Contributions of Design Thinking in Inter and Transdisciplinary Communication, Research & Co-work Environment for Complex Problem Solving

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ABSTRACT

Design, as research process, management strategy or problem-solving methodology, is nowadays embedded on organizational structures, social demands and in human interaction and experiences. Involves digital & analogue technologies, requires immersion in complex problems and systems, since the stage of identifying problems, constraints and consequently needs and opportunities, with constant feedback that prompts multidisciplinary team's cooperation looping, from gathering data, to ideation, model and prototype, analysis, and synthesis, evaluate and test, experiment, thus presenting solutions. This cybernetic loop research process stimulates and feeds itself of feedbacks gained also from Inter and Transdisciplinary Communication, that stimulates new knowledge[7], in Research & Development + Innovation (R&D+I).

This exploratory research approaches a Project-Based Methodology known as Design Thinking (DT), considering four models: Stanford d. School - 5 Step Design Thinking; Design Council - Double Diamond; IDEO Human-Centered Design, 3I's model (Inspiration, Ideation, Implementation); and Katja Tschimmel - Evolution 6², and the Creative Techniques used in these methodologies.

The present deductive research tries to explain correlations between its use in academia/business/social environments, as a transdisciplinary communication approach, to complex problem resolution, embedding Design Thinking methodologies in applied research.

Key Words: Project-Based Methodologies; Design Thinking; Creativity; Creative Techniques; Complex Problem Solving; Transdisciplinary Communication; Applied Research; Research & Development + Innovation.[1]

1. INTRODUCTION

This exploratory research approaches a Project-Based Methodology known as Design Thinking (DT), in order to find evidences in two domains: 1) That DT methodologies and Creative Techniques require inter and transdisciplinary communication approaches, in order to frame research and solve complex problems in intricate systems; 2) DT should be embedded into applied research[2] conceptualized as involving professionals, academics, society, and organizations (enterprises, education, government, nonprofit associations) leading to Research & Development + Innovation.

2. CONCEPTS SCOPE

To ensure the understanding of concepts mentioned in this research, from different areas of knowledge and academia, we clarify the following: Design, Project-Based Methodologies, Creativity, Creative Techniques, and Design Thinking.

Design, as research process, management strategy or problem-solving methodology has become part of organizations attending to social challenges with a human-centered approach. It extends beyond the common output of Design such as product or service, further addressing systemic and strategic issues, with transdisciplinary communication in a multidisciplinary environment. This novel approach to design, also seen in Design Management, emerged from the design profession. It requires a high level of integration between teams to optimize decision making, mitigate and minimize errors, and anticipate product/service/experiences release. Thus, when facing complex problems or systems, individual designers have difficulty to devise solutions, especially when involving different areas of knowledge that require a Transdisciplinary Communication[3], and a cooperative and collaborative environment in support of a project-based methodology.

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[2] "R&D is increasingly viewed as an input to innovation in the context of the overall efforts made in a knowledge-based global economy." pp.3 [9] "2.9. The term R&D covers three types of activity: basic research, applied research and experimental development. … Applied research is original investigation undertaken to acquire new knowledge. It is, however, directed primarily towards a specific, practical aim or objective." pp.45 [9]

[3] "…trans-disciplinary communication means to **communicate** 1) "across", "through" disciplines and/or 2) "beyond", "on the other side" of, disciplines, i.e., "to go beyond" disciplines. In the first meaning,

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From this contemporary approach in Design, we revise Project-Based Methodologies that conveyed us to our study – Design Thinking and its Creative Techniques to sustain its use and benefits regarding transdisciplinary approaches for complex problems solving, in Applied Research.

Project-Based Methodologies, as Design uses methods, processes, techniques, and tools towards project development, undertaking research, framing, organizing, assessing needs and opportunities, identifying problems, developing solutions, testing, evaluating, and finally guaranteeing its implementation. Revision of these methodologies leaded us to the following DT models: Stanford d. School, 5 Step DT; Design Council, Double Diamond[4]; IDEO Human-Centered Design (HCD) of 3I's (Inspiration, Ideation, Implementation)[5]; Katja Tschimmel, Evolution 6² Model[6], and the respective Creative Techniques.

