Article

Biology of Creativity: A Nondesign-Inspired Model to Enhance Creativity and Innovation Skills

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Abstract: From the merge of arts and crafts towards a practice for mass production of desirability, consumption and product development in a capitalist economy of scale, design has lost its natural ability of problem comprehension and tension alleviation. The modern world needs the creativity, flexibility, and responsiveness embedded into design practices, mostly when a behavioural change, either individual or organizational, is intended. Still, the informality nature of the field is creating a gap between the study, research, and industrial design practice. Here it is presented the Biology of Creativity Model (BoC) which is a design-by-analogy method that promotes an empowered design practice through analysis of mostly biology reference texts for enhanced creativity and innovation performance in a diverse array of contexts.

Keywords: design education; design activity; design model(s); analogical reasoning; bio-inspiration

1. Introduction

Design has been exploring artistic fields however its practice has been neglecting other fields of knowledge. The multifactor nature of current challenges is paving the way to wider perspectives about the practice of design (Whitney and Nogueira, 2020). Therefore, in the recent years, biology has entered the design field as a discipline of inspiration and manufacture (Yargin *et al*., 2018; Chirazy *et al*., 2019; Cao *et al*., 2021), through analogy (Fu *et al*., 2014; Moreno *et al*., 2016; Nagel *et al*., 2018) and abstraction-based design models and processes (Goldschmidt and Sever., 2011; Lenau *et al*., 2015; Deng *et al*., 2021). However, in contrast with other sciences, the design field is coined with a fragmentation of its body of knowledge which makes it harder to solidify new discoveries into a standardized practice (Whitney and Nogueira, 2020; Meyer and Norman, 2020). Therefore, it is paramount to foster a simple language upon which further methodologies can be built on, increasing the design-led practitioners to solve planetary challenges in a more comprehensive way.

2. The Problem of Design

The current challenges for designers are systemic since the boundaries between objects, structures, systems, and processes are less defined and much more continuous and evolving (Meyer and Norman, 2020). It may seem obvious, but the speed of change unveils a challenging question for the current design paradigm, which is the inability of approaches developed in the 20th century to solve 21th century challenges. We live in the storm of the fourth industrial revolution, and it is disrupting the production, management, and government realities we have known for several decades (Schawb, 2017). Therefore, designers need to be empowered by new competences in the physical, digital, and biological spheres (Wilde, 2020).

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2.1. A new educational approach for design

A novel transformation in design is necessary, one that encompasses a refocus of the design practice, that merges the individual, industrial, and governmental behaviours that allow a healthier planet, safe from disastrous human activities that could potentially eliminate the risk of a global emergency. So, a suitable approach in design education must embrace a deep awareness for a competency-based model that paints a picture for the student rather than starting from the 'blank' (Baha *et al*., 2020). If not diverse and independent, design education will form students with tendencies for those biased and standard practices and strategies, hampering their career development. Whilst seeking confirmation and comfort design students will undermine their full and unique potential (Adams *et al*., 2011; Gray, 2014; Kosonen, 2018; McDonnel, 2015; Tracey and Hutchinson, 2018; Baha *et al*., 2020).

2.2. A revitalized design practice

At today's perspective, the design practice has lost the critical thinking referential through which designers ask themselves what the necessary "whys" and "hows" are for a good design and for a certain desired effect (Dorst, 2003). The current limited scope of design practice is seen in the absence of designers in the decision-making fora. Contrary to science or management areas, there is a lack of standardization in the design field (Whitney and Nogueira, 2020; Meyer and Norman, 2020). According to Whitney and Nogueira (2020), "design continues to produce novel solutions to specific problems but falls short in building knowledge that acts as a context for the various activities we call design". Therefore, it is urgent a novel and rigorous approach that capacitates designers with new competencies and lexicon in order to follow the world's needs and trends regarding development of products and services. Simultaneously, it is also urgent to exponentially increase the designers' comprehension of the broader setting where they operate.

3. Biology of Creativity model

3.1. Definition and purpose

The Biology of Creativity (BoC) model is an internationally validated process of innovation and creativity that makes use of reference texts originated essentially from biology to perform critical analogic thinking. The underlined provocation follows the question: What we ought to know about design if we only know and stay within the design field?

