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Science in Design

Solidifying Design with Science and Technology

by
Tarun Grover and Mugdha Thareja

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Preface

What does society expect from technological innovations? How can they be calibrated with scientific techniques to guarantee their goodness?

These queries have always risen during the authors' research and teaching of courses on design and engineering offered to graduate and postgraduate students at different academic institutions. Today, the majority of the courses in academia focus on educating learners on a plethora of design disciplines, technological and engineering practices, and research methods to bring an innovative idea to life. But the value of design knowledge and methods in the improvement of the framework or the technology is only partially realized; the fact is that the importance of the scientific approach, while very important, is not extensively dealt with by educators and industry practitioners. Some recent studies show a dire need for design research in education that the academia sector is lagging behind, eventually creating a gap between knowledge gathering and its application for designing in practice. The contribution of design and technology research is always sought after during studies in engineering/design/management, or when defining objectives for upcoming research initiatives or during the instructional design of a course study. The need for this book became obvious when both authors initiated a search for proof of concept that addresses the aforesaid issues.

The book starts with the recognition of design as art, science, process, and outcome. A design as art holds ideation, and as a process illustrates the relationship between framework and development; equally important, however, science validates the selection and application of a theory or method for the discovery of knowledge, and as an outcome holds the benchmark for a new innovation. Design science as the science of design holds certain objectives toward the construction of different artifacts for a specific solution based on the environment, technology, and people involved in the domain problem space. Research in design science, as defined in this book, is unlike researching in the domain of social science or applied science.

The research questions involve whether the adopted artifacts are indeed the most efficient and viable as a means to reduce the complexity of a problem. Knowledge about the most advanced technologies and research methodologies; their degree of success in the contextual implementation of a solution; the scope of developing a novel creation, design innovation, or a computational algorithm: all of these should be considered as an agenda to operationalize hypotheses and design practices in order to meet the final criteria of effective performance in different dimensions.

Science in design reveals the design of a product or process aimed at accommodating a development cycle that is scientific rather than descriptive. The goal is to show how empirical research and the design cycle rely on a scientific approach and computational intelligence for validation of their purpose and the selection of design attributes. In our conception, design science research is a foundational practice that happens to be interdisciplinary and instrumental to the formulation and evaluation of various design theories and implementation in a given situation – to be validated

by domain professionals in terms of relevance to the aim of a research project. The objective of this edition is to provide a comprehensive study of design knowledge and how it can be created using design science research and methodology, keeping in view technology, methods and practices, and knowledge utilization in a particular system's environment. Science "in" design is used here in a very specific sense: to denote domain studies and systems that have obtained a given behavior because they are adapted in particular reference to well-executed empirical methods. The artifacts and their construction in terms of behavior are driven by scientific explorations.

The environment of the physical world lies in the realm of natural science, but linking humans to the digital world of information and applications is possible in the domain of "the artificial". When an artificial system adapts to the behavior of humans in a controlled environment, it signifies the design of robotics, which becomes the objective of system development. The breakthrough technology of sixth sense robotics using gesture recognition has been included in this edition. Developing in some detail of two specific examples – design thinking and design science research – describes the shape of designers as they emerge from technological developments over the decades.

Beyond specific illustrations, the authors have indicated how the presence of science and technology is relevant to textile and apparel production, computing, graphics, fashion, etc. to all fields that converge on the essence of design to achieve specific goals and functions. Ultimately, this book will help you navigate through the complex layers of design concepts, background theories, design methods, and technologies for designing in different fields while providing you information on how to effectively think about using all these technologies and the appropriate research methodology to design the next.

We hope you enjoy learning from this book as much as we enjoyed writing it for you!

Acknowledgments

Writing the acknowledgments is an opportunity to pay gratitude to all those who matter in our lives and helped us along in achieving our dream and aspirations. With the grace of God and our efforts, we have reached this stage.

Owing this achievement to her paternal uncle and world-renowned author Dr. B. L. Thareja, Mugdha with her authoring partner Tarun appreciate the writings of recognized research authors like Dr. Reema Thareja, Dr. Shakti Kumar, Dr. Kaleshnath Chatterjee, Dr. Rajkishore Nayak, Prof (Dr.) Sanjay Gupta, and Dr. Asimananda Khandual, who have been a great source of motivation for us to step up in this journey toward contribution to research and education by writing simplified content focusing on transformative technologies and trends of the digital age.

Thanks to the two great leaders and philosophers whose inspirations helped us through the development of thought leadership: Dr. Vishwanath Karad, a well-known Educationist and Ambassador and torch-bearer of World Peace, and Dr. Mangesh Karad (Executive President, MIT Art Design & Technology University Pune) for providing a multidisciplinary university environment that nurtures aspiring minds and faculties with collective wisdom and collective knowledge of art, science, design, and technology to achieve the satisfaction of realizing impossible dreams. Fortunately, we have had the support of our fellow members of The Technological Institute of Textile & Sciences, Bhiwani Haryana, Mr. T. H. Ansari (Arahne Software), Mr. Sunil Kumar Puri (Techknit Overseas Pvt. Ltd.), Team Tukatech, and the Institute of Design at MIT ADT University, Pune Maharashtra.

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Comments and suggestions for the improvement of the book are welcome.

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I wish to dedicate this book to my late father Mr. Rakesh Thareja.

Dad! As you look down from heaven, I hope
you're proud of your daughter.

-Mugdha Thareja

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Tarun Grover is currently working as Assistant Professor at MIT-ADT University, India, in the department of fashion design. A postgraduate (M-Tech) in Textile Chemistry with specialization in material studies and textile, Mr. Grover has worked with various universities of repute, technical research organizations, and government agencies for numerous projects. He is an alumnus of TIT&S Bhiwani, an institution established in 1943, renowned for its state-of-the-art research initiatives and higher education in Textile Science and Engineering. He wrote the Chapter "Selecting Garment Accessories, Trims, and Closures" in the book *Garment Manufacturing Technology* (1st ed.), published by Woodhead Publishing, and another chapter, "Integrating Sustainable Strategies in Fashion Design by Detox 2020 Plan – Case Studies from Different Brands" in the book '*Detox Fashion*' – (Vol.4) published by Springer Singapore. He is a lifetime associate member of TAI (Textile Association of India), and also a member of WDO (World Design Organization, Canada).

Mugdha Thareja is a research enthusiast and qualified professional in the field of computer science and information technology. A postgraduate (M-Tech) in Computer Science Engineering with a specialization in software engineering and image processing, Mugdha Thareja has around seven years of combined experience in academic research and education and the IT sector. She has served various premier engineering and higher education institutions in India as an academic faculty and has done research and publishing projects on the multidisciplinary approach. She possesses niche experience holding responsible positions at IT companies of global repute, including Genpact and e Software Solutions. She has offered her services as a consultant and instructional designer for various government projects sponsored by NABARD, TSSC, and NSDC in the field of technical education, skill development, and women empowerment. Her specialized areas of interest include software engineering, research methodologies, design research, agile methodology, human–computer interaction, user experience and multimedia, web technologies, and software project management.

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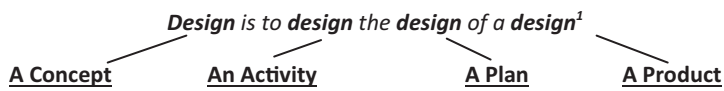
1 General Aspects of Science, Design, and Engineering

1.1 WHAT IS DESIGN?

A design is a strategy or specification for the development of a system or object. In other words, design can be thought of as the implementation of a plan or a process to achieve an objective. More often, the term "design" is used to indicate the outcome of a process or strategy in the form of a prototype or a final product. The broader meaning of design can be interpreted more easily with the following narration.



Undoubtedly, the term "design" encompasses the varying viewpoints of people who understand its meaning through different lenses. In general, "design" is the process of visualizing and planning the development of systems, objects, methods, products, etc. The definition of design is versatile and artful, and design has taken many shapes and forms based on multidisciplinary concepts. Besides the major cluster of design disciplines (engineering, information systems, industrial, architecture, textile, and fashion), experience design, service design, and interactive design have evolved as new domains for design enthusiasts to explore deeper insights.

