could be easily faced through routine procedures. This has besides resulted in the disregard of design activities requiring a higher degree of creativity and innovativeness [18] and in the erection of inertial barriers in terms of exploring original solutions by hindering the representation of new concept models [19, 20]. Therefore, on the one hand, it results desirable for commercial CAD systems to allow users to carry out proficiently initial design tasks [21]. On the other hand, new ICT instruments for the FFE (and tailored to Product Planning in particular) are viable to observe a shift towards computer coaches according to Lubart's [22] definitions about the forms of interaction between men and machines.
In this sense, the developed method and computer application work like a coach, since the latter suggests areas to be investigated for the identification of new product attributes, whose way of monitoring can be gradually subsumed in the thinking of perspective users. More specifically, the scrutiny of new features consists in mapping their so-called dimensions, i.e. what characterizes the benefits they provide, and finding unprecedented situations to offer value by asking some classical "*wh* question":

- *what* and *why*: the nature or the essence of the given benefit, the reasons behind its fulfilment (General Demand dimension, labelled as GD);
- *who*: the involved subject within the value chain (Stakeholder dimension, SH);
- *where*: the locus at which an useful interaction takes place (System hierarchy dimension, SYS);
- *when*: the time frame during the product lifecycle in which the benefit occurs (Lifecycle dimension, LC).

It is worth remarking that the *how* aspect has not been taken into account, since it concerns different NPD phases devoted to establish working principles and technologies through which to fulfil initial design specifications.
The article is organized as follows. Section 2 analyses the background of the present research and individuates the requirements and the evaluation metrics to be considered for the scope of fine-tuning an original idea generation tool. Section 3 investigates the attempts to address the ideation of new product characteristics, by surveying both scientific literature and existing software applications. Section 4 describes the proposed approach and its implementation into a prototype software. The verification of their effectiveness is illustrated in Section 5 through a testing campaign involving 24 Master Science (MS) students in Mechanical Engineering. Subsequently, Section 6 documents the outputs of the methodology employment in the industrial field. Eventually, Section 7 summarizes the main findings and draws final remarks and planned future activities.

2. Background

The quality of ideation processes is commonly linked with the capability to explore the design space, generally defined as the count for all possible options to address a posed problem [23]. For the scopes of the present paper, treating Product Planning and hence the definition of the objectives a NPD cycle should accomplish, the design space can be intended as the entirety of potential benefits to be offered by a new artefact.
Many literature contributions dealing with ideation issues in design substantially refer to generation of solutions for assigned technical problems or, more vaguely, to initial product development activities. Hence, this branch of literature predominantly focuses on Conceptual Design. However, we can extend the validity of the presented findings to Product Planning, since reference sources are committed to investigate the mechanisms underlying design phases requiring a great extent of individual creativity.

2.1 Analogies in creative design phases

Creativity contributes to the exploration of the design space and subsequently to limit design fixation, which is seen as the most harmful phenomenon at the beginning of NPD cycles. According to in-depth studies, design fixation leads to, among the others, repetitive ideas, small quantities of proposed solutions, imitation of provided examples [24, 25]. In this sense, we could assume that examples or any kind of stimuli producing analogical thinking give rise to the drop of creativity.

On the contrary, design-by-analogy represents a fundamental process guiding idea generation and problem solving appropriately [26]. As a result, the research in engineering design witnesses several experiments related to the generation of ideas pushed by various kinds of stimuli, whose consequent manipulation of human memory is studied in [27]. Among the others, examples and descriptions from biology field [28, 29] claim to foster creative design solutions. Different experiences consider the exploitation of stimuli pertaining to product domain [30] and to examples taken from firms' information repositories [31].

Ogot and Okudan [32] show the growth of ideation effectiveness brought by systematic procedures fostering analogical thinking, already for first-year Engineering Students. More recent studies compare the outcomes of initial design activities undertaken through structured methods and intuitive/cognitive approaches [33, 34], showing that the former generate more appropriate solutions, while the latter give rise to more novel ideas. Reviews point out how the number of cognitive approaches is overwhelming in the context of the instruments dedicated to the generation of ideas [12, 35-37].

Despite the variety of stimulation methods based on analogical thinking, the factors underpinning the success of these techniques are still insufficiently researched [26]. In this context, an in-depth study is constituted by the work described by Vargas Hernandez et al. [38], who underline the potential of intuitive ideation methods in terms of the capability to enlarge the design space of exploration. Within intuitive methods, engineering design and cognitive psychology communities share many ideation components, such as Provocative Stimuli, Suspended Judgment, Flexible Representation, Frame of Reference Shifting, Incubation, Example Exposure. The scholars test the effect of these components against metrics that assess the goodness of ideation outcomes. Just Incubation results as a statistically significant driver to guide appropriate ideation procedures. However, it is worth noting that such a factor refers to the timing of ideation processes and cannot be considered as a measure to distinguish between good and bad creative methods.

Tseng et al. [39] demonstrate that analogies that are more distantly related to the core of the design activity result particularly beneficial when design goals are not well defined yet, hence at the very beginning of NPD cycles. As far-field analogies show considerable advantages [40], domain-specific hints should be avoided. Moreover, studies explain how the employment of abstract linguistic representations increase the effectiveness of design-by-analogy [41]. The quantity of offered analogies positively influences the creativity of generated ideas [42]. In addition, administering manifold and continuous stimuli can give rise to considerable workload and perceptible mental stress that are, in turn, judged as phenomena producing enhanced design creativity [43, 44]. This circumstance finds confirmation in the effectiveness of analogies in idea generation tasks, which involve designers for a large amount of time, thus avoiding productivity drops observed after approximately 30 minutes [45].

With respect to the above theoretical background, an original tool to properly support ideation in Product Planning should:

- foster the exploration of the design space;
- provide a large number of stimuli, in such a way that designers' workload is augmented and analogical thinking is aroused for a long time;
- employ abstract concepts to the greatest extent.

2.2. Metrics to assess idea generation in Product Planning

Despite some criticism (e.g. [46]), the variables introduced by Shah et al. [47] represent the most acknowledged factors to judge the effectiveness of ideation processes for design tasks. Thus, the reference metrics include quantity, variety, novelty and quality of generated ideas.

These criteria commonly refer to the output of ideation sessions that aim at finding solutions for posed problems; therefore, they best fit the evaluation of Conceptual Design outcomes. In the followings, the authors clarify the meaning of the criteria and argue about the usability of these metrics for Product Planning.

Quantity stands for the number of generated ideas and it can be plainly used with the same meaning within Product Planning.

Variety represents the extent to which different areas of the design space have been explored. It assesses the distance between concepts according to a predefined taxonomy. For instance, a large amount of variety is implied by the use of two different working principles to solve an equivalent problem. Although it potentially represents a significant indicator for the efficacy of idea generation processes within Product Planning, variety cannot be used because of the lack of an established taxonomy to characterize NPD objectives. In addition, in the investigated phase of engineering design, functions and objectives have still to be formulated, hence a defined problem to solve is missing. In this sense, variety cannot be included within the metrics to evaluate ideation performances.

Novelty stands for the degree to which new ideas differ from existing systems. It ranges among the most acknowledged dimensions of creativity. In many cases, especially within creativity assessment, the measure of novelty is determined through experts' evaluations. However, in order to avoid biases ensuing from subjective estimations, objective metrics are gaining consensus in the academic field. Among the available criteria, the procedure developed by Sarkar and Chakrabarti [48] allows assessing products' novelty according to the ontological elements for which modifications can be observed with respect to existing artefacts. More in detail, the employed ontology refers to the so-called SAPPhIRE model [49], which defines the product in terms of structures, working principles, functions, environment in which it is collocated, required resources, effects of its use. With regards to observed changes, the assessment of novelty is made through a scale ranging from "none" to "very high".

Eventually, quality measures the degree to which a given problem is solved correctly, by evaluating the appropriateness of solutions with respect to given constraints, environment of use and industrial domain. By missing a predetermined function to be fulfilled in Product Planning, such a metric cannot be included in the set of criteria to assess ideation performance.

As a result, quantity and novelty stand in the employable metrics for comparing the outcomes of idea generation sessions. This couple of dimensions can be considered sufficient for the scopes of assessing ideation effectiveness in Product Planning, since authoritative contributions describing the performance of ideation experiences exploit just these two criteria, e.g. [50, 51].

3. Methods and software tools to stimulate idea generation tasks

The present Section overviews diffused methods and existing software applications that can potentially enhance idea generation within Product Planning. Their pros and cons will be subsequently discussed with a specific reference to the requirements and metrics reported in Section 2.

Some scholars have surveyed the available computer applications that support the FFE [52, 53]. Nevertheless, most of the software tools described in said citations are no longer available and an updated review is therefore needed of the computer-aided instruments for stimulating idea generation. The search criteria are disclosed at the beginning of Subsection 3.2 through which such a survey has been conducted in June 2014. This part is anticipated by the description of diffused models for Product Planning (Subsection 3.1), whose names have been used as terms for carrying out the search. Subsequently, the outcomes of the investigation are presented and discussed in the second part of Subsection 3.2, while Subsection 3.3 clarifies how current criticalities can be overcome by means of an original idea generation method.

