Industrial Designeramong "Design thinking, Scientific thinking & creative thinking

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Abstract

TIM BROWN, Executive chair of IDEO" https://designthinking.ideo.com/" defines Design thinking as a human-centered approach to innovation that comes from the designer's skills to make an integration between the needs of people, technology, and the requirements for business success.

Studies refer to Design Thinking by explaining the design process. In which we start with a research and discovery phase, analysis& exploration, followed by problem definition, ideation, prototyping to test our assumption "our new design in that case" allowing for the development or furthermore discoveries and analysis to have more new Ideas by another round of observation, and so on.

Scientific thinking starts by making observations, which are at that point formulated into testable assumptions/ hypotheses. At that point, one can collect data to either prove or modify those initial assumptions/ hypotheses, At the end, allowing for the development of furthermore complex theories, followed by another round of observation, and so on.

From the previous we can connect design thinking with scientific thinking but, as designers we feel the core of design is different, this is where creative thinking shines, a glimpse of art prevails to add the fingerprint of the designer Research Problem:

This literature analysis-based research aims to figure out the importance of mixed thinking skills to add personality to industrial designers' innovations through answering the following question:

What are the thinking skills needed to be mastered by industrial designers??

Keywords

Creative, Design, Thinking, science, art.

الملخص

يعرّف تيم براون، الرئيس التنفيذي لشركة IDEO "https://designthinking.ideo.com/" التفكير التصميمي بأنه نهج يتمحور حول الإنسان بهدف الابتكار ويكون نابعاً من مهارات المصمم لتحقيق التكامل بين احتياجات الأشخاص والتكنولوجيا متطلبات نجاح الأعمال. تشير الدراسات إلى التفكير التصميمي من خلال شرح عملية التصميم نفسها. نبدأ فيها بمرحلة البحث ، والتحليل ، والاكتشاف يليها تعريف المشكلة، والتفكير، والأفكار والنماذج الأولية لاختبار الفرضيات "التصميم الجديد في هذه الحالة" مما يسمح بالتطوير أو العودة للمزيد من الاكتشافات والتحليل للحصول على المزيد من الأفكار الجديدة بواسطة جولة أخرى من الملاحظة، والتدقيق، وهكذا... . يبدأ التفكير العلمي بإبداء الملاحظات، والتي يتم صياغتها عند هذه النقطة في افتراضات / فرضيات قابلة للاختبار. عند هذه النقطة، يمكن لمن يمارس التفكير العلمي جمع

البيانات إما لإثبات أو تعديل تلك الافتراضات/الفرضيات الأولية، مما يسمح بالتوصل لنظريات أكثر تعقيدًا، تليها جولة أخرى من الملاحظة، وما إلى ذلك.

مما سبق يمكننا ربط التفكير التصميمي بالتفكير العلمي، لكن كمصممين نشعر أن جوهر التصميم مختلف، هنا يتألق التفكير الابتكاري، وتسود لمحة من الفن لتضيف بصمة المصمم نفسه.

مشكلة البحث: يهدف هذا البحث القائم على تحليل الدراسات إلى معرفة أهمية مهارات التفكير بأنواعه المختلفة في إضافة ملامح مميزة إلى ابتكارات المصمم الصناعي من خلال الإجابة على السؤال التالي: ما هي مهارات التفكير التي يحتاج المصمم الصناعي إلى إتقانها؟؟

الكلمات المفتاحية

الابتكار، التصميم، التفكير، العلم، الفن.

1-Introduction

Industrial Designers use different thinking techniques as they practice the profession of industrial design process .In her explanation for what Design thinking is (DT) McKinsey's Jennifer Kilian said that "Design Thinking is a methodology that we use to solve complex problems, and it is a way of using systemic reasoning and intuition to explore ideal future state. We do this with the end user or the customer in mind, first and foremost."

Design Thinking is a comprehensive customer-oriented innovation approach that aims to generate and develop creative business ideas or entire business models. The first mouse for the Macintosh computer was created after a similar approach, or the first toothbrush with a wider ergonomic shaft. Design thinking is popular among practitioners because it approaches problem solving from the point of view of the end user and calls for creative solutions by developing a deep understanding of unmet needs within the context and constraints of a particular situation. The importance of utilizing Design Thinking (DT) for successful product development is effective in early stages of product development. Divergent thinking is also a fundamental concept of DT and refers to a thought process used to generate creative ideas by exploring as many solutions as possible. Scientific thinking not only focuses on the practical use of a design product but also sets a significant mental framework for industrial designers. The principle of "form follows function" remains widely accepted among industrial designers. Scientific thinking is an essential mental component in the design process. Industrial design education includes basic science courses like physics, chemistry, and calculus as necessary supplements. The steps involved in scientific thinking—hypothesis, research, testing, and analysis—are fundamental to both design thinking and the scientific method.

Creative thinking is applicable in various fields, including science, medicine, philosophy, law, management, and more. In design, the goal is to create something original and new for others to experience. Any discussion on the thinking processes involved in design must include an examination of creativity and creative thinking. There is a vast body of literature on creativity, studied extensively by psychologists, philosophers, cognitive scientists, and computer scientists. Some of the most profound insights into creativity come from famous and exceptionally creative individuals who have described and reflected on their creative processes.

Understanding how the three thinking types affect the Industrial design process and when to get the most out of them for a better design process.

2- Design Thinking:

2-1 Design Thinking Process:

Design thinking eliminates the "death by analysis" scenario that often hinders companies from launching bold initiatives. This method promotes the rapid generation of numerous ideas followed by rigorous experimentation. Starting with a human-centered perspective, the process then incorporates other crucial factors such as viability, feasibility, and usability. Recognized in literature as a potent tool for innovation in engineering design, design thinking has gained significant attention recently. It is a comprehensive, customer-focused innovation approach aimed at generating and developing creative business ideas or entire business models. For instance, the first mouse for the Macintosh computer and the first toothbrush with a wider ergonomic handle were created using this approach.

Design thinking is favored by practitioners because it tackles problem-solving from the end user's perspective, fostering creative solutions by deeply understanding unmet needs within specific contexts and constraints. It is an integrative approach, meaning that problem-solving is considered alongside its framework conditions. Problem analysis and solution development are systematically and holistically addressed as a process. Various experts necessary for problem analysis and solution development collaborate and exchange ideas. The working environment for this process is designed to enhance creativity.