1.1.1 Definition of Design

First, let's glance at some of the noteworthy definitions of design by well-known authors.

> *A design is a plan to make something new for people that they perceive as beneficial.*
>
> **– Koss Looijesteijn**

> *Design is a reflective conversation with the materials of a design solution.*
>
> **– Donald A. Schön**

It's the difference between your favourite and least favourite thing you use.

– Scott Berkum

Design is its own culture of inquiry and action.

– Harold Nelson, Erik Stolterman

Having these in mind, the ability to design and the notion of design relating its associative aspects are the key focus in conceiving the definition of the term "design". Design can be classified based on three fundamental perspectives: art, problem solving, and the pursuit of the ideal [2].

a) Ability to Design

The importance of designing ability has been realized by many design educators and practitioners for enhancing learners' skills to design. However, there is no clear picture of what constitutes traits of designing aptitude, since the various meaning of design makes this perspective a much broader concept. The classification of designing ability is aimed at encouraging efforts toward addressing challenges like contributing to building the future world, solving difficult problems pertaining to the environment, and acting as a guide for the next generation to follow. Therefore, the classification of design and designers' perspectives plays an important role in formulating a definition of design.

b) Notion of Design

Here, we explain the three notions of design and discuss their influence on the development of a new product or system.

Class A: Art

Design is widely assumed as the expression of ideas in the form of sketches or drawings, commonly known as art. This is the classification of design on the basis of its common use. Although art seems to be creative, the creativity itself involves the process of transforming an imaginary picture into a concrete object. In particular, the process of creative art involves an examination of the past, since the image for an abstract idea comes from the designer's own mind and memory.

Class B: Problem solving

In this notion of design, the main focus is on how to design in the context of the current problem rather than on what to design. In this case, the procedural design is depicted within the framework of problem solving. Within this framework, the process of designing a solution requires identifying a problem and examining the gap between the existing state and the target design goal. In other words, the solution to a problem lies hidden in the designing gap. Therefore, a problem-solving activity cannot generate a new goal unless the procedure of determining the desired goal is complete. "To design is to plan, to order, to relate and to control", says Emil Ruder.

Class C: Pursuit of the Ideal

The term "design" can be used to explain the pursuit of certain ideals, i.e., solving evident problems. This notion of design can be understood easily from a social perspective and contains within it the definition of the future. The classification of design in the context of ideal pursuing refers to anticipating the future. It involves the process of abstraction in an ideal environment. Furthermore, this notion describes the nature of design that conforms to the future perspective that only humans can perceive. According to the design definition by Herbert Simon, "To design is to devise courses of action aimed at changing existing situations into preferred ones".

On the basis of above classifications, design can be defined as "the composition of a desired goal toward the future".

1.1.2 Themes of Design

In order to set the theme of design, lots of different permutations and combinations can be applied, but the most straightforward way of explaining design would be through design education. Education in design is a way to know what and how, which are the means to a qualified design profession, which is a means to well-designed processes and products, which are means to economic competitiveness, which is a means to job creation, which is a means to economic wealth, which is a means to the quality of life [1]. There are a variety of approaches to defining the curriculum of design where the perspective, context, training, and goals may vary. Some of the approaches common to all perspectives are illustrated below (Figure 1.1).

- *Project-based Learning*
  This is one of the best approaches to learn "design by doing design", which gives hands-on experience to learners and students. Throughout the project, the designer has the responsibility to define the problem, ideate and present designs, and then make refinements on receiving feedback through "Critiques".
- *Visualization*
  With a foundation in aesthetics, designers practice visualization techniques to quickly sketch the abstract image and efficiently turn complex ideas or problems into easy-to-understand visuals.
- *Insight, Research, and Co-creation*
  Designers need to walk in the shoes of customers to gain better insight into their problems. There are various methods to collect information or data about the defined/unknown problems. Examples include learning interview techniques, design research, co-creation, and mapping techniques, through which designers can grow their empathy for users and train to move past their own preconceptions and biases.
- *Prototyping*
  Prototyping allows designers to rapidly build a test module, and then evaluate and iterate the design process based on the new concepts and feedback, saving time and money during a project.

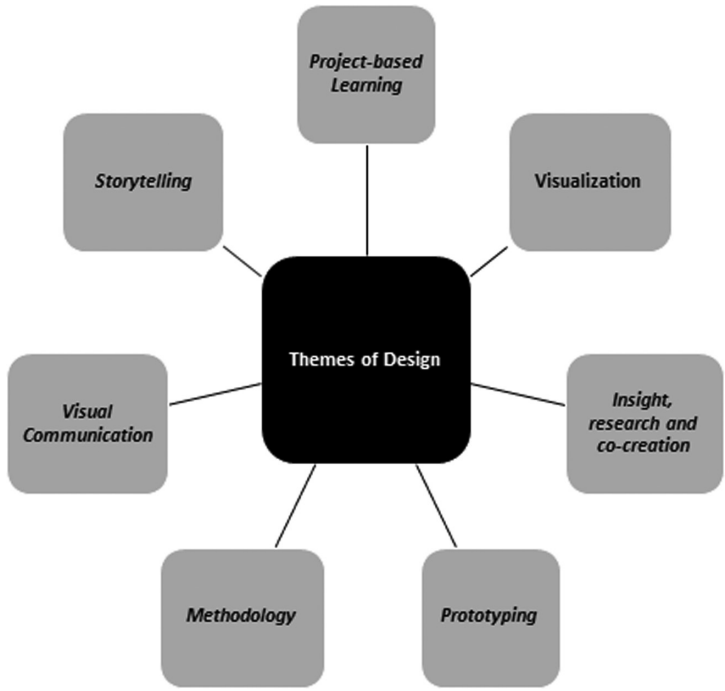


FIGURE 1.1: Themes of the design curriculum.

- *Methodology*
  Methodology entails the final process for narrowing down to the best-fit solution after executing a number of trials that generate numerous concepts for exploration.
- *Visual Communication*
  Visual communication enables human power to receive and respond to visual information by seeing the shape, line, color, and type of visual elements. Having a strong visual communication theme allows designers to create different gestures and emotions.
- *Storytelling*
  We humans respond best to stories — it is how we naturally process and store information. Likewise, designers learn to harness this approach both in text and in user flows in order to sell concepts.

1.1.3 Multiple Facets of Design Paradigm

According to Bryan Lawson and Kees Dorst (author of *Design Expertise*), "One of the difficulties in understanding design, is its multifaceted nature. There is no one single way of looking at the design that captures the 'essence' without missing some other salient aspects". Therefore, it is a big challenge to define the design in

one frame. This is considered as a process of design activities – inputs, evaluations, and outputs. Design is truly multifaceted; it is a composition of many different disciplines of work coming together. The concept of the design paradigm is used to illustrate the model of an object that alters the layout with an aim to address changing demands and problems facing the distinguished design professions. A design paradigm can be envisioned as a prototype or a solution considered by a community as being effective, influential, and sustainable for growth. A design paradigm is a three-dimensional structure of a working relationship between groups of components and serves as an epitome for business success that ensures the quality of deliverables. The latest emerging and most powerful aspects of design paradigm are as follows:

- *Experience Design*: Experience design or XD is a cross-disciplinary perspective of design paradigm that involves the practice of designing an object, process, service, or environment, with a focus on delivering the best quality experience to the end user through interactive solutions. Experience design takes into account human factors applied during the design process. An innovative experience design rivets minds and increases the business appetite for radical ideas.
- *Eco Design*: Also known as sustainable design, eco-design involves the creation and redesign of products and services to bring configuration changes that reap many business benefits including but not limited to reduced cost, increased customer satisfaction, improved economy, and reduced damage to the environment.
- *Service Design*: Service design is the activity in which the designer specifies and creates a process to deliver an optimal solution for specific user requirements. It is a process of planning the arrangement of service components in order to increase the customer's interaction with the brand. It primarily informs the need for change in the existing process and for building a new product based on past experience design outcomes.
- *Sustainable Design*: Sustainable design is the practice of multiple disciplines that integrate an environmentally friendly approach and consider nature's resources as part of the design assets so that they exist in harmony with natural systems. The goal of sustainable design is to achieve a better future for the human race through the wise and low-volume consumption of Earth's resources. This design approach is most sought after in the concept of circular economy business models.