The roots of DT as methodology to creatively solving problems comes from the development of psychological studies in creativity in the 1940's, creative techniques in the 1950's and design methodologies in the 1960s.

Creativity, as a cognitive process allows individuals to address underlying issues. It requires mental flexibility and understanding of what matters to people, involving behavior, from frustration to comfort, thinking about context and user-experience, connecting different issues to create added value, and consequently changing society. It involves curiosity, observation skills, acquired knowledge, previous experience, encompassing different subjects, and the ability to think beyond common constraints. [14]

Neuroscientist António Damásio defined how the brain processes, and understands the world (cognition), starting with sensory stimuli that turns into emotions, and into mental and imaginative recreations generated, also, to tackle problems. Consequently, creativity is embedded in cognition, problem solving and novelty that might lead to innovation:

- From a **cognitive** point of view, creativity is a set of processes that seek variations around concepts, obtaining new and unprecedented forms of grouping, generally selected by value.
- From a **neuroscientific** point of view, a set of activities performed by the brain searching for patterns that incites a perceptual identification of new "objects", using fragments of previous perceptions, presenting a singular resonance, creating a new value worthy of attention.

Creativity techniques (CT) provide different viewpoints towards problems, transforming constraints into opportunities, freeing mental barriers, expanding imagination, thus combining ideas that would not normally occur. Specialized literature presents a wide range of techniques and tools to support ideation and for framing, questioning, testing, and evaluating problems or opportunities, ideas, and solutions. It is worth mentioning the following Creative Techniques: Alex F. Osborn - Brainstorming (1953); Stephen R. Grossman - Reversing Assumptions Technique; Genrich Altshuller, Theory of Inventive Problem Solving (1946) Nine Window Technique[7]; Tony Buzan - Mind Map (1970); Alex F. Osborn and Robert Eberle – Substitute. Combine. Adapt. Modify. Put to another uses. Eliminate. Rearrange - SCAMPER (1971) [11]; Robert Platt Crawford, Attributes Listing (1931) [12]; Edward de Bono –Plus, Minus, Interesting [1] also referred as Positive, Negative, and Interesting, and Six Thinking Hats (1985); Alex F. Osborn and Sidney Parnes – Creative Problem Solving (1954)[8]. All the above methods can be combined depending on needs and context. Nonetheless, we considered the creative techniques of the four previously mentioned DT methodologies.

Design Thinking (DT), simultaneously as: - A method of stimulating ideation and insight when dealing with issues, research, information gathering, knowledge processing, and solution analysis, testing and implementation; - A human-centered problem-solving tool combining empathy and creativity.

DT has seen its influence grow across many disciplines and organizational contexts, solving intricate problems in complex systems. Since the 1980's, and with the contribution of post-modernism, the focus of the design process contemplates social, cultural, economic, ecological issues, emotions-feelings, and the relations between subject-object-context, developing human-centered design and design-oriented management.

The focus on inspiration, insight, ideation, and empathy of DT processes is a paradigm shift, contemplating user-experience and user-interface variables, taking into consideration the individual and his socio-cultural interaction in a given context.

As stakeholders (all those involved) become central to project development, constant data collection and analysis is required to reassure success. Culture, context, personal experience, and processes are crucial to understand and identify obstacles and thus create viable options.

DT is focused on an empathic approach, using methodologies such as Focus Groups, placing all users in the core of the project development process, thus generating desirable, adequate and functional outcomes', guarantying the financial and technical sustainability, innovation and added value.

DT and CT, both aim at problem-solving from different perspectives, focusing on collaborative work and multidisciplinary teams to come up with innovative solutions. Therefore, inter and transdisciplinary cooperation and communication methodologies are vital when pursuing for solutions facing complex problems/ systems.