3.1 Acknowledged techniques to support idea generation

The best-known idea generation technique is the Brainstorming method, originally developed by Osborne [54]. This approach is diffused in the industrial practice [55, 56], because it can be easily and intuitively implemented. A group of designers, marketing experts and/or customers is organized in order to discuss about new product ideas. The discussion is generally guided by a moderator, who keeps the focus on the main objective and tries to avoid the excessive influence of any participant on other attendees. Practices and techniques to enhance the performances of brainstorming sessions have been experimented, e.g. Synectics [57], Brainwriting [58], Mind Maps [59], Bodystorming [60], KJ Technique [61] and so on (see [37] for more details). In addition, several software tools to support brainstorming have been developed in the last years giving rise to the so-called "electronic brainstorming" [62, 63]. Although several variants of the original Brainstorming method can be identified in the literature, companies often employ tailored techniques according to specific needs. This approach observes limitations in terms of the high variability of the results according to the involved subjects, by suffering from a very low systematic level [64, 65]. In addition, some studies highlight that groups employing Brainstorming produce a smaller quantity of ideas (besides less feasible) rather than entrusting idea generation to a plurality of individuals working separately, namely nominal group technique [65-68]. Besides, it is claimed that electronic brainstorming, whereas face-to-face interaction is avoided, can improve idea generation both in terms of productivity (number of ideas per participant) and effectiveness (ideas viable to be successfully implemented) with respect to conventional sessions [52].

Lateral thinking [69, 70] is another well-known idea generation technique, with a not negligible diffusion in industry [56]. This approach, unlike logical "vertical" thinking, pushes individuals or teams to think from different perspectives, overcoming their psychological inertia and generating as many new ideas as possible. Different methods can be used in

conjunction with lateral thinking, e.g. Delphi method [71, 72] and Six Thinking Hats [73]. The main weaknesses of lateral thinking reflect the shortcomings of Brainstorming, especially in terms of its low systematic level [74].
The scenario-based technique [75, 76] is employed by design teams to identify the potential user needs and product requirements by simulating the most likely scenarios for product use. A remarkable limitation is constituted by the need of involving large design teams, since the members have to exchange views with each other during idea generation to obtain reliable results (as pointed out in [75]).
The idea generation task can be supported by the toolkit of Blue Ocean Strategy [77], with a particular reference to the Six Paths framework and the so-called BEC/BUM (standing for Buyer Experience Cycle/Buyer Utility Map). Single users and design teams can exploit both the techniques. The former suggests six ways to think about new strategies analysing new stakeholders, complementary products and services and trends in the reference industrial field. By providing only qualitative indications and hints for idea generation, the Six Path framework is not considered sufficiently capable to support the designer [78]. The latter guides the idea generation process through the combined analysis of product life cycle phases and some kinds of customer needs (e.g. simplicity, convenience, fun, environmental friendliness). The limited sample of indicated product attributes can be seen as a constraint of the analogical thinking process.
Approaches to gather and manage ideas from customers and/or employees are widely implemented in the companies. Among the others, the Lead user method [79, 80] points the attention just to ideas generated by pioneer users. Indeed, this category of consumers have spent more time with the product with respect to other customers, hence they are supposed to have accumulated experience and individuated unfulfilled latent needs [81]. Conversely, all potential customers and/or employees are involved within several approaches, commonly designated as crowdsourcing techniques [82]. Crowdsourcing is diffusedly incentivized through contests [83-86] and/or rewards [63, 87], observing an increasing participation of Internet communities [88]. It results apparent that neither the Lead user method, nor crowdsourcing can ensure positive outcomes, since the collected users' ideas might result distant from companies' expectations.
Random ideation processes and limited design spaces to be explored are the main weaknesses of found methods. This results in design outcomes that greatly depend on users' creativity and in the potential loss of valuable ideas as a consequence of continuous and unstructured flows of stimuli that do not allow the proper reflection upon thought product benefits. From a different perspective, the most diffused systematic techniques conversely suffer from limited capabilities of developing out-of-the-box solutions. Besides, being they particularly tailored to the conceptual design phase, their names will not be considered as inputs for the survey of computer applications supporting idea generation.

3.2 Overview of the outcomes emerging from the survey of software applications for idea generation

The monitoring of computer applications for idea generation has been performed by browsing the World Wide Web through common search engines and the electronic stores of the most diffused operating systems (Android, Apple and Windows). The keywords for individuating sound results included:

- terms identifying the typology of required tools: software, support system, computer-aided, app/application;
- words featuring the objective to be attained through the above instruments: idea generation, idea stimulation, analogy, creativity, opportunity identification, business opportunity, New Product Development, Product Planning;
- terms standing for the most acknowledged methods or procedures inherent to the very early design stages: Brainstorming, Mind Maps, Blue Ocean Strategy, Lead User, Lateral Thinking, Scenario Model, Crowdsourcing.

According to the results of the survey, the main categories of computer-supported idea generation tools can be identified. Whereas some of them directly descend from the implemented models described in Section 3.1, some of them emerge as new classes. The individuated categories of software applications follow:

- Brainstorming and Mind Maps that support it. Some of the tools include additional features to improve the creative process, e.g. they allow making sketches (mainly in touch screen devices), inserting images and/or photos, attaching virtual sticky notes, developing diagrams, performing analyses through SWOT (Strengths, Weaknesses, Opportunities, and Threats) and SCAMPER (Substitute, Combine, Adapt, Modify, Put to other use, Eliminate, Reverse). In addition, some of them provide generic questions and/or hints to help exploring creative directions and finding new ideas. Furthermore, many of these tools allow sharing generated ideas.

- Patent inspiration tools: they allow browsing patents databases, by simply indicating the main topic in the search bar. The identified patents can belong to different fields with respect to the context of the research and they are claimed to support the generation of new ideas in both Product Planning and Conceptual Design.
- Web inspiration tools: they allow searching on the web new ideas, inventions, concepts, scientific researches, etc. The search can be addressed by terms related to the main topic or work in an unconstrained way. New ideas are inspired by a mix of images, descriptions and links.
- Crowdsourcing: these ICT tools for idea management support the collection and sharing of new ideas generated by employees, customers, and/or generic users. In addition, these applications are capable to put into relationship the individuals participating to the creative NPD tasks, thus taking the form of digital brainstorming instruments.
- Random words and random image, which are combined to stimulate new ideas. Some of these tools even allow moving the generated words and images in the screen, with the aim of organizing them like in a real desk, thus facilitating the creative process. These software applications can support both design processes and other creative activities, such as art and poetry.
- Creative cards, consisting in digital collections of images and/or photos combined with words, descriptions and/or short stories. Some of these cards bundles suggest possible scenarios of use in order to stimulate the creative process. Other decks provide generic hints and, like the previous category of ICT tools, they can be used by artists and writers too. Some literature contributions show successful implementations of Creative cards [89,90], which are however consistently oriented towards the support of Conceptual Design. Halskov and Dalsgård [89] even claim that this kind of tools is more effective than Lateral thinking, because, in their test, Creative Cards provide a larger number of sources of inspiration. However, their application in the engineering design is too restricted and it is not possible to use these instruments as a starting point for the development of further methods and tools.
- Lateral thinking: the research allowed identifying few tools that support the implementation of Lateral Thinking (and the related Six Thinking Hats approach).
- Blue Ocean Strategy: two mobile applications implementing BOS tools have been individuated. The former supports the sketching of Strategy Canvas, i.e. value curves schematizing new ideas in terms of product attributes and related performances. The curves allow representing an idea and comparing the proposal with competitors' deliverables. The latter trivially implements the BEC/BOM.

A representative collection of the identified tools is presented in Appendix 1, in which these applications have been grouped according to the supported Operating Systems and the categories recalled in the above bulleted list.

3.3 Outcomes of the survey and research objectives

The outcomes of the investigation show a large number of computer-aided applications supporting idea generation in a variety of fields, abundantly crossing the borders of design domain. By focusing on those techniques closer to the engineering world, the research confirms the considerable diffusion of heuristics that leverage human reasoning and analogical thinking in order to conceive new hints for product development. The advantages in using computer-aided systems (instead of the frameworks that are implemented) seem to stand just in favouring the communication between parties and better visualizing the generated ideas. The main limitations of the reference techniques (mentioned in Section 3.1) are conversely not overcome, despite the possibilities offered by Artificial Intelligence.

It emerges that illustrated tools and software applications do not ensure a suitable exploration of the design space. Still with respect to the indications arisen in Section 2, knowledge is missing with respect to the produced workload and to the time the presented stimulation tools can support in proposing analogies. The kind of aroused analogies is remarkably variegated, ranging from very generic tendencies (e.g. Six Path Framework) to random images (e.g. Creative Cards). In some cases, stimulation patterns are not predefined and analogies come out accidentally from group discussions (e.g. Brainstorming). Anyway, the overviewed instruments are not plainly concerned with the need of systematically inducing far-field abstract analogies. With respect to metrics to assess ideation effectiveness, much knowledge is missing. Brainstorming performances represent an exception in this sense, at least in terms of quantity, which is the dimension that Osborne [54] primarily stressed. Furthermore, as previously mentioned, whereas Brainstorming advocates state that such a method is more effective than entrusting idea generation to a plurality of individuals working separately, other studies reverse this claim.

By observing the shortcomings of and the missing knowledge about existing techniques and ICT tools, the authors have evaluated the opportunity of developing an original method for supporting idea generation in Product Planning. We propose first to scan the opportunities of introducing new product attributes, so to organize a vast collection of useful hints. A structured roadmap displays to designers such hints, expressed through abstract and general terms. The roadmap benefits from a classification of the hints, as it will become more apparent in Section 4, allowing to combine stimuli in order to favour the exploration of design opportunities. The capabilities of computers are employed in order to support the user in searching for said opportunities and organizing the relevant information and the generated ideas. Hence, with reference to the fundaments of idea generation processes (Section 2.1), the planned requirements of the method stand in:

- improving the exploration of the design space, that is supposed to be achieved by offering diversified hints;
- augmenting designers' workload, by encouraging the user in reflecting upon a rich collection of stimuli, whose display is potentially long-lasting;
- providing stimuli in abstract forms.

The effectiveness of the proposed Product Planning methodology will be determined in terms of quantity and novelty, as the reference metrics pointed out in Section 2.2.

4. Developed methodology and computer implementation

The goal of scanning the mare magnum of possible product features to be implemented in new deliverables necessitates a taxonomy categorizing the potential sources and circumstances viable to provide value for customers. Indeed, according to authors' vision, it is critical to build clusters of recurring useful stimuli in order to perform a structured investigation as opposed to the random stimulation approach characterizing the cognitive techniques discussed in Section 3. In other words, it is hereby proposed to properly organize the design space to be explored within idea generation activities.