1.1.4 Design Questions

Questions are an interesting aspect of defining design, as questions are a concrete outcome of the everyday problems design tends to solve — including the core values and ideology of a designer. These questions do not require special tools and can be asked by anyone from any field, not the designers only. Having this, the design is inevitable, as long as there is a continuous stream of questions being asked with

different objectives. Some of the most common questions that aid in formulating design definitions are the following:

- Who are the target customers? What is their common problem space? How to get the customer requirements?
- How do people communicate with and use the existing solution? What are its limitations right now?
- What are designers aiming to achieve? How does this impact the user experience?
- What is the objective of product design? How can it reach the people with a quick time to market?
- How can designers perform research and gather input from domain experts?
- What dependencies or regulations may affect the design experience?

After receiving answers to these questions and understanding the essence of new design and improvement, designers and research practitioners can definitely work on deriving the meaningful sense of design: what the "design" thing is.

1.2 FIELDS OF DESIGN DISCIPLINE

The term "design" has many synonyms, where each designer has a unique way to formulate the solution of any problem, whether it's related to the technical domain of design or to the applied arts. Underpinning the role of the designer in various fields might be different, but the principles remain the same, that is, to redefine how problems are approached, to identify opportunities for action, and to help deliver more complete and resilient solutions.

In the era of the 21st century, designers, researchers, and practitioners have been expanding the design to be more "designerly" through deep rooting in an interdisciplinary approach and methodological, conceptual, and theoretical frameworks to encompass ever-wider disciplines, activities, and practice. The following are disciplines which have been recognized as discrete design disciplines such as product, graphic/visual communication, interior, textile, retail and e-commerce, art and jewelry, furniture, and fashion design. The key foundational concepts that are recognized to have revolutionized the modern design arena are design management [14], design education, design research, and design science methodologies. These concepts play an important role across all the disciplines of design for the development of user-centered or humanized products (Figure 1.2).

1.2.1 Product and Industrial Design

Industrial designers are also known as product designers, as they are particularly concerned with those aspects of products that relate to human usage and behavior and product appeal. In the view of manufacturing and marketing the products, design is the most important "feature" that helps designers grasp a real edge over competitors. Product design is the process of identifying a market opportunity, defining the problem, developing a proper solution for that problem, and validating the solution

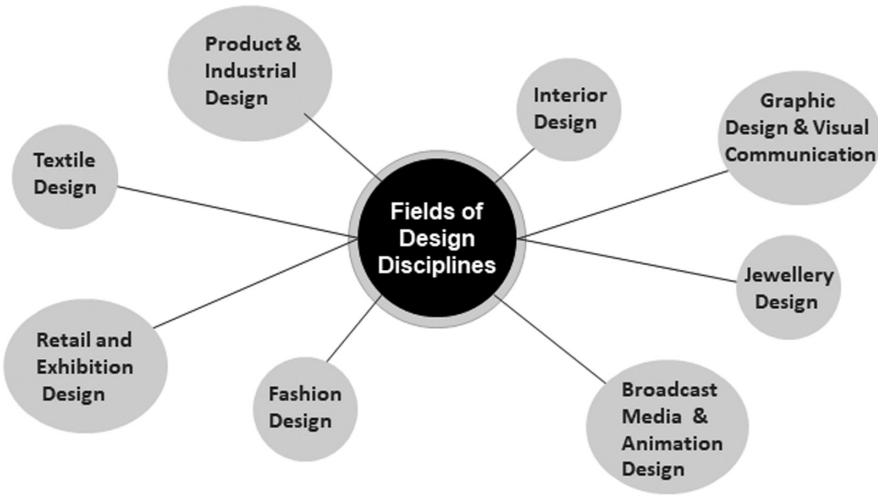


FIGURE 1.2: Fields of design disciplines.

with real users. Therefore, designers have to follow a design process which starts from doing ideation through drawings, rough sketches, and illustrations of products, selecting the best match model, and then creating prototypes to demonstrate and test products. It is common for industrial designers as well as product designers to work as a part of product development team.

1.2.2 Graphic Design and Visual Communication

Graphic designing has always been the most striking benchmark of any successful brand in the market with an aim to increase business outreach. Various materials and software tools are being used for creating a brand identity that could enable communication with a broad audience across the globe. Both manual creativity using paper or printed materials and technology using digital software help in keeping in touch with customers and keeping record of feedback for further reproduction. Graphic designers develop and prepare information for publication with a sound understanding of text-based communication along with the smart utilization of communication properties, including symbols, colors, and pictures. The key role of graphic designers is to develop concept layouts and subcontract diagrams, illustrations, photography, and mock-ups to discuss project details with clients. The rapidly developing areas of digital media relating to the Internet and multimedia business presentations are opening up new areas of employment for graphic designers.

1.2.3 Interior Design

In the midst of urbanization, the migration of people to other cities in search of bread and butter as well as better lifestyles has increased requirements for qualified interior designers and design engineers in the real estate and architectural sectors. They are

engaged in planning commercial and residential building exteriors and interiors by understanding the concept of minimalism, which is already pushing our style of living and work environment to the next level. Designers are trained in postulating the layout of space planning, space creation, building services, furnishings, and multilevel modifications that are more aesthetically consummate and provide a more functional environment. Today, the outlook of interior design plan requires not only a captivating look but also a designer to understand technical intricacies like structures, purchase of materials, risk and budgeting, furnishings, and most importantly expert skills to implement a project in good order to arrive at an optimal design.

1.2.4 Textile Design

Textile design is one of the disciplines that nurture the beauty of fashion design and apparel production. By understanding material science through the knowledge of textile materials and their scientific properties, designers in the fashion industry move forward to producing different categorized garments using the appropriate manufacturing process. The role of textile designers is not limited to the development of patterns, knit and weave construction, textures, and illustrations for fabrics, but also includes evaluating how the fabric appears and performs to meet the objective. Textile design as a discipline builds textile designers who are employed in the capacities of designers, trend analysts, dyers, colorists, and stylists in different market verticals like textile mills, export houses, design studios, merchandising business, craft houses, and retail stores. These designers are trained professionals having sound technical knowledge of each and every aspect of fiber to fabric processing including yarn making, weaving, knitting, dyeing, and finishing processes. Also, they demonstrate good command over the interpretation of different types of looms, knitting machines, and printing processes, which are in-demand skillsets of designers.

1.2.5 Retail and Exhibition Design

Retail and exhibition designers create and balance the building and installation of trade exhibitions, permanent shop displays, museum exhibits, pop-up stores, and interpretive displays. They use their inherent creative skills and those gained from the study of graphics, product design, and market research to capture, inform, and involve common people as the subject of their research and inspiration. The retail and exhibition design field is open to trained newcomers and professionals from industrial design, product design, graphic design, interior design, social science, and digital design areas like multimedia, web design, and e-commerce. Industrial designers use their abilities to design form and mechanical detail, interior designers use their abilities to design the function and aesthetics of spaces for human occupation, and graphic designers use their skills in presenting messages in visual form.

1.2.6 Fashion Design

In general terms, fashion design is considered one of the happening branches of design which attracts interesting characters, and its glamorous attributes tend to

connect everyone. But designers have to really work hard to launch a particular collection inspired by a particular theme, which includes illustrations, drawings, pattern making, stitching, and an overall understanding of colors and fabrics.

Fashion designing has become very popular in India in the last few years, and many people are now considering it as a career choice. With economic prosperity, the average income of Indians has increased. Hence, people have better lifestyles compared to the past and they can afford to spend more on their attire. As a result, there is an increased demand for professionals who can design and create new garments, dresses, and attire to cater to the tastes of people from different walks of life.