Therefore the purpose of the BoC model is to facilitate the relationships between different areas of knowledge by the meaning of straightforward abstractions that will interact among themselves, creating a fertile ground for creativity and innovation to happen in a multitude of contexts (Graff *et al*., 2020). This way the BoC model produces abstractions that allow the better comprehension of dissimilar phenomena. The resulting descriptive equation occurs from their detected similarities. The ultimate goal is to empower the creative and innovative processes of people and organizations, irrespectively of their *modus operandi*, allowing a healthier and necessary maturation period in order to achieve a more complete productivity.

3.2. The BoC model process

One word worth more than a thousand images. The interaction between texts is a relevant form of comprehension of psychological, social, and economical phenomena (Kintsch, 1988, LaRusso *et al*., 2016). Each text, paragraph, word, and each element gathered from a group of texts, forms a coherent content that originates a collective and multiple entity that evolves and renews itself into new, different, and unexpected perspective-dependent configurations. Therefore, the comprehension of texts is a powerful and simple method to create an ever-renovated movement of comprehension.

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In physics anisotropy is usually defined by a body's responsive behaviour when stimulated to act in different spatial directions (Rajagopal, 2015; Parisi, 2022). Thus, the same can be assumed when an array of discrepant perspectives (that may be related to modern trends, music, arts, of even to scientific fields) are applied to the comprehension of texts. This event creates an uncomfortable perception that generates curiosity, reflection and, potentially, innovation and creativity.

The incorporation of a single new element creates a disequilibrium due to the non-stable character of the properties that are originated from the comprehension of a groups of texts. Such disequilibrium is not trivial and encompasses the basic notion of resiliency happening throughout the learning process, which may be defined by the interchange of equilibrium and disequilibrium states (Che *et al*., 2010; Parisi, 2022).

According to literature there are several benefits of using design-by-analogy models. They are mostly related to the novelty of ideas, and they were defined as the "threshold of open goals" (keeping the original goals in the short-term memory while performing analogical thinking), "narrowed scope of design space" (through the design fixation problem), "full functionality points to (holistic) system level of design, limited functionality points to limited scope of problem" (by addressing the big picture of the design problem), "difficulty in mapping narrow functionality" (allowing a better comprehension through the use of less functional analogies), "more functionality equals to more opportunity for analogical transfer", and "potential sweeter spot in level of functionality" (through the combinatorial effect of the analyses) (Fu *et al*., 2015). Although, these assumptions were not directly addressed in the BoC model. The intention of the BoC model was to simplify the analogical effort of the participants by making use of a stepwise process with facilitating tools to expand and improve the fluidity of creativity and innovation processes, taking advantage of reference texts mainly sourced from the biological sciences.

3.3. Methodology

The BoC's methodology starts from the assumption that all companies, organizations, processes, products, territories, *etc*, continuously compare past experiences, and design and update their point of view as active members of the society (Taylor and Greve 2006; Easton and Rosenzweig, 2012; Christensen and Ball, 2016; Alerasoul *et al*., 2022).

In a broader design of innovative and creative content and processes, a relationship between disperse elements are established which force the design approach to respond to the new information. In summary, relationships might occur in two main spectra: spatially – resulting from distant elements – and temporally – resulting from time-separated elements. Therefore, these two spectra potentially originate constructs that can be homogeneous (constituted by similar elements), or heterogenous (constituted by dissimilar elements).

In practice the BoC model is constituted by four phases and two facilitating working tools. Thus, the BoC model is a closed model represented by a guidance reference letter that is explained as follows:

1. Phase 1 – Information is characterized by a contextualization of the texts to be analysed;
2. Phase 2 – Objectives is characterized by the definition of what is meant to be achieved;
3. Phase 3 – Actions is characterized by the enunciation of the planned activities;
4. Phase 4 – Project is characterized by the practical definition of the project structure and consequent action plan.

3.4. Scientific assumptions

The scientific conjecture of the three first Phases – Information, Objectives, and Actions – is developed by the means of reflection exercises based on analogic thinking. Every moment and thinking steps of the BoC model are based on the exposition of reference

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texts in the form of paragraphs. These paragraphs are curated from a diverse array of fields of knowledge, predominantly from biology, but also from economy, anthropology, archaeology, genetics, psychology, sociology, cosmology, history, *etc*. The intentional appropriation of other disciplines has the intention to provoke associations between the texts, images, and subsequent constructs. The BoC model promotes an analogical thinking between these texts and organizations, companies, products and services, territories, *etc*. Moreover, the achieved text-text or text-image-construct associations resemble a spatial resonance – possessing a semantic elasticity through approximation and separation –, and a temporal resonance – in a chronological perspective.