The taxonomy requires being flexible enough to fit any industrial field and situation in which a NPD task has to be tackled, besides including a large number (ideally all-encompassing) of triggers for idea generation. According to authors' knowledge, no shared scheme of fulfilled benefits has been proposed up to now, if popular groupings of human needs (e.g. Maslow's hierarchy [91], List of Values [92], Max-Neef's classification [93]) are considered too general to categorize customer requirements. Indeed, since these models are organized in terms of psychological benefits for individuals, they do not clearly refer to a large number of practical needs fulfilled through technical functions (e.g. transporting, data processing, lighting).

Thus, an original abstract representation with the above characteristics has to be built. As already introduced in Section 1, the advanced proposal reflects the nature of customer attributes as typically defined in the Product Planning, i.e. whereas just the core aspects are specified. The description includes the definition of a specific need to be fulfilled in order to delight specific beneficiaries in a certain circumstance which involves different levels of interaction with the developed system. The articulation of product requirements in such terms, although intuitive, is not reported in any previous literature source. However, the following Subsection illustrates how the four ways of characterizing designed benefits (Dimensions onwards) make sense as a driver for searching new development opportunities or distinguishing forms of customer value. More in detail, paragraphs 4.1.1-4.1.5 treat a specific Dimension each, while 4.1.5 shows how illustrative Product Planning approaches can be schematized in terms of the four clusters. The original contribution of the paper lies in the possibility to combine all the presented Dimensions suitably and, more specifically, the items described in Subsection 4.2. Subsection 4.3 presents the combination roadmap and its software implementation, standing for the preferred embodiment of the matching procedure.

4.1 Definition and description of the four Dimensions

4.1.1 General Demands

General Demands (GDs) are meant in the present paper as distinct typologies of benefits that can be delivered by correctly designing a new product. They can be broadly referred to kinds of existing, emerging or unspoken needs, otherwise defined as "value opportunities" [94], "utility levers" [77] or "customer perceived value evaluation factors" [75] on which Product Planning tasks are set. They represent the basic characterization of product attributes that specifies the met needs or wants [5] referable to both functional and emotional perception of value.

4.1.2 Stakeholders

The design field is increasingly employing the concept of stakeholders (SHs), by addressing all the subjects that interact with the product, extracting value from the artefact or, generally speaking, are aroused of some interest as a result of the existence of the system. As in [37], design processes require individuating the reference actors standing for the key constituents of projects. With this meaning, SHs include the individuals that participate to the design task and the company that organizes innovation initiatives to generate turnover. On the other hand, product attributes are planned to satisfy needs of subjects that interact with the deliverables of design and manufacturing processes. From this viewpoint the relevant SHs to classify product features include all the actors that are influenced by the artefact in the lifecycle phases following its market launch. In each case, the concept of "customers", which has been traditionally employed, is extended from buyers to users, beneficiaries, service recipients and outsiders, with the aim of identifying new opportunities to increase the delivered value. As underlined in [95], buyers and users might be different individuals (e.g. parents and children) and the actor(s) that will ultimately benefit from the product might be different from either the buyer or the user.

4.1.3 Lifecycle phases

Life Cycle phases (LCs) concern the circumstances that may occur along the different stages of product existence. Coherently with the observation advanced for SHs, the relevant domain to categorize product attributes starts with the market introduction, thus ranging from this moment to the end of product functioning [95]. By analysing the possible situations to be faced, scenarios where different SHs may perceive value can be identified [96]. A correct scrutiny of LCs is deemed crucial to avoid focusing only on the phase of product's use [97], losing opportunities to identify sources of value. Not surprisingly, the correct examination of LCs is traditionally deemed critical within the correct definition of product specifications in engineering tasks [98, 99].

4.1.4 Hierarchies of systems

This dimension suggests analysing the product at different levels of detail, including the "super-system" in which the product is situated, as indicated by classical TRIZ nine-screen scheme [100] to individuate valuable suggestions for product development. The design of the product taking into account different hierarchical levels of the systems (SYSs), from the external environment, which strongly characterizes design requirements [101, 102], to parts and components, is viable to guide the individuation of business opportunities [103]. Besides, the literature reports examples concerning the exploitation of products' hierarchical and functional decomposition to deliver customer needs [104] and to generate concepts [21, 105].

4.1.5 Characterizing Product Planning approaches with the Four Dimensions

As inferable from Section 3.1, some Product Planning instruments are oriented towards the exploration of a subset of Dimensions. For instance, the mentioned BEC/BUM proposed within Blue Ocean Strategy aims at stimulating ideas by involving a rich collection of LCs and a sample of GDs.

Popular design methods that are expanding their boundaries towards the initial phases of NPD tasks can be interpreted in terms of the proposed Dimensions. Among them, eco-design tools swivelling on Life Cycle Assessment procedures to address Product Planning [106, 107] take into account a reference GD (i.e. environmental friendliness) and analyse opportunities and threats along a detailed list of LCs. Design methods seeking to fulfil new needs by scrutinizing the User Experience (recently surveyed in [108]) observe the behaviour of different kinds of users (then a specific typology of SHs) when interacting with products, with a specific emphasis on the utilization phase, hence a well-defined stage constituting the LCs. Besides, with respect to Product-Service Systems, the basic issues to be taken into account for design scopes pertain to subsets of GDs (not otherwise specified needs), LCs, SHs (generally indicated as actors) and SYSs (the employed term "periphery" indicates the surrounding environment and the available infrastructure), at least according to [109].

The combination of Dimensions is common also for other tasks tailored to support engineering design. For instance, Metzler et al. [110] deliberately employ LCs and SHs in order to integrate systematically cognitive functions into product concepts derived from new ideas and existing artefacts. The ontology proposed in [111] to organize the knowledge relevant for products and manufacturing processes makes use of GDs (with a particular focus on costs), LCs and SHs, by considering the different expectations of the company and its customers.

4.2 Elements and Specifications to identify new product attributes

The task of stimulating new ideas by contextually considering the four Dimensions requires individuating objects referred to each of them to be favourably combined. As previously clarified, populating the Dimensions with all the possible items represents a challenging task, because of the lack of sources claiming to be all-encompassing to characterize any fundamental issue of the taxonomy.

The authors decided to employ available schemes supposed to provide an exhaustive picture of the terms and the concepts representative for each Dimension. As indicated in Tables 1-4, the items constituting the Dimensions were organized in terms of Elements, i.e. abstract concepts representing large categories of the matched cluster, and Specifications, i.e. more concrete examples of common characteristics linked with the mentioned Elements. With respect to GDs, an available list of objects was found in [2], whereas a catalogue of needs was employed to estimate the success chances of innovative products. Given the large number of listed typologies of customer requirements, the sample was used to denote GDs' Specifications, subsequently grouped by the authors into a set of Elements (Table 1). On the other hand, the Elements pertaining to SHs, LCs and SYSs were extracted from the representation provided by [95], the relevant objects reported in [112] and the mentioned TRIZ nine-screen framework, respectively. Specifications for the indicated Dimensions were elaborated by the authors on the basis of empirical observations of innovative aspects shown in successful products (Tables 2-4).

Table 1: Elements and corresponding Specifications belonging to the Dimension "General Demands"

Elements	**Specifications**
Fulfilled needs	• Quality of the expected outcomes; • Quantity or extent of the expected outcomes; • Duration of the expected outcomes; • Fun and adventure.
Versatility of use/ adaptability	• Suitability of the product according to different demands; • Adaptability of the product in diverging conditions with respect to the designed preferred ones; • Expand or upgrade the range of product functionalities.
Reliability/ safety	• Controllability of the system in order to obtain the expected outcomes; • Integrity of the product itself, its resistance to planned or accidental stress or collisions, the strength against wear or corrosion; • The limitation of damages towards the external environment; • The limitation of damages provoked by the external environment; • The safety and innocuousness for human health and people's psychological and social conditions; • The duration, the expected life of the product.
Ease	• The reduction of the information and skills to be gathered during the product life cycle; • The ease of acquiring the product, due to market penetration and distribution policies; • The ease of managing, maintaining, assembling, disassembling, upgrading, substituting components or accessories; • The independence from the use of other materials, instruments, technical systems; • The reduction of auxiliary functions to be delivered; • The additional services provided in order to attenuate the consumption of individual resources, the customer care.
Aesthetics/ style/ethics	• Customize the product or certain properties; • The possibility of benefitting of the product (or its parts) for different employment after the end of its life; • The aesthetical requirements and the emotional dimension of the product, the style, the fashion content; • What the product evokes, the lifestyle that the object implies, the prestige it generates for the owner as a feeling of distinction and recognition; • The environmental sustainability; • The ethics as a distinguishing factor.
Quickness	• The reduction of time to be waited before the functioning of the product delivers the expected outcomes; • The limitation of the time required to perform operations.
Cheapness	• The reduction of the consumption of parts, components or consumables; • The limitation of the required energy (or human power) needed for the product during its lifecycle; • Product/service cheapness; • Accessories cheapness; • Cheapness of various activities during product life cycle.
Comfort/	• The absence of bother for the people;

ergonomics	• The comfort of use, the ergonomics, the manageability; • The limitation of occupied space; • The lightness and the portability.

