Introduction

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Many researchers would say that this edition of the Design Thinking Research (Understanding Innovation) series addresses the need to know and understand prototyping. However, if we look deeper, we can detect two other important categories: translation and measurement**.** In engineering design thinking, not only the products and services are examined under the microscope, but also the innovators themselves. How do design thinkers reach their goals? And what are they doing differently this year? Let us see why these variables work together.

Prototyping—making one's ideas real and substantial—is the most critical phase in the design paradigm. First, one must specify the user being studied in exacting detail. Then, one must define a research protocol that will examine these users and how they interact with specific prototypes.

In this edition of our research book series, we report details of our study of remote collaboration "Innovation Teams" and the neurophysiological realities of the team members. These studies also look closely at the team organization structure on a global scale.

Details include definition of the nature of these design prototypes and the energy a team should invest in creating and testing the prototype with the designated users. Prototypes may be hardware, software, and/or both. We then address the machine learning and artificial intelligence dimensions of potential prototypes in the context

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of their real-world applications and their expected impact. Addressing the nature of "Reflective Design Practice," we dive deeply into the need to understand both the user and our own cognitive biases.

Dominating all of our efforts, we must seek to understand why things are happening as they are. This search for the why is closely associated with the fact that most design research must seek to discover a hypothesis. This "hypothesis discover" focus contrasts dramatically to most engineering and science research, which seeks to validate an existing hypothesis.

But how is "hypothesis discover" operationalized? We know we have to progress from concept to functional proof of concept and incorporate hardware, software, and experience. That is a tall order. We do however have improvised tools at our fingertips. It is important to keep available resources in mind when moving toward a goal. For your prototype, use objects at hand, such as Lego, craft material, or other prefabricated modeling sets. Be creative, but also methodical. Make lists. When making the passage from concept to testing, think of your team as a team of teams. Disagree freely. The more diverse the team, the higher probability of producing breakthrough innovation. And never forget the basics in engineering design teams: research, redesign, and re-innovate. Remember you as a team have the technological know-how. Within the team, your emotional interaction dynamics predict team performance. And to explain why this is the case, we ask another question: why are you challenged? Of course the answer is that life is open, complex, dynamic, and networked.

The science paradigm asks how. The design paradigm asks why.

We can correct the imbalance between science and design. When you improve the balance, you improve the impact. To improve the balance, bring the how and why together. To break it down, this means that we take existing (validated) hypotheses in science as building blocks but we do not refrain from reaching for a "hypothesis discover." Team interaction dynamics pave the way to new solutions.

It is clear that prototyping is essential to design thinking. But why is this volume concerned with translation? Over the last 12 years of the Hasso Plattner Design Thinking Research Program, we have made great strides forward. Our researchers doing the cutting edge work have come from many different multidisciplinary backgrounds. Therefore, it is fitting to detail how a social science concept—translation—finds its place here. If this were a social science book, we would then trace the translational back to the linguistic. For our purposes, the term is introduced as a vehicle to understanding transfers between scientific cultures and as an analytical category. (Bachmann-Medick, 2016) Translation provides us with a new lens through which to investigate and negotiate complex shifts.

The pandemic has necessarily changed how society works. One reality—the in-person reality—is at present no longer an option. In 2020, we translated most of our activities to the virtual realm. The *Wissenschaftsrat* (German Science Council) has reported how educational institutions were forced to quickly transition to digital teaching without adequate preparation time and with many users lacking technical skills and sufficient access to technology and without significant guidance. (Wissenschaftsrat pp. 11–12). In 2020, a profound transformation came about: in-person to digital.

Our researchers focus their lens on something such as remote design technology and try to understand, for example, how interbrain synchrony functions in a zoom world. Yet another team focuses on decoding nonverbal actions. A third team attempts to understand how design thinking was leveraged across cultures—this was only possible through translation of the term design thinking.

It is fruitful to visualize translation as a descriptor for the analysis of complex shifts taking place and which are the object of study within design thinking research. The authors approach an understanding of everyday phenomena, contemporary issues, and human-centered design through application of the design thinking toolkit at hand. The questions being asked allow design teams to find answers through the study of complex shifts. Engineering design teams examine phenomena over extended periods of time, prototyping in more than one way, ranking the prototypes, and assessing potential. Translation is a good term to describe the passage and development, process and result of design team performance.

Whereas in prototyping, researchers search for notable hypotheses, and measurement helps us quantify developments. Contributing authors assess what improvements can be implemented in areas and fields through the application of design thinking and how the effectiveness of these improvements can be quantified. Measurement allows us to draw comparisons. Standardizing and unifying measurement are essential for the professionalization of Design Thinking. Researchers strive for replicable results, especially when "hypothesis discover" is new.

The design thinking process has established phases. It is clear that innovation is no longer a by-product of some other intention. It is the ultimate goal for design thinkers. The three variables that we focus on in this volume are all integral to the design thinking process. Of course prototyping is a phase in the design thinking process, so its importance is unquestionable. Translation and measurement are tools that help us in each phase along the way to the final results of testing. With the increasing professionalization of the field, translation, prototyping, and measurement are invaluable. It is our hope that this series volume will be a starting point for dialogue in these areas.

Please join in our search for notable hypotheses and in understanding why those hypotheses are critical to the implementation of Design Thinking and Design Thinking Research. Join us.

Road Map through this Book.

Researchers from HPI and Stanford University have conducted a wide range of research projects on design thinking. This annual publication is a compilation of their findings. The shared outcomes are arranged in three parts that illustrate the comprehensive approach of the program to design thinking research, namely translation, prototyping, and measurement.

Part 1 Translation in Design Thinking.

The first part of this book concerns itself with the category of translation in several senses. Translation provides us with a new lens through which to investigate and negotiate complex shifts. In the first text (Balters/Baker/Hawthorne/Reiss), the concept is applied to understand modernization in answering the question, how is design

research translated to the digital sphere? COVID-19 is given as a cause for the rise in virtual interfacing. The assessment of collaborative outcomes is central as is the nuanced discussion of interbrain synchrony in virtual versus in-person interactions. The second team of researchers (Domingo/Gutzeit/Kim/Leifer/Auernhammer) also examines societal changes as a result of COVID-19. However, in this piece, the focus is on defining the challenges in design collaboration and design work. The team offers up questions such as whether engagement in physical movement might be a prerequisite to thinking while carrying out certain activities. In the third study (Traifeh/Abou Refaei/von Thienen/ von Schmieden/Mayer/Osman/Meinel), the text builds upon the assumption that there is an absence of a direct translation for DT in the Arab world. The authors successfully stake out the development of the DT concept in five sectors of the Arab world.

The stated goal in the fourth text (Park/Whiting/Shanks) in this section is to design social platforms for user–user interactions online. To accomplish this, the authors investigate nonverbal actions and underline in their work the importance of understanding rationales for nonverbal interactive experience on online platforms. The final chapter in this section (Plank/von Thienen/Meinel) raises the questions: what is design thinking empathy? And what sub-capacities are involved when a design thinker tries to understand a user? In order to understand empathy, the authors parse the term to find biases and pitfalls in empathy as well as to delineate empathy versus compassion.

The contributions in this section all rely on translation: the translation of DT to the virtual sphere, the translation of concepts across cultures, a scientific look at interbrain synchrony, physical movement, and nonverbal actions and how these activities translate to action in two different realities in-person and virtual. And in the final text, the authors take the assumptions of neuroscience and apply them to the conceptual distinctions of empathy.

Part 2 Creation of Models for Prototyping.

In this volume's second part, HPDTRP researchers identify challenges and in many instances create models for prototyping to meet design challenges. The first chapter (Taeumel/Rein/Hirschfeld) identifies four patterns in the field of software engineering and describes how the team drafted a pattern language to enable and control exploration. A second chapter (Jane L.E./Landay) tackles the subject of iterating in photography, drawing a fruitful comparison between the parallels in DT and the photographic process. The researchers created guided photography interfaces to aid iteration. The third text (Siu/Chase/Kim/Boadi-Agyemang/Gonzalez/Follmer) addresses improved design education for impaired people. The authors created PantoGuide, a low-cost system that provides audio and haptic guidance for students who are learning remotely.

The next chapter (Miller/Gutzman/Bailenson/Mabogunje/Sonalkar) concerns itself with Interaction Dynamics Notation (IDN). The research team explores the role of IDN and traces the path of IDN development over many years. In addition to information on how it inspired other research, the chapter also offers an outlook for two directions in future work. The fifth chapter (Edelman/Santuber/Owoyele)

in this section introduces PretoVids, a method for structured prototyping without engineering and code in design. The research team places value on prototyping new (low cost and agile), digital products without code or software development. In the sixth chapter, contributing authors (Mullings/Utterback/Bernstein) developed the application Drawventure to enable self-directed learning in design sketching. The paper-prototyped and user-tested application reframes sketching lessons as micro-challenges. In the final chapter (Royalty) of this section, reflective design practice is associated with increased metacognitive awareness. This can then be harnessed to optimize the student experience and awareness of growth in design classes.

The chapters in this section all help the reader to visualize models and prototypes for understanding DT in various settings. Some researchers build upon existing models and others create new prototypes. This section, in particular, offers a glimpse of the technology that is currently being developed to understand the why. The purpose of a prototype is to learn from it. Our researchers are pushing forward and constantly refining. Read the chapters and understand the process and how it is possible to move to the final product.

Part 3 Measurement in DT: How to Improve Different Areas and Fields by Applying DT.

The third part of this volume is concerned with measurement in DT. Contributing authors assess what improvements can be implemented in areas and fields through the application of DT. Researchers evaluate and leverage assets for the enhancement of DT processes. Sometimes it is a small adjustment, and other times it is a drastic modification.

Section three begins with a chapter (Mayer/Schwemmle/Nicolai/Weinberg) proposing new foundations for the impact assessment of DT in organizations. The contributing authors argue this is the only avenue for DT to move forward. The second piece in this section looks to measurement as a mindset for transformation. The author (Haskamp) answers the question of how is it possible to quantify design thinking. He concludes that a differentiated understanding of DT is needed after staking out different frameworks: DT as a set of methods, DT as a process for innovation, and DT as a mindset for driving transformation. Chapter three of this section (Sheppard/Chen/Toye/Kempf/Elfiki) describes the process of designing a survey instrument to measure the engagement of Stanford alumni. By examining the relationship between the ME310 curriculum and alumni engagement in entrepreneurship and innovation, the authors attempt to understand how course-based training in DT can translate to professional endeavors and entrepreneurial outcomes. The fourth set of researchers in this section (Dobrigkeit/Matthies/Teusner/Perscheid) apply DT to scrum. Their findings reveal that agile practitioners changed scrum to improve collaboration by incorporating teamwork, innovation, and design activities. They find that design thinking techniques provide a fruitful addition to the scrum meeting toolkit. The final contribution of this section (Auernhammer/Sonalkar/Xie/Monlux/Bruno/Saggar) and of the series volume looks to create a foundation for training the next generation of entrepreneurs and managers. The authors investigate the cognitive basis of applied creativity in

business—a very little known area—by comparing the neuropsychological profiles of entrepreneurs with those of administrators and managers.

Process improvement can improve not only team productivity but also produce better calibrated metrics. A whole range of products, services, and relationships can be augmented through measurement. Obtaining a more nuanced understanding of remaining shortfalls is a targeted goal. As processes improve, the actors involved are better equipped to make smarter decisions.

Outlook.

Since 2008, researchers in the Hasso Plattner Design Thinking Research Program have arrived at valuable insights on why and how design thinking works. Our researchers share with you formats, methods, and their evaluation. Concrete examples of successes and failures are identified in this book. We encourage you, the reader, to engage with us. At www.hpi.de/dtrp, you will find the latest information on all research conducted within our HPDTRP program and learn more about our contributors.

Another resource is the Web site https://thisisdesignthinking.net, which offers a comprehensive overview of current developments in design thinking. Rich descriptions including advantages and disadvantages of particular strategies are provided. The collection of examples and interviews is appropriate for all educators and design practitioners. Here, you will also gain a better understanding of the current challenges in the field of design thinking. Experiences, stories, and inquiries can be sent to thisisdesignthinking@hpi.de.

Notable hypotheses are critical to the implementation of Design Thinking and Design Thinking Research. Enter the dialogue. Help us ask why, and you too can influence future design thinking action to form a smarter world.

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