The correspondent extrapolation to putative new realities is participant-dependent, since they belong to different contexts (e.g., companies, organizations, processes, products, territories, *etc*). In each of the first three Phases it is asked three questions mainly coming from the biology field. These questions invite the participants to further ask questions in relation to their own setting, in an innovation and creativity manner. The Phase 4 – Project is developed in terms of a new project, taking in consideration its characterized elements and their relation to the theoretical scope of the previous Phases.

3.5. Phases – Information, Objectives, Actions, Project

3.5.1. Phase 1 – Information

During this Phase the goal is to answer the following questions through the reference texts as guidance:

A – Are we homogenizing the environment?;

"Among other organisms, the genetic variability in insects is negatively affected in more populated human area. Additionally, the human interference in the more remote areas is stressing insects' populations as well. As an example, researchers have found that the introduction of European plant species in Antarctic remote islands decreased the local insect's species' richness. We are homogenising the environment" (Milman, 2023).

A – Are we homogenizing the products?;

Analogically, we may state that the variability between products is less in more populated areas. Additionally, the interference that exotic products exert on local cultures is contributing to the local products' extinction, or at least overshadowing them. We may say that the introduction of exotic products in more remote locations tend to uniformise local products. Therefore, we are homogenising the products.

B – City birds have an increased capacity to approach strange objects?

"The neophiliac attitude, *i.e.* the animals' ability to approach and interact with uncommon objects, is seen for instance in the increased capacity that city birds have to approach strange objects in comparison to non-city birds. Thus the city birds are less cautious than usual when facing the new and strange objects present in their environment for evolutive reasons" (Schilthuizen, 2019).

B – What companies, organisms, etc, have the capacity to approach uncommon environments?

Analogically, we may state that there are neophiliac companies and enterprises, with the ability to approach and explore uncommon environments. This behaviour manifests itself in the ability and interest that multinational companies have in approaching strange contexts in a swift manner compared to local ones. Multinational companies are less cautious than usual in relation to the risk they assume for new and unknown objects present in their environment.

C – Are we becoming only capable of prosper in specific habitats?

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"The evidence leads us to believe that the human species – generalist and able to colonize every environment – is quickly becoming in a specialist species, only able to prosper within specific habitats, like our cities. We can describe our cities using the concept of ecological niche, embodied by the habitat's essential characteristics; the only place where our specialization path is allowing the best survival chances" (Mancuso, 2020).

C – What companies, organisms, etc, have the capacity to approach uncommon environments?

Analogically, we state that companies, organisms, *etc*, possessing a generalist profile (able to adapt a different environments) are becoming into specialists, only able to prosper in specific habitats/contexts/markets. We may also describe most companies using the concept of ecological niche, embodied by the habitat's essential characteristics; the only place where our specialization path is allowing the best survival chances.

After this Phase, it is introduced a theme associated with one sociological context that aims to:

1. Its own relation to the three analysed reference texts;
2. Its succession (by concatenation) outcome, seen as cause-effect relation;
3. The generation of emergent properties, where each reference text's limits are blurred allowing the appearance of culturally enriched undefined constructs.
4.

3.5.2. Phase 2 – Objectives

During this Phase the goal is to answer the following questions through the reference texts as guidance:

A – Are the today's adaptations the product of yesterday's natural selection?

"Evolution is in many aspects a sort of a late nature's conscience upon which the today's adaptations are the product of yesterday's natural selection. How can an animal species be pre-adapted if evolution is unable to see the future or to prepare any organism for what is coming? The urban environment offers conditions that accidentally resembles, by one or more features, the way of life of some species before the appearance of cities" (Schilthuizen, 2019).

A – Is the companies', organisms', products', etc, innovation the result of a pre-adaptation?

Analogically, the innovation seen in companies, organisms, *etc*, and their products, are, in many aspects, some late consciousness in which the today's adaptations are the result of the yesterday's natural selection. The new environments, like new markets, offer conditions that resemble (by accident), by one or more characteristics, the previous ones, resulting in a pre-adaptation, before new contexts being born.