DT describes a sequence of processes that use a model, method, or methodology, stressing the visualization of the overall process. Visual perception plays a crucial role in all DT processes. Models and toolkits emphasize the importance of processes' graphic representation and visual communication.

Inter-disciplinary Communication relates **academics** and in its second sense, it relates **Academy and Society**." [7]

[4] Double Diamond Model and Stanford d. School 5 Steps Creative Thinking Model have been developed based on academic research. The Double Diamond Model is used by the non-profit organization Design Council. Stanford d. School Model developed Double Diamond as a supportive tool for Stanford University's staff and students in their academic activities.

[5] IDEO has been one of the first product design company that introduced the human-centred design approach. Their 3 I's model had been initially developed to support the company's main activities: designing products and services. Later they develop it into a thought-out model that might be used in different areas and industries.

[6] Design Thinking Model Evolution 6² has been developed based on solid academic research and could be implemented in all types of business and organisations. It is effortless in visual perception.

[7] Described IN: D. Silverstein, & P. Samuel, **The innovator's toolkit 50+ techniques for predictable and organic sustainable growth,** second edition (2nd ed.). Hoboken, N.J.: John Wiley & Sons, 2012.

[8] To see its evolution - https://www.creativeeducationfoundation.org/wp-content/ uploads/2015/06/CPS-Guide-6-3-web.pdf

The purpose is to easier envision ideas, concepts and processes. We can observe this approach to visual representation in the following diagrams of the four DT models in analysis, as follows:

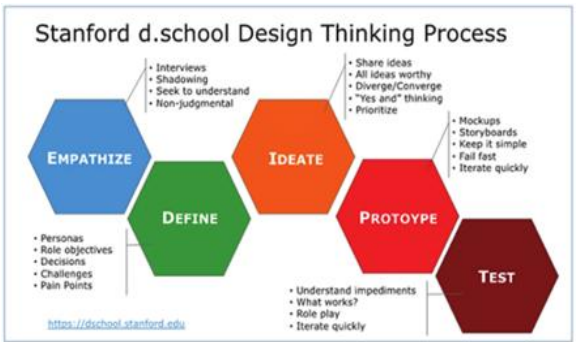

Figure B - Stanford d. School, 5 Step model. [13]

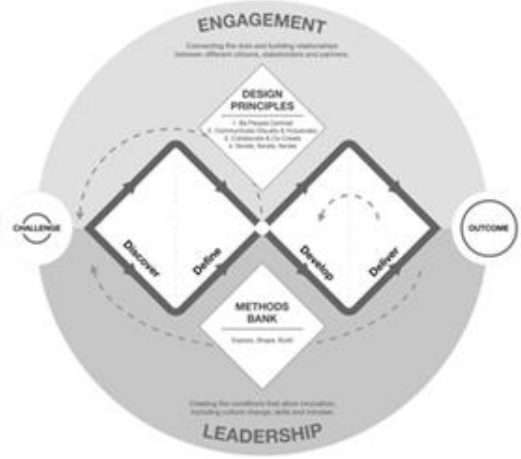

Figure C - Design Council, Double Diamond model[9] [2]

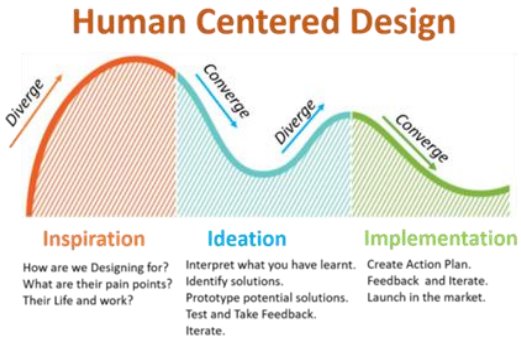

Figure D – IDEO, Human-Centered Design, 3I's model [3]