Table 2: Elements and corresponding Specifications belonging to the Dimension “Stakeholders”

Elements	**Specifications**
Buyers	• Manager, decision maker • Parents or tutor • Reseller • Professional • Agent
Users	• Teacher/trainer • Worker, employee • Disabled person • Not-standard user
Beneficiaries	• Community, citizenry • Children • Patients • Animals
Outsiders	• Maintenance technicians or helpers • Third party developers • Assistants • Neighbours • Relatives • Consultants, advisors • Unknown people coming into casual contact with the product

Table 3: Elements and corresponding Specifications belonging to the Dimension “Lifecycle phases”

Elements	**Specifications**
Purchasing, choice and access activities	• Identifying the product on the web • Identifying the product on leaflets, brochures • Identifying the product in the shop • Identifying the product on various kind of advertising • Comparing with similar products • Communicating with the firm • Reaching the shop • Waiting to be assisted • Managing the payment (cash, credit card, etc.) • Using coupons and discounts • Receiving prizes or free accessories/services
Before use operations	• Shipping • Carrying • Unpacking • Training • Assembling • Managing administration issues, bureaucracies • Communicating with the firm
Utilization time	• Switching on/off • Handling • Feeding • Performing other operations in the mean time • Using the product • Using accessories
Elapsed time before further exploitations	• Exploiting the outcomes of the product utilization • Maintaining • Cleaning • Repairing • Storing • Mounting accessories or changing parts • Protecting the product

	• Carrying • Waiting for the system being ready • Receiving assistance
End of the functioning	• Reselling the product and its accessories • Recycling or disposing of the product • Donating the product to needy people • Using the product as a collection item • Using the product for alternative employments

Table 4: Elements and corresponding Specifications belonging to the Dimension "System hierarchies"

Elements	Specifications
Environment in which the product is situated	• Weather conditions • External environment • Place in which the product is situated (room or virtual space) • Tools or matched machinery • Matched or surrounding items • Other similar or identical systems placed nearby
Product or service level	• Product in general • Service in general
Parts, components and accessories	• Case • Engine and transmission • Connecting or fastening means • Handle • Opening/closing means • Movement means • Expansions • Aesthetic accessories • Bags, packaging • Fuel or consumables • Battery and chargers

4.3 Combination procedure and computer application

As clarified at the beginning of Section 4, any way of advantageously relating the contents of the Dimensions can be seen as a peculiar procedure to stimulate idea generation through the proposed approach. In this sense, the authors propose a set of preferred combination modes, which were subsequently implemented in a computer application. The manners of linking the Dimensions were preliminarily evaluated in a positive way in terms of the ratio between the benefits in employing the matching mode and the time spent to carefully consider the emerging combinations. It is worth noticing that matching all the Elements and/or Specifications composing the Dimensions would give rise to thousands of combinations, whereof many of them could result meaningless in the majority of industrial contexts. In order to reduce the number of combinations drastically, the authors opted not to consider all the four Dimensions contextually. The combination modes swivel on GDs, seen as a fundamental characterization of product attributes, to which the contents of the other Dimensions are associated to generate ideas. In other words, two concepts are matched simultaneously, whereas one of them refers to GDs' Dimension. More in details, three different combination procedures (to be exploited separately) are proposed:

- quick: any benefit (without indicating any particular content of GDs) with the Elements of SHs, LCs and SYSs;
- standard: Elements of GDs with the Elements of the other Dimensions;
- detailed: a subset of the Specifications of the GDs with particular Specifications of the residual Dimensions, as shown in Table 5. This kind of association is grounded on the observation of GDs' Specifications, which can vary with respect to particular Specifications (e.g. the customization of a product according to different exigencies of different stakeholders). Said Specifications correspond to all the items included in a certain Dimension (indicated with "all" in Table 5) or in tailored subsets.

Table 5: Suitable combinations of the Specifications belonging to the General Demands with those forming the Elements of other Dimensions (detailed mode of association)

Specifications of the General Demands	**Specifications combined in the detailed mode: reference Elements they belong to**

Quality of the expected outcomes	-
Quantity or extent of the expected outcomes	-
Duration of the expected outcomes	-
Fun and adventure	LC: Utilization time
Suitability of the product according to different demands	SH: all
Adaptability of the product in diverging conditions with respect to the designed preferred ones	LC: all
Expand or upgrade the range of product functionalities	-
Controllability of the system in order to obtain the expected outcomes	SYS: Product or service level; Parts, components and accessories
Integrity of the product itself, its resistance to planned or accidental stress or collisions, the strength against wear or corrosion	SYS: Parts, components and accessories
The limitation of damages towards the external environment	SYS: Environment in which the product is situated
The limitation of damages provoked by the external environment	SYS: Environment in which the product is situated
The safety and innocuousness for human health and people's psychological and social conditions	SH: all
The duration, the expected life of the product	SYS: Product or service level; Parts, components and accessories
The reduction of the information and skills to be gathered during the product life cycle	LC: all
The ease of acquiring the product, due to market penetration and distribution policies	LC: Purchasing, choice and access activities
The ease of managing, maintaining, assembling, disassembling, upgrading, substituting components or accessories	SYS: Parts, components and accessories
The independence from the use of other materials, instruments, technical systems	SYS: Environment in which the product is situated
The reduction of auxiliary functions to be delivered	LC: all
The additional services provided in order to attenuate the consumption of individual resources, the customer care.	-
Customize the product or certain properties	SYS: Product or service level; Parts, components and accessories
The possibility of benefitting of the product (or its parts) for different employment after the end of its life	LC: End of the functioning
The aesthetical requirements and the emotional dimension of the product, the style, the fashion content	SYS: Parts, components and accessories
What the product evokes, the lifestyle that the object implies, the prestige it generates for the owner as a feeling of distinction and recognition	SH: Buyers; Users
The environmental sustainability	LC: all
The ethics as a distinguishing factor	-
The reduction of time to be waited before the functioning of the product delivers the expected outcomes	LC: Before use operations
The limitation of the time required to perform operations	LC: all
The reduction of the consumption of parts, components or consumables	SYS: Parts, components and accessories
The limitation of the required energy (or human power) needed for the product during its lifecycle	LC: all
Product/service cheapness	-
Accessories cheapness	SYS: Parts, components and accessories
Cheapness of various activities during product life cycle	LC: all
The absence of bother for the people	SH: all
The comfort of use, the ergonomics, the manageability	LC: Before use operations; Utilization time; Elapsed time before further exploitations; End of the functioning
The limitation of occupied space	LC: Before use operations; Utilization time; Elapsed

	time before further exploitations; End of the functioning
The lightness and the portability	SYS: Product or service level; Parts, components and accessories

Any perspective user of the method and the corresponding matching procedures can accomplish the test manually, by exploiting the lists reported in Tables 1 and 2. The developed computer-aided application supports the task in terms of easing the combination of the items and the management of the generated ideas, making the developed method more usable. Any interested reader can freely download the tool (named iDea) from the Internet at the web address: http://goo.gl/AwzZHF. In addition to the automatic execution of the above combination options, the prototype software allows selecting and customizing subgroups of Elements and/or Specifications in order to fit better the requirements of the industrial context in which the designer operates. Figure 1 presents the flow chart implemented in said ICT tool, shedding light on the possibility to select the contents of the Dimensions to be exploited and to switch between the three combination alternatives. A guide reporting the main functions of the software tool is included in the software application, downloadable from the above link.

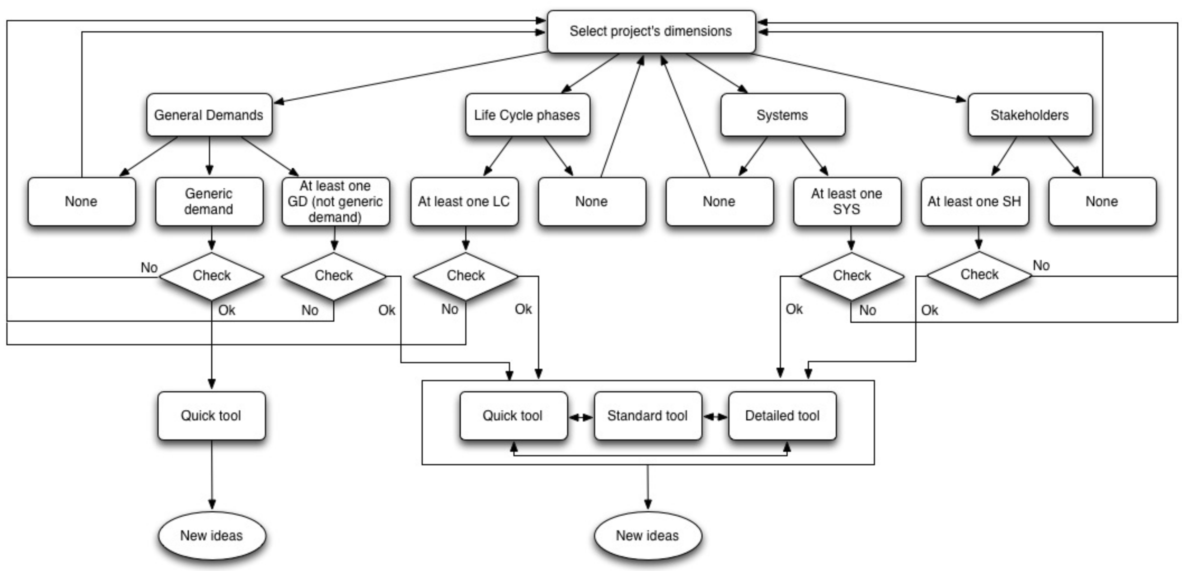

Figure 1: working flow of the prototype software aimed at stimulating ideas by combining concepts organized according to the developed taxonomy of product attributes

5. Testing activity

A testing campaign was required to assess potential advantages and criticalities of the method and the prototype software application. The authors planned the test in order to assess the quantity and the novelty of generated ideas. By exploiting these metrics, the scope stood in comparing the performances of the presented proposal and those of traditional ideation approaches. The paper has already clarified how most of idea generation processes in industry are essentially entrusted to intuition and random stimuli (e.g. recently consulted information sources, new products of the competitors). Analogies come out accidentally, based on teamwork members' inspiration, personal creativity and talent. Hence, the free and unsupported search for new ideas represents the most proper benchmark for the sake of comparison.