B – Do animals and plants have a kind of evolutive capital?

"The permanent genetic variation is, thus, some sort of evolutive capital, that allows the species in possession of such capital to take advantage of its genetic wealth, and to quickly produce any combination of genes required by an altered environment. Animals and plants, for instance in need to adapt to an added element in the environment, do not need to wait to mutations to happen. In most cases, the necessary genetic variations are already there" (Schilthuizen, 2019).

B – Do companies, organisms, etc, and products have some sort of evolutive capital?

Analogically, we may observe that companies, organisms, *etc*, and products in possession of evolutive capital – allowing them to take advantage of their genetic wealth, like

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experiences, technologies, processes, *etc* – quickly produces any combination of characteristics required by an altered market environment. Companies, organisms, *etc*, and products that, for instance, need to adapt to an added market element, do not need to wait until deep mutations occur. In most cases, the necessary variations are already there.

C – Can we have different results when starting from the same DNA?

"We know that the human skin can darken tan if exposed to sunbathe and the hair can lighten. In most of our physical features both nature and environment's influence play a role. And it applies to all animals. That is what is called plasticity, in which different results may occur when starting with the same DNA. For instance, when we observe a difference in the colour between the populations of the same animal or plant species living in different ecosystems, it may be an example of plasticity" (Schilthuizen, 2019).

C – Can the same inherent characteristics in companies, organisms, etc, and products, may have different results?

Analogically, in some companies, organisms, *etc*, and their products, the inherent characteristics are not everything. There is a group of emergent characteristics that result when the environment's influence enters in play. That is what is called plasticity, in which different results may occur when starting with the same inherent characteristics. For instance, when we observe differences in different environments, it may be an example of plasticity.

After this Phase, similarly to the previous Phase – Information, it is introduced a theme associated with one sociological context that aims to:

1. Its own relation to the three analysed reference texts;
2. Its succession (by concatenation) outcome, seen as cause-effect relation;
3. The generation of emergent properties, where each reference text's limits are blurred allowing the appearance of culturally enriched undefined constructs.

3.6. Phase 3 – Actions

During this Phase the goal is to answer the following questions through the reference texts as guidance:

A – Are there organisms that adapt to other organisms that in turn can evolve?

"There is one type of evolution, empowered by the unlimited possibility of the adaptation process, that is observed when one organism must adapt not to something physical, but to other organism, that in turn may evolve. The evolution of one part stimulates the evolution of the other and has one ecological interaction that connects both organisms as a net result, as two engaged species in a single continuous relationship of predator/prey, evolving continuously, both in the scope of processes, or the offensive/defensive techniques" (Schilthuizen, 2019).

A – Are there companies, organisms, etc, and products that adapt to other entities that in turn can evolve?

Analogically, there is one type of evolution in companies, organisms, *etc*, and products that is empowered by the unlimited possibility of the adaptation process, that is observed when one company, organism, *etc*, or a product evolve and adapt to other company, organism, *etc*, or product, that in turn can evolve. The evolution of one part stimulates the evolution of the other, and has one interaction that connects companies, organisms, *etc*, and products between themselves, becoming engaged into a continuous relationship with the purpose of, for instance, one overpowers the other, or that they progress together.

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B – Can two plants unite into one unique individual under particular circumstances?

"By Merging two bionts – independent living material units – through a graft, we may in theory, create a new plant that unifies the positive characteristics, like two apple trees, *i.e.*, a new apple tree that is simultaneously resistant to drought and able to produce magnificent apples. Two similar plants that face permanent contact, for instance at the trunk or between branches, can, under particular conditions, merge into a unique individual, by inserting a part into the other" (Mancuso, 2020).

B – Can two companies or products unite into one unique individual?

By Merging two companies, organisms, *etc*, or products through a graft, we may in theory, create a new company or product that unifies the positive characteristics, like two products, *i.e.*, a new product that is simultaneously adaptable to two different environments. Two companies, organisms, *etc*, or products that face permanent contact, for instance by being present in the same market, can, under particular conditions, merge into a unique company, organism, *etc*, or product, by inserting some characteristics from one into another.

C – Is it possible that some temporary combinations last longer than others?