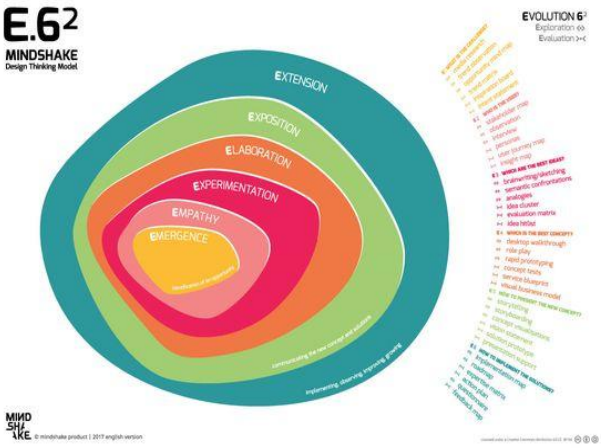

Figure E - Mindshake, Evolution 6² model[10]

Generally, DT models provide sequential methods and techniques, used in context to explore different issues, and devise solutions, such as Figure F. displaying the full process:

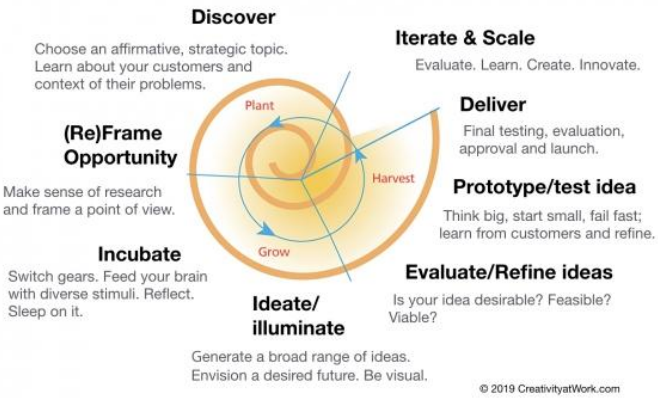

Figure F - A framework for the DT process. [8]

The nature of DT is both linear and non-linear, considering it should not be understood as a sequential process of phases, but as a process with permeable phases, compliant to sequential alteration towards the reframing and (re)evaluation of ideas, problem(s), and solution(s). One of the DT outputs is feedback resulting from the process itself, allowing constant evaluation with transdisciplinary communication in a multidisciplinary team that contributes with specialized knowhow, academic and professional, working in constant linear and non-linear cybernetic relations.

It is unattainable to describe all mentioned referred DT models, nonetheless, the following comparison considers different phases, while listing applied creative techniques included in the following models - Stanford d. School 5 Step; IDEO Human Centered Design (HCD) 3I's; Evolution 6²:

[9] "*The Design Council released an update on the renowned Double Diamond (established in 2004). Originally, the main four steps were: Discover, Define, Develop, and Deliver. They've kept those steps, but added 'Engagement' and 'Leadership', as well as 'Design Principles' and 'Methods Bank'."* [2]

[10] Retrieved from https://www.mindshake.pt/en/design-thinking/

3. DESIGN THINKING MODEL COMPARISON

3.1. Stanford d. School 5 Step – Define phase; Design Council Double Diamond - Discover (insight of the problem) and Define (focus area) phases; IDEO HCD 3I's - Inspiration phase; Evolution 6² - Emergence phase

The starting point for innovation and the design process is to understand and identify constraints, generating opportunities, towards a viable solution. This is achievable with a plan, usually materialized in a brief that defines/ frames problems and constraints, identifies all stakeholders involved, and consequently raised opportunities that provide a framework and benchmark from which to start, along with a set of objectives/ goals to attain.

It includes building a team, recruiting and devise tools and support materials necessary for project implementation. This team approaches a problem from multiple perspectives, depending on individual points of view and fields of expertise, identifying players and processes, defining constraints towards an initial exploratory field research, and desk research from multiple references, thus generating reflections and preliminary conclusions.