5.1 Organization of the experiment and participants

The conducted experiment has involved 24 volunteer MS Students in Mechanical Engineering, University of Florence (Italy), which were attending the Course in Product Design and Development. The experiment consisted in two individual idea generation sessions, lasting three-hours, during which each participant working individually tried to identify original product features.

Before the first session, the students were trained about the fundaments of Product Planning and the role of information gathering in this design phase. Besides, prior to the first session, the Course had illustrated the cited Blue Ocean Strategy and Brainstorming, thus providing references about individual and group ideation techniques. In addition, the

authors had illustrated to the students the opportunity of exploiting Brainstorming strategy by individuals instead of teams, like in the mentioned nominal group technique.
At the beginning of the first session, the students were randomly subdivided in two groups (A and B). The authors, which were supervising the experiment, encouraged both clusters to write down as many new product characteristics as possible, by exploiting personal creativity, any source of information or any notion descending from the themes of the Course. At the end of the generation task, each participant was asked to pick up one or more benefits descending from the generated original features and briefly describe the main traits of a new product consistent with the individuated advantages. The experiment foresaw different reference products to work with; group A dealt with cameras, while group B analysed domestic coffee makers. The two categories of product represent everyday devices, about which students were supposed to have already sufficient information about recent developments, thus avoiding time-consuming information gathering.
Between the two sessions, the basic notions of the proposed methodology and iDea software application were illustrated. The second session was performed with the same format of the first one, with two differences only:

- each participant was asked to use iDea to stimulate new product features, by exploiting one or more combination tools (quick, standard, detailed), according to their preferences;
- the products to deal with were reversed between groups A and B, so as to avoid conditioning from the first session, potentially leading to replicate the results.

5.2 Assessment of quantity and novelty

The first task of the tests, i.e. the generation of new product attributes, aimed at assessing quantity. Indeed, the authors attribute this variable to the number of new product features that students have identified and listed.
The evaluation of novelty represents the objective of the second task of the test, i.e. describing a more elaborated idea treasuring (some of) the identified original product features. It is worth noting that novelty metrics cannot be applied to any of the identified product features, by not including the ontological components foreseen in the SAPPhIRE model. Then, according to the criteria described in [48], the following degrees of novelty were associated to new product ideas:

- None, when there is no difference with respect to already existing products; e.g. a camera with interchangeable covers[1];
- Low, when components or subassemblies are substituted to achieve the same functions through a known behaviour or when parts from other devices are originally integrated to perform the functions they are commonly intended to; e.g. a coffee machine with an integrated radio;
- Medium, when besides changing the disposition or the presence of components, the working principle is modified; e.g. a coffee machine whereas brews are delivered upwards and stored into thermally insulated bins, so to avoid temperature losses as it normally happens to coffee drops falling into mugs by gravity;
- High, when, besides structural and behavioural changes, the delivered function requires different inputs and/or implies consequences or transformations which were not displayed by existing products; e.g. a camera which distinguishes pictured colours and automatically retrieves objects with the same hue on the Web, so to find clothes or other items to be suitably combined with available stuff;
- Very high, when unprecedented functions are displayed; e.g. a coffee machine brewing transparent drinks that do not blemish clothes, paper sheets or other objects in general.

5.3 Outcomes of the test and assessment of the role played by the use of the proposed methodology

The authors gathered the results of the tests and, for each participant, observed the number of identified new product features, as well as determined the degree of novelty for the final ideas. With respect to the former, the analysis took into account just those product attributes clearly not included in commercial products.
Table 6 reports all the results of the two-session experiment. The Table indicates, besides the quantity of features and the novelty of ideas, if each single test (marked by an ID) has treated cameras (if No, the topic is coffee machines) and has benefitted from the use of iDea (if No, it refers to the intuitive session).

Table 6: outcomes of the experiment in terms of quantity of new generated product features and novelty of described final ideas

Test ID	Camera as a	Use of iDea	Quantity of new product	Novelty of final ideas

[1] See e.g. Canon Powershot D10

	topic		features	
1	Yes	No	3	Medium
2	Yes	No	2	None
3	Yes	No	6	Low
4	Yes	No	3	None
5	Yes	No	5	Low
6	Yes	No	3	Low
7	Yes	No	7	Low
8	Yes	No	2	Low
9	Yes	No	3	Low
10	Yes	No	1	None
11	Yes	No	5	High
12	Yes	No	8	None
13	No	No	3	Low
14	No	No	5	Low
15	No	No	3	None
16	No	No	4	Low
17	No	No	5	Low
18	No	No	5	None
19	No	No	3	Low
20	No	No	7	None
21	No	No	10	None
22	No	No	7	None
23	No	No	5	Low
24	No	No	3	None
25	No	Yes	20	High
26	No	Yes	21	Low
27	No	Yes	31	Medium
28	No	Yes	12	Low
29	No	Yes	14	High
30	No	Yes	20	None
31	No	Yes	28	High
32	No	Yes	8	None
33	No	Yes	16	Low
34	No	Yes	7	Low
35	No	Yes	21	High
36	No	Yes	39	Very high
37	Yes	Yes	28	High
38	Yes	Yes	17	High
39	Yes	Yes	15	Low
40	Yes	Yes	13	Low
41	Yes	Yes	19	High
42	Yes	Yes	13	None
43	Yes	Yes	27	High
44	Yes	Yes	34	None
45	Yes	Yes	20	Low
46	Yes	Yes	18	Low

47	Yes	Yes	14	Low
48	Yes	Yes	30	Low

By considering students' individual creativity as a random factor, each tests differs in terms of the treated case study and the employed support for Product Planning. These two different conditions represent the applied treatments potentially influencing the results. By using Stata software (release 11.0), the authors built two-predictor regression models assessing the role played by the case study and the idea stimulation support with respect to quantity and novelty. Both the influencing factors were introduced as dummy variables. The statistical models aim at verifying the confidence level to which the predictors can be considered influencers of quantity and novelty, by observing the variability of regression coefficients. As foreseen by the software, the null hypothesis is that each independent variable has no effect (has a coefficient of 0). Hence, by studying the simultaneous effect of the two treatments, null (*H0i*) and alternative hypotheses (*H1i*) can be formulated as follows:

H0a: The subject of the test (i.e. cameras instead of coffee machines) does not affect the results of idea generation processes in terms of quantity
H1a: The subject of the test (i.e. cameras instead of coffee machines) affects the results of idea generation processes in terms of quantity

H0b: The employed tool does not affect the results of idea generation processes in terms of quantity
H1b: The employed tool affects the results of idea generation processes in terms of quantity

H0c: The subject of the test (i.e. cameras instead of coffee machines) does not affect the results of idea generation processes in terms of novelty
H1c: The subject of the test (i.e. cameras instead of coffee machines) affects the results of idea generation processes in terms of novelty

H0d: The employed tool does not affect the results of idea generation processes in terms of novelty
H1d: The employed tool affects the results of idea generation processes in terms of novelty.

The regression results display P-values, showing the probability of mistakes in rejecting the null-hypotheses under a suitable statistical model, which differs according to the chosen typology of regression.

5.3.1 Quantity

The term standing for quantity, which is expressed through a natural number, can be conveniently treated as a continuous variable. Therefore, the authors performed a multivariate linear regression to infer the role of case study and employed method. Table 7 shows the results of the regression (R^2=0,64).

The constant stands for the number of expected new product features, which a designer should generate in a three-hour session by exploiting its individual creativity and by treating coffee machines. The results clearly show how the influence of the case study on quantity is marginal (very low coefficient and very high P-value, *H0a* is accepted). Conversely, the employment of iDea is expected to increase the number of generated features to a remarkable extent (about additional 16 new characteristics on average). Besides, the emerged P-value allows claiming the positive effect of the method on quantity with abundant reliability (the probability of its influence is greater than 99,9%), thus leading to reject *H0b*.

Table 7: results of the linear regression model explaining the effects of independent variables on quantity

Regressor	**Regression coefficient**	**P-value**
Camera	-0,042	0,981
iDea	15,708	0,000
Constant	4,521	0,005

5.3.2 Novelty

According to the criteria described in [48], novelty is an ordinal variable. Hence, the authors performed a multivariate ordinal regression to infer the role played by the case study and the proposed methodology. Table 8 reports the results of the statistical model (Pseudo R^2=0,07).
The coefficients associated with the independent variables are the expected increase in log-odds of being in a higher level of novelty, given that the other explanatory factor is kept constant. The constants shown at the bottom of the Table are useful to compute the thresholds where novelty is cut to make the five groups that we observe in our data. For the sake of clarity, with regards to the statistical laws governing ordinal logistic models, we can calculate the ratio between the probability of overcoming a given degree of novelty (*j*) and the probability of obtaining such a level or lower, as follows:

$$\frac{P(Novelty>\mathrm{j})}{P(Novelty \leq \mathbf{j})} = \mathrm{e}^{-constant\_\mathrm{j}+0{,}103\times Camera+1{,}688\times \mathrm{i}Dea} \quad (1).$$

In the formula, the terms *Camera* and *iDea* represent the introduced dummy variables; thus, the factors in the exponent should hold the value 0 or 1 according to the test conditions.

Table 8: results of the ordinal regression model explaining the effects of independent variables on novelty

Regressor	**Regression coefficient**	**P-value**
Camera	0,103	0,852
iDea	1,668	0,005
Constant_none	-0,188	
Constant_low	2,098	
Constant_medium	2,231	
Constant_ high	5,034	

Table 8 highlights that, as in the case of quantity of new product features, the novelty of ideas is positively influenced by the methodology (*H0d* is rejected with a 99,5% probability) and the case study plays an arguable role (*H0c* is accepted).
By assuming the marginal impact of the subject of investigation in idea generation tasks, a new regression was performed viable to isolate the influence of the introduction of the proposed methodology. With reference to the new model, Figure 2 illustrates the 95% range of probabilities in obtaining each level of novelty by exploiting just designers' intuition and benefitting from the presented ideation approach and prototype software. The diagram shows that marginal transformations appear in terms of the percentage of low novelty ideas by using an intuitive approach or the proposed method. Conversely, the employment of iDea allows diminishing the definition of ideas characterized by no novelty and increasing the chances of producing ideas whose novelty ranges from medium to very high.