"There is no differential reproduction in the abiotic world, but we may get variations of differential persistence: some temporary pieces' combinations last longer than others, thus having more time for reviewing and adjustments. The differential persistence must, somehow, transform itself gradually into differential reproduction, multiplying its advantage by… multiplication. The differential reproduction may happen because of a 'lucky collision' of two non-related elements, 'serendipity', with a happy outcome, as opposition to a 'demolition' with a destructive outcome" (Dennett, 2017).

C – Is it possible that some temporary combinations of elements last longer than others?

Analogically, both in the context of companies, organisms, *etc*, as in products, some temporary combinations of elements, characteristics, technologies, materials, markets, *etc*, last longer than others, thus having more time for reviewing and adjustments. The differential persistence must, somehow, transform itself gradually into differential reproduction, multiplying its advantage by… multiplication. The differential reproduction may happen because of a 'lucky collision' of two non-related elements, 'serendipity', with a happy outcome, as opposition to a 'demolition' with a destructive outcome.

After this Phase, similarly to the previous Phases – Information, Objectives, it is introduced a theme associated with one sociological context that aims to:

1. Its own relation to the three analysed reference texts;
2. Its succession (by concatenation) outcome, seen as cause-effect relation;
3. The generation of emergent properties, where each reference text's limits are blurred allowing the appearance of culturally enriched undefined constructs.

3.7. Phase 4 – Project

The three questions presented during this Phase show the idea of concatenation as an assumption, which results from a previous association, and in succession with the three reference texts discussed during the previous Phases. Thus, starting from the Phase 1 – Information, until the Phase 3 – Actions, there is an objective rationale directed to a context of project, and under the scope of a cause-effect relationship.

A – What is the reference board, the context, and the elements of the project?

This happens when each project's proposed element has a meaning that depends upon a reference context.

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B – What are the combinatory probabilities/possibilities between the project's elements?

This happens because of the possible number of modes, in which a group of elements, context, and reference board, can be exposed or combined, thus resulting into a possible project's 'object'.

C – What are the emerging properties resulting from the pertinent combinations?

This happens when the project's 'object' results into a property/characteristic that does not come from the description of its individual elements but from the interaction and junction between the elements to form an entity.

During the development of the Phase 4 – Project, it is introduced themes from the scope of sociology, anthropology, culture studies, *etc*, that stimulate and focus a better and broader contextualization for the working projects, that polarizes themselves amongst: a strategic dimension like the incorporation of design within organizations; passing through communication actions like the creation of narratives; until the corporeality of 'products'.

4. Extenders and Unlockers

Extenders and Unlockers are active working tools that are used during the entire BoC process. Extenders have the objective of extending a particular subject or text towards another reference resource, or towards a similar theme, thus improving its comprehension. They are usually used during Phase 1 – Information, Phase 2 – Objectives, and Phase 3 – Actions. Unlockers are mostly used during the Phase 4 – Project, and their objective is to unlock certain project moments that, for some reason, presented hurdles for the creative progression. The Unlockers are texts that allow a better decision-making process based on the elements of the project and let the widening of the observing and thinking ability of the audience. Therefore, Unlockers present a practical feature of the project, improving the deliberation of its actionable parameters.

In summary, Extenders and Unlockers' aim is to facilitate the learning of concepts and the materialization of project's constructs. These two tools are used in accordance with particularities related to the target audience, the quality, and characteristics of the previously considerations, analogies and associated themes analysed and generated.

4.1. Examples of Extenders

As an example, we may refer a first text that can be introduced in the reflection process, that points to the concept of 'entanglement' that results when quantum particles entangle each other and thereafter cannot be described as independent particles. This concept allows for instance to reinforce texts and questions enunciated in the Phase 3 – Actions, such as: "Can two plants unite into one unique individual under particular circumstances?"; which in turn refers to an associated question: "Can two companies or products unite into one unique individual?"

As a second example of Extenders, we may refer a second text that can be further introduced which mentions to the idea of 'speciation' that results from the process upon which natural populations evolve to become distinct species, generating variety. Similarly to the previous extender text, it allows for instance the reinforcement of texts and questions enunciated during the Phase 2 – Objectives, such as: "Can the same inherent characteristics in companies, organisms, *etc*, and products, may have different results?"