Research is then followed by a context exploration of the problem, gathering data through different research methods, often using techniques adopted from Social Sciences in general, that vary depending on project objectives such as: interviews, immersion[11], fieldwork, direct observation and others.

Collected data organized, for instance in insight cards[12], facilitates input consultation for analysis and synthesis (organization and pattern identification). Furthermore, during analysis and synthesis, uses several tools such as: affinity diagrams (similarities, dependencies, proximities, in an organized chart), conceptual maps (graphical visualization, built to organize fieldwork data), usually prompting to (re)frame guiding criteria (project limits guidelines), etc.

- IDEO HCD 3I's inspiration phase uses the following methods: Align on Your Impact Goals; Photo journal; Body Language; The Five Whys; Frame Your Design Challenge; Recruiting Tools; Interview; Group Interview; Expert Interview; Conversation Starters; Analogous Inspiration; Card Sort; Collage; Create a Project Plan; Guided Tour; Draw It; Peers Observing Peers; Build a Team; Define Your Audience; Immersion; Secondary Research; Resource Flow; Extremes and Mainstreams; [5]

- Stanford d. School 5 Step model the Define phase tools are: In-depth Interviews; Personas; Role-play; Decision-making matrix; How can we questionnaire [6]. The Define phase presents a challenge to in depth assessment due to initial problem definition, especially when omitted facts are not addressed nor understood in empathize phase.

- Evolution 6² Emergence phase tools include: The Inspiration Board, Intent Statement, and Opportunity Mind map.

3.2. IDEO HCD of 3I's and Stanford d. School 5 Step - Ideation/ Ideate phase; Evolution 6² - Experimentation phase

Ideation is idea generation. This phase defines the target audience, to whom the solution is designed.

Synthesis generated from the previous stages is used as input. In addition to the multidisciplinary team involved in the entire process, other subjects are included such a stakeholder's and end-users to obtain insights to devise a proficient result.

Brainstorming and co-creation sessions, in a multidisciplinary team using established procedures, generate ideas that will be registered and then further explored. Initially, bold ideas are welcomed, and critique should be refrained. Furthermore it is crucial debating, organizing and prioritizing (analysis and synthesis) the ideas generated. A procedure characterized by the alternation of divergent and convergent thinking (also emblematic of design thinking processes):

- Divergent thinking, for ideas generation, usually requires a wide-ranging team, with members profiled complying devised criteria, its immersion in the process, beginning with a structured brainstorming process of *thinking outside the box*, guided by the "equation" of problem(s) *versus* solution(s).
- Convergent thinking, on the other hand, aimed at focusing on different proposals, leads a team to go through a process of pattern identification and synthesis in which ideas must be interpreted, transformed into insights leading to solutions[13] or opportunities for change, finally selecting the best and more viable ones to achieve final goals.

This DT phase is also dedicated to analyzing other collected data, further identifying opportunities (market of society at large), for this envisaged solutions, and building rough prototypes from selected ideas. It assumes iteration towards the building of a refined deliverable solution.

There are many different tools (besides Brainstorming) such as: insight statements, development frameworks, selection of promising ideas, rapid prototyping, Business Model Canvas, feedback, and iteration accordingly.

- IDEO HCD 3I's Ideation phase, uses the following methods: Explore Your Theory of Change; Create a Logic Model; Build & Run Prototypes; Journey Map; Ways to Grow Framework; Brainstorm Rules; Download Your Learnings; Design Principles; Create Frameworks; Create a Concept; Bundle Ideas; Gut Check; Mash-Ups; Share Inspiring Stories; Determine What to Prototype; Co-Creation Session; Role Play; How Might We; Storyboard; Get Feedback; Rapid Prototyping; Business Model Canvas; Integrate Feedback and Iterate; Find Themes; Get Visual; Explore Your Hunch; Top Five; Create Insight Statements; [5]

- The ideation phase in Stanford d. School 5 Steps uses: Brainwriting; Swap; Fast Idea Generator; "The Worst Possible Idea"; Brainstorming; What if…; Analogies: The World Café; Clustering; Future Scenarios. [6]

- Evolution 6² proposed tools are: Brainwriting or Sketching, Semantic Confrontations or Evaluation Matrix.