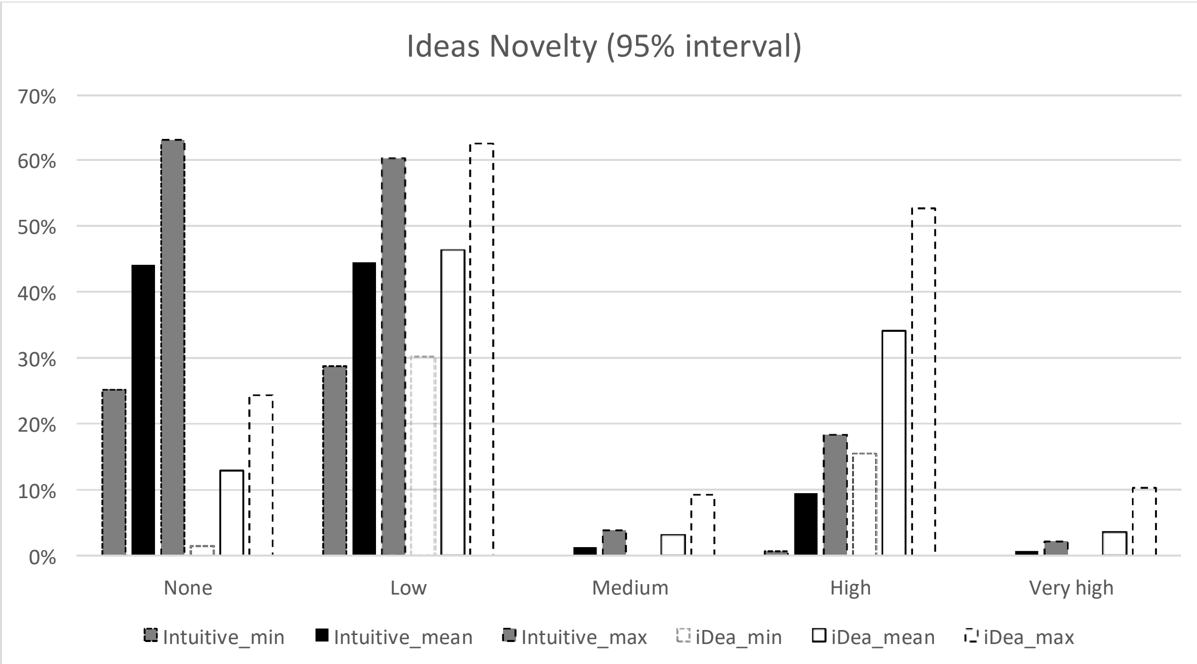

Figure 2: 95% interval and mean probability values of observing a given degree of novelty when relying on intuition (black column for the average value, grey columns for interval extremes' values, with dotted and dashed border for the minimum and the maximum, respectively) and exploiting iDea (white columns, continuous border for the average value, dotted border for the minimum, dashed border for the maximum).

5.4 Implications and limitations

The above regression models remark the powerful influence of a methodology attempting to browse a considerable part of the design space in Product Planning. Despite the limited explanatory power of the tool employment in terms of displaying ideas novelty (low R^2), the exploitation of iDea has resulted fully impacting in shaping ideation processes. In addition to the illustrated outcomes, we can claim the appropriateness of the presented instrument in terms of increasing designers' workload. The authors have observed a growth of the time dedicated to ideation from 106 minutes (on average) for the intuitive session to 148 minutes for iDea session (students were left free to conclude the tests if they thought to produce new ideas no longer).

However, despite the underlined role played by iDea in the experiment, the assessment of its utility in the industry cannot be automatically inferred from the presented results. The first testing session has simulated the ideation process of a designer in an industrial context, in which, as observed in many companies, formal Product Planning methodologies have been not introduced and the generation of novel attributes is entrusted to intuition. In each case, this simulation can result inaccurate by considering the differences between the volunteer students and members of R&D departments, e.g. in terms of experience, domain knowledge, motivation. Besides, certain firms can benefit from different idea stimulation techniques or design-by-analogy methods.

Further on, whereas the main purpose of the developed tool consists in enlarging the explored design space, evaluations can be performed in terms of novelty, but not on variety. The expected reduction of design fixation can be thus deducted by observing the good performances of sessions with iDea, but not verified in a rigorous way.

Section 6 documents the application of iDea performed by a scholar with a great experience on NPD techniques and some specific industrial sector and the chief of a start-up enterprise. The results provide a first overview of the capabilities of the proposed methodology in the industrial environment, thus partially filling the gaps of the above-described experiment.

6. Industrial applications of the methodology: description and discussion

The methodology was thus tested through two additional experiments in which the developed prototype software was exploited. In both cases, the authors participated to the test, by providing any explanation requested by the user in terms of procedures to follow and the meaning of the concepts underlying Dimensions, Specifications and Elements.

However, the authors did not influence the creative process of the users at all, since their participation substantially aimed at saving the time of experimenters, who should otherwise consult the guide.
The purpose of the tests consisted in verifying the applicability of the proposed instrument and its effective capability to stimulate new product ideas for industrial players too. At the same time, the experiments revealed problems related to the utilization of the tool and not predicted benefits descending from its application, further considered as side results. More in detail, the first case study was carried out by a scholar with a vast knowledge about design methods and a great experience in the field of household electrical appliances, matured in manifold projects involving branches of big corporations and SMEs working as specialized suppliers in such an industrial domain. The second experiment involved the project coordinator of a start-up firm, named B10nix (see more at www.b10nix.com). The enterprise designs and produces innovative artefacts exploiting the latest advances in Human-Computer Interaction (HCI) field, with a particular focus on wearable technologies. The involved subject currently coordinates B10nix's research team, besides being legal representative and co-founder of the firm after many years of experience in the field of HCI. Whereas the former was mainly thought to evaluate the usability of the tool and assessing its capability to investigate the design space, the latter mostly aimed at estimating its utility in industrial contexts, by drafting a comparison between the developed method and seeded practices. The tests will be widely illustrated in the following Subsections 6.1-6.2, while further considerations will be drawn in Subsection 6.3.

6.1 Test one: household ovens

The tester decided to analyse the field of household ovens, since he has been recently involved in several research activities devoted to innovate this kind of products. Thanks to his active participation in these activities, the experimenter possesses an up-to-date knowledge about the current competing factors of household ovens and the topics of many long-term NPD projects in this industrial domain.
The employment of iDea regarded all the three combination procedures, whereas no item concerning Dimensions, Specifications and Elements was deselected. This choice was performed for a twofold motivation: on the one hand, all the items were considered pertinent in the given industrial field; on the other hand, this could help the developers assessing the reference time for a full exploration of the associated concepts, as proposed by the methodology. The tester decided to take note of all the emerging product attributes, regardless they were seeded in the industry or original. At the end of the whole idea stimulation task, all the emerged competing factors were classified in known properties, benefits which have been already conceived through previous NPD activities (but not implemented yet), totally original characteristics. Table 9 provides an overview of the results, including the quantity of attributes generated through and the time dedicated to the three modules of iDea.

Table 9: overview of the outcomes of the first experiment involving the developed methodology and iDea prototype software in terms of distinct product attributes generated or clearly identified through the three modules

	Already known and implemented competing factors	Conceived competing factors, not implemented yet	Newly emerged competing factors	Spent time (about)
Quick module	29	15	2	40min
Standard module	93	30	15	40min
Detailed module	143	77	39	3h
TOTAL	**265**	**122**	**56**	**4h 20min**

The outcomes reported in Table 9 demonstrate the capability of the instrument to perform an accurate examination of the possible sources of value characterizing an artefact. Unfortunately, such results cannot be compared with any reference list of attributes and, hence, no statement can be formulated about the capability of the instrument to perform all-encompassing explorations. In any case, the usability of the method through iDea computer application has been verified, since the tester has autonomously produced an articulated bundle of competing factors, including original ideas. The new attributes include both benefits that can be easily fulfilled through existing technologies and more bizarre or futuristic ideas. None of them will be revealed, since the tester will employ them as a driver for proposing the new R&D objectives to partner firms.

6.2 Test two: wearable systems to capture and analyse the movement of people

The products offered by B10nix, although being relatively new in the marketplace, follow a continuous innovation process in order to improve their performance and enlarge the context of use of the developed systems. In this sense, the artefacts that are presented in the homepage of the firm well suit the application of instruments intended to individuate new sources of value. In this perspective, the tester decided to exploit iDea to approach the identification of new business opportunities concerning the use of wearable HCI systems in the context of rehabilitation through physiotherapy. More in detail, the analysed artefacts currently stand in arrays of sensors and electrodes hosted in worn garments or tailored bands, capable to assist injured people in performing physiotherapy exercises and evaluating the extent of improvements. Dedicated software gathers relevant data and supports physiotherapists in the post-processing phase.

The experimenter employed the three combination modules, but some items were excluded, because of being deemed not pertinent to the analysed product (at least in its current stage of development), while some group of Elements was customized by introducing specific terms. Although during the discussion many implemented product attributes were clearly revealed, just new product ideas were recorded. New product attributes, likely to be implemented in subsequent versions of the treated HCI system, emerged by using the combination options as follows:

- 4 new ideas with the Quick module (about 25 minutes spent);
- 9 new ideas with the Standard module (about 2 hours spent);
- 4 new ideas with the Detailed module (about 3 hours spent, whereas the duration of the procedure for customizing the items lasted 25 minutes).