1.2.7 Jewelry Design

The boom in the gem and jewelry industry has brought innumerable employment opportunities for jewelry designers. The role of designers is to conceptualize, prototype, and detail for manufacture items of jewelry such as rings, brooches, bracelets, necklaces, watches, eyewear, and earrings. They have specialized knowledge of the metals, jewels, precious stones, and other materials associated with personal adornment. They may develop designs for mass or batch production, or they may develop special items to satisfy one-off commissions. Jewelry designers may be employed within manufacturing companies specializing in jewelry or in other decorative personal and home wares such as silverware, cutlery, eyewear, watches, and trophies.

1.2.8 Broadcast Media and Animation Design

A broadcast designer is a person involved with creating animated designs, graphic designs, and electronic media incorporated in television channels and production houses. The job of the designer is to create a look and feel for a specific idea or subject. Animation design is the art of creating special effects and other designs for various forms of media, including video games, movies, and even social media posts. The role of animation designers is to make animated TV shows or games, design settings, and create computer-generated images (CGI) to bring special effects to life. The industry of Broadcast Media and Animation Design has generated rapid growth in the unending demand for talented and aspiring individuals in this field.

1.3 SCIENCE AND DESIGN

Design as a field occupies more space when coupled complementary to science than any other field [3]. It was difficult to talk about any coexistence of science with design until the 20th century, when designers and science experts worked on various artistic monuments and the art of design proved its potential to bring life into objects. The creation of famous museum exhibits, innovative design of informative graphic material, or the interactive simulation of an experiment: all these can convey scientific insights in an intelligent, informative, and delightful way. Until the 19th century it was apparently believed that design relates closer to the fine arts than to science in general. Since scientific intellects ignored the commotions of the design

space, designers and artists tended to share the same universities to learn skills and still share the same mindset.

In the recent course of history, the role of science in design has dramatically evolved with the introduction of new principles and practices. Earlier, scientific knowledge was related to direct experience, but now with the gradual development of different kinds of experimental theories and hypothesis, scientific knowledge has become fundamental and abstract and need not be associated with direct life experience only. Undoubtedly, scientific knowledge is more important in shaping the backbone of a design structure and needs the third eye of the user to realize its existence in the state of design. Scientific methods and scientific knowledge are increasingly used to develop a sophisticated design enabled with technology. For example, in a racing car in which the use of scientific knowledge provides the means for designing the system and operating its speed parameters, technology and mechanics provide power to the engine. To design scientifically is of paramount importance; this process is accompanied by methods like experimental variation, quantification, simulation, and mathematical descriptions. The social dimensions of scientific knowledge are useful in understanding the relations between science and social practices.

Science takes advantage of design research and development. The principles of empirical science rely on the observation of empirical data and are governed by empirical laws. Advanced scientific rules are based on scientific queries and research, intended to bring change into the world, improve quality of life, and create new horizons of knowledge. It is hard to decide whether science or design is more powerful in the modern technology era, but nonetheless they can benefit each other.

Bringing things to a head, this section introduces a special strand of relationship between science and design – Design Science, a scientific study of design artifacts that focuses on its multidisciplinary nature and recommends developmental research methods.

1.3.1 Design Science

Design science is composed of two principal words – design and science. Where design depicts the sphere of multifaceted art, science underlines the logical patterns of the intent behind the selection of a particular design. The concept of design science was introduced in the late 1950s by R. Buckminster Fuller, who defined it as “a systematic form of designing”. This term was later expanded in conceptual breadth by S. A. Gregory, who proposed a distinction between scientific method and design method.

According to Van Aken, the main goal of design science is to develop knowledge that professionals of different disciplines can use to design versatile solutions for real-world problems. Having said this and taking into account the wonders of design science research seen during the past few years, there is no denying the fact that the interactive collaboration happening between these two worlds offers a more focused scientific study of designed artifacts with the explicit intention of improving the aesthetics and functional performance of a system. Over an arbitrary period of time, the interchanging use of design science as the study of design and systematic

designing has comingled the two meanings to a point where this term exhibits pragmatic behavior of both design as a science and the science of design.

1.3.2 Design and Design Science

Nowadays, science is making a buzz by being applied across many fields, including wireless, mobile communication, automobile, healthcare, life science, information systems, defense, design, and engineering. Undoubtedly, design is the frontier of any product, which attracts its users' attention and compels them to experience the quality and utility of the product at least once. The common factor in both terms is the focus on the development of novel artifacts or the investigation of original artifacts that differ from existing ones. However, the objectives of both terms in terms of people and practices differ in their respective contributions to the knowledge base and in their ability to be generalized.

Design is a process to articulate a solution for a problem which is encountered locally and focuses on a particular target, organization, or end user, whereas design science works more toward the general interest of solutions designed to produce results that are relevant for the local and global community of practitioners and researchers. To reduce the gap between design as a practice and design science, the foundational requirements of design science research need to be satisfied per the following criteria:

1. Firstly, the purpose of creating new knowledge of general interest requires design science projects to make use of rigorous research methods.
2. Secondly, the knowledge produced has to be related to an already existing knowledge base in order to ensure that the proposed results are both well founded and original.
3. Thirdly, the new results should be communicated to both practitioners and researchers.

To understand these three requirements, consider an example of a project for designing a new electronic health record system. In order to classify the project as a subject of design science, the following three conditions in reference to the above criteria are postulated:

- *Use of rigorous research methods*: The foremost requirement of project development is to build an overall research methodology that encompasses problem investigation and the collection of relevant data, which can be carried out through survey questionnaires for large groups of healthcare professionals and expert interviews with physicians and healthcare providers working in relevant functional areas. Following this, the pre-evaluation of the artifact produced as a result of the analysis of collected data should be executed using grounded theories, research strategies, and methods.
- At the second stage, data inputs and the need for projected artifacts are analyzed in comparison with the already existing knowledge base of health

informatics and electronic information systems to point out the scope of improvement in the new version. Furthermore, this also helps in assessing the utility, originality, and validity of the artifact in context.
- The next step in the project is the dissemination of research outcomes and experimental results to both researchers and healthcare professionals through media like publication in journals and conferences, presentations at healthcare seminars, professional conferences, symposiums, and other similar events.

1.3.3 Principles and Recommendations

Current design research and methodologies advocate for design science as a present-day, state-of-the-art form of design beyond the abstract forms of human, natural, and social science. The core objective of design science is to create artifacts that are used in solving real-time problems [4, 5]. The parameters of design science are derived to meet certain criteria of rigor and relevance that approach a determination of their functionality in organizations' context of work, usefulness, and ease of use [7]. Design science aims at bridging the gap by bringing theory into practice, which is, however, not readily applicable for designing management processes. The primary goal of design science research is to manage planning, design, implementation, improvement, monitoring, or evaluation of information systems in an organization.

Design Science can be emphasized as an organized approach to design, making the design process itself a scientific activity. In general, the design process follows design science principles to create purposeful artifacts for the problem identified in design and management. The design science process is underpinned by several key principles, which we have summarized in Table 1.1.

1.4 EXAMINING DESIGN PROCESS FROM DESIGN SCIENCE OUTLOOK

Design Process is an approach for breaking down a large project into manageable and achievable chunks. Architects, engineers, scientists, and other thinkers use the design process to solve a variety of problems. A generic design process model [6] defines a designer's journey to tackle a project. Beginning with defining a problem, justifying the tasks, and generating prototypes followed by the design refinement, impact evaluation, and communication, a design lifecycle comprises of multiple small set of activities backed by background research. Nevertheless, gathering feedback from as many people as possible helps in making the decision whether to take the designed solution back through the process for improvement in quality standards.