[11] "The Inspiration Phase is dedicated to hearing the voices and understanding the lives of the people you're designing for. The best route to gaining that understanding is to talk to them in person, where they live, work, and lead their lives. Once you're in-context there are lots of ways to observe the people you're designing for. Spend a day shadowing them, have them walk you through how they make decisions, play fly on the wall and observe them as they cook, socialize, visit the doctor—whatever is relevant to your challenge." [5]

[12] "Insight Cards generally contain a title that summarizes the finding, and the original text compiled during the research, in addition to the source. They can include other items (like the place of collection; stage of the relevant product/service life cycle; etc.) that facilitate analysis." [6]

[13] Brainstorming result might be either visions of new products, new services, new experiences, or different strategies.

3.3. Stanford d. School 5 Steps - Empathize phase; Evolution 6² - Empathy phase

Phase allowing understanding of relevant human issues such as clients, stakeholders, end-users and concerns to be dealt with, in a user-centered environment.

Designers analyze end-users with a goal of understanding their wants and needs, what might make their life easier and more enjoyable and how products, services, experiences, technology, strategies can be useful for them. Empathic design transcends ergonomics, it includes the understanding the psychological and emotional needs - the way humans act, why and how they think and feel about the environment, and what is of meaning. Empathy is key to better devise design solutions regarding a human-centered design approach. One can pose four questions to obtain such information:

- What do people talk about?
- How do people act?
- What do people think?
- How do people feel?

- Stanford d. School 5 Steps, Empathize phase uses: Actors Map; Desk Research; HCD Matrix; Empathy Map; User Journey; Fly on the Wall; Insight Cards; The 5 Whys; Shadow; Analogy Research.[6]

- Evolution 6² proposed tools in phase include - Interviews, Persona, and User Journey Map.

3.4. IDEO HCD of 3I's - Implementation phase; Stanford d. School 5 Steps - Prototyping and Testing phases; Evolution 6² - Elaboration, Exposition and Extension phases

Phase for validation of ideas selected, proposals testing, and of tangible representation of the learned content.

This is the testing phase towards implementation of the solution. It involves working prototypes, real world testing, business strategy road mapping, organization, partnerships, time efficiency, pitching the idea to investors/ partners/ customers, and ultimately monitoring and evaluating feedback of the overall process.

IDEO's model implementation phase considers the best ideas generated during the ideation phase, now to be turned into something concrete. Crucial to the implementation process is prototyping, when ideas become tangible and through test, evaluation, iteration, are therefore further refined to become a product/ service/ experience/ strategy.

A prototype or mock-up helps test usability and user experience evaluation, gathering feedback to improve the idea of the product/ service. Prototyping speeds the design process, from idea and concept, user-testing, identification of strengths and weaknesses, refinement of proposed solutions, prompting innovative ideas.

- IDEO HCD 3I's Implementation phase uses: Optimize and Adapt for Scale; Define Your Indicators; Live Prototyping; Pilot; Roadmap for Success; Explore Scalability; Sustainable Revenue; Build Partnerships; Keep Iterating; Staff Your Project; Monitor and Evaluate; Capabilities Quicksheet; Create a Pitch; Funding Strategy; Keep Getting Feedback; [5]

- Stanford d. School 5 Step, Prototyping phase tools: New User Journey; Storyboard; Volumetric or Scale Model; Role-Play; General Prototyping; [6]

- Stanford d. School 5 Step, Test phase tools: Wizard of Oz; Context Inquiry; Test/Iteration; Feedback; Project Mural. [6] During the prototype testing phase, is advised to revisit the empathy phase so its tools can be re-used, like - empathy maps, user journeys, etc., to compare feedback received from users.