4.2. Examples of Unlockers

As examples of Unlockers, we may refer a first text that points to the concept of 'counter examples', that results from the association between negative and positive examples, which in turn focus the relation between characteristics that opposes each other and so they can be contained or excluded into a project's 'object', allowing a better objects' definition.

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A second example, acting in sequence from the previous Unlocker, refers to the concept of 'polarity', that results from the higher or lower tension between two opposing elements, and that are defined in the scope of the same project's 'object', or between 'objects'.

5. Reflection's example

Following the next examples, the purpose of the BoC model can be stated in thesis as the reflection and identification of elements aiming the careful definition of an action plan.

5.1. Example 1

Let's take as example one real 'problem' that can interfere in the context of companies', organizations', processes', products', territories', *etc*, activities, that is mentioned in the Jeremy Rifkin's book entitled "The Zero Marginal Cost Society: The Internet of Things, the Collaborative Commons, and the Eclipse of Capitalism":

"Everywhere a younger generation is sharing bicycles, cars, houses, clothes, and many other numerous articles, preferring the access to the possession. An increasing number of young adults choose not to have branded articles in favour of more generic ones or brands with a higher purpose. These youngsters are revealing themselves as much more interested in the materials' goods usability value, rather in the interchangeability or status value. An economy of share comprised of collaborative prosumers is, in its genesis, a more empathetic and less materialistic one. The unbridled consumption was replaced by an economy of sharing" (Rifkin, 2014).

This reference text refers to the essential question – Are companies, organizations, processes, products, territories, *etc*, prepared to a shift in the economy that tends in a greater extent to sharing and to the common goods? In this context, what elements are necessary to answer to this new reality, in the scope of the questions enunciated in the BoC model, such as: "What companies, organisms, *etc*, have the capacity to approach uncommon environments?", or, "Are companies, organisms, *etc*, only capable of survive in specific markets?" In summary, do companies, organisms, *etc*, that show elements pre-adapted to the new context have more chances to adapt and thrive in the new reality characterized by the change in the economical paradigm?

5.2. Example 2

Let's take as example one real 'problem' that can interfere in the context of companies', organizations', processes', products', territories', *etc*, activities, that is mentioned in the Gilles Lipovestky's book entitled "Le Sacre de L'autenticité":

"There is no exclusive value attributed to the singularity of subjects, but also to the singularity of objects; there is no exclusive fidelity's glorification to the subjective self, but also to the fidelity of brands in relation to themselves; there is no exclusive appreciation for the 'natural' behaviour of people, but for the ecological products that respect the environment as well. The authenticity ideal, originally intra-personal, penetrated in the universe of the 'things' and of the company: we desire, everywhere, meaning, truth, transparency, naturality, sincerity, fidelity to the new self. The hypermodern universe is characterized by the authenticity ethics' extension to the products' saleable sphere" (Lipovetsky, 2021).

This reference text refers to the essential question – Are companies, organizations, processes, products, territories, brands, *etc*, prepared for a fidelity ideal towards themselves, one of authenticity that penetrates the universe of products, and to the creation of transparent and truthful narratives? In this context, what elements are necessary to answer to this new reality, in the scope of the questions enunciated in the BoC model, such as: "Are we homogenizing the products?", and "Do companies, organisms, *etc*, and products have some sort of evolutive capital?" In summary, do companies, organisms, brands, *etc*, have an evolutive capital that distinguish themselves as the singular authentic subjects, that allows them the creation of transparent and truthful narratives? And that in a

 doi:10.20944/preprints202303.0272.v1

way that allows them the creation of non-homogeneous products in the cultural context that tends to the globalization trend and loss of identity?

6. Evaluation and Results Parametrization

The BoC model, its process and setting, throughout its four Phases – Information, Objectives, Actions, and Project, permit the identification of a transversal structure of innovation and creativity, and allows the evaluation and parametrization of the obtained results. Hence, by the identification of variables, features, and patterns, the participants improve their operative lexicon, thus granting the development of the BoC model itself as well.

Specifically, the BoC model makes use of four expansive parameters for its evaluation and parametrization:

1. Creative Cycle;
2. Imaginative Capacity;
3. Patterns' Identification; and
4. Lexicon Enrichment.

6.1. Creative Cycle

The first parameter is related to the Creative Cycle offered by the BoC model and it can be defined by four distinct creative moments observed by the:

1. Capacity of identifying pertinent texts;
2. Capacity of apprehend and formulate abstractions; and by the
3. Capacity in completing the creative working sequence, generating new objects of knowledge.