It is worth highlighting that some idea was stimulated through different modules and combinations. The above numbers refer to product characteristics that had not previously emerged during the test.

The content of the ideas will not be revealed, since the tester considered them relevant for future developments of the wearable system to monitor people's movement. They regard both new features to improve the functioning of the product and additional services likely to enhance the experience of using the analysed artefact with respect to a variety of stakeholders.

A final interview was conducted to evaluate the applicability of the proposed instrument in industrial contexts and its supposed efficacy if compared with commonly employed Product Planning practices. The design team is currently performing Brainstorming sessions to generate ideas and planning to follow a more customer-oriented approach, by asking potential users for feedback with respect to new products the firm intends to develop. The outcomes of conjoint Brainstorming meetings are variable in terms of both quality and quantity of produced ideas; the main limitation of this approach stands, according to the experimenter, in the generation of very fuzzy concepts that do not undergo sufficient elaboration because of continuous shifts towards different areas of the design space. In these terms, the employment of the methodology and the developed software allows generating a larger number of ideas if the time spent and the human resources are taken into account. The tester greatly appreciated the possibility to write down and subsequently better define the new benefits to be offered. Indeed, it often happened during the test that new ideas were refined by considering different combinations of dimensions at any detail level. Other strengths of the approach were individuated in the capability to perform a very wide exploration of the possible benefits a product should fulfil, by pointing out the full spectrum of main characteristics taken into account during the initial development of the wearable HCI system, lasting four years. Furthermore, the same experimenter revealed the intention to replicate the task both alone and together with other members of the research team and/or perspective customers. In addition, he affirmed to be optimist about the possibility of individually subsuming the approach of the methodology through a learning-by-doing process, gaining more and more confidence with respect to introduced terms and combinations.

6.3 Discussion of the results of the industrial applications

The tests demonstrated the capability of the discussed tool to help identifying new product features and ideas also for people with a great orientation towards the industrial world. In particular, the application of the developed methodology in a real industrial case (second experiment) shows how the proposed approach has qualitatively overcome the performances of common Product Planning practices. If compared with the time and human resources dedicated to idea generation, the employment of the methodology results a brief task, also thanks to the presence of iDea software prototype. Whereas industrial practitioners would not be inclined to modify their established approach to Product Planning, the exploitation of the developed tool would not however result in a significant loss of time (if the common duration of NPD cycles is considered). In another perspective, the described instrument can be seen as a support for Brainstorming sessions, whose idea stimulation is fostered by the systematic way of exploring potential benefits for users and stakeholders. In this sense, more clear indications will emerge from future tests in B10nix, which should involve more designers simultaneously. Sound indications should be obtained however with regards to the time and difficulty in learning how to effectively use the proposed tools, since both tests were carried out with the presence of the authors.

Further on, both tests have remarked the capability of the method to generate a detailed framework of existing competing factors, besides supporting the generation of new ideas. This side result could be exploited when requiring to perform benchmark activities or to carry out innovation initiatives swivelled on the enhancement of current product attributes. A not minor advantage (see experiment 2) has emerged in terms of highlighting potential benefits by providing services matching the functions of a reference product. In this sense, the developed framework is likely to represent a support in the field of designing Product-Service Systems. The capabilities to better structure the emerged ideas has already been pointed out in Subsection 6.2.

With respect to the number of generated ideas, the quantities of new attributes emerging from the two tests clearly differ. Very diverging outcomes concern also the pace of generating new ideas by using the three modules, as highlighted in Table 10. Whereas standard and detailed modules show the best generation frequency in the first experiment, the quick combination strategy results the most prolific within the second test. These varying results do not allow individuating a most suitable matching mode and, hence, additional tests are required to fine-tune the combination procedures.

Table 10: approximate average time elapsed to stimulate new ideas with the proposed matching modes

	Experiment 1	**Experiment 2**
Quick module	20 minutes	6 minutes
Standard module	3 minutes	20 minutes
Detailed module	5 minutes	39 minutes
Overall	5 minutes	20 minutes

The main weakness of the developed instrument, as revealed by both testers, stands in the possibility of provoking a sense of boredom by submitting the user to a very large number of stimuli. According to their comments, this bad feeling is tolerated whereas the motivation in employing the instrument is high, but drops of attention can likely occur also in these cases. This aspect partially conflicts with the effort paid to increase individuals' workload. The experimenters suggested inverting the items standing for the GD and the other Dimension. They believe that thoroughly analysing aspects concerning a LC, SYS or SH would be preferable rather than specifying GDs with respect to all the variants they can assume by simultaneously considering other Dimensions.

Additional strategies, already outlined by the authors stand in:

- enriching the HCI with pictorial communicational;
- changing the modality through which the suggestions for new attributes are offered (e.g. through formats resembling conceptual maps).

7. Main findings and final remarks

The paper describes an original method to be employed in the initial phases of engineering design tasks, specifically to stimulate the individuation of original benefits in the critical activities constituting idea generation within Product Planning. The authors claim the lack of appropriate instruments to browse the possible sources of value for innovative products and propose an approach that monitors the drivers of new ideas by exploiting a schema constituted by four Dimensions and combination rules among them. The structuring of said dimensions in two different detail levels represents a further original contribution of the paper. The association between items belonging to two different dimensions is believed to favour the creativity process of perspective users. A software prototype has been developed to enhance the usability of the approach and to allow customizing the items to employ for the exploration of new value drivers, which have to be subsequently exploited in the design task.

The development of the present proposals has benefitted from the fundaments of ideation processes illustrated in the literature (see Subsection 2.1). More in particular:

- favouring the exploration of the design space was a premise of the work; unfortunately, the lack of suitable metrics to assess variety in the Product Planning does not allow claiming if this objective has been fully achieved;
- the increase of designers' workload has been verified by observing the rise of the time dedicated by MS Engineering students to perform ideation activities when employing the presented methodology;
- the utilization of general and abstract concepts to arouse analogies has been foreseen, besides allowing the authors to fine-tune a general-purpose instrument, usable in multiple industrial domains.

An articulated testing campaign has revealed the capability of the tool:

- to foster the generation of new product features, by drastically augmenting their number if compared to intuitive strategies;
- to increase the degree of novelty of new product ideas that follow the initial conception of the above features;
- to provide a support for industrial players both for mature systems (such as household ovens) and innovative products developed through long-lasting and accurate design processes (such wearable HCI artefacts);
- to browse existing customer requirements, thus easing benchmarking activities.

The first two points of the above bulleted list represent fundamental criteria to evaluate the effectiveness of idea generation techniques (see Subsection 2.2).

The main drawbacks of the shown toolkit seem to stand in the boredom arising from submitting the user to a protracted series of questions and stimuli, despite the benefits of mental stress claimed in the literature. In this sense, some hypothesized measures are described in Section 6, beyond improving the interface of the software by benefitting of studies in the field of HCI.

Despite the manifold outcomes provided by the two-session tests with Mechanical Engineering students and industrial applications, a complete validation activity is still required. It would consist in the exploitation of the emerged value drivers, their industrial implementation and the verification of the success of the so designed innovative products. Hence, such a validation should require long times before observing market results, clearly incompatible with the divulgation of the findings.

Sections 5 and 6 outline open issues about the effective capabilities of the proposed method. More specifically, a major understanding would be required with respect to the usability of the instrument by research teams instead of individuals, the dependence of the results from individual skills, the capability to support more or less creative people, the potential benefits of introducing stimuli through forms of pictorial communication. Eventually, the developed instrument has to be better linked with the subsequent NPD phases, with a particular attention to idea selection tasks, resulting consistently critical as the number of stimulated product attributes grows.

Any interested reader willing to obtain details about the utilization of the method and the software prototype (as well as its installation for Windows and Mac operating systems) can contact the corresponding author.

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Appendix 1: Most remarkable results of the survey about software applications to aid idea generation: the classification is based on the source through which they were identified and the kind of logic/approach they implement

Source	Name or web address	Category	Functionalities and additional notes
Web (Google search)	http://coggle.it	Brainstorming and Mind Maps	It allows making Mind Maps
	http://creately.com	Brainstorming and Mind Maps	It allows making Mind Maps, diagrams and SWOT analysis
	http://crowdicity.com	Crowdsourcing	It supports the idea management, the collaboration during the NPD and allows making digital Brainstorming sessions
	http://freemind.sourceforge.net	Brainstorming and Mind Maps	It allows making Mind Maps
	http://hypeinnovation.com	Crowdsourcing	It supports the idea management, the collaboration during the NPD and allows making digital Brainstorming sessions
	http://ideagenerator.creativitygames.net	Random words and random images	
	http://innovation.qmarkets.net	Crowdsourcing	It supports the idea management, the collaboration during the NPD and allows making digital Brainstorming sessions
	http://inspire.quirky.com	Patent inspiration tool	
	http://watchout4snakes.com	Random words	
	http://web.singnet.com.sg	Brainstorming and Mind Maps	It allows making Mind Maps
	http://www.accept360.com	Crowdsourcing	It supports the idea management
	http://www.brainbankinc.com	Crowdsourcing	It supports the idea management, the collaboration during the NPD and allows making digital Brainstorming sessions
	http://www.brainstormsw.com	Brainstorming and Mind Maps	It allows collecting and organising photos and texts
	http://www.brightidea.com	Crowdsourcing	It supports the idea management, the collaboration during the NPD and allows making digital Brainstorming sessions
	http://www.comapping.com	Crowdsourcing	It supports the collaboration during the NPD and allows making digital Brainstorming sessions
	http://www.creax.com	Patent inspiration tool	
	http://www.datastation.com	Crowdsourcing	It supports the idea management
	http://www.debonoconsulting.com	Lateral thinking	It also support the implementation of the Six Thinking Hats approach
	http://www.ideo.com	Creative cards	They have been developed to support NPD processes