- Evolution 6² proposes the following tools:

- Elaboration (stage that proposes to work on material and semantic solutions for the selected concepts): Rapid Prototyping, Service Blueprint or Concept Testing;
- Exposition (stage that highlights the importance of proper communication of the new concepts and solutions): Solution Prototypes, Vision Statement or Storytelling Technique;
- Extension (implementation phase, observing, improving, and further developing the selected on previous phases solutions): Implementation Map, Action Plan or Roadmap;

Despite being the logical final phase of DT, it can permeate the other phases of DT models process, or its findings might lead teams to go backwards regarding feedback findings of the overall testing procedures.

4. CONCLUSIONS

4.1. Design Thinking and Creative Techniques contributions

4.1.1. Visual representations in Scientific Communication: scientific communication requires explanations; this is achieved through visual representations. Analyzed DT models have proven to be straightforward and efficient in the use of semiotic language, equating syntactic, semantic, and pragmatic aspects.

Although the paradigm of scientific communication remains mainly written, it is necessary to underline the importance of visual depictions of data, ideas, concepts, processes, and their systemic relations, critical to the understanding of complex problems and systems. This is particularly important when considering the visual translation of Big-Data-Analysis.

Communication designers are fluent in schematic design and infographics[14], as a result they are actively involved when it comes to translating text meaning and data into visual information.

Undoubtedly this is not only an attribute of DT and CT, but of graphic and communication design at large. However, DT and CT stresses the use of visual representations, indicating the significance of visual perceptions for conveying a message, might it be to guarantee individuals literacy (thus its importance in education), might it be to academia or the business world.

Therefore, at this point we can underline the added value of schematic design in the context of communication of research outputs/ outcomes conceptualized as - visual scientific communication

If we would envisage another future for scientific communication, we could speculate about the use of Infographics, with its multimodal communication potential (using text combined with non-verbal elements such as images, sounds, graphics, hyperlinks...), in scientific communication and thus in transdisciplinary communication.

4.1.2. Visual Representations in Inter and Transdisciplinary Communication: efficacious (efficient and effective) static visual depictions tend to be of universal understanding, generating a synthesis of information and knowledge, thus adequate to inter and transdisciplinary communication, being crucial in fostering disciplinary

[14] Infographics is an area of Information design (an area of communication and graphic design).

collaboration towards a desired groundbreaking knowledge and Applied Research outcomes.

4.2. Applied Research in multidisciplinary teams using DT

The characteristics of the four DT models and its CT allowed the correlation of uses and benefits of these methodologies in different environments, by means of inter and transdisciplinary communication, and a human-centered approach, towards the resolve of complex problems achieving viable solutions and unforeseen opportunities that might lead to innovation and added value.
Comprehensive applications of DT, especially in research, education, communication, management, and strategy, all of which require a human-centered approach, confirms its suitability to deal with complex problem-solving in intricate systems. Outcomes that can only be achieved with knowledge exchange between disciplines and individuals, turning DT into one excellent example of an Inter and Transdisciplinary Communication paradigm that truly connects Academia and Society at large. Plus, DT is per se Applied Research, but beyond that fact, and as a methodology it should be embedded in all Applied Research that wishes to move from R&D to R&D+I, because it involves:

a) Problem, constraints, challenges, needs, opportunities, detection, and framing.

b) Benchmarking (search for similar implemented solutions and outputs, framing differentiations, characteristics, weaknesses, and strengths).

c) Building a brief and briefing and debriefing with the team(s) involved.

d) Research management strategies such as:

- Building a team adequate to each phase of the research process, identifying the adequate professional and academic area profiles;
- Identifying stakeholders (users) for whom the solution(s) are envisaged;
- A human-centered approach that implicates using empathic methodologies, dealing with subjective variables, using tools and research methods from social and human sciences;
- Generating, collecting, and analyzing gathered data during the different moments of the Exploratory Research, Desk Research and Action Research;
- Prototyping, test, and evaluation in a real-life context, towards the feedback of stakeholders, especially end-users, regarding expected outcomes.