Design science research is a practical approach for creating new artifacts to solve defined problems or for redesigning an existing solution to achieve the goal of process improvement. Two basic activities, namely "build" and "evaluate", are involved, where building is the process of designing an artifact for a specific purpose, and evaluation is the process of determining how well the artifact performs and fits into

TABLE 1.1
Principles of Design Science and Literature

Principle	Description	Key References
Design as an Artifact	The development of useful artifacts is a core requirement. Artifacts include: constructs to describe problems or solution components; models to represent the problem and its solution space; methods to provide guidelines for task performance; instantiations to demonstrate the utility of the artifact.	[4, 5, 8–10]
Design Problem Relevance	DS research is problem driven, aimed at addressing the problems situated at the intersection of people, organizations, and information technology.	[4, 8, 10]
Design Cycle	Design cycle activities iterate between building and evaluating artifacts and are based on both relevance and rigor, focused on addressing application domain requirements, while drawing on existing theoretical foundations and methodologies in the knowledge base.	[4, 8, 11]
Design Research Rigor	A design requires the use of methods and analysis appropriate to the tasks at hand. The DS rigor cycle links build and evaluate activities with existing foundational theories, frameworks, artifacts, processes, methodologies, and application domain expertise in the knowledge base.	[4, 8, 11, 12]
Design Artifact Evaluation	Rigorous evaluation methods are required to demonstrate the design of artifact's utility, quality, and efficacy. Metrics are used in comparing the performance of artifacts. Evaluation approaches may include case studies, field studies, analytical methods, experimental methods, testing, or descriptive methods.	[4, 5, 8, 9, 11, 13]
Design Research Contributions	Contributions of DS research include: an artifact that adds to the existing knowledge base; design construction knowledge improving foundations; design evaluation knowledge enhancing methodologies; experience gained from the design and evaluation of activities.	[4, 5]
Communication and Dissemination of Research Outputs	The results of design science research should be communicated and presented in an appropriate form to the technical and managerial community.	[4, 12]

the design framework [9]. In particular, a process-based approach follows multidisciplinary aspects of design and is evaluated in the following key seven design science principles, which are also listed in Table 1.1.

1. **Design as an Artifact**
   This principle demands that design science research focuses on building and evaluating an artifact in the form of a construct, a model, or a method [4, 5]. The process-based approach aims at producing a management process and produces therefore an artifact, which is a method to achieve something.
2. **Design Problem Relevance**
   The designed artifact should be relevant to the domain discipline [4, 8, 10]. According to Hevner et al. [4], artifacts in IS, for example, can be technology-based, organization-based, or people-based artifacts, which are all necessary to address problems in IS. On the other hand, a management process is an organization-based artifact.
3. **Design Cycle**
   Design science is described as a Generate/Test cycle and is therefore an iterative process to find a solution for a problem [4, 11]. In the process-based approach, a process is repeatedly applied and refined until it solves the problem. In addition, designing an artifact necessitates knowledge in the application and solution domain.
4. **Design Research Rigor**
   Design research rigor has to be evaluated in the light of how well an artifact works and not by how well it can be explained why it works [8, 12]. This brings the applicability and the generalizability of the artifact into the center of focus, which is also the primary goal of the process-based approach. Applicability and generalizability are achieved by application of the designed process in a number of organizations in different industries.
5. **Design Artifact Evaluation**
   Evaluation of designed artifacts is crucial for a design science researcher in order to justify an artifact's relevance for practice based on the business environment. In general, the artifact evaluation method is based on the criteria of measuring the utility, quality, and feasibility of an artifact.
6. **Design Research Contributions**
   The major contributions possible out of process-based design science research [4, 5] are as follows: (a) addition of artifact to existing knowledge body, (b) design development knowledge improving the generic structure and enhancing methodologies, and (c) experience gained from "build and evaluate" activities.
7. **Communication and Dissemination of Research Outputs**
   An important part of design science research is the effective communication and dissemination of research results [4, 12]. Hevner et al. argue that research in design science has to "be presented both to technology-oriented as well as management-oriented audiences" [4].

1.5 CONTRIBUTION OF DESIGN SCIENCE IN BUILDING DESIGN

Design is inevitably a continuous process, and its knowledge is entangled in science and technology. While the role of science in design remains a topic of deliberation and deep understanding, the development of artifacts using advanced scientific rules has been acknowledged to bring transformation to the world of design innovation, by improving the efficiency of the system and by creating new horizons for digital agility in the design process. Therefore, some sort of annotation is established between design science and design, which clearly opens up entirely new avenues of human endeavor. While design follows professionally recognized methods and its results are typically compared to the state of the art, design science on the flip side provides design researchers with critical analysis of outcomes based on the scientific body of knowledge and technological tools for evaluation and testing.

Gregor and Hevner et al. [15] proposed that the contribution of design science research knowledge to the maturity of the design research process and its artifact construction can be explicated in two dimensions: Application domain and Solution. An application domain maturity graph seeks improvement in the practice for which the contribution is intended, whereas a solution maturity graph states the maturity of artifacts that can be utilized as a foundational step toward finding an appropriate solution. Based on these dimensions, a 2×2 matrix depicting the four coordinates of design science contribution framework is illustrated in Figure 1.3:

a) *Invention*: This is the act of bringing new solutions for new problems, leading to radical innovation. An invention that achieves a completely unique function or result may be a comprehensive breakthrough. As Jeff Bezos puts it, "Every new thing creates two new questions and two new opportunities". The sharing of ideas in networks with actors from various sectors unlocks the potential for innovation. The panoply of such works is novel, and their contribution can enable new practices and create the basis for new research fields. Some examples of inventions are the first car, the first X-ray machine, and the first data mining system. For digging out the way of inventions require a good understanding of existed work and patience with a bit of luck in order to occur.
b) *Improvement*: This kind of contribution brings new solutions for addressing already existing problems. The contribution of design science in improvements is to propose solutions that actually improve on state of the art in efficiency, usability, safety, maintainability, or other qualities of the product. Some examples of improvements are the first sportbike, an X-ray machine with substantially reduced radiation, and a data mining system able to handle very large data sets.
c) *Exaptation*: Exaptations occur frequently in design science research in order to adapt an existing solution for a problem for which it was not originally intended. In simple words, an existing artifact is repurposed, or exapted, to a new problem context. For example, Hydroxychloroquine drugs are used to fight against malaria but after thorough research and evaluation,

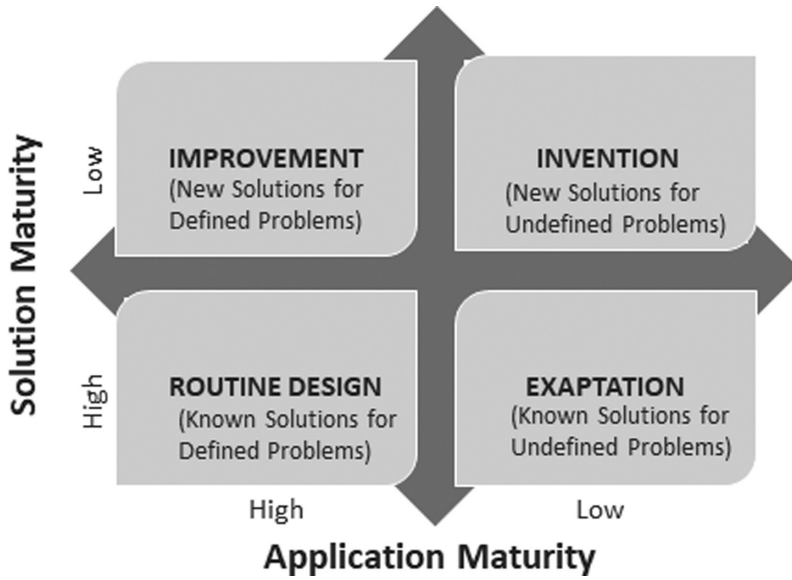


FIGURE 1.3: Contributions of design science in building design [15].

they have been acclaimed to save the lives of corona patients. To understand from the designer perspective, the designer usually produces not only an artifact in isolation but also a use plan for it. The use plan tells when and how people should use the artifact. Another example seen in the field of human-computer interaction is called reappropriation. Initially, cameras were built into mobile phones to capture images, but later on they were transformed into scanners, mirrors, note-taking tools, etc.

d) *Routine Design*: This kind of contribution is determined for known solutions for known problems. This kind of credential is used for incremental innovation that addresses a well-known problem by making minor modifications to an existing solution. Much practical professional design would fit into this category, e.g., the design of a new smartphone with slightly better specifications than its predecessor. Routine designs typically do not count as design science contributions because they do not produce new knowledge of general interest, but they can still be valuable design contributions.