6.2. Imaginative Capacity

The second parameter is related to the Imaginative Capacity in analysing dissimilar texts with a variable degree of distance, which implicates a variable and associated imaginative capacity to build interesting, innovative, and creative narratives.

6.3. Identification of Patterns

The third parameter is related to the Identification of Patterns. It results from the identification of words and meanings from the exposed texts that motivated analogic thinking and further lead to a better comprehension of practical realities. This capacity depends on the audience and its efficacy varies depending on the tailored introduction of different perspectives.

6.4. Lexicon Enrichment

The fourth and last parameter is related to the Lexicon Enrichment throughout the process, and it is observed by the increase of the available lexicon. In practice, the quality of the available lexicon is observed by the participants' improvement of thinking, comprehension, and description of the exposed realities. The Phase 4 – Project is the one that enables the validation of the achieved progress, by the evaluation of more elaborated and meticulous definitions.

7. Application

The BoC model here presented was previously developed and validated in a set of workshops realized in the context of University Programs (Bachelors, Masters, and PhDs programs) and Research Groups, Business Associations, and blended groups of students and professionals, in Spain, Italy, Brazil, Portugal, Japan, and China.

The BoC model can be applied during workshop sessions that are developed during an ongoing methodology of 16 hours. The practice is preferably divided in four sessions

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occurring in different days. A single Phase – Information, Objectives, Actions, Project – is developed during each session.

At the beginning and at the end of each workshop session and in accordance with the audience's profile, four questions are asked for implicitly influence every BoC model Phase – Information, Objectives, Actions, Project. They have the goal to analyse the progression and improvement in the reflection and comprehension, and innovation and creativity skills of the participants during the entire process. Therefore, the BoC model assumes the main purpose of improving such skills in a tangible way. The questions are:

1. What is the surrounding sociological perspective of your organization?
2. What are the actionable points that you wish to obtain and develop?
3. What 'products' do you hope to make?
4. What are the particular features that these new 'products' must possess?

Consequently, the answers to the same questions happening at the end of the workshop must reveal an improved capacity of creative competence, observed by a more complete "Creative Cycle", a greater "Imaginative Capacity", a better "Identification of Patterns", and a clear "Lexicon Enrichment".

Additionally, these four Evaluation Parameters serve the diagnostical purpose for a variety of audiences, such as companies and organizations, and to creative practitioners (like designers) as well. These parameters allow the tangible evaluation of competences for innovation and creativity. So, it is possible that one entity may be able to critically observe and comprehend practical realities using abstractions although being unable to complete the creative process and consequently unable to generate new objects of knowledge. This setting is casually observed, and it may be explained by the homogenization of the technical and managerial competences within the organization. Other causes may also explain this dogmatic setting like the absence of progressive learning practices (Alerasoul *et al*., 2022), the exclusive orientation towards specific and known markets (Mutanen, 2008; Kurniawan *et al*., 2021), thus avoiding the risk-taking activities associated with the exploration of unfamiliar environments (Bertola and Teixeira, 2003; Rhee *et al*., 2010). Such limitations are aggravated by the utilization of a poor lexicon in the definition of strategies, objectives, and other leadership decisions (Buehring and Bishop, 2020; Wan and Lin, 2022).

8. Conclusions and future work

If companies, organizations, processes, products, territories, *etc*, in a first moment must have the capacity of moving between apparently dispersed signals, in an expanding attention, that widen the horizon, in a second moment, they must have the capacity of concentrating themselves, ignoring and selecting the pertinent signals. It is this transition process, from a space of attention to a space of concentration that characterizes the BoC model, throughout the four Phases – Information, Objectives, Actions, Project. Additionally, it is also the main objective in the context of companies, organizations, processes, products, territories, *etc*, to provide them a new biology of creativity and innovation, making them able to widen and coordinate multiple areas of knowledge. And to provide them the capacity to reconfigure, optimize, and continuously update their activity in a broader perspective of content and processes' design, but mostly in a more active perspective towards a richer, more complex, and challenging society.