The three Ps of Design Thinking—People (the human element), Process (the problem-solving process), and Place (the working spaces)—are essential for successful idea development. A fourth P, Partnerships, is also crucial, as many partners must be involved in the development and implementation of ideas. Design thinking emphasizes early customer orientation, starting with people rather than technology or business goals. Ultimately, customers should have a decisive influence on the "go/stop" decisions in the process. Traditional market research methods are no longer sufficient.

According to Brown (Tim Brown.2008), "Design thinking(figure1&2) is a human-centered approach to innovation that draws from the designer's toolkit to integrate the needs of people, the possibilities of technology, and the requirements for business success." Design thinking is a non-linear process. For example, teams may move from the test stage back to the define stage if tests reveal insights that redefine the problem. Alternatively, a prototype might inspire a new idea, prompting the team to revisit the ideate stage. Tests can also generate new project ideas or provide insights about users.

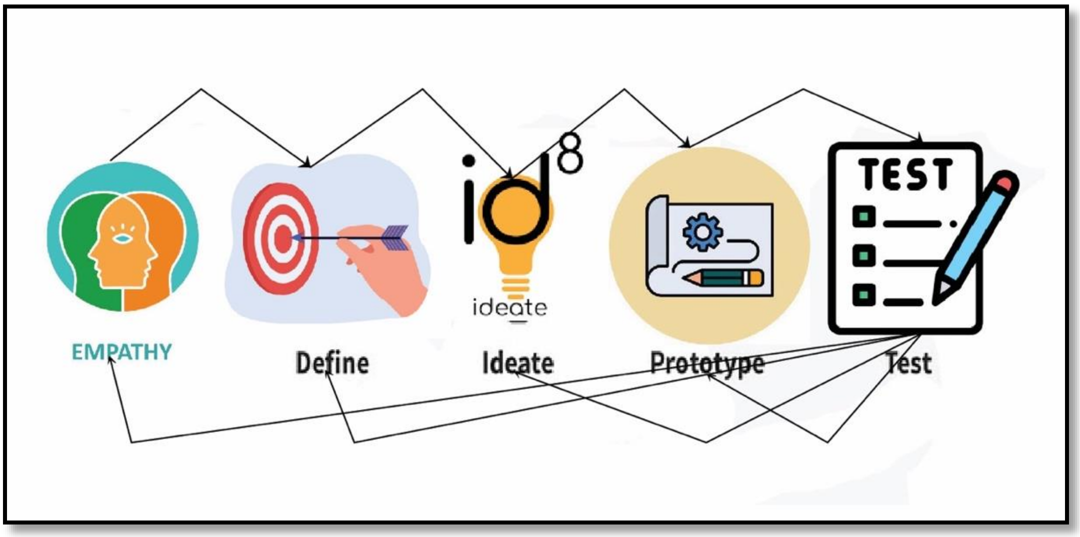

Figure1: Design thinking as a nonlinear.

phase	Empasize& Define	Ideate	Prototype	Test
purpose	Rediscover Your User Deep Needs	Refresh Your Solutions & Innovative Ideas	Reaffirm Your User Needs	Review Your Activities & Strategies
Module	Inspiration & Problem framing	Ideation Problem solving		IMPLEMENTATION (Solution Testing)

Figure2: connecting Design thinking as a process with purpose and problem-solving module.

Empathy:

The initial stage of the design thinking process emphasizes user-focused research. The goal is to develop a deep, empathetic understanding of the problem at hand. This involves consulting experts, conducting observations, and engaging with users to truly empathize with their experiences and motivations. Immersing yourself in the users' physical environment can provide a more personal and profound understanding of the issues involved. Empathy is essential for problem-solving and a human-centered design process, as it helps designers set aside their own assumptions and gain genuine insights into users' needs.

Depending on the time available, you will gather a significant amount of information to use in the next stage. The primary objective of the Empathize stage is to achieve the best possible understanding of your users, their needs, and the underlying problems related to the product or service you aim to create.

Define:

At this stage, you need to define the problem and create a problem statement in a human-centered way. This involves articulating the problem from the users' perspective, such as: "Teenage girls need to eat nutritious food to thrive, be healthy, and grow." The Define stage helps the design team gather great ideas to establish features, functions, and other elements to solve the problem or at least enable real users to resolve issues with minimal difficulty. During this stage, you will begin to transition to the third stage, the ideation phase, by asking questions that help you seek solutions, like: “How might we improve hand blender ergonomic qualities for left-handed users?”

Ideate

In the third stage, designers are ready to generate ideas. By now, you have a solid understanding of your users and their needs from the Empathize stage, and you have analyzed your observations in the Define stage to create a user-centric problem statement. With this foundation, you and your team can start to view the problem from different angles and brainstorm innovative solutions. There are numerous ideation techniques available, such as Brainstorm, and writing, Worst Possible Idea, and SCAMPER. Techniques like Brainstorm and Worst Possible Idea are typically used at the beginning of the ideation stage to encourage free thinking and expand the problem space. This allows you to generate as many ideas as possible. Towards the end of this stage, you should use other ideation techniques to investigate and test your ideas, selecting the best ones to move forward with—either because they seem to solve the problem or provide the necessary elements to address it.

Prototyping

In this phase, the design team creates several inexpensive, scaled-down versions of the product (or specific features within the product) to explore the key solutions generated during the ideation phase. These prototypes can be shared and tested within the team, other departments, or a small group of people outside the design team. This experimental phase aims to identify the best possible solution for each problem identified in the first three stages. The solutions are implemented within the prototypes and are then tested, improved, or rejected based on user feedback.

By the end of the Prototype stage, the design team will have a clearer understanding of the product’s limitations and the challenges it faces. They will also have a better idea of how real users would interact with the final product.

Test

In the final stage of the design thinking process, designers or evaluators thoroughly test the complete product using the best solutions identified during the Prototype stage. Although this is the last stage in the five-stage model, design thinking is iterative, meaning the results often lead to redefining one or more problems. This deeper understanding can help you explore the conditions of use and how people think, behave, and feel about the product, potentially prompting a return to a previous stage in the process. This allows for further iterations, adjustments, and refinements to eliminate alternative solutions. The goal is to gain a profound understanding of the product and its users. During the Define stage, you

organize the information gathered in the Empathize stage and analyze your observations to pinpoint the core problems faced by you and your team.
Design thinking is a human-centered approach to innovation that leverages the designer's toolkit to integrate people's needs, technological possibilities, and business success requirements. Businesses are adopting design thinking to become more innovative, differentiated, and efficient. This demand has led to universities and institutions offering master's and professional programs to teach the design skills needed by corporations seeking innovation expertise.