	http://www.infinn.com http://www.brainstorming.co.uk	Crowdsourcing, random words and random images	It allows making digital Brainstorming sessions and includes several other tools, e.g. SCAMPER, frame change, etc.
	http://www.innovationportal.eu	Crowdsourcing	It supports the collaboration during the NPD and allows making digital Brainstorming sessions
	http://www.inspiration.com	Brainstorming and Mind Maps	It also allows making diagrams
	http://www.matchware.com	Brainstorming and Mind Maps	It allows making Mind Maps
	http://www.mindgenius.com	Brainstorming and Mind Maps	It allows making Mind Maps
	http://www.mindjet.com	Crowdsourcing	It supports the idea management, the collaboration during the NPD and allows making digital Brainstorming sessions
	http://www.moreinspiration.com	Web inspiration tool	
	http://www.mywebspiration.com	Brainstorming and Mind Maps	It allows making Mind Maps
	http://www.nchsoftware.com (ClickCharts)	Brainstorming and Mind Maps	It allows making diagrams
	http://www.patentinspiration.com	Patent inspiration tool	
	http://www.play-factory.it (Cards)	Creative cards	They have been developed to support NPD processes
	http://www.thebrain.com	Brainstorming and Mind Maps	It allows making Mind Maps
	http://www.thoughtrod.com	Brainstorming and Mind Maps	It provides question and hints to help exploring creative directions and finding new ideas
	http://www.xmind.net	Brainstorming and Mind Maps	It allows making Mind Maps
	https://bubbl.us	Brainstorming and Mind Maps	It allows making Mind Maps
	https://company.podio.com	Crowdsourcing	It supports the collaboration during the NPD and allows making digital Brainstorming sessions
	https://www.stormboard.com	Crowdsourcing	It supports the collaboration during the NPD and allows making digital Brainstorming sessions
	www.inova-software.com	Crowdsourcing	It supports idea management and technology scouting
App Store/iTunes (Apple devices)	Blue Ocean Strategy Visualizer BEC-BOM	Blue Ocean Strategy	It includes the BEC-BOM tool
	Blue Ocean Strategy Visualizer (Strategy Canvas)	Blue Ocean Strategy	It includes the Strategy Canvas tool
	Blue Ocean Strategy Canvas	Blue Ocean Strategy	It includes the Strategy Canvas tool
	BigMind - Mind Mapping	Brainstorming and Mind Maps	It allows making Mind Maps
	Brain squeezer	Crowdsourcing	It supports the collaboration during the NPD and allows making digital Brainstorming sessions
	Brainsparker - Creativity and ideas booster	Random words and random images	
	Brainstorming canvas	Brainstorming and Mind Maps	It allows making sketches and organising sticky notes

	Business Idea Generator	Web inspiration tool, Patent inspiration tool	
	Cell storming	Brainstorming and Mind Maps	It allows making Mind Maps
	Concept	Brainstorming and Mind Maps	It allows collecting and organising photos, texts, sticky notes and making sketches
	Effective mind	Random words and random images	
	Evernote	Brainstorming and Mind Maps	It allows collecting and organising photos, texts and making sketches
	iBrainstorm	Brainstorming and Mind Maps	It allows collecting and organising photos, texts, sticky notes and make sketches
	iBrainstormer	Brainstorming and Mind Maps	It allows making Mind Maps
	Idea Generator	Random words	
	ideaMan	Random words	
	Idea sketch	Brainstorming and Mind Maps	It allows making Mind Maps
	IdeaDeck	Brainstorming and Mind Maps	It allows collecting and organising sticky notes and make SWOT analysis
	Ideas (brainstorming, mindmapping and inspiration)	Brainstorming and Mind Maps	It allows collecting and organising thoughts (texts, words)
	Ideas Blitz	Brainstorming and Mind Maps	It allows collecting and organising thoughts (texts, words)
	Ideas flux	Brainstorming and Mind Maps	It provides hints to help exploring creative directions and finding new ideas
	Ideator	Random words	
	Ideatron	Brainstorming and Mind Maps	It allows making sketches and notes
	IDEO Method Cards	Creative cards	They have been developed to support NPD processes
	Inkflow Visual Notebook	Brainstorming and Mind Maps	It allows collecting and organising photos, texts and making sketches
	iMindQ (mind mapping) | Brainstorming app	Brainstorming and Mind Maps	It allows making Mind Maps
	iMindMap/iMindMap HD	Brainstorming and Mind Maps	It allows making Mind Maps
	Innovate - Innovation & Creativity Community	Web inspiration tool	
	Inspireme	Random words	
	Intuiti	Creative cards	
	MindNode	Brainstorming and Mind Maps	It allows making Mind Maps
	MindMeister	Brainstorming and Mind Maps	It allows making Mind Maps
	MyInvention	Brainstorming and Mind Maps	It provides hints to help exploring creative directions and finding new ideas
	Popplet	Brainstorming and Mind Maps	It allows making Mind Maps
	Riffer idea generation and brainstorming tool	Brainstorming and Mind Maps	It allows collecting and organising photos, texts, and make sketches
	SimpleMind	Brainstorming and	It allows making Mind Maps

		Mind Maps	
	Super research idea generator	Random words	
Google Play Store (Android devices)	Android Idea Book	Brainstorming and Mind Maps	It allows collecting and organising thoughts (texts)
	Brainstorm List: Brainstorming	Brainstorming and Mind Maps	It allows collecting and organising thoughts (texts)
	Brainstorming App	Brainstorming and Mind Maps	It provides hints to help exploring creative directions and finding new ideas
	Brainstorming: Dynamic New Way	Brainstorming and Mind Maps	It provides hints to help exploring creative directions and finding new ideas
	Brainstream	Brainstorming and Mind Maps	It allows collecting and organising thoughts (texts)
	Business Ideas Pro	Web inspiration tool	
	Connected Mind	Brainstorming and Mind Maps	It allows making Mind Maps
	Create-O-Mat	Random words	
	Creative Ideas (App Innovation)	Web inspiration tool	
	creative ideas (AnaCoder)	Web inspiration tool	
	Creative Thinking	Brainstorming and Mind Maps	It provides hints to help exploring creative directions and finding new ideas
	Creative Thinking Techniques	Lateral thinking	
	Creative Ways Wallpaper	Brainstorming and Mind Maps	It provides hints to help exploring creative directions and finding new ideas
	Creativity Inspire Innovation	Brainstorming and Mind Maps	It provides hints to help exploring creative directions and finding new ideas
	Creator Studio	Brainstorming and Mind Maps	It provides hints to help exploring creative directions and finding new ideas
	Entrepreneur Business Ideas	Brainstorming and Mind Maps	It provides hints to help exploring creative directions and finding new ideas
	Idea (hwkhlp.com)	Crowdsourcing	It supports the collaboration during the NPD and allows making digital Brainstorming sessions
	Idea (Idea App, LLC)	Brainstorming and Mind Maps	It allows collecting and organising photos and texts
	Idea Card	Creative cards	
	Idea Generation MindMap	Brainstorming and Mind Maps	It allows making Mind Maps
	Idea Generator	Random words	
	Idea Growr	Brainstorming and Mind Maps	It allows collecting and organising thoughts (texts) and provides hints to help exploring creative directions and finding new ideas
	Idea Napkin	Brainstorming and Mind Maps	It allows making sketches
	Idea Note	Brainstorming and Mind Maps	It allows collecting and organising thoughts (texts)
	Idea Share	Brainstorming and Mind Maps	It allows collecting and organising thoughts (texts)
	Idea Tracker	Brainstorming and	It allows collecting and organising

		Mind Maps	thoughts (texts)
	idea Training	Brainstorming and Mind Maps	It provides hints to help exploring creative directions and finding new ideas
	Ideas by Brightidea	Crowdsourcing	It supports the idea management, the collaboration during the NPD and allows making digital Brainstorming sessions
	iMindMap/iMindMap HD	Brainstorming and Mind Maps	It allows making Mind Maps
	Inspiration	Random words and random images	
	Intuiti	Creative cards	
	MindCanvas	Brainstorming and Mind Maps	It allows collecting and organising photos, texts, and making sketches
	MindMemo	Brainstorming and Mind Maps	It allows making Mind Maps
	Mindomo	Brainstorming and Mind Maps	It allows making Mind Maps
	Random Ideas	Random words	
	SimpleMind mind mapping	Brainstorming and Mind Maps	It allows making Mind Maps
	Thinker	Brainstorming and Mind Maps	It allows making Mind Maps
Store (Windows devices)	Idea Sketch	Brainstorming and Mind Maps	It allows making diagrams
	Think creative	Brainstorming and Mind Maps	It allows collecting and organising photos, videos, texts and making sketches
	Flow Chart Marker	Brainstorming and Mind Maps	It allows making diagrams
	Brainstorming	Brainstorming and Mind Maps	It allows making Mind Maps
	Mind Map	Brainstorming and Mind Maps	It allows making Mind Maps
	Brain_Squeeze	Brainstorming and Mind Maps	It allows collecting and organising thoughts (texts)
	Concept Mapper	Brainstorming and Mind Maps	It allows making Mind Maps
	FtsMind	Brainstorming and Mind Maps	It allows making Mind Maps
	MindMaps	Brainstorming and Mind Maps	It allows making Mind Maps
	Simple Thoughts	Brainstorming and Mind Maps	It allows making Mind Maps
	InvulgoMindMapper	Brainstorming and Mind Maps	It allows making Mind Maps
	Mindmap	Brainstorming and Mind Maps	It allows making Mind Maps
	Mapidea	Brainstorming and Mind Maps	It allows making Mind Maps
	Blue Ocean Strategy	Blue Ocean Strategy	It includes the Strategy Canvas and Four Action framework tools
	Evernote	Brainstorming and Mind Maps	It allows collecting and organising photos, texts and making sketches
	M8! –Mind Map	Brainstorming and Mind Maps	It allows making Mind Maps
	Freemind	Brainstorming and Mind Maps	It allows making Mind Maps