The following section details the multidisciplinary nature of science in design, along with relationships and practices in different disciplines.

1.6 PEOPLE AND PRACTICES

A set of different activities is carried out by people in an orderly way that produces some meaningful results. In general, this cluster of activities performed by people is known as practices. One example would be the practice of an orthopedic doctor who engages in repairing injuries to the musculoskeletal system and many other activities related to the spine and other bones and joints. When humans practice their skills, they utilize different tools to handle certain objects. An example is the use of X-ray machines and bone pillars for joint and knee surgery.

Practices can be categorized as formalized practices and structural practices. Some practices involve individual performing actions, while other activities involve the participation of groups. Engaging in some practices may give rise to some practical problems that need immediate attention. These practical problems can be puzzling questions, troublesome situations, or obstacles to achieving the desired result. The invention of the X-ray is one such innovation that offered aid to medical doctors dealing with the limited ability to view the deep structure of internal organs.

1.6.1 Science and Engineering Practices

The strong relationship of science with engineering has played an important role in shaping the evolution of design. The important practices in science and engineering with underlined research pamper the development of scientific knowledge to develop model and carry out evaluation. The research cycle starts with asking questions, formulating problems, and continuously engaging learners in developing computational solutions to represent meaningful data.

The scientific body transforms knowledge into new ideas giving birth to new innovations. Engineers work on the principles of the foundation of science in application development to create systems in a controlled environment.

1.6.2 Design and Engineering Practices

Design with science can be described as a scientific study of emerging methodologies, tools, and practices. It is accepted across multiple domains that the blend of design and engineering has made technical innovations possible, affordable, and accessible to the wider community. The advent of engineering design has built a dynamic relationship between the science of design and design engineering. Redefining the way design methodology was assumed to be independent of the nature of problems and type of knowledge used, today the impression of the design process is validated based on analysis and scientific study of different engineering domains and their degree of involvement in design methodology.

The interlacing of design and engineering practices can be looked at in design journals having valuable contributions of authors from different engineering disciplines. A focused design process should also take the mechanical behavior of the product into consideration for a project to be successful. A product in a physical form (e.g., lever, elevator, footwear, tech textile) not only should be aesthetically appealing

but also should be able to perform the underlying engineering function or mechanics it was designed for.

1.6.3 Design Science and Practices

There is an intricate relationship between a design science project and its scope to local and global practices. In connection with design science with local practices, Figure 1.4 illustrates that design science projects may or may not utilize empirical data from that particular practice, but its results may contribute to building a scientific knowledge base. This body of knowledge, while benefiting local practitioners and the research community, should also be of significant relevance to a global practice.

Having this, a design science project seeking to contribute to the creation of a new knowledge base and to the global community can still be executed within the boundaries of local community practice. Thus, stating that design science is able to reach to a broader range of practices is not superlative, since the researcher remains involved in the design science project within the local community practice from an initial stage, building artifact solutions using the knowledge base, till he succeeds in generalizing the design of the artifact and refining the design knowledge toward the end of the project in order to obtain a generic solution for global practices as well.

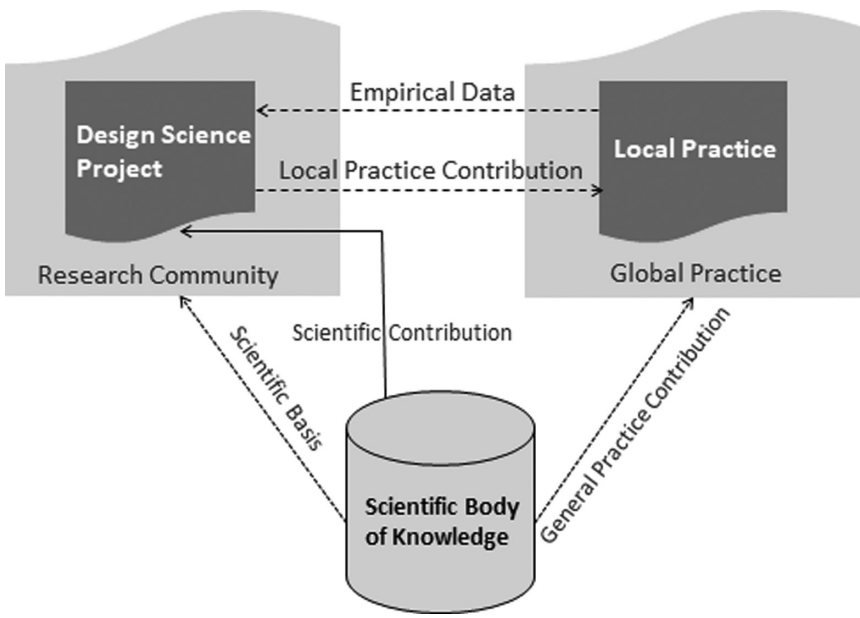


FIGURE 1.4: Local and global practices in design science research [16].

1.6.4 Science and Design Engineering

Right from the invention of simple devices like the wheel and the spoon to the complex models that designers create today, almost all artifacts involve design engineering with a scientific rationale behind it. The design of an artifact like a table fork as a product is available to the consumer in different shapes and materials, but the fundamental utility remains the same – to help eating. While the visual forms may differ, there is a common and essential component of engineering design that makes it useful to eat food. Not surprisingly, the foundation of any engineering design is based on the scientific approach, which implies the utility of scientific theories and principles, technical information, and pattern realization for a system to perform predefined functions at the highest optimal efficiency.

Nevertheless, a scientific basis is evidently present in the basic components of a design process, including the formulation of design objectives and evaluation criteria, creation, and testing. Primarily, design in engineering projects applies scientific knowledge to derive appropriate and valid solutions for technical problems. Understanding the importance of science in design engineering helps designers to ensure that the end product is made to achieve the purpose while using sophisticated design tools to automate the involved tasks systematically.

1.7 KREB'S CYCLE OF CREATIVITY: BLURRING THE BOUNDARIES

The ground truth knowledge of theories stating the degree of association between different disciplines comes from Neri Oxman's exemplary diagram of "Kreb's Cycle of Creativity". Featured in the *Journal of Design and Science* in 2016, Oxman's illustration (Figure 1.5) establishes a holistic view of the mutual relationship between four domains – Art, Science, Design, and Engineering.

Dividing the cycle into distinguished boundaries and dominions, the Kreb's Cycle [17] aimed at bringing together design and science in a way that further allows a deep understanding of the interrelationships among these disciplines.

According to Kreb's Cycle of Relationship, design and science lie opposite to one another in one circle. In contrast to engineering and design, science and design as individual disciplines do not depend on each other for input or output in the cycle. But they do form an incredible connection if we dig down deep by making a lens to view the fusion of design and science. Design and science are linked in an interactive yet complex relationship that exists with its own patterns of recognition.