2-2 Design Thinking Principles:

Design thinking, based on a "human-centered problem-solving" approach, has several easy-to-understand principles:
User Centricity: Design-centric organizations encourage teams to observe consumer behavior rather than making general assumptions. They aim to understand what people need and want, their emotional and psychological experiences, potential barriers, attitudes, and opportunities. Techniques like journey maps, persona creation, task analysis, and interviews help gather data from actual service users. Personas help designers empathize with consumers throughout the design process.

- **Collaboration:** Design thinking supports collaboration between diverse, multidisciplinary teams, such as marketing and design teams, which may not usually work together. This ensures actionable cues and guidance for the design process, supporting innovation. Teams review for new unmet needs or unexpected barriers, compile and present this data to business stakeholders, and ensure that the information architecture, interaction patterns, visual design, common icons, and style guides are aligned.
- **Generation of Ideas & Solutions:** Ideation is a crucial step in design thinking. Industrial designers generate many ideas using techniques like brainstorming, mind mapping, and other methods to produce many ideas before filtering them.
- **Experimentation and Replication:** To turn an idea into a final concept, experimenting with the quality and success of the product is essential. The experimentation process varies depending on the product type and incorporates changes based on user feedback and other testing methods.
- **Proactive Engagement:** This involves the early involvement of users to address real-life problems and discover latent needs.
- **Preparation for Setbacks:** Design thinking is not a linear process; there must always be room for failure, messes, and setbacks.
- **Flexibility:** Design thinking should anticipate changes in user needs based on market demands and various factors such as age, health, and education. This adaptability ensures that the design remains relevant and effective over time.
- **Simplicity:** Design thinking should adhere to the principle of simplicity, following the "less is more" philosophy championed by Bauhaus pioneer Mies Van Der Rohe. This approach has consistently proven successful for design thinkers.

3- Scientific Thinking

3-1 Scientific Thinking Process:

Scientific thinking not only focuses on the practical use of a design product but also sets a significant mental framework for industrial designers. The principle of "form follows function" remains widely accepted among industrial designers. Scientific thinking is an essential mental component in the design process. Industrial design education includes basic science courses like physics, chemistry, and calculus as necessary supplements. The steps involved in scientific thinking—hypothesis, research, testing, and analysis—are fundamental to both design thinking and the scientific method.

Principles of Scientific Thinking:

Principle 1: Extraordinary Claims Require Extraordinary Evidence

This principle is straightforward: If someone makes extraordinary claims, they must provide substantial evidence to support them. Such claims must undergo rigorous cross-checks, explanations, and questioning. The theory must be backed by extraordinary evidence to be justified. This principle is closely related to cognitive and behavioral concepts, emphasizing the need to develop the ability to tackle problems. For example, the OPERA neutrino experiment faced extensive scrutiny and verification before being accepted. Scientists involved in the experiment aimed to send a beam of particles 400 miles faster than the speed of light, challenging the established speed limit of light. Antonio Ereditato, a spokesman for OPERA, emphasized the continuous verification of their devices. After numerous checks, the experiment was eventually validated, illustrating that extraordinary claims require extraordinary evidence.

Principle 2: Falsifiability

This principle is crucial for thinking skills: It states that for a theory to be meaningful, it must be falsifiable. The gathered data and observations must be able to prove the theory wrong. This principle is related to general behavior, as people tend to continue thinking about a statement once they have formed an opinion on it.

Principle 3: Occam's Razor

According to this principle, when faced with two compatible statements, the simpler one should be preferred. This aligns with the natural tendency to choose the easier path. It relates to behavioral theory, as humans generally prefer simpler solutions. For example, if a person in an organization faces a problem and has two compatible ideas, they are likely to choose the simpler one to resolve the issue. This principle reflects the human inclination to deal with problems in the easiest way possible.

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Principle 4: Replicability

Replicability refers to the ability to repeat an experiment or study multiple times and achieve the same results. This principle is crucial in scientific research, as it ensures the reliability of findings. For example, the polio vaccine consistently produced the same results when tested on animals before being released to the market. This success is attributed to the scientific thinking and collaborative efforts of doctors. However, this principle does not apply to scenarios like meditation, where one person might solve 60 IQ questions while another person, despite meditating, might not achieve the same results. This is because intellectual power is influenced by inner concentration and cognitive abilities, which vary among individuals.

Principle 5: Ruling out Rival Hypotheses
This principle involves evaluating a claim by considering other possible explanations. It emphasizes the importance of not accepting a claim without exploring alternative hypotheses. This principle is linked to social learning, which stems from behavioral learning.

Principle 6: Correlation vs. Causation
This principle highlights that two ideas may not necessarily be related or cause each other. For instance, overweight individuals might claim they eat more, but obesity is not directly linked to mental tension. Such misconceptions are rooted in behavioral psychology. It is essential to understand that correlation does not imply causation, and two factors may not be causally related.
It’s hard to imagine solving any complex problem without moments of insight. Relying solely on linear, analytical thinking for complex issues often leads to solutions that lack elegance and efficiency, resulting in unproductivity, stress, and sub-optimal performance. When tasks are highly complex and deadlines are tight, “insightful thinking” becomes crucial. Insightful thinking helps individuals and teams achieve peak performance through sudden insights. For example, Edison’s use of power naps generated numerous insights, keeping him productive and motivated. His constant flow of ideas inspired him to keep working, trusting in his ability to find the next idea when the current one failed.
The scientific method is essential for laying the groundwork for scientific discoveries and validating their authenticity. Suggesting that anyone following the scientific method could have discovered gravity, relativity, or quantum physics undermines the genius required for such discoveries. Understanding a scientific discovery is one thing, but making those discoveries is entirely different. The scientific method helps design experiments, create results, and gather data, but it takes a genius to connect the dots and form a hypothesis. The same applies to technology; this can be illustrated by comparing carrying luggage by lifting it versus using wheels and trolleys, we should focus our efforts on pushing the wheels and trolleys rather than lifting the luggage.