e) Complex problems that create viable outputs, a solution or a set of solutions, specifically a product, a service, an experience, or a strategy in a complex system, can lead to innovation and the creation of added value for society at large.

f) DT whole creative process works in constant feedback, in cybernetic relationships that combine loops of negative and positive feedback generated by creativity processes and thus generating creativity which might lead to innovation - "*Cybernetic Lops of co-regulation (negative feedback and feed-forward) and synergetic co-amplification (positive feedback*)" [7] framed by disciplinary and inter-disciplinary synergies, implying transdisciplinary communication in the multidisciplinary teams involved, and therefore knowledge integration, to attain research goals.

4.3. Constraints/ Opportunities of this exploratory research:

a) These methodologies, methods, and tools are not *per se* a guarantee for "success", so finding case studies that confirm identified DT contributions, would bring a further quantifiable indication to our conclusions.

b) Further comparison and practical application of listed CT techniques, concerning presented DT models requires understanding of other academic and business areas where inter and transdisciplinary cooperation exists, sustaining viability of DT models and application regarding visual representations with a human-centered approach to Applied Research, communication, and creativity towards innovation.

5. REFERENCES

[1] E. De Bono, **De Bono's thinking Course,** Ariel Books: London, 1985.

[2] F. Van De Ven, "A quick look at the new Double Diamond model", 2020. https://frankvandeven.medium.com/a-quick-look-at-the-new-double-diamond-model-d7f04cacd4e4

[3] G. Chung & G. Kong, "Human Centered Design. Learn 6 Phases of the Human Centered Design Process", 2016. https://www.yukti.io/what-is-human-centered-design-and-why-it-works/

[4] H. Rittel & M. Webber, "Dilemmas in a General Theory of Planning", **Policy Sciences** 4.2, 1973, pp. 155–69

[5] IDEO.ORG, Design Kit. IDEO.ORG. https://www.designkit.org/methods

[6] Instituto Tellus, **Design Thinking ToolKit.** Brasil: Tribunal de Contas da União (Design Thinking para os serviços públicos), https://portal.tcu.gov.br/designthinking/index.html

[7] J. Horne & N. Callaos, **Call for Articles, Reviewers, and/ or Co-Organizers. Inter-Disciplinary Research, Education, and/ or Communication IDREC 2022**, 2021. https://www.iiis-spring22.org/IMCIC/abssub/default.asp?vc=26

[8] L. Naiman, "Design Thinking as a Strategy for Innovation", **Creativity at Work**, 2016. https://www.europeanbusinessreview.com/design-thinking-as-a-strategy-for-innovation/

[9] OECD, **Frascati Manual 2015: Guidelines for Collecting and Reporting Data on Research and Experimental Development, The Measurement of Scientific, Technological and Innovation Activities,** OECD Publishing, Paris, 2015, DOI: https://www.oecd.org/publications/frascati-manual-2015-9789264239012-en.htm

[10] R. Buchanan, "Wicked Problems in Design Thinking", **Design Issues**, vol. 8, no. 2, Spring 1992.

[11] R. Eberle, **SCAMPER: Games for imagination development,** Buffalo, NY: D. O. K. Publishers, 1971.

[12] R. P. Crawford, **The Techniques of Creative Thinking: How to Use your Idea to Achieve Success.** Virginia, USA: Fraser Publishing Co., 1964.

[13] S. Yahyaoui, "The Design Thinking Toolkit: 100+ Method Cards to Create Innovative Products", 2020. https://uxplanet.org/the-design-thinking-toolbox-100-tools-to-create-innovative-products-50ede1f5e3c1

[14] Springer, L., **Creative Inspiration.** 12th International Conference on Applied Human Factors and Ergonomics. Manhattan, NY-USA. Springer Professional, 2021.