> Science converts information into knowledge. Engineering converts knowledge into utility. Design converts utility into cultural behaviour in context. Art takes that cultural behaviour and questions our perception of the world.
>
> **– Neri Oxman**

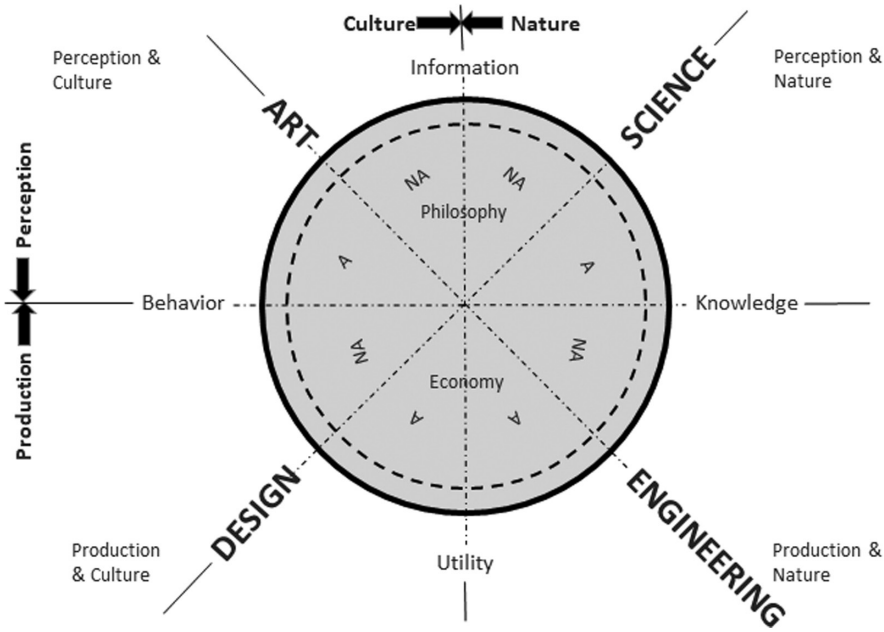


FIGURE 1.5: Krebs cycle of creativity (A – applied, NA – not applied).

1.8 DESIGN THINKING – INNOVATING DESIGN WITH COGNITIVE SCIENCE

Design thinking is a universal approach for solving a set-in-stone range of problems by means of designing better solutions, services, and experiences. Design thinking as a panoply of design science outlines a completely new and dynamic approach to hitting the touchpoints of consumer behaviors and expectations. It is an integral part of innovation that allows consumers, teams, designers, and organizations to have a human-centered perspective with a scientific approach to address a problem. Design Thinking addresses a wide range of issues and is best used for bringing about innovation in multiple contexts [18].

- Redefining design value
- Human-centered innovation
- Quality of life
- Shifting markets and social behaviors
- Issues relating to corporate culture
- Issues relating to new technology
- Reinventing business models
- Scenarios involving multidisciplinary teams
- Entrepreneurial initiatives
- Educational advances

- Medical breakthroughs
- Problems that data can't solve

1.8.1 Nature of Design Thinking

Design thinking is in many ways the inverse of scientific thinking [18]. Where scientists explore theories and facts to discover insights, designers discover new patterns to address facts and possible solutions. In a world with increasing problems that greatly need attention to understanding the need for ideas, design thinking makes a valuable contribution toward innovative design strategy for creating a new solution.

Design thinking encourages the development of real collaboration between the designers and practitioners to solve emerging problems of different types. On the organizational front, adopting design thinking principles will help remove the existing silos and lubricate the system through team initiatives and cross-disciplinary research. Moreover, design thinking aims at creating a conductive environment for design innovation.

1.8.2 Design Thinking and Innovation

Design thinking in a process-based approach offers understanding capabilities as well as means for grappling with environmental factors to act immediately to the change in human behavior. This is crucial in developing and refining the methods used to create a working model of the final product.

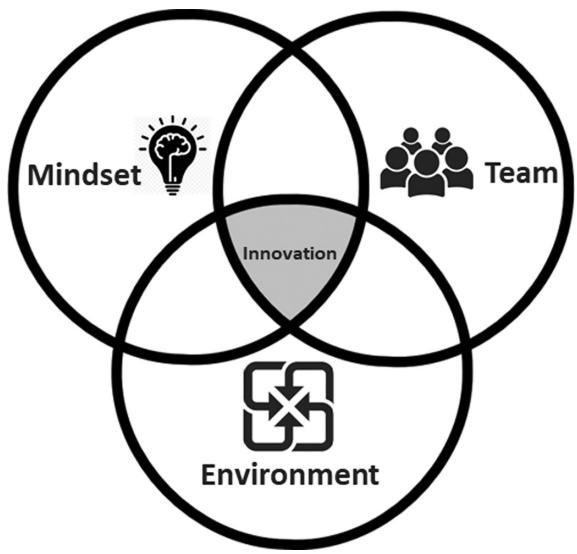


FIGURE 1.6: Design thinking and interactions [18].

In order to embrace design thinking in a real sense, and to innovate for sustainable development, we need to ensure that we have the right things in the right place and in order, e.g., mindsets, collaborative teams, and conducive environments.

Figure 1.6 illustrates that creating the right mindsets, selecting the appropriate team, and setting up environments for exemplary innovation to take place are three of the essential aspects of fostering sustainability in organizations of all scales.

To create new innovative solutions, design thinking helps to develop a truly open, explorative work culture and ethos and combines the magic of both analytical skills and imaginative piece of work. In view of this, famous technology kingpins like Microsoft, IBM, and Google invest in creating state-of-the-art workspace environments for employees where they can play with real-world objects, dissemble, rearrange, and increase their appetite for creative thinking through innovative solution designs. Some companies have adopted the policy of sending their entire staff on team-building getaways where they behave in their natural manner, arrange rafts together, jump around in circles and, in the best way possible, nurture their minds like kids. The goal is to make employees feel comfortable and safe and invent breakthrough solutions in a playful manner.

> *A purely technocentric view of innovation is less sustainable now than ever, and a management philosophy based only on selecting from existing strategies is likely to be overwhelmed by new developments at home or abroad. What we need are new choices – new products that balance the needs of individuals and of society as a whole; new ideas that tackle the global challenges of health, poverty, and education; new strategies that result in differences that matter and a sense of purpose that engages everyone affected by them. It is hard to imagine a time when the challenges we faced so vastly exceeded the creative resources we have brought to bear on them.*
>
> **– Tim Brown**

1.9 TOWARD DESIGN INNOVATION

There is a close relationship between design and innovation. Design is the backbone of innovation, and innovation is considered as the driving force of a market economy. The elaboration of design innovation as a new concept contributes to the academic research and industrial discourse of design. A conceptual definition of design innovation provides the basic tools for understanding design models to build innovation theory inspired by design, currently dominated by professional engineering discourses [20].

Design by innovation is understood and used in various conventions. In general, design innovation depicts the process of product development, where the resulting output is a complete product or a module alone. The importance of design innovation is recognized as a means of achieving excellence in niche product competition. The essence of design innovation is the need for the continuous improvement of products and the creation of new designs with ideal features (Figure 1.7).

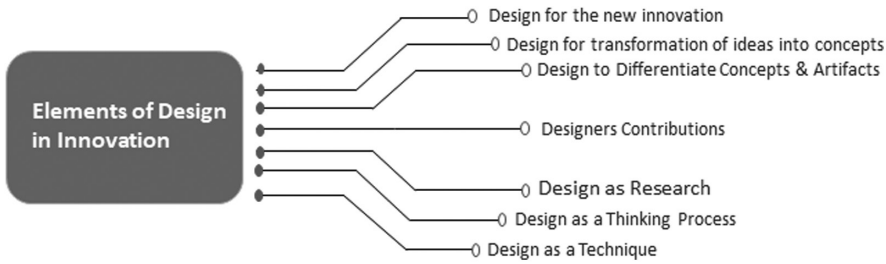


FIGURE 1.7: Elements of design in innovation [22].

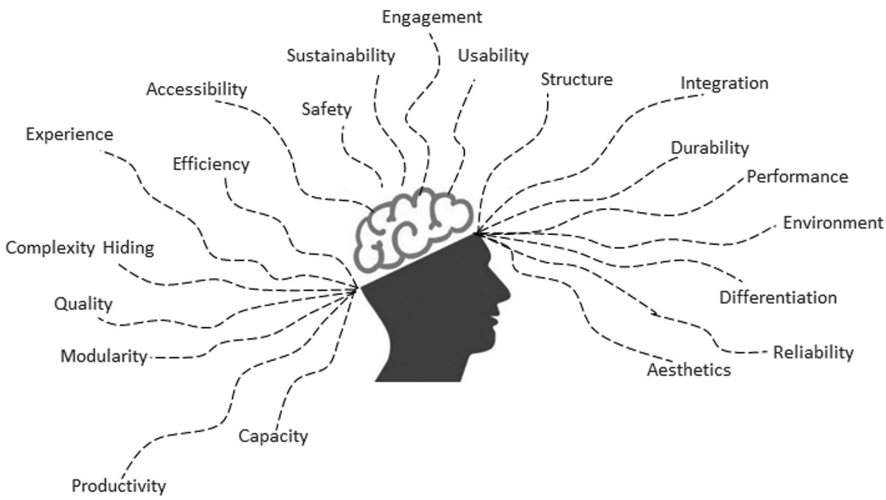


FIGURE 1.8: Mind mapping of design innovation [24].