4- Creative Thinking

4-1 Creative Thinking Process:

Creative thinking is applicable in various fields, including science, medicine, philosophy, law, management, and more. In design, the goal is to create something original and new for others to experience. Any discussion on the thinking processes involved in design must include an examination of creativity and creative thinking. There is a vast body of literature on creativity, studied extensively by psychologists, philosophers, cognitive scientists, and computer scientists. Some of the most profound insights into creativity come from famous and exceptionally creative individuals who have described and reflected on their creative processes.

There are many who write about enhancing creativity, offering techniques for individuals or groups. Margaret Boden (1990) suggests distinguishing between H-creativity and P-creativity. H-creativity results in novel and fundamentally new ideas in history, like Einstein's discovery of relativity or Archimedes' 'Eureka!' moment. P-creativity, while less glamorous, is still significant as it involves ideas that are novel to the individual, even if not new to the world. In design, significant developments often make it hard to pinpoint who had the original H-creative idea. History tends to credit individuals as if they worked alone, but many innovations are collaborative.

For example, Alec Issigonis revolutionized car design with the Mini by turning the engine sideways, compressing the engine compartment, and removing the traditional boot. This made the car more than just a vehicle; it became a fashion accessory. Similarly, Mario Bellini's Golfball typewriter for Olivetti introduced new possibilities by replacing the moving carriage with a stationary paper feed and a rotating ball-shaped device for characters, allowing font changes.

Innovative designs often become timeless classics, not just solving problems but changing the world. The Mini led to a series of small, maneuverable city cars, making small cars chic and fashionable. The Barcelona Pavilion by Mies van der Rohe in 1929 changed building design fundamentally. Great ideas rarely come without effort; simply sitting in the bath or dozing off is not enough. As illustrated in (figure3), the creative process typically involves five phases: First insight, preparation, incubation, illumination, and verification.

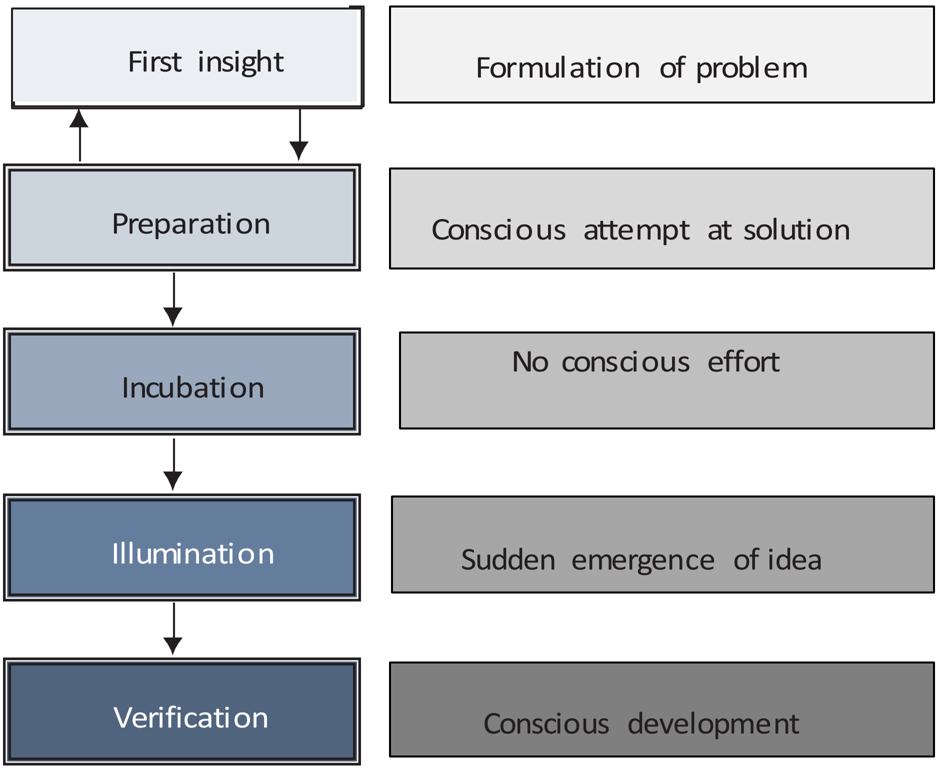


Figure (3) creative thinking process

The "first insight" phase involves recognizing that a problem exists and committing to solving it. This phase, where the problem is formulated and expressed mentally, can be of brief or last many years. In design, the problem is often not clearly defined at the start, requiring significant effort. Many experienced designers, like Santiago Calatrava and Barnes Wallis, emphasize the need for a clear problem to work creatively (Marzieh Allahdadi et al 2015). They suggest that their most creative work arises when problems are imposed from outside.

The "preparation" phase involves a conscious effort to find a solution. In design, this phase often overlaps with the first insight phase as the problem may be reformulated or redefined while exploring possible solutions. This intense, deliberate work is usually followed by a more relaxed "incubation" period. For instance, Poincare's incubation came during a journey, though such opportunities may not always be available to practicing designers.

Alexander Moulton, known for his innovative bicycle and the rubber cone spring suspension system used in the Mini, exemplifies how intense preparation can lead to significant innovations. Despite some views in design education advocating for free and open situations to foster creativity, the preparation phase remains crucial. This phase involves considerable effort in searching for solutions, often requiring back-and-forth between defining and redefining the problem (Marzieh Allahdadi et al 2015).

Writers on creativity agree that intense, deliberate work is often followed by a relaxed incubation period, allowing ideas to mature and develop.

We've already discussed how Poincare's incubation came from a journey, but such opportunities aren't always available to practicing designers. Alexander Moulton, known for his innovative bicycle and the rubber cone spring suspension system used in the Mini, which later evolved into the Hydrolastic and Hydragas systems, advises having one or two different lines of thought to follow. This allows the mind to rest one idea while working on another. Both practicing designers and students need multiple projects to avoid wasting time during incubation.

The exact workings of the human mind during incubation are not fully understood. Some believe that the mind continues to reorganize and re-examine data absorbed during intensive periods. Changing the direction of thinking is often relied upon, as it's easier to continue in the same direction than to start a new one. The incubation period can also bring a line of thought to a halt, allowing for a fresh perspective when returning to the problem.