Lastly, and referring to the initial question – In the context of a 'Biology of Creativity', is there a maturation time necessary for a company, organism, *etc*, or product to reach their complete productivity? – Yes, as an embryo develops until it reaches adulthood, there is the need to some years for a child to reach her complete productivity, fully able to be integrated in the society. Analogically, companies, organizations, processes, products, territories, *etc*, also need time to make reviews and adjustments to fit into society.

Contrary to other disciplines where the focus is dedicated to the understanding and analysis of the target phenomena, design is a discipline focused on synthesis and creation

 doi:10.20944/preprints202303.0272.v1

of novel things (Meyer and Norman, 2020). Hence, it is obvious that design teaching and practice must incorporate a wide range of disciplines, mostly outside of the design scope, like business administration, ethics and sociology, biology and ecology, *etc*, to be able to better fit into a multisectoral context. Accordingly, the noticeable climate crisis constitutes evidence of the opposite point, that design has promoting an unbalanced practice in a world hit of constant crises.

The power of the BoC model relies on the use of non-design text references to expand the comprehension, lexicon, and action of the participants, irrespectively of their provenience. The observed creativity empowerment is a natural achievement of the BoC model that is encouraged by the reasonable easiness of interpretation of the novel texts, allowing a practical comparison with the current reality of each participant's sociological context. Thus, the participant is urged to act upon the new ability to analyse and compare, creating space to a more motivated, active, and responsible individual in an ambitious and empowered action plan.

The BoC model forces the questioning of diverse elements and features that constitute the structure of a manyfold of cases studies. Thus, the BoC model helps creativity professionals, innovators, companies and organizations, and other entities in general, to develop capacities of reflection and action into the innovation and creativity setting.

Design-by-analogy methods are a way to solve design fixation (Crilly and Cardoso 2016). Although fixation may be helpful for developing extremely focused projects and tailor product development efforts for known markets, it is valuable to solve fixation to potentiate creativity and help guide further projects that relate to challenges coming from unpredictable events and for perhaps unknown markets. Therefore, further research must be performed in order to decipher the complex causes of design fixation and individual and collective limitations to creativity and innovation, such as cognitive entrenchment (Dane, 2010), confirmation bias (Nickerson, 1998), psychological ownership (Baer and Brown, 2012), tolerance for ambiguity (Budner, 1962; Mahmoud *et al*., 2020), *etc*.

Similar to what was observed by others (Moreno *et al*., 2014), the BoC model also promotes the rise of ideas from the analogies permitted by the reference texts and throughout the different BoC's Phases – Information, Objectives, Actions, Projects. Additionally, the particularities of the participants, like their expertise and career paths, enrich the learning experience and the constructs generated (Christensen and Ball, 2016). Therefore, the introduction of novel texts, perspectives, and other elements, into the innovation and creativity processes allows a satisfactory approximation to the real world (Graff *et al*., 2020).

Despite its international validation, the BoC must be further developed and improved. So, the next steps may rely in the application of the BoC model to more audiences that could continue the validation of its assumptions, processes, and evaluation methods, and identify limitations that could be optimized. Moreover, the last Phase – Project, should be further developed in order to allow an upscaled approach for participants from high valued enterprises and governmental bodies, with a diverse background and expertise. However, it must be interesting to develop tailored project sub frameworks that could encompass the manyfold variables coming from different industries and sectors. Nevertheless, an improved validation must be addressed in upcoming research endeavours to enable a standardization of research and implementing practices of the BoC model (Eisernmann *et al*., 2021). Still, we believe that the BoC model presents a proper and detailed stepwise process that can be easily evaluated and parametrized for self and autonomous use of improvement.

A possible critique to the BoC model is the constant appropriation of references that are distant to the design education and practice standards, increasing the chance of misinterpretation of seminal concepts and theories. Another critique is the fact that some of the referenced texts may be outdated, and novel perspectives are now more accepted in the scientific community. However, these two critiques do not hamper the strengths of the BoC model since its aim focus in the analogical power of the references to provide enhanced creativity and innovation skills (Muratovski, 2015; Buehring and Bishop, 2020;

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Meyer and Norman, 2020). Nevertheless, the scientific rigour of the BoC model is paramount and it must be pushed forward in the design practice in general to strengthen the activity of designers where a broader knowledge and experience are essential.

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