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A Longitudinal Case Study of the Aviation Industry

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Advancing Industry through Design: A Longitudinal Case Study of the Aviation Industry

Abstract Design educators and industry partners are critical knowledge managers and co-drivers of change, and design graduate and post-graduate students can act as catalysts for new ideas, energy, and perspectives. In this article, we will explore how design advances industry development through the lens of a longitudinal inquiry into activities carried out as part of a Dutch design faculty-industry collaboration. We analyze seventy-five (75) Master of Science (MSc) thesis outcomes and seven (7) Doctorate (PhD) thesis outcomes (five in progress) to identify ways that design activities have influenced advances in the Dutch aviation industry over time. Based on these findings, we then introduce an Industry Design Framework, which organizes the industry/design relationship as a three-layered system. This novel approach to engaging industry in design research and design education has immediate practical value and theoretical significance, both in the present and for future research.

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Introduction

Design's economic influence, as Gjoko Muratovski identifies, has become apparent during a period of global rebalancing of power.[1] The resulting tensions and new possibilities have in turn provided ample subject matter for designers, especially those willing to step into areas of social and organizational reform.[2] The design research landscape reflects this economic shift in the discipline, offering a greater emphasis on organizational perspectives of design in business. There has been a marked increase in engagement between industry and design as stimulus for what Andy Dong titles *Innovation × Design*.[3] Dong identifies innovation led by design produces successful outcomes for organizations and industries, yet the exact practices of *innovation × design* require further scientific attention.

Industry – any configuration of value-creating organizations present within a specific domain – has been actively reaching out to universities in search of support and inspiration.[4] This presents opportunities for strategic partnerships in education and research to be formed. Cara Wrigley notes industry demand for design in particular can be an education and research opportunity.[5] Post-graduate design students can be the vital catalysts for design innovation within organizations. From a research perspective, industry engagement provides a multi-layered system in which to study the potential impact of design.

The concept of designing an industry is not new; however, at present, notions of industry design[6] are mostly conceptual rather than empirical. Here we present our findings from a seven-year inquiry into design implementation in various areas of the aviation industry. Our primary aim was to identify how implementing design practices over time can lead to advances within a specific industry – in this case: aviation. We also sought to shed light on how a multi-layered research context can be articulated in tandem with industry stakeholders. We draw upon Jeanne Liedtka's notion that design is a social technology[7] – a collection of methods, processes, and skills used to negotiate problems and explore possibilities – and Clayton Christensen's fundamental insights[8] regarding the form and function of diffuse innovation and the nuances of technology adoption. We also explore the realm of complexity and impact currently referred to under the umbrella term DesignX.[9] We do not seek to define DesignX, but rather contribute to an understanding of how design can be applied within an industry characterized by complexity, speed, and volume while remaining extremely reliable.

This inquiry examines the question: "How has design advanced the Dutch aviation industry?" Firstly, we will recount events, workshops, keynotes, and partnerships that together represent the depth and breadth of our interaction with the industry over the past seven years. Secondly, we narrow our focus to examine this engagement via graduate and post-graduate thesis projects, and demonstrate the growth that occurred in both number and variety of outcomes for each project. Interestingly, that variance followed a pattern consistent with Christensen's prescriptive S-curve strategy for innovation.[10] Based on these findings, we present our Industry Design Framework, which we hope will serve as a guide for future industry design projects. Given some early, positive feedback using this framework we have received from actors in the Dutch retail industry, we maintain that our contribution holds value for scholars, industry partners, design educators, design students, and design practitioners.

Design, Complexity, and Systems Thinking

A central notion in design is that it has the capacity to address so-called wicked problems.[11] Designerly strategies (such as problem-framing) are particularly, if not uniquely, suited to dealing with ill-defined problems, as they stimulate integrative

1 Gjoko Muratovski, "Paradigm Shift: Report on the New Role of Design in Business and Society," *She Ji: The Journal of Design, Economics, and Innovation* 1, no. 2 (2015): 118–39, DOI: https://doi.org/10.1016/j.sheji.2015.11.002.

2 Richard Buchanan, "Worlds in the Making: Design, Management, and the Reform of Organizational Culture," *She Ji: The Journal of Design, Economics, and Innovation* 1, no. 1 (2015): 5–21, DOI: https://doi.org/10.1016/j.sheji.2015.09.003.

3 Andy Dong, "Design × Innovation: Perspective or Evidence-Based Practices," *Journal of Design Innovation and Creativity* 3, no. 3–4 (2015): 148–63, DOI: https://doi.org/10.1080/21650349.2014.943294.

4 Lars Frølund, Fiona Murray, and Max Riedel, "Developing Successful Strategic Partnerships with Universities," *MIT Sloan Management Review* 59, no. 2 (2018): 71–79, available at https://sloanreview.mit.edu/article/developing-successful-strategic-partnerships-with-universities/.

5 Cara Wrigley, "Design Innovation Catalysts: Education and Impact," *She Ji: The Journal of Design, Economics, and Innovation* 2, no. 2 (2016): 152–53, DOI: https://doi.org/10.1016/j.sheji.2016.10.001.

6 Heather M.A. Fraser, *Design Works: How to Tackle Your Toughest Innovation Challenges Through Business Design* (Toronto: University of Toronto Press, 2012); Sam Bucolo, *Are We There Yet? Insights on How to Lead by Design* (Amsterdam: BIS, 2015).

7 Jeanne Liedtka, "Perspective: Linking Design Thinking with Innovation Outcomes through Cognitive Bias Reduction," *Journal of Product Innovation Management* 32, no. 6 (2015): 925–38, DOI: https://doi.org/10.1111/jpim.12163.

8 Clayton M. Christensen, "Exploring the Limits of the Technology S-curve. Part I: Component Technologies," *Production and Operations Management* 1, no. 4 (1992): 334–57, DOI: https://doi.org/10.1111/j.1937-5956.1992.tb00001.x.

9 Donald A. Norman and Pieter Jan Stappers, "DesignX: Complex Sociotechnical Systems," *She Ji: The Journal of Design, Economics, and Innovation* 1, no. 2

action.[12] In the last few decades, the design discipline has expanded. Richard Buchanan describes this expansion as taking place across four orders: (1) signs and symbols; (2) physical objects; (3) activity, service, and process; and (4) systems, environments, and organizations. According to Buchanan, the four orders demonstrate "the evolution of the design professions from graphic and industrial design to interaction design, and then to the design of systems, environments and organizations that is the hallmark of the current design movement."[13] Examples and applications are increasingly extensive and continue to grow, especially in the last two orders of listed above (3 and 4), where some have portrayed design as responsible for driving innovation and helping to resolve societal problems.[14]

While Buchanan deconstructs design subject matter to explain the evolving relationship of design to matters of complexity, other scholars turn to methodological developments to describe the expansion of its remit. Scholar Peter Jones goes back to 2005 to highlight the emergence of a series of new design methodologies that include transformation design, service design, and transition design.[15] Each approach addresses a range of design challenges oriented to new perspectives and experiments with practices and methods in search of the disciplinary confidence to address multi-layered systemic issues loaded with uncertainty and ambiguity.

In 2014, a series of discussions among several leading figures in design[16] and within the global design community led to an evolution in the notional and practical relationship between design and its focus that accommodates complexity. This movement is termed *DesignX*. Don Norman and Pieter-Jan Stappers point out that the major challenges presented by DesignX problems stem not from trying to address design problems, but rather during the implementation phase when a combination of political, economic, cultural, organizational, and structural dynamics overwhelm. They note that "designers cannot stop at the design stage: they must play an active role in implementation, and develop solutions through small, incremental steps – minimizing budgets and the resources required for each step – to reduce political, social, and cultural disruptions."[17] Successful design implementation requires collaboration among a range of stakeholders and a modular approach, which yields measurable progress, enables participation, and facilitates effective outcome management.

Of similar systemic focus is the rapidly emerging practice of transition design.[18] Transition design is a methodological movement shifting rhetoric from commercial principles such as innovation viability and competitive advantage toward a more holistic perspective that encompasses concerns related to social, economic, political, and natural systems to more fully address today's complex problems. Wicked problems such as climate change, loss of biodiversity, and increasing wealth disparity require not just the design of products and services, but the design of entirely new sociotechnical systems. The rhetoric accompanying transition design acknowledges that a crisis can be a gateway to novel action.