The "verification" period involves testing, elaborating, and developing the idea. In design, these phases are not as distinct as they might seem. Often, the verification period reveals the inadequacy of an idea, but its core might still be valid, leading to a reformulation of the problem and a new investigation phase. Thinking is a demanding process, requiring significant mental effort. Designers must thoroughly observe and mentally manipulate their ideas. After this process, they can let their subconscious mind work while they tackle another problem.

Creative thinking is about developing innovative solutions to problems. Creative thinkers brainstorm many ideas, exploring a variety of options. In the workplace, creative thinking has roots in psychology and education, developed as a systematic approach to fostering creativity and solving problems. Creative problem solving (CPS) enhances creative thinking and generates novel solutions. CPS follows a structured process with stages like Problem Clarification, Idea Generation, Solution Development, and Implementation Planning. It involves techniques such as lateral thinking and reframing problems to generate innovative ideas, using methods like brainstorming, mind mapping, and random stimuli to trigger new ideas.

Creative Design Thinking

Creative Design Thinking occurs when there is attentive awareness, commitment, resourcefulness, a fertile imagination, heightened expressiveness, innovative procedures, significant goals, and reflective insights in purposeful thought about a problematic situation. It involves positive attitudes, initiatives, and techniques that apply purposeful thought in highly creative ways to resolve complex problems and go beyond familiar solutions (Sibel Demir Kaçanet al 2018). This includes goal setting, gathering and organizing relevant information, synthesizing appropriate expressions, executing effective procedures, evaluating goals, and applying knowledge to improve a situation or meet an unfulfilled need. Creative designers are extremely curious, self-reliant, and often unique in their interpretation of information. They remember large amounts of information that may not be well-structured or directly related to their immediate concerns. They are especially alert, aware, and attentive to events, resources, features, and potentials relevant to their interests. They seek and exploit resources, focusing on relevant aspects while ignoring irrelevant ones. They pay close attention, re-categorize, re-present, re-define, re-classify, and reinterpret information from various sources to explore how it might help them achieve their goals. They consider uniquely interesting information not usually deemed relevant or critical.

Verbal, visual, and symbolic representations are used freely to define, describe, and specify objects of interest. When information is lacking or not well-organized, desirable properties, attributes, representations, and objects of reference are often invented (Sibel Demir Kaçanet al 2018). Creative design thinking in the Referential mode occurs through insightful recognition, imaginative selection, unusual definition, pruning or ignoring unpromising information, and redefining and re-categorizing objects of thought. Unconventional categorization and emphasis allow creative designers to differentiate and exploit information in new ways. Semantic fluency, discerning intelligence, and access to varied and detailed knowledge are important factors.

Referential Design Thinking is divergent when it seeks to expand the range of considerations and convergent when it focuses on identifiable objects of thought or their attributes. Recognizing differences in elements of thought is particularly useful for determining the relevance of the information considered.

Creative Thinking Strategies (NABC):

- **N:** What is the most important user market Need?
- **A:** What is your unique Approach?
- **B:** What are the specific user advantages (Benefits)?
- **C:** How do these advantages differ from the competition?

Principles of Creative Thinking

Creative thinking is shaped by three principles, referred to as three strands:

Strand 1: Generation of Ideas

At its core, creative thinking is a generative process. This strand highlights the importance of producing many different ideas, sometimes called ideational fluency, in the creative thinking process.

Aspect 1.1: Number of Ideas

The tradition of assessing creative thinking by counting the number of ideas generated is strong. While this aspect does not address the quality of the ideas, generating many ideas is essential for developing a creative solution. The more ideas produced, the higher the likelihood of finding a truly creative one. Multiple ideas can be combined to create a new, creative product. Although some researchers argue that idea generation may be domain-specific, assessing creative thinking across multiple domains can address this issue.

Aspect 1.2: Range of Ideas

The belief that producing more ideas increases the likelihood of a creative one relies on the production of distinct ideas. If many ideas are produced but share fundamental similarities, the level of creative thinking exhibited by each idea will be similar. Likewise, if several similar ideas are produced, they are less likely to be combined or synthesized into a new idea or solution. This aspect explicitly addresses the number of distinct ideas presented. The concept of assessing both the number of ideas and the number of different categories represented in a set of ideas was introduced in the early work of Guilford on divergent thinking and remains present in modern assessments, having an established research history.

Strand 2: Experimentation

A crucial aspect of creative thinking is the ability to experiment with both existing and new ideas. This involves consciously considering ideas from multiple perspectives and thinking creatively within the constraints of a task. This process can lead to new ideas through adaptation and synthesis.

Aspect 2.1: Shifting Perspective

Creative thinking occurs within the constraints set to achieve the task's purpose. One challenge is to think flexibly enough to find novel ways to navigate these constraints. Often, we impose more constraints on ourselves than necessary. Creative thinkers consciously shift their perspective on a problem to redefine its context and discover new approaches to finding solutions. This perspective shifting is not limited by conventional uses of objects or typical perspectives on ideas, helping to overcome cognitive biases like functional fixedness, where individuals only see a problem from one angle and miss other possibilities. The ability to think creatively about the boundaries of a task, and how they might be moved or changed, is often described as "thinking outside the box." Creative thinkers who can shift

perspective typically ask “what if” questions to renegotiate the known constraints of the problem context, opening up new possibilities.
The willingness to actively shift perspective and consider new ways of seeing a problem is partly related to disposition, as it involves suspending judgment and tolerating uncertainty. Creative thinking requires an open mind, a willingness to experiment, and the exploration of possibilities that may initially seem hopeless. Creative thinkers are willing to consider what may seem impossible and follow unlikely paths.
While skills like critical thinking and collaboration also involve acknowledging other perspectives, this is generally about identifying and addressing knowledge gaps. In creative thinking, the ability to be flexible and see things from different perspectives is about viewing known information in new ways.
To think creatively, learners need to push the boundaries of a task to maximize creative thinking space. Conscious shifts in perspective can help identify which aspects of a task can be changed.

Aspect 2.2 Manipulating ideas
Flexible thinking is essential for manipulating ideas. Creative thinkers know how to alter the elements of a task or prompt in various ways to generate new ideas. They combine, twist, subvert, or merge elements in unexpected ways to open up new possibilities and radically different ways of thinking. This aspect acknowledges that creative thinking often involves adapting or synthesizing existing ideas rather than generating entirely new ones, a concept supported by research.

Strand 3: Quality of Ideas
Creative thinking doesn’t exist in isolation. This aspect focuses on ensuring that the ideas generated are of high quality. Evaluating the appropriateness of a solution is a common theme in most frameworks. The ACER approach highlights not only the importance of the solution as a creative product but also specifies the key features of a product that demonstrates creative thinking.

Aspect 3.1: Fitness for Purpose
While definitions of creativity vary, there is a fundamental agreement that the end result must be fit for purpose. Influential definitions use terms like “appropriate” (Sternberg & Lubart, 1999) and “useful” (Plucker et al., 2004) to express this idea. This aspect acknowledges that creative thinking has a purpose, and if the end product is of no value, it does not fully demonstrate creative thinking.

Aspect 3.2: Novelty
A creative product must be new, a fundamental idea in existing definitions of creativity (Plucker et al., 2004; Sternberg & Lubart, 1999). In educational assessment, this aspect remains important but requires qualification. Students are unlikely to generate ideas that are entirely new in an absolute sense. However, an idea that is new to a student, even if not new in an absolute sense, can still be considered creative.

Generating novel or original ideas is relative to the social context. For example, a student may generate ideas that are highly unusual compared to their classmates but similar to ideas from another class. Ideally, students should work in an environment where the evaluation of novelty is generous enough to provide opportunities for success while challenging them to think differently.

This idea is especially important for young students, who have limited experience and a different perspective on what constitutes novelty. Many ordinary ideas may seem new to them. They may also generate truly novel ideas without the ability to differentiate them from commonplace ones. Supporting creative thinking involves providing opportunities for experimentation and risk-taking, with teachers modeling the value of unusual responses.

Aspect 3.3: Elaboration

Elaboration involves illustrating the richness of an idea's potential to meet a given purpose. It may require providing detail to explain how an initially far-fetched idea could be effective. Elaboration gives substance to an idea and supports its fitness for purpose.

While recent frameworks may not emphasize the level of detail in a response, its importance was acknowledged in early work, with elaboration included as a response measure in Guilford's influential work (1950).

5- Discussion Conclusion:

5-1 Design thinking and scientific thinking

Many design theories have been inspired by scientific disciplines, particularly the natural sciences. In such cases, design is envisioned as an objective, rational procedure that draws on the same rigorous standards of testing and verification as the sciences. These theories focus on problem framing and problem solving.

Design theorist and educator Horst Rittel called design problems "wicked" and proposed that we need a completely different approach, what he called a second generation of design theories and methods. He advocates that if the first generation was aiming to make design a purely rational process, the second generation recognizes that the notion of rationality implies serious paradoxes and that distinctions between systematic versus intuitive and rational versus nonrational design are untenable.

Design thinking is a human-centered approach in which intangible things such as emotion and visual design play a key role. This is less important in the scientific process which focuses on tangible, objective, and measurable results. Design thinking starts with a problem, it tests assumptions about the solution to the problem and creates innovative solutions to things that do not exist yet. Scientific education starts with a question, it tests hypotheses and looks at what is already exists in the world. You could say that design thinking images the future and the scientific process examines the past (or observable). Looking at the steps of design thinking and the scientific process, there are a few similarities and difference.

5-1-1 The Steps of Design Thinking vs Steps of the Scientific Method1.

- Empathy & Question

In science, the goal of any researcher is to answer a question, what, why, and how, are the key drivers of any scientific work. Researchers who are trying to work out the world around them will ask themselves questions beginning with these words to kickstart their work, in design thinking, product developers are challenged to put themselves in the user's shoes and do the same thing. To empathize with the user, product developer must ask, “what are my users using this product for”? Why are they using this product over any other? And how are they using it.? We all have products that we use in a myriad of ways no developer ever imagined, the key driver of the first step is understanding the user.

Define & Research

You've now asked all the questions you can think of, you've surveyed and interviewed enough people to be confident in your assertion of the problem, what do you do now? In science, at this step, you need to research the context of your efforts. You research if these questions have been asked before and if your questions make sense. In the case of scientific research, context should present itself however it's important to sense check, if you are working in the field of condensed matter and your research turns out looking like a fluid, something has gone wrong in your research.

In the design process, a well-known example is London Heathrow's Terminal 5. The designer's initial research identified that older people use airport bathrooms more often, so the obvious solution was to construct more bathrooms. Luckily, they decided to look at the qualitative side of the data which revealed the public announcement system was louder in the bathrooms and therefore easier to hear. Suddenly, the solution changed from constructing several more bathrooms at a massive cost to simply installing a louder speaker system. The goal of researching and defining your problem is identifying that you are indeed solving the correct problem for the user and not blindly following a red herring.

Prototype & Hypothesis

Once you've understood your problem, developed the context around it and you are certain you really understand the user, now it's time to build in product development, this is where you should set about building something, putting together your Minimum Viable Product (MVP) and in science, developing your hypothesis. Your MVP, just like your hypothesis should offer your unique solution to this problem and should be testable in real-world conditions. Your hypothesis and MVP are the first solutions you offer to the problem you have identified and researched.

Test & Experiment

Get your data! And, get enough of it, make sure your results are statistically significant. While scientists will ensure themselves of the statistical significance while developing new products you must do the same. You need to test for product fit, for pricing, packaging, market size and so much more. For scientists to collect data on every measurable data point is natural and it's an important businesses to take a paper from this book.

- Ideate & Analyze

So, you now have your data, what next? In the scientific method, you look at the data, look for potential sources of error in your experiment, compensate for those errors, test your results against the hypothesis and improve your experiment until you can draw an accurate conclusion.

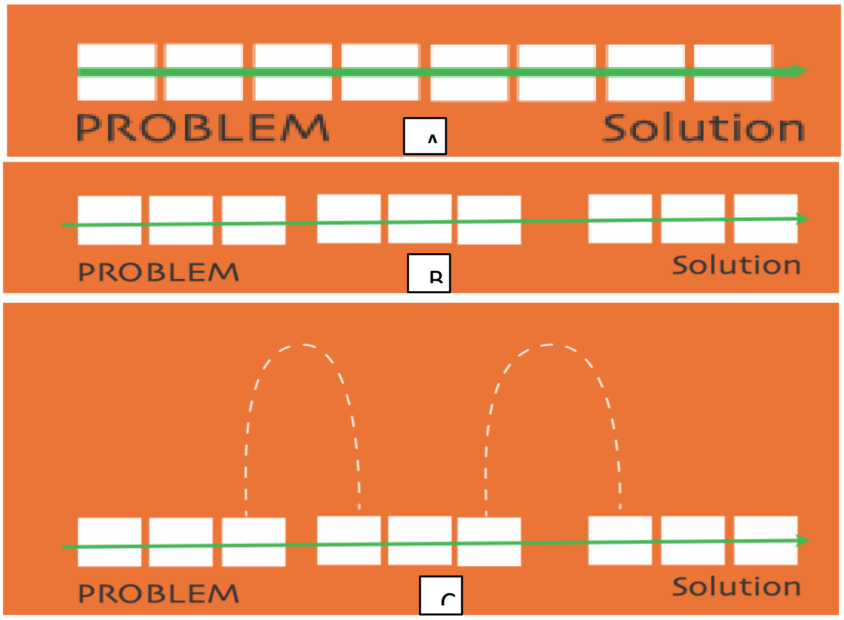
In design thinking, it is the same. Look at your data, look for the errors and feedback. Test that feedback against your prototype, ideate and improve upon your prototype until you can draw an accurate conclusion as to the product and offering you should offer. An often overlooked but valuable test to run on any software product is a simple hotspot test. This test will give you an insight into how users are interacting with the product interface.

5-2 Design Thinking& Creative thinking

Design thinking originated in design and emphasized user-centric solutions, while creative thinking has a broader origin and focuses primarily on generating novel ideas. While both approaches follow structured processes, their specific stages and tools may differ. Design thinking tools often revolve around understanding user needs while CT tools are geared toward novel Ideas. Design thinking places a strong emphasis on empathy and understanding user needs, whereas creative thinking emphasizes fostering a creative mindset and generating innovative ideas. Design thinking is often applied in product and service design and innovation, with a strong user-centered focus. Creative thinking can be used in various domains including business, education, and arts. In practice, Industrial Designers use both design thinking and creative thinking depending on the nature of the problem, the goals of the problem-solving process, and whether a user-centered approach is a primary consideration (Matthews, Judy2017). They are both valuable tools for fostering innovation and finding solutions to complex challenges industrial Designers.

Scientific thinking refers to the mental processes used when reasoning about the content of science (e.g., force in physics), engaged in typical scientific activities (e.g., designing experiments), or specific types of reasoning that are frequently used in science (e.g., deducing that there is a planet beyond Pluto).

Analytical and Logical thinking are linear steps (Matthews, Judy2017). They function in the domain of familiarity. Analytical and Logical thinking begins with a known idea, and we apply various logical transformations to the idea or a group of ideas, leading to new ideas. One step leads to another. However, these ideas all lie in the zone of familiarity. On its own, linear Analytical and Logical thinking cannot lead us from problem to a Solution end-to-end unless we are dealing with straight forward approach defining problems. Linear thinking can work on small fragments of a complex problem, but not on the complete problem in entirety. (Figure4) shows how leaps of creative insights are needed to fill the disconnected gaps in the journey from problem to solution. Insightful thinking helps us leap over the chasms and complete that journey.

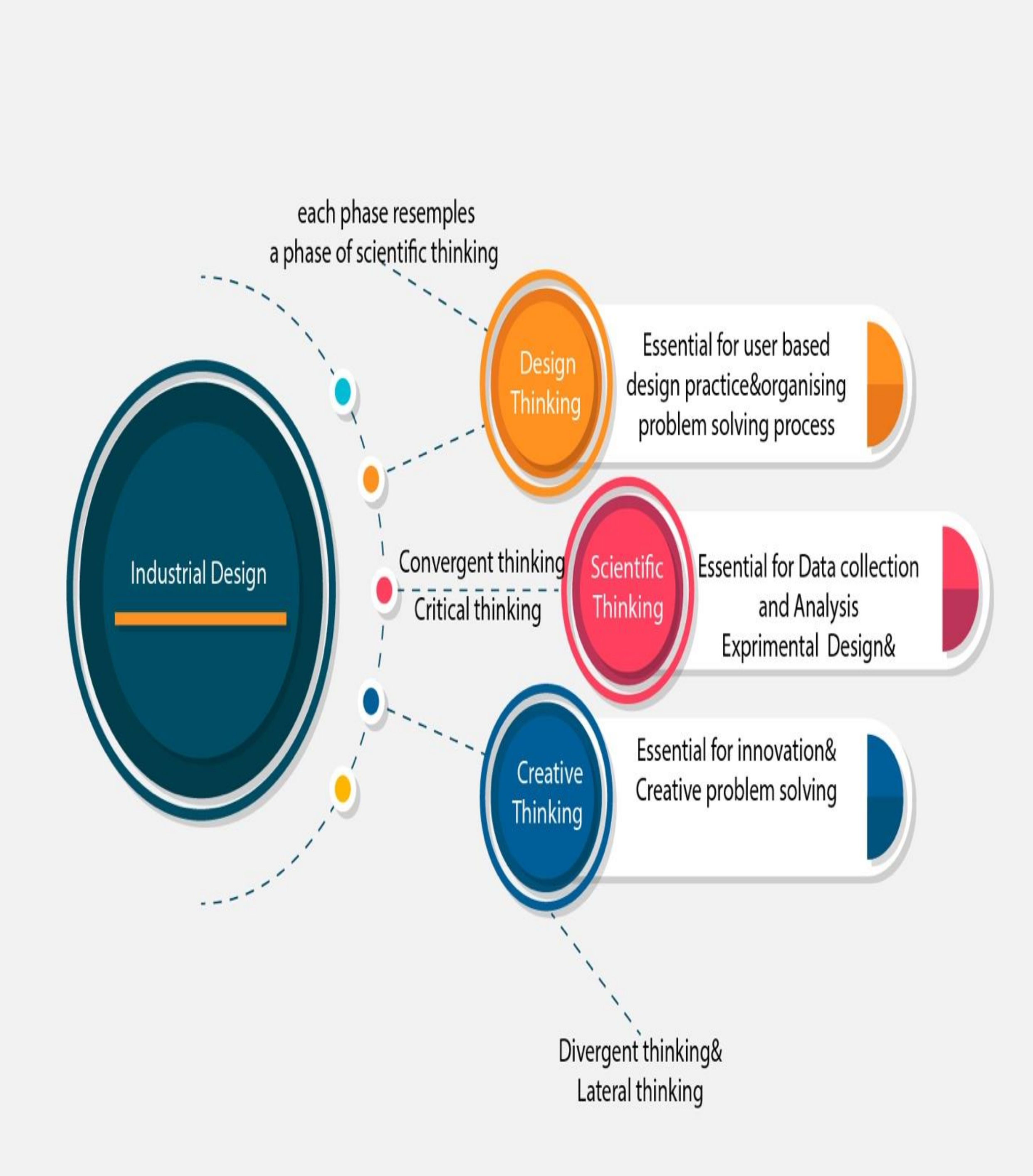


(Figure 4) scientific thinking process: A) represents the linear steps of the process. B) small fragments of a complex problem in linear steps. C) show the innovation leaps that can take place in the linear steps of scientific thinking process.