1.9.1 Features of Design-Driven Innovation

Innovation is defined as both a process and an outcome. It has been widely accepted as a driver of ongoing success in the competitive market. A growing number of research studies have a major focus on unfolding the translucent connection between design, innovation, and performance improvement. Design is increasingly recommended as a strategy rather than purely as a function within the innovation task. The process of innovation by design generates certain characteristics that are novel from various aspects, including components and their features, functional operations, scalability, and framework associated with the new design [21] (Figure 1.8).

1.9.2 Design Innovation by Communication

The digital revolution has created new technological demands for multifaceted designers. In the current environment, it's no longer acceptable to have knowledge

about design aesthetics only; one must also know about holistic product development. Designers working on innovation paradigms should be able to demonstrate their intelligence, coding knowledge, and practical exposure to building communication strategies based on user experience research. Communicating design concepts and ideas in an empathetic manner is far more likely to support a well-thought-out design process down the road.

Design-driven innovation explores the ways in which designers and research communities of art, science, and engineering are influencing each other toward creating new products for the materialist culture world. Assuming the result of design innovation requires bringing an imaginary design blueprint to life. Some general questions that contribute to problem formulation and method selection follow:

Q1: What makes a product great?
Q2: What is the need for designing a new product?
Q3: What is the role of design firms in the development of creative products?
Q4: How is the role of people and technology changing the facets of design innovation?
Q5: How are the methods of design communication creating benchmarks for innovation?
Q6: How does visualization of design inspire a design innovation?

1.9.3 Languages of Design Communication

Communication design is a system-based approach that focuses on the exchange of media and messages to communicate instantly with the people. Examples of this approach are used to create new media channels to ensure the message reaches the target audience along with already existing channels like print, crafted, electronic media, or presentations. Basically, this approach is designed to integrate multimedia components into a single model rather than a series of discrete efforts within the culture or organization. The following are a few languages of design communication that play a significant role in communicating a design to a larger audience [19].

1. **Visual Stories**
   To design a visually strong product, it must have an emotional component in the form of a story, since a story will leave permanent footprints on the mind of the user. The concept of visual design can be taken in a broader sense to understand that the designed entities we see, or otherwise perceive, can't exist without a bit of a story behind them. Many products in the market become obsolete and neglected by consumers due to bad visual storytelling that fails to stand out among various other competitors. To capture a good share in the market, designers have to come up with a strong identity not only for product or service but also for the customer and end users. A new design can be developed by utilizing the various elements of visual communication like color, position, texture, size, orientation, shape, tone, images, symbols, animation, and videos in order to deliver the intended message more effectively.

2. **Use of Technical Terms**
   Another approach to reach the design target is by considering technical terms related to the product. This is purposefully done to build customers' trust in products by making them aware of the featured process used for designing the product, e.g., responsive design, immersive reality, etc. Technical terms depict the core environment, components, and behavior of a design system (Figure 1.9).
3. **Analogy**
   Design-by-analogy is a powerful tool for design innovation, especially when thinking about conceptual ideation. The approach of analogous design thinking helps designers to identify design concepts and define their goals. Analogy in design communication is a cognitive process that is assumed to be a major source of new concepts that link cross-domain knowledge by means of common attributes and the relationship between the end user's situation and other related areas. One such tool is bio-mimicry, which applies learning from nature toward problem solving. Taking insights from natural systems like honeycomb pattern, designers can create analogous spaces and communicate their inspiration behind the design of structures.
4. **Gesture**
   Gesture has been studied from various perspectives, sometimes with respect to computer support for human communication and collaboration but also with respect to the psychology of gesture (see chapter 6). Human gestures are used predominantly to depict a number of aspects of the design. The General use of gestures for design communication has been found in building HCI systems, robotics, interactive dialogue systems, collaborative task completion tools, semiotic analysis, and sign language development. Gesture recognition is an emerging approach that suggests the design of new technologies for interacting with digital information and involves the use of hand and arm movements.
5. **Typography**
   Typography is all about adjusting the text within the design while creating powerful content. It provides an attractive appearance and preserves the aesthetic value of your content. It plays a vital role in setting the overall tone of your website and ensures a great user experience (Figure 1.10).

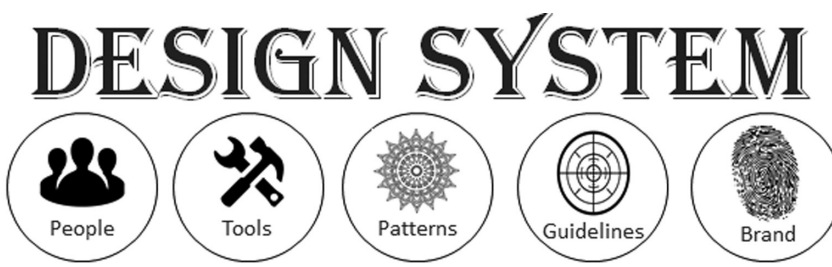


FIGURE 1.9: Components of a design system [23].

FIGURE 1.10: Understanding of typography.

FIGURE 1.11: Manual sketch and digital sketch.

The advent of science and technology has been continuously pushing designers to come out of their comfort zone and use digital tools to produce advanced sectional drawings. Designers use typography to communicate different feelings and create a mood that enhances the brand's influence.

6. **Sketching**

Sketching offers ways to convey and receive messages about that which is tacit. Earlier, most designers simply relied on manual sketching, but now designs are entirely done with computer-aided design software that aids in drawing global orders. There is no doubt that sketching by hand allows a designer to capture an idea quickly, but due to its limitations is restricted in its ability to draw multiple sketches, and it is also difficult to sketch in a very short cycle. Therefore, CAD/CAM technology has brought a new hope in providing computer-based methods, which can provide three-dimensional renderings, rotating or moving the "sketch" in realistic ways on the screen and allowing a product to be assembled and disassembled in a virtual world. Thus, end users may observe and react to amazingly realistic representations of products still in the idea stage (Figure 1.11).

If a sketch in whatever form gives the end user an idea about functionality, it offers more than a hint of the design language to be applied. Several such sketches may offer more about what kind of "soul" the product will have than any well-phrased verbal description: emotions, messages, and meanings are tacit, not fully describable with words, formulas, or mathematics.

Design denotes thought processes and practices that result in the development of an object. Many roles that a design activity can play in innovation and how that activity leverages different design theories toward the success of innovative products are often studied to limited details. Different types of methods and techniques used by designers for creating products and services, independently or in collaboration, are also classified in terms of design. In fact, design indicates an association between research, ideation, and professional activity.

1.10 SUMMARY

This chapter has suggested the importance of science as a foundation for designing a product that contributes to the betterment of the modern world. The combination of design and science plays an important role in bringing out the quality deliverables that are inherent in design to the sciences. In order to ensure success in the science–design collaboration, both communities need to explore more and engage with each other. The sociological perspective allows us to better understand the peculiar nature of design and to reveal "why" and "how" the role of science is engaged with design, art, and engineering.

Furthermore, the latter sections described the assessment of a design process using the lens of design science principles and guidelines. As many of the existing guidelines for design science research (e.g. [1]) focus on artifacts, we found that the design process–based approach can be a very useful component that refines and adapts the design science approach to build and test management processes in system designing.

Future scope of literature review and hands-on research in the same field will be sure to test and modify the communication pathways of system units to meet the functional and non-functional needs of the system. This chapter encourages discussion on design science methodologies and pitches potential recommendations for the development of design processes.

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