On the rise is thing-centered design,[19] another methodology that embraces complexity. Thing-centered design encourages designers and other actors to make use of technological advancements such as machine learning and the Internet of Things (IoT). Intelligent objects – once useless beyond their primary functions – now have the capacity to observe humans, offering new perspectives on patterns in human activity. This network of things witnesses and records aspects of use and interaction, and the data they generate reveal emerging patterns in human behavior. This feeds into a new kind of ethnographic research that studies our behavioral patterns to obtain critical insights for the design of new sociotechnical systems.

Practicing design across an entire system – "a collection of real or abstract interdependent segments (hardware, software, people, facilities, and procedures) acting as planned … organized as a whole in order to accomplish a common

(2015): 83–106, DOI: https://doi.org/10.1016/j.sheji.2016.01.002.

10 Christensen, "Exploring the Limits," 340.

11 Richard Buchanan, "Wicked Problems in Design Thinking," *Design Issues* 8, no. 2 (1992): 5–21, DOI: https://doi.org/10.2307/1511637; Horst W. J. Rittel and Melvin M. Webber, "Dilemmas in a General Theory of Planning," *Policy Sciences* 4, no. 2 (1973), 155–69, DOI: https://doi.org/10.1007/BF01405730.

12 Nigel Cross, *Designerly Ways of Knowing* (Basel: Birkhauser, 2007); Jodi Forlizzi, Erik Stolterman, and John Zimmerman, "From Design Research to Theory: Evidence of a Maturing Field," *IASDR Proceedings 2009: Rigor and Relevance in Design* (Seoul: Korean Society of Design Science, 2009), available at http://www.iasdr2009.or.kr/; William W. Gaver, "What Should We Expect from Research Through Design?," in *CHI '12: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (New York: ACM, 2012), 937–46, DOI: https://doi.org/10.1145/2207676.2208538.

13 Buchanan, "Worlds in the Making," 14.

14 Alastair Fuad-Luke, *Design Activism: Beautiful Strangeness for a Sustainable World* (London: Routledge, 2013), 81.

15 Peter Jones, "The Systemic Turn: Leverage for World Changing," editorial, *She Ji: The Journal of Design, Economics, and Innovation* 3, no. 3 (2017): 157–63, DOI: https://doi.org/10.1016/j.sheji.2017.11.001.

16 Ken Friedman, Yongqi Lou, Don Norman, Pieter Jan Stappers, Ena Voûte, and Patrick Whitney, "DesignX: A Future Path for Design," *jnd.org*, December 2, 2014, http://www.jnd.org/dn.mss/designx_a_future_pa.html.

17 Norman and Stappers, "DesignX," 83.

18 Terry Irwin, Gideon Kossoff, and Cameron Tonkinwise, "Transition Design Provocation," *Design Philosophy Papers* 13, no. 1 (2015): 3–11, DOI: https://doi.org/10.1080/14487136.2015.1085688.

19 Elisa Giaccardi et al., "Things as Co-ethnographers: Implications of a Thing Perspective for Design and Anthropology," in *Design*

mission or fundamental objective" – presents unique challenges.[20] Sergio Cavalieri and Giuditta Pezzotta[21] note that an industry is also a system, one composed of actors, entities (content and channel), and lifecycles (phases and iteration). Tim Ingold extends the principle of systems theory to creative practice, noting that making becomes an art of inquiry where "the conduct of thought goes along with, and continually answers to, the fluxes and flows of the materials with which we work."[22]

These methods and principles come from diverse schools of thought in systems and design thinking. Together, they provide a rich and multi-disciplinary set of methods and principles that enable to design a system.[23] The objective of systemic design is to utilize systems thinking and systems methods to guide human-centered design for complex multi-system and multi-stakeholder socio-technical systems. In the context of complex systems, design emerges as a practice of ultimate pragmatism. Design thinking borrows from and integrates relevant disciplines that are not design through collaborative inquiry, sensemaking, and form giving. We see design as a universal, integrative approach to systemic inquiry and formative intervention, informed by Jeanne Liedtka's notion of design as social technology.[24] Design is a collection of methods, processes, and skills to negotiate problems that concern industries, networks of organizations, and society as a whole.

Designing Industry: Three Levels

The practice of design requires a subject – something to be designed. Fundamentally, that "thing" involves a problem to be solved, and the materials associated with the solution.[25] Our theory development was heavily influenced by Richard Buchanan and his four orders of design. The four orders are a means of differentiating among the often indiscernible activities that a designer undertakes when navigating between analysis and synthesis – and from problem to solution. Each order arranges (and enables the designer to consider) the elements of a design process from a different point of view: signs and symbols, physical objects, activities and processes, and environments and systems. Buchanan acknowledges that the four orders might point to certain kinds of design subjects, but he further argues that they should not be seen as a straightforward categorization of design activity. Instead, they should be seen as perspectives a designer can adopt to approach the same object of design. Given that every order looks at the same thing from a different angle, sometimes those lines of sight intersect. For example, each order reveals unique problems associated with its particular perspective, but those problems might also be associated with other orders (depending on the topic). The four orders' inherent inter-relatedness makes it virtually impossible for us to include them into our tri-level framework of design subject matters. Even so, they remain a valuable lens through which to examine what he describes as the "classic issues of design theory and practice: what do we design, how do we design, and why do we design?"[26]

Buchanan's determination that design encourages an experienced-based paradigm for organizational culture has underpinned our own work with the aviation industry. In particular, breaking from an adherence to statistical forecasting within the aviation industry as the status quo to focusing on forming deeper relationships with customers, employees and business partners as the basis for innovation. This has been a consistent challenge with each industry partner during this longitudinal study.

The table in Figure 1 presents some leading authors' notions of what categories there are of things to be designed. Peter Joore and Han Brezet[27] identify four categorizations of subject matter that all encompass a systems perspective. Their

Anthropological Futures, ed. Rachel Charlotte Smith et al. (London: Bloomsbury Academic, 2016), 235–48.

20 Dennis M. Buede, *The Engineering Design of Systems: Models and Methods*, 2nd ed. (Hoboken: John Wiley & Sons, Inc., 2009), 47.

21 Sergio Cavalieri and Giuditta Pezzotta, "Product–Service Systems Engineering: State of the art and research challenges," *Computers in Industry* 63, no. 4 (2012): 286, DOI: https://doi.org/10.1016/j.compind.2012.02.006.

22 Tim Ingold, *Making: Anthropology, Archaeology, Art and Architecture* (Abingdon: Routledge, 2013), 6.

23 Jones, "The Systemic Turn."

24 Liedtka, "Perspective"; Jeanne Liedtka, "Design Thinking as a Social Technology" (keynote speech, Design Management Academy Conference 2017, Hong Kong, June 7, 2017).

25 Richard Buchanan, "Rhetoric, Humanism, and Design," in *Discovering Design: Explorations in Design Studies*, ed. Richard Buchanan and Victor Margolin (Chicago: The University of Chicago Press, 1995), 24.

26 Buchanan, "Worlds in the Making," 9.

27 Peter Joore and Han Brezet, "A Multilevel Design Model: The Mutual Relationship between Product-Service System Development and Societal Change Processes," *Journal of Cleaner Production* 97 (2015): 92–105, DOI: https://doi.org/10.1016/j.jclepro.2014.06.043.

multi-level design model involves a cyclic arrangement of design activities that contribute to solutions. Product-technology systems address operational problems, and product-service systems address functional problems. At the socio-technical system level, system deficiencies are the focus of design. At the highest tier, societal problems receive designers' attention. At each level, Joore and Brezet make recommendations regarding the type of design process that will enable designers to tackle the problem, or opportunity, at hand.

Pieter Jan Stappers[28] expands this categorization to six levels of subject matter. Stappers considers various design problems and how they inform method and methodology selection by the designer. This instrumental perspective has educational value, as it allows design students to identify the type of design projects they are undertaking and pick suitable methods to assist with exploration and ideation.

According to Nicola Morelli,[29] product design that conforms to an industrial paradigm used to be the traditional realm of designers. But with the advent of human-computer interactions in the digital age, product utility was extended into product-service systems that cover the supply chain from product acquisition to service delivery and product support. This perspective centers on the presence of a physical product, while Stappers and Joore and Brezet cling less to design's tangible material outcomes.

Anders Kretzschmar[30] builds a perspective of design as a set of capabilities that can be acquired through education and participation, and can assist with complex problem solving related to public housing and urban planning, for example. Through project participation, organizations can increase their internal design capabilities. Sam Bucolo[31] and his colleagues build upon Kretzschmar's ladder, adding two steps that reflect the rise of design as a vital tool in business environments where transformation is mandated. If a company's own existence is under threat, design capabilities can provide an organization with the means to develop and action deeper customer insights as source of differentiating innovation.

While each author has a unique perspective, general patterns do emerge, and we have used those patterns to create our tri-level framework of design subject matter. To us, there are three levels of things to be designed: (1) integrated products; (2) services, processes and interactions; and (3) systems and organizations (see Figure 1).

The three layers of design subjects are not rigidly separate; they can occupy the same territory at times. In real life, that overlap emerges as a plurality of things being designed – and yet to be designed – as in when a new branding campaign leads upper management to explore uncharted territory in terms of business strategy, for example, or when a newly-designed graphic representation of a product spurs the internal development of roadmaps to organize its design process. Remember, too, that a physical object in the age of digital technology rarely operates in isolation – typically it connects in some way to a service, process, or system. This connectedness also reflects the pervasiveness of IoT vectors in the thing-centered design literature.[32]

Designing integrated products remains autonomous from service, process, and interaction design according to this model, given the specific capabilities and tactile imperatives required to conceptualize tangible artifacts. Here are our traditional "solutions" – and emphasizing these resonates with industry partners, who are motivated by tangible results. One thing to note: overall, a sensitivity to rhetoric during industry engagement should not be underestimated.

The design of services, processes, interactions, and integrated products narrows the activities of the designer to a set of relationships that are constrained in scope by the design problem – a beginning and an end to the design process are each discernable. On the other hand, systems thinking requires consideration of

28 Pieter-Jan Stappers, as discussed in Sapna Singh, Nicole Lotz, and Elizabeth B.-N Sanders, "Envisioning Futures of Design Education: An Exploratory Workshop with Design Educators," *Dialectic* 2, no. 1 (2018): online, https://doi.org/10.3998/dialectic.14932326.0002.103.

29 Nicola Morelli, "Designing Product/Service Systems: A Methodological Exploration," *Design Issues* 18, no. 3 (2002): 3–17, DOI: https://doi.org/10.1162/074793602320223253.

30 Anders Kretzschmar, *The Economic Effects of Design* (Copenhagen: National Agency for Enterprise and Housing, 2003).

31 George Peppou, Clementine Thurgood, and Sam Bucolo, "Designing Competitive Industry Sectors," *Design Management Journal* 11, no. 1 (2016): 5, DOI: https://doi.org/10.1111/dmj.12029.

32 Giaccardi et al., "Things as Co-ethnographers," 235.

an entire organization within the context of its environment in order to design multiple interconnected systems (human and non-human). Systems need to work together for the whole to function successfully. In the design of open systems there is no definitive threshold delineating the scope of design. This challenges the systems thinker to remain synthetic in his or her approach, and thus able to process non-linear, causal relationships.

In the following sections of this article, we apply this tri-level perspective to analyze how design supported innovation within the Dutch aviation industry.

Figure 1 Overview of Design Subject Matter. © 2019 by Rebecca Anne Price, Christine De Lille, and Katinka Bergema.

	INTEGRATED PRODUCTS	SERVICES, PROCESSES, AND INTERACTIONS					SYSTEMS AND ORGANIZATIONS		
Joore and Brezet, 2015 [i]	Product-technology system					Product-service system	Socio-technical system	Socio-technical system	
Stappers, 2016 [ii]	Product design	Interface design	Interaction design	Experience design	Service design		System design		
Morelli, 2002 [iii]	Product design					Product-service system			
Kretzschmar, 2003 [iv]	Design as form giving	Design as process					Design as strategy		
Peppou et al., 2015 [v]	Design as styling	Design as an innovation process					Design as a business strategy	Design as a community and organizational transformation	Design as national competitive advantage
Example	The design of a suitcase	The interface design for a bag drop terminal	The bag drop terminal interaction design (screen, physical interface)	The bag drop terminal experience design	The design of a home luggage pick up service	The design of the interplay of services for door-to-door service delivery	Design facilitates/ structures business strategy creation and implementation via innovation	Design brings diverse stakeholders together to collaboratively innovate	Design leads a government's macroeconomic agenda, and unites stakeholders from across industry to innovate collaboratively

[i] Joore and Brezet, "A Multilevel Design Model," 95–96.
[ii] Sapna Singh et al., "Envisioning Futures of Design Education," online.
[iii] Morelli, "Designing Product/Service Systems," 3–17.
[iv] Kretzschmar, *The Economic Effects of Design*, 28–32.
[v] George Peppou et al., "Designing Competitive Industry Sectors," 5.

33 See https://www.tudelft.nl/en/ide/research/research-labs/aviation/ for more information.

Designing an Industry: Dutch Aviation

Aviation is an extremely relevant and significant industry for a large portion of today's societies. The context is ideal, because it represents a complex intersection of diverse populations, cultures, technologies, risks, rewards, regulations, environmental concerns, reliability concerns, and competing commercial organizations. There has been a strong movement toward developing sustainable practices that will curb the industry's ecological footprint. There is a palpable sense of urgency around this, which means conditions conducive to exploration and experimentalism. The industry comprises a significant number of highly performing, extremely reliable traditional manufacturing organizations.

Examples of the various types of projects can be found on our faculty's dedicated aviation industry page.[33] You may be able to detect our three-layered approach to industry design, which integrates products; services, processes, and interactions; and new systems and ways of working inside an organization. The website also lists the kinds of industry partners we collaborated with during our design projects and challenges.

Table 1 is an overview of the design faculty/aviation projects completed from 2011 to 2017, including topic areas and the names of the collaborating organizations. The MSc projects lasted from six to eight months, and the PhD projects lasted four years. All projects were captured in thesis format as per university requirements.

Table 1. Collaboration activities between design faculty and aviation industry.

Year	Key Activities	*Number of Projects* and Subject Matter	Project Partners
2011	2 Graduation projects 1 PhD project launched	*2* Service, process, and interaction designs	Airline, airport
2012	1 Graduation project	*1* Integrated product design	Airline
2013	12 Graduation projects 1 PhD project launched	*6* Integrated product designs *5* Service, process, and interaction designs *1* System and organization design	Airlines, airline seat manufacturer, airport, aircraft parts manufacturer suppliers, OEM
2014	12 Graduation projects	*3* Integrated product designs *7* Service, process, and interaction designs *2* System and organization designs	Airlines, airport, aircraft parts manufacturer
2015	23 Graduation projects 1 PhD project completed Contract with supplier Horizon2020 EU project	*7* Integrated product designs *14* Service, process, and interaction designs *2* System and organization designs	Airlines, airports, airport parts manufacturer, OEM, aircraft parts manufacturer
2016	13 Graduation projects Present at multiple industry conferences (keynotes, exhibitions, workshops) Industry Expert Activities	*2* Integrated product designs *9* Service, process, and interaction designs *2* System and organization designs	Airlines, airports, aircraft manufacturer, airport parts manufacturer
2017	12 Graduation projects 5 PhD projects start 1 PhD project completed 2 Contracts (with airline and supplier) Present at multiple industry conferences (keynotes, exhibitions, workshops) Industry Expert Activities Start training programs for partners	*2* Integrated product designs *8* Service, process, and interaction designs *2* System and organization designs	Airline, aircraft seat designer, airport, aircraft parts manufacturer, airline alliance, airport manufacturer

Figure 2 Overview of the growth in activities between 2015 and 2017. © 2019 by Rebecca Anne Price, Christine De Lille, and Katinka Bergema.

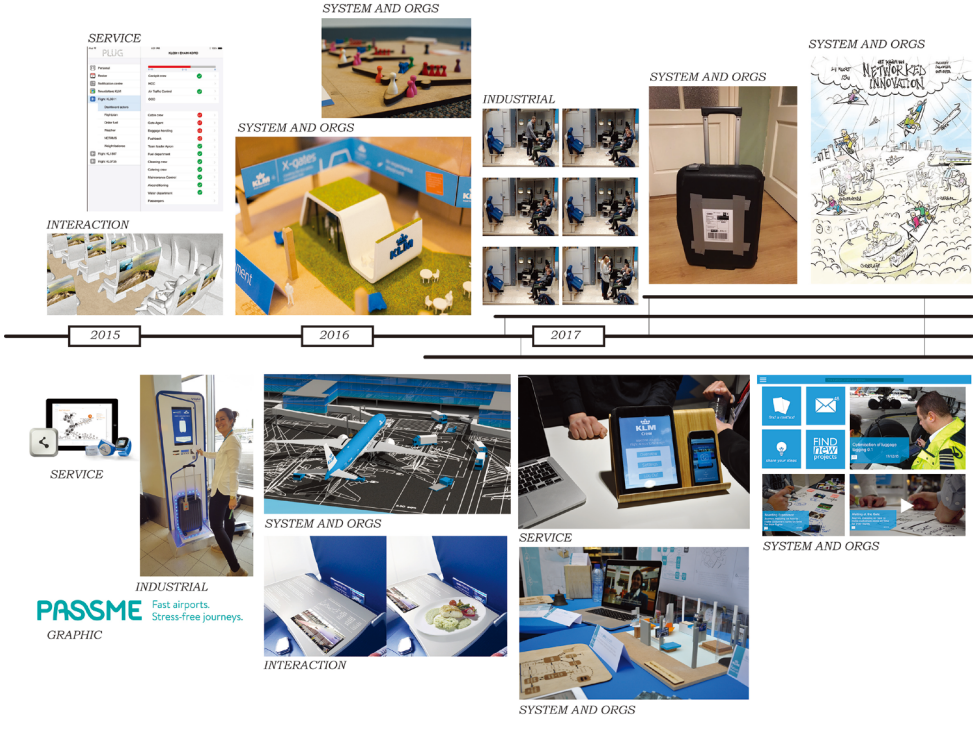

Figure 3 Overview of the expansion in design subject matter between 2015 and 2017. © 2019 by Rebecca Anne Price, Christine De Lille, and Katinka Bergema.

Figures 2 and 3 highlight recent activities that took place between 2015 and 2017. Figure 2 showcases the variety of activities and how this variety has increased. Figure 3 depicts the range of subject matters covered by projects between 2015 and 2017.

Research Approach

The Faculty of Industrial Design Engineering at Delft University of Technology has a recognized partnership with the aviation industry. The projects we include

here were completed between 2011 and 2017. In total, we input data relative to seventy-five (75) MSc theses and two PhD theses, plus five more in progress, into a database and prepared these data for analysis.[34] For doctoral projects in-progress, we analyzed the contents of reports that the students had prepared at the nine- or twelve-month stage of their research processes.

Content analysis enables qualitative material such as text and visuals to be treated in a quantitative manner. We defined three categories to classify the projects and their impacts. In each category, as per content analysis protocol, we created subcategories to enhance specificity.[35] Table 2 lists our specific objectives and protocol for content analysis.

Table 2. Content analysis foci.

Category	Subcategories	Objective of Analysis	Protocol
Project Outcome	Integrated products; services, processes, and interactions; systems and organizations.	Identify outcomes produced	Read thesis line-by-line and code according to subcategories
Partner Organizations	Airlines; airports; original equipment manufacturers (OEMs); suppliers; maintenance providers; etc.	List and code partnerships to ensure anonymity and enable us to track the coupling of themes with specific partners or particular areas of the industry value chain	Read thesis line-by-line and code partner organizations (names explicitly provided in the majority of theses)
Impact	e.g., Project continued by partner organization; designer hired immediately as result of project; intellectual property formalized as result of outcome; industry award received.	Identify projects that, through completion, had led to a change in the way the industry operates	Consult with alumni, university, and industry supervision team to determine status of project after completion (high impact = coded more than once)

Two coders performed the content analysis. We then conducted an intercoder reliability test in line with the work of Matthew Lombard and colleagues,[36] by comparing and contrasting the two coders' analysis across a sample of 10 projects. Of the 10 theses, 9 were coded similarly, generating an intercoder reliability coefficient of 0.9. Their disagreement concerned a distinction between a product-service system and an integrated product. This difference was reconciled by identifying whether the service was transactional (paid for by the customer) or contractual (implying an offer, a consideration, and an acceptance). Because the industry partners were identified explicitly in each thesis, industry coding immediately achieved consensus. This agreement provided a guideline for how the remaining sixty-five theses were coded. The results of the content analysis were then plotted onto a yearly timeline and the tri-level perspective of design to scaffold the visualization. The aim of visualization is in line with Johanna Nieminen and Tuuli Mattelmaki's call for visualized approaches when working with systems.[37] We will specifically report and discuss high impact projects within our findings.

Findings

Figure 4 visualizes the growth that took place across the 32 high impact MSc projects. The PhD projects are included later on the timeline, which we feel provides insight into the future of the Dutch aviation industry's engagement. A trend line represents the aggregated growth curve of all the projects included in this study.

34 See Appendix A for the full roster of projects.

35 Philipp Mayring, "Qualitative Content Analysis," *Forum: Qualitative Social Research Sozialforschung* 1, no. 2 (2000): 1–7, DOI: https://doi.org/10.17169/fqs-1.2.1089.

36 Matthew Lombard, Jennifer Snyder-Duch, and Cheryl Campanella Bracken, "Content Analysis in Mass Communication: Assessment and Reporting of Intercoder Reliability," *Human Communication Research* 28, no. 4 (2002): 587–604, DOI: https://doi.org/10.1111/j.1468-2958.2002.tb00826.x.

37 Johanna Nieminen and Tuuli Mattelmäki, "Navigating in the World of Services Visualizing a System of Systems," in *Proceedings of Nordes 2011, the 4th Nordic Design Research Conference*, ed. I. Koskinen et al. (Aalto: Aalto University, 2011), 263–68, available at https://research.aalto.fi/en/publications/navigating-in-the-world-of-services-visualizing-a-system-of-systems(48d5d725-b691-41fe-999c-65bc35ad504a)/export.html.

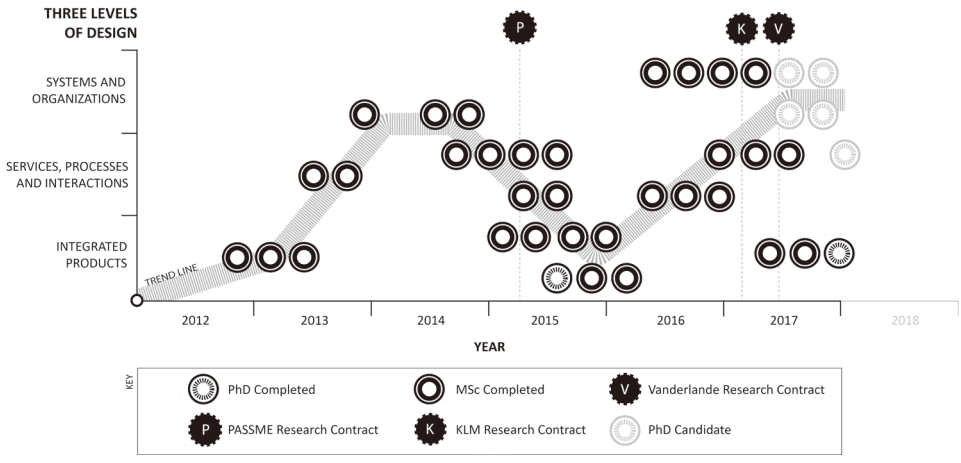

Figure 4 Timeline and trajectory of high impact faculty/industry projects. © 2017 by Rebecca Anne Price, Christine De Lille, and Katinka Bergema.

Along the top of the timeline we plotted the dates of three research contracts, which together formalized and furthered our faculty's partnership with members of the industry. The first funding phase began in 2015, when EU Horizon 2020 funding was granted under the project title PASSME. Two additional funding phases were launched in 2017; these involved partnerships with KLM (Royal Dutch Airlines) and Vanderlande (hardware and systems supplier). These three funding stages tell a story of successful long-term industry engagement, given the scale of the funding and the scope of the relevant projects.

Although the lead designer on each project was always different, industry mentors and university mentors were more stable presences. In many cases, the same chair supervising a master's project (or its principle supervisor) went on to chair or mentor follow-up projects with an industry partner to safeguard the progress and knowledge gained. Project completion created impact in the industry, but the university mentor also ensured that knowledge was consolidated from one project to the next to increase the overall impact of the partnership over time. Key activities for consolidation included carefully developing design briefs with industry partners to test surfacing assumptions and explore implications; conducting student seminars and workshops to share knowledge; and closely monitoring project recommendations as input for the next project.[38]

Over the last seven years, there have been two troughs and two peaks in the trends line, as depicted by the s-curve shown in Figure 4. This cycle of growth has acted as a catalyst for change within industry – moving from principally deductive and inductive value creation mechanisms emphasizing efficiency to human-centered perspectives consistent with design.[39]

The projects with outcomes that integrated products, services, processes, and interactions reveal insights about the industry's operations (2012 to 2013). Project efforts focused on identifying needs, deep user research, idea generation, and prototyping in addition to delivering a final concept design. Any new knowledge and learnings were outcomes of the design process, and were often captured in personal reflections or recommendations.[40] The projects developed new knowledge that allowed for re-imagining of systems downstream and new perspectives on organizational activities (predominantly from late 2013 to 2014). Insights gained at this level – for example, knowledge about policies, future visions, and growth strategies – were operationalized through projects at the integrated product and interaction design level (predominantly occurring during 2015). Earlier strategies and policies were prototyped during these projects with resulting new knowledge again informing the design of future systems and organizational endeavors (predominantly in 2016 and 2017). Visualizations of these insights will be broken up into

38 For more information, see Roxanne van Rijn, Matthijs Netten, and Rebecca Price, "U and I: Insights from a University-Industry Design Collaboration" (paper presented at the *21st DMI: Academic Design Management Conference*, London, UK, August 2018), 1–24, available at https://www.researchgate.net/publication/325782664.

39 Liedtka, "Perspective."

40 Sara L. Beckman and Michael Barry, "Innovation as a Learning Process: Embedding Design Thinking," *California Management Review* 50, no. 1 (2007): 25–56, DOI: https://doi.org/10.2307/41166415.

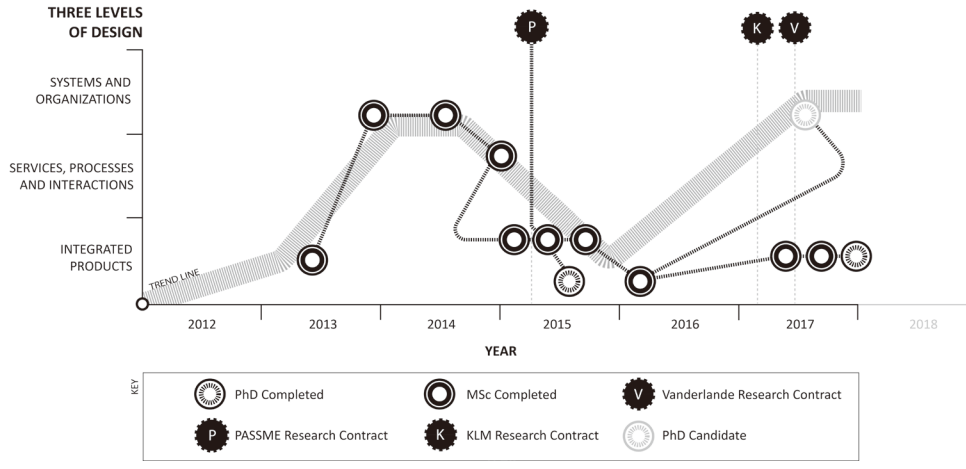

Figure 5 Timeline and trajectory of industry comfort and ergonomics projects. © 2019 by Rebecca Anne Price, Christine De Lille, and Katinka Bergema.

multiple figures in the following pages. Each figure describes a cluster of projects related to one of three streams of research and innovation: comfort and ergonomics; KLM Airlines; or luggage handling.

The effect of this continued application of design across the Dutch aviation industry reveals that as design capabilities emerged, these counterbalanced the exceedingly efficiency-conscious operations present within a number of leading organizations towards becoming more experience oriented.[41] Further, our study found that to transform underlying value creation mechanisms and cultures within organizations, successive projects must be carried out.

Figure 5 depicts the succession of projects related to comfort, ergonomics, and usability. These projects occurred in tandem with various partner organizations, including manufacturers, OEMs, and airlines. The Myseat project, completed in 2013, delivered a design for new aircraft passenger seats targeting increased comfort and more easeful navigation within the aircraft during boarding. The project involved a partnership between a design master's student and an aircraft parts manufacturer. It was eventually nominated for a prestigious Crystal Cabin international industry award. To capture the design approach that led to the success of Myseat, the partner manufacturer swiftly opted to begin another project the year that Myseat was completed. This new project envisioned an innovation lab and a set of design methods and tools that enabled the stakeholders, inspired during the Myseat project, to prototype cabin crew and passenger experiences. The partnering organization fully implemented this design project; design is now an integral aspect of their innovation activities.

Later projects took advantage of the innovation lab's expanding capacities to formulate new products and services, which included upgrading cabin crew inflight workspaces and designing passenger seating to increase comfort. Two projects in 2017 were outliers in the domain of integrated products, challenging the trend line, possibly because their topics – both dealt with comfort and ergonomics – were integrated concepts. We were conducting multiple, high impact projects simultaneously, an indication of design's evolving influence in and on the industry and the maturity of our relationship. The PhD presented in 2017, which dealt with business-to-business collaboration across the aviation supply chain, successfully leveraged knowledge gained over the course of several prior master's and PhD projects.

Figure 6 shows the progression of KLM airline related projects. The airline stream began as an exploration of the organization's existing integrated range of products. Insights gained during 2012 and 2013 became the foundation for new strategy designs in 2014. These new strategies and ways of operating were then operationalized during 2015 via new and integrated service, process, interaction,

41 Jonathan Schanz and Christine De Lille, "Customer Experience Strategy Turned into Hands-On Actions through a Design Approach," *Design Management Journal* 12, no. 1 (2017): 28–39, DOI: https://doi.org/10.1111/dmj.12037; Niya Stoimenova and Christine De Lille, "Building Design-Led Ambidexterity in Big Companies," *Conference Proceedings of the Design Management Academy, vol. 4*, ed. Erik Bohemia, Cees de Bont, and Lisbeth Svengren Holm (Loughborough: Design Research Society, 2017), 1043–61; Christine De Lille, Julia Debacker, and Manuel Pardo Maldonado, "Weight, Safety, and/or Services? An Aviation Manufacturer Tackling Challenges of Servitization through Design," in *Proceedings of the Spring Servitization Conference 2015*, ed. Tim Baines and David Harrison (Birmingham: Aston Business School, 2015), 18–25, available at https://pure.tudelft.nl/portal/en/publications/weight-safety-and-or-services-an-aviation-manufacturer-tackling-challenges-of-servitization-through-design(87eff997-51d7-491e-b384-1191db83634c)/export.html.

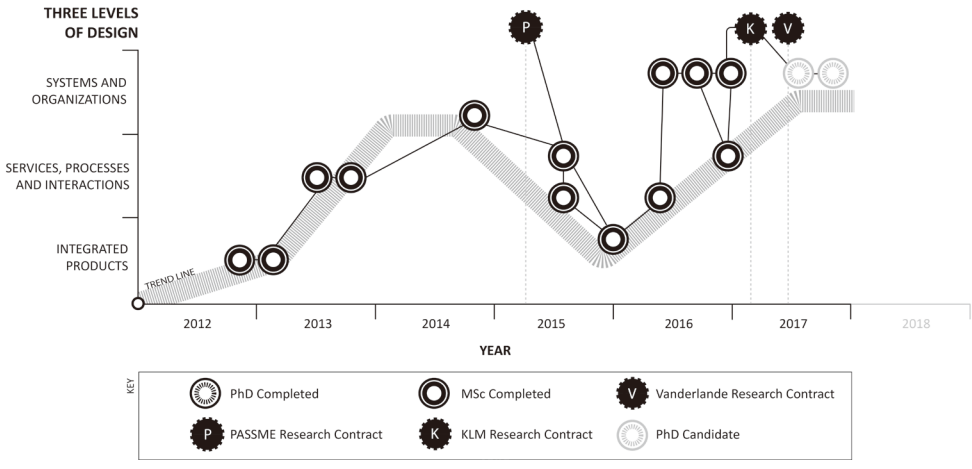

Figure 6 Timeline and trajectory of KLM related projects. © 2019 by Rebecca Anne Price, Christine De Lille, and Katinka Bergema.

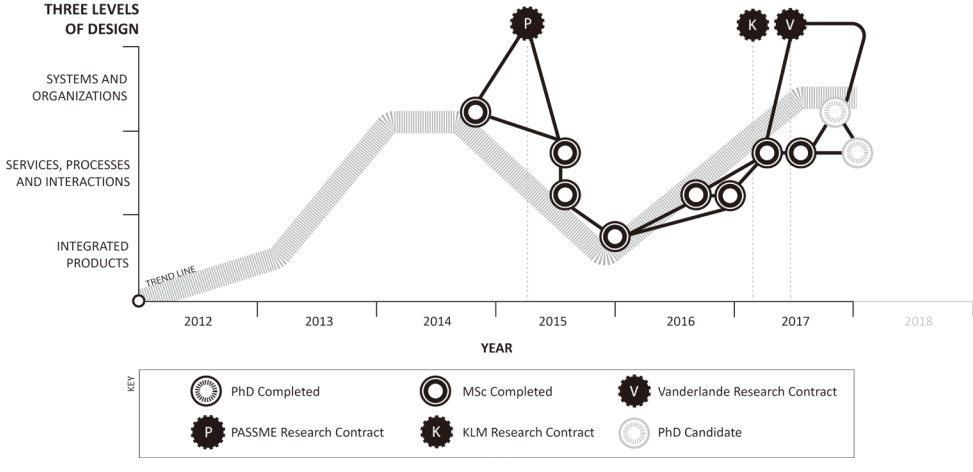

Figure 7 Timeline and trajectory of high impact luggage projects. © 2019 by Rebecca Anne Price, Christine De Lille, and Katinka Bergema.

and product designs that were vital to realizing the airline's vision for the future. Insights gained from these projects then led to the refinement of the airline's internal systems and the structure of its organization in 2016 and 2017, when the airline began to undergo a significant digital transformation and became dedicated to developing its internal design capabilities.

Figure 6 has a distinct flux line consistent with the s-curve trend line observed in Figure 4. There was an abrupt rise in the number of projects geared toward designing systems and organizational aspects in 2017, in support of the airline's digital transformation. This peak corresponded with a funding phase: KLM invested in order to develop its internal design capabilities via new management trainee programs. There is a video[42] outlining the nature of the collaboration between KLM and our design faculty available online.

Figure 7 presents projects related to a stream of research looking at ways to disrupt legacy travel regulations related to baggage. These regulations are built into the contract of carriage (or terms and conditions of any airfare purchased) and forbid luggage on planes without an accompanying passenger. By opening up this regulation, entirely new systems, stakeholder organizations, services, and products would be possible, all related to a new concept: "door to door." Although the concept is simple – your luggage travels ahead of you and arrives at your destination neatly in your hotel room – the changes required to achieve this would entail a complete overhaul of the airline's internal regulations, systems, services, processes, and products that had met the standard of the commercial air transport industry since the airline's inception.

42 "Design Doing at KLM Royal Dutch Airlines by TU Delft," YouTube video, 2:58, posted by IDE TU Delft, March 16, 2017, https://www.youtube.com/watch?v=TrzNAtcDatI. Although the origins of this video are not treated in this article, it is a useful example of how to design and depict the relationship between one particular aviation partner and a design faculty.

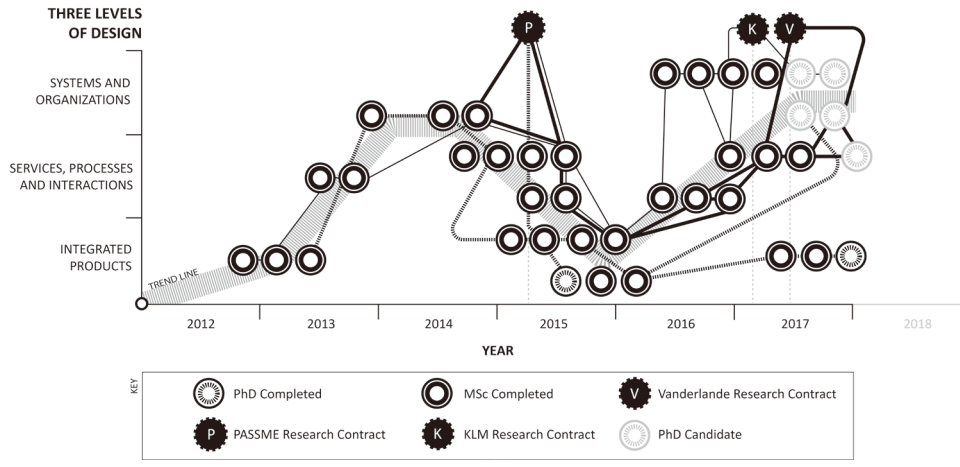

Figure 8 Timeline and trajectory of research: combined streams. © 2019 by Rebecca Anne Price, Christine De Lille, and Katinka Bergema.

The luggage stream began with the design of the disruptive vision and accompanying system that conceptualized the door-to-door luggage service (2014). Subsequent projects then built upon this disruptive momentum, exploring customer needs and desires, enabling business models and new technologies (2015 and 2016). Knowledge created as part of these projects was consolidated and furthered by a PhD candidate researching networked innovation through design.[43]

Figure 8 depicts the combined streams of projects. The outlier projects, which took place in 2017, are indications of a kind of maturity in the work that was achieved thanks to greater resources: more funding, increased numbers of academic and administrative staff, and dedicated physical spaces for prototyping labs. Sustaining this maturity required researchers and industry partners to explicitly ensure coherence and unity across the range of facilities awarded so that they might advance using a shared vision for how to move the industry forward.

Designing Industry

Jeanne Liedtka's call to reclaim the word "technology" from its use in the physical sciences provides a valuable reframing for the design discipline and starting point for our discussion According to her, design is a *social technology* that provides a collection of methods, processes, and skills to negotiate problems and explore possibilities.[44] As a social technology, design connects people in a way that enables agency for change. When this technology is utilized across a network of stakeholders within a single industry, significant advancements can be achieved.

In this article, we have presented a sequence of projects that give substance to the notion of design as a social technology. The trajectory of the project pattern is consistent with traditional technology and diffuse innovation literature that describes growth and maturity in the form of an s-curve.[45] Each project connects people and knowledge as part of the general advancement of the aviation industry from an overwhelmingly efficiency-based heritage toward people-centric air travel.

Of course, design is more than methods, processes, and skills deployment. The spirit of design should not be overlooked. A design culture involves, but is not limited to, curiosity, democracy, and openness to pluralism. The cultural aspects of design have to be championed during industry projects to the same degree as its practical and tangible methods, processes, and skills.

When the partnering company has a limited design capacity, a situation that Pia Storvang and her colleagues describe in their work,[46] the challenge of championing design as an alternate or complementary culture is a task not to be underestimated. An internal culture cannot be shifted overnight. A longitudinal approach,

43 Of importance to note here is that in 2017 and 2018, one of the driving researchers in the luggage stream—who had supervised many projects—was invited to advise the Airports Council International and International Air Transport Association regarding the reform of luggage policies. This interaction is not represented in our figures as it did not correspond with a specific project. However, it is an important indication of how a multi–level, longitudinal design approach led to a seat at the decision makers' table for designers. We find that an evidenced based approach—which demonstrates what design can achieve, rather than merely presenting or describing the possibilities offered by design via workshops—an essential part of building rapport with industry leaders. The first author and her colleagues have also written about this notion of "show, not tell" as vital when building design capability within a corporate environment. See Rebecca Price, Cara Wrigley, and Judy Matthews, "Action Researcher to Design Innovation Catalyst: Building Design Capability from Within," *Action Research* (June 2018): 1–20, DOI: https://doi.org/10.1177/1476750318781221.

44 Liedtka, "Beyond Better Solutions," 8.

45 Christensen, "Exploring the Limits."

46 Pia Storvang, Susanne Jensen, and Poul Rind Christensen, "Innovation through Design: A Framework for Design Capacity in a Danish Context," *Design Management Journal* 9, no. 1 (2014): 9–22, DOI: https://doi.org/10.1111/dmj.12006.

like the one we describe in this article, builds pressure for cultural reform through repetition of project formats, topic matter, outcome areas, and processes. The design students worked at the university and at the industry partners drove a gradual yet recognizable shift toward a customer-centric ways of thinking and doing. Cara Wrigley calls the role they played the *design innovation catalyst*.[47] Beyond research per se, design educators and administrators act to ensure knowledge developed in one project informs future projects with various industry partners. They recruit industry partners as champions[48] of the design process responsible for sharing project findings within their own organizations to raise design awareness.

While knowledge management occurred smoothly in each of the project streams, integrating parallel project streams posed a greater challenge to knowledge management activities. We recommend formalizing broad organizational research groups within design faculties or schools with a mandate for knowledge and resource sharing. These labs must be appropriately funded by both industry and faculty and afforded physical lab spaces for prototyping. To this end, the formation of a *People in Transit* research group at the Faculty of Industrial Design Engineering at Delft University of Technology is intended to cross-fertilize knowledge from various projects and extend the logic of industry advancement to encompass road and rail transportation systems.

In Figure 9, we distil our findings into an *Industry Design Framework*: the x-axis relates to time, and the y-axis relates to the three layers of design subject matter we have proposed. There are two starting points within this framework. If a project is launched from the Bottom-Up (1), then it looks at designing integrated products. Insights are derived through completion of these projects, and will inform the future design of services, processes, and interactions, and eventually the design of new systems and forms of organization. The new systems and organizational aspects are then operationalized through new projects that demonstrate how the organization might operationalize a vision or strategy. Insights derived from these operationalization projects then inform a second round of systems and organizations design.

Starting from the second starting point, Top-Down (2), the designer begins by considering a strategy or vision from the perspective of (re)designing a system or the organization more broadly. These design strategies are operationalized through projects that prototype new services, processes, interactions, and integrated products before a second iteration of strategizing takes place. Projects can also occur in parallel if there are sufficient resources and continuity to manage multiple streams of

47 Wrigley, "Design Innovation Catalysts."

48 Steven Kyffin and Paul Gardien, "Navigating the Innovation Matrix: An Approach to Design-Led Innovation," *International Journal of Design* 3, no. 1 (2009): 67, available at http://www.ijdesign.org/index.php/IJDesign/article/view/305.

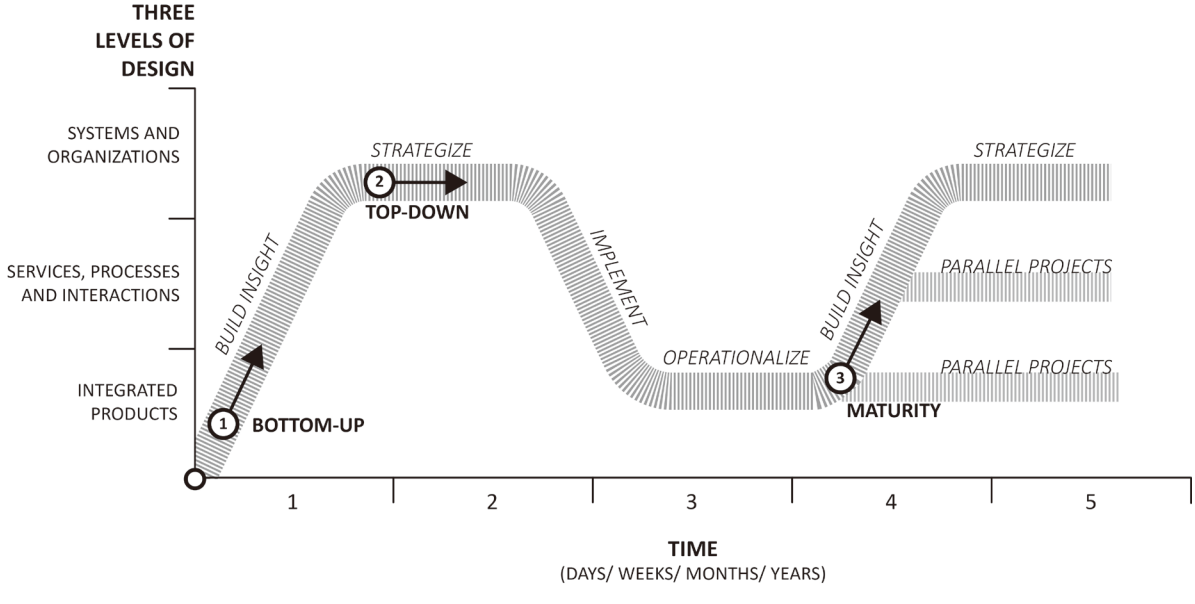

Figure 9 Industry Design Framework. © 2019 by Rebecca Anne Price, Christine De Lille, and Katinka Bergema.

49 Rijn et al, "U and I."

50 Morelli, "Designing Product/Service Systems."

51 Bucolo, *Are We There Yet?*

projects, an event we term Maturity (3). In summary, there are multiple entry points for working in systemic collaborations with industry. The framework is intended to provide guidance regarding where and how to begin systems design collaborations.

Based on our experiences piloting this research since 2011, when establishing design research relationships that involve actors from across an industry, we recommend the work be conducted at three levels: integrated products; services, processes, and interactions; and systems and organizations. In addition, we recommend that when working with companies who possess a limited design capacity, that engagement should begin informally (bottom-up), to demonstrate the potential of design beyond styling. For organizations with higher levels of design capability, we believe it is possible to begin using the top-down approach.

The shift toward a more mature stage in the research/industry relationship requires an increase in industry investment in terms of time, effort, and financial resources. Our experience tells us that to progress from informal partnerships to strategic partnerships that include investment in design is vital, as the process builds legitimacy for transformative change through design within an organization. Roxanne van Rijn and her colleagues conducted research into the specific activities of university and industry partners during this longitudinal collaboration.[49] Their study contains a set of specific recommendations on how to establish and maintain strategic partnerships between a university and stakeholders from across an industry.

The Industry Design Framework is intended to be adaptable, given the context and ambition of participating organizations. When time is modified on the x-axis, for example shortened to *n* number of weeks, design projects can be conducted in sprints. The timeframe might also be shortened to hours, to provide a framework for a generative workshop or studio learning. The workshop facilitator or sprint lead may choose to approach the project top-down or bottom-up. They might even begin in the middle – at the level of services, processes, and interactions – then explore the system and organization level and consider integrated products. As our research did not reveal this as a strategy, this opportunity in particular is an avenue for further research. Our application of the framework with the Dutch retail industry to design a national retail plan has provided positive preliminary feedback. This partnership involves a consortium of Dutch private and public organizations across the industry. We have applied the framework, using the top-down entry point, to first assist the industry consortium to envision the future of retail experiences. Eleven retail labs across the Netherlands are now in place to design and prototype retail experiences based on this shared vision. While this is very much research in progress, early indicators regarding the value of the framework are positive.

During longer engagements with industry partners, the extent to which projects occupy the three levels can also be modified. Putting together a consequential design brief in tandem with industry partners is a vital management activity for design educators and design managers. Further, awareness of one's current position within the framework can only assist successful management of industry design. When the y-axis is modified, an alternative but perhaps more contextually specific view of design subject matter can guide industry design in line with Nicola Morelli's emphasis on product-service centric contexts[50] or Sam Bucolo's emphasis on design as source of competitive advantage.[51] The strength of the Industry Design Framework lies in the visual guidance about advancing industry through design it offers.

Role of the Designer/s

Now our discussion turns to the individual designer and the roles they play in designing at the industry-wide level. Figures 4 to 8 depict design projects completed by a lone designer. The designer was working at a specific level – either integrated

product design; service, process, and interaction design; or system and organization design. Visionaries such as Steve Jobs, Bill Gates, and Elon Musk have also operated across all three of these levels of design to shape their industries. Their future visions were and are realized by journeying across all these domains – coalescing company strategy with services, interactions, and physical products to produce a coherent development trajectory. Out of professional necessity, though, many designers choose to specialize in one level or another. The independent fields of graphic design, industrial design, service design, and system design are outcomes of the drive toward specialization. Nevertheless, designers can become experts in content and still gain the requisite knowledge to deal with similar subject matter – it is not uncommon for an industrial designer to develop a service or an interaction designer to consider new products. The notion of a 'T' shaped designer is relevant here.[52]

52 Jay Peters, "Educating Designers to a *T*," *Design Management Review* 23, no. 4 (2012): 62–70, DOI: https://doi.org/10.1111/j.1948-7169.2012.00213.x.

A product designer is an expert in user research and design for manufacturing – with mastery of material properties to give form and resolve function. The strategic designer is expert in shaping the organization in a similar way through vision, key performance indicators and innovation roadmaps. These two domains of knowledge are distinct and take time to master, yet the design process is inherent to each. If the two designers swapped roles for a week, progress would be enabled by general knowledge, but difficulties would likely arise from a lack of specific knowledge. A question for future researchers to probe is to what extent proximity between levels supports the diverse practice and knowledge of a single designer.

When a designer cannot operate across all levels, industry advancement through design then necessitates a collective, collaborative effort across many projects. Here we raise the issue of an underlying tension between domains of subject matter. In the struggle to build practical and theoretical legitimacy amongst their peers, design educators, researchers, and practitioners must inevitably demonstrate how a specialization is distinct yet integrates into the discipline as a whole. And adopting hierarchical corporate discourses associated with the newfound strategic context of design would be a shift away from the democratic and pluralistic spirit of the discipline. As we have identified, shaping an industry requires growth that relies on a sustained collaborative application of design at all levels and continuous learning as the core outcome of design. Therefore, any tension among disciplines would be counterproductive to the greater aspirations of design as social technology. For design to be capable of unlocking even the most wicked of problems facing society, now more than ever designers must collaborate and embrace intra-disciplinary diversity in order to shape better futures.

Conclusion and Future Research

In this article, we have presented a multi-level, longitudinal approach to advancing industry through design. Analysis of an engagement with the aviation industry during 2012 to 2017 found that advancing industry through design requires the consolidation of many projects with varying subject matter and contact with industry partners across the value chain. The Industry Design Framework distils our findings into a visual contribution that supports the formation and sustainment of industry collaboration. While this framework has been developed with the aviation industry, we recommend future application in alternative industries to both retrospectively describe a collaboration that has taken place or is occurring, and to generate new collaborations with industry.

Our recent applications of the framework within the Dutch retail industry have been positive and have given us confidence in the practical value of the Industry Design Framework. We anticipate that this approach will also hold value for those engaged in grant writing, who need resources that demonstrate why, how, and

when design activity phases will take place within a greater program of research and innovation. Our immediate future steps are to continue replicating this study with the Dutch retail industry. Further, we will be mapping healthcare and circular economy projects to the Industry Design Framework to build cross-industry comparative cases. We welcome diverse application of the framework, constructive critique and academic dissemination to further deepen knowledge regarding how design can advance industry.

Acknowledgments

The authors wish to thank our aviation partners and design students for embracing design. Without the quality of partnerships across industry and the courage of our students to challenge the status quo, this research would not be possible.

Appendix A. Project Roster

Year	Project Title	Project Outcome (Level)	Partner Organization	High Impact Y/N
2011	The Airport Experience: Building a Seamless Travel Experience through Information & Interaction	Service, process, and interaction	Airport	N
	Using Dynamic Seat Allocation to Improve Aircraft Comfort	Service, process, and interaction	Airline	N
2012	Now Boarding 2025: Groups in Control	Integrated product	Airline	Y: Project continued
2013	A Brand & Product Development for High Performance Body Boarding, on the Atlantic Coast of Ireland	Integrated product	Independent	N
	Airline Lounge 2020: A Vision and Concept for the New Lounge at Airport	Service, process, and interaction	Airline	N
	The Experience Lab | Lifting Zodiac to New Heights of Innovation	Systems and organizations	Aircraft Part Manufacturer	Project continued and eventually led to PhD start
	Aircraft Interior Design in 2050	Integrated product	OEM	N
	Xperience the City	Service, process, and interaction	Independent	N
	A User-Focused Food Tray Design to Enhance The Airline Inflight Experience	Integrated product	Airline	Y: Project continued
	Myseat: Development of a User Focused Aircraft Seat	Integrated product	Airline Seat Manufacturer	Y: Project nominated for industry award
	Not Just Green: Developing a Sustainable Elevated GRT System Infrastructure for Airports	Integrated product	Airport	N
	Design for Interactions between Dutch Cabin Crew and Chinese Passengers	Service, process, and interaction	Airline	N
	Arrivals 2020: A Vision and Concept for the Anonymous Arrival Process at Airport In 2020	Service, process, and interaction	Airline	Y: Project Continued and fed into PASSME deliverables
	The Optimization of a Lower Deck Mobile Crew Rest	Integrated product	Aircraft Part Manufacturer	N
	Boarding 2016 | Design of a Vision and Concept for the Airline Boarding Process at Airport in 2016	Service, process, and interaction	Airline	Y: Project continued and fed into PASSME deliverables

(*Continued on next page…*)

Appendix A. Project Roster (*Continued*)

2014	A New Aircraft Seat Using Nature Inspired Design	Integrated product	Airline Seat Designer	N
	Modern Dutch Heroes: A Concept and Strategy for a Dutch Innovation Platform at Airport	Service, process, and interaction	Airport	N
	Designing an Intuitive Crew Application for Airline	Service, process, and interaction	Airline	Y: Project continued and near implementation
	Anonymized for IP-reasons	Service, process, and interaction	Airline	N
	A 2020 View on Catering, Personalization, and Unbundling on the European Network	Service, process, and interaction	Airline	N
	Up in the Air: The Application of Self-Reinforced and Thermoplastic Composites in a New Generation of Lightweight Air Cargo Container	Integrated product	Aircraft Part Manufacturer	N
	Fly Your Dreams	Service, process, and interaction	Airline	N
	Airline Transfer 2023	Systems and organizations	Airline	Y: Project continued
	SHAREABLES: Designing an Enhanced Crew-Passenger Interaction For Airline	Service, process, and interaction	Airline	N
	Design of a Passenger Experience-Driven Inflight Service Concept for 2020	Systems and organizations	Aircraft Part Manufacturer	Y: Project received industry award nomination
	Signature: Lightweight Design Without Compromise of Comfort	Integrated product	Aircraft Part Manufacturer	Y: Project received industry award nomination
	Improving Boarding Efficiency and Experience	Service, process, and interaction	Airline	Y: Project continued and fed into PASSME deliverables
2015	Graduation Project | Concepts for a Large Commercial Aircraft Rudder	Integrated product	OEM	N
	Departures 2020: A Vision and Concept for the Non-Schengen Passenger Ground Process Of Airline at Airport	Service, process, and interaction	Airport	N
	The Optimization of Airline's Hand Luggage Checking Process: Improving the Overall Passenger Experience and Operational Efficiency	Integrated product	Airline	Y: Project continued and fed into PASSME deliverables
	In-Flight Experience Centre: A Study on Organization and Potentialities	Service, process, and interaction	Airport	N
	The Guardian: A Holistic and User-Centered Design Approach to Optimize Patient Transport by Airplane	Integrated product	Airline	Y: Project continued
	An Innovation Framework for the Research and Technology Department of Air Catering Equipment	Systems and organizations	Aircraft Part Manufacturer	N
	The Design of the Future Bird Repelling Device	Integrated product	Independent	Y: Project continued
	Retina: New Headrest Concept	Integrated product	Aircraft Part Manufacturer	N
	A Mobile Solution for Inexperienced Passengers of Airline	Service, process, and interaction	Airline	N
	JAY: Kitting as Optimization Tool in Aircraft Maintenance	Service, process, and interaction	Airline	Y: Project continued

(*Continued on next page…*)

Appendix A. Project Roster (*Continued*)

	Opportunities for Additive Manufacturing in Galley	Integrated product	OEM	N
	Headrest: Design of a Headrest Enabling Sideward Leaning and Seclusion on Long-Haul Economy Flights	Integrated product	Aircraft Seat Manufacturer	Y: Project continued and received Crystal Cabin industry award
	Redesigning Airline's Service Regarding Unaccompanied Minors	Service, process, and interaction	Airline	Y: Project continued and student employed
	Conceptualization of a Smart Communicative Luggage that Communicates to the User and Its Environment	Service, process, and interaction	Independent	N
	The Future of the Automated Passenger Procedure 2025: Designing Happy Flows	System and organization	Airline	N
	Oxygen: The New Generation Lower Deck Commercial Cabin	Service, process, and interaction	Aircraft Part Manufacturer	Y: Project received industry award nomination.
	Optimization of Aircargo Containers: Design of a New Door for an Aircargo Container	Integrated product	Aircraft Part Manufacturer	N
	Improving Airline Customer Ground Handling's Competitive Market Position	Service, process, and interaction	Airline	N
	Redesigning Airline's Services Regarding Passengers with Reduced Mobility	Service, process, and interaction	Airline	N
	All Passengers Satisfied and on Time: Supported by an Integrated, Up to Date Information and Wayfinding System	Service, process, and interaction	Airline	N
	Luggage Solutions	Service, process, and interaction	Airline	N
	Staff Travel Revision: Exploiting and Redefining the Airline Staff Travel Services Business Model	Service, process, and interaction	Airline	N
	Plug Graduation