To sum up (figure5), how industrial designers benefit from the three within study thinking types:

- Empathy phase: Scientific thinking with its linear steps fits first phase of the design process which aims to have full understanding of the user and the product to be designed, depending on data collection, observation and role playing. To narrow down the outcome (formulation of the problem) based on logical inference and get to know user needs with a clear& subjective vision. Convergent thinking is essential to" tools like persona, product scenario, know how would take place in this phase".
- Define phase "in this phase, focus will be on interpretation of user needs, classifying, and arranging them according to market research and studies, analyzing design requirements of existing products and listing final specifications of the developed product" requires critical thinking to target the essential scientific reasoning needed to achieve the goals of this phase (conscious attempt at solution).
- Ideation phase requires creative thinking (divergent way of thinking takes place) based on the insight gained by applying scientific thinking in the previous phases, this is (sudden emergence of idea).
-Prototype phase, now the design team is using the Vault technique where ideas are filtered, unneeded ideas going to the vault where it is kept for later and the best idea to be turned into an experimental model". Scientific thinking is needed to decide how the model will be executed, and for finishing decisions creative thinking would be essential.
- Testing phase: As a final step in the design thinking processes the product development team will take decisions based on real experiments data using critical thinking. If the

feedback is satisfying for the stakeholders the prototype would be prepared for production stage, if not the team will go back to the design thinking phase where the issue needs fixing and that's why design thinking is not linear.



(Figure5) Illustration of the 3 thinking types and how industrial designers can benefit from them

References

1- Blair Miller, Jonathan Vehar, Roger Firestein, and Bob Eckert. (2022). FOUR KEY PRINCIPLES OF CREATIVE THINKING TRAINING. Conference proceedings: An international conference on creativity and innovation management Book 2, p. 59-69. Buffalo, NY: Buffalo State.

2- Marzieh Allahdadi and Farzaneh Honarbakhsh (2015). EXAMINE THE ROLE OF CREATIVITY IN INDUSTRIAL DESIGN. Indian Journal of Fundamental and Applied Life Sciences ISSN: 2231– 6345 (Online) An Open Access, Online International Journal Available at www.cibtech.org/sp.ed/jls/2015/01/jls.htm 2015 Vol.5 (S1), pp. 557-564/Allahdadi and Honarbakhsh
3- Matthews, Judy (2017). Experimenting and innovation: purposes, possibilities and preferred solutions. CERN Idea Square Journal of Experimental Innovation, 2017; 1(1): 17 DOI: https://doi.org/10.23726/cij.2017.459
4- Mathias Benedek, Julian Jurisch, Karl Koschutnig, Andreas Fink, Roger E. Beaty. (2020). Elements of creative thought: Investigating the cognitive and neural correlates of association and bi-association processes. Journal homepage:www.elsevier.com/locate/neuroimage. Neuro Image 210 (2020) 116586
5- Miller, B.J., Vehar, J.R., & Firestein, R.F. (2004). Creativity unbound: An introduction to
creative process (4th Edition). Evanston, IL: THinc Communications.
6- Sibel Demir Kaçan1,* , and Fatma Şahin2(2018). The Impact of Scientific Creative Thinking Skills on Scientific Process Skills. SHS Web of Conferences 48, 01060 (2018) https://doi.org/10.1051/shsconf/20184801060 ERPA 2018.
7- Plucker, Jonathan & Beghetto, Ronald & Dow, Gayle. (2004). Why Isn't Creativity More Important to Educational Psychologists? Potentials, Pitfalls, and Future Directions in Creativity Research. Educational Psychologist. 39. 83-96. 10.1207/s15326985ep3902_1.
8- Ram, Ashwin & Wills, Linda & Domeshek, Eric & Nersessian, Nancy & Kolodner, Janet. (1995). Understanding the Creative Mind: A Review of Margaret Boden's. Artif. Intell.. 79. 111-128. 10.1016/0004-3702(95)90027-6.
9- Sternberg, R. J., & Lubart, T. I. (1999). The concept of creativity: Prospects and paradigms. In R. J. Sternberg (Ed.), Handbook of creativity (pp. 3–15). Cambridge University Press.
10- Tim Brown. (2008). Design Thinking. Harvard Business .https://hbr.org/
11- Xiantong Yang a b, Mengmeng Zhang c, Yuehan Zhao d, Qiang Wang a, Jon-Chao Hong e (2022) Relationship between creative thinking and experimental design thinking in science education: Independent or related. Thinking Skills and Creativity, Volume 46, December 2022, 101183

Websites

12- https://www.interaction-design.org/literature/topics/design-thinking?srsltid=AfmBOoqXFw_CubMYwYdszhEHBR0t2Am_CYHkDuJopxYcp3H-tjoOeGxe#docs-internal-guid-6067c79e-7fff-51cc-df4d-6c90ccf0bce0
13- https://www.theforage.com/blog/skills/creative-thinking
14- https://medium.com/wayfair-design/is-product-design-an-art-or-a-science-d62f103d18a5

15- https://uxdesign.cc/scientific-thinking-vs-wishful-thinking-in-product-design-9ee33691b6c8
16- https://coonoor.medium.com/design-thinking-the-scientific-method-for-innovation-f5912e721063#:~:text=Discovery%20and%20hypothesis%2Dbased%20problem%20solving&text=In%20a%20nutshell%2C%20the%20scientific,those%20experiments%20with%20existing%20facts
17- https://www.linkedin.com/pulse/science-vs-creativity-navin-sinha/
18- https://growthtribe.io/blog/design-thinking
19- https://www.ukessays.com/essays/psychology/principles-scientific-thinking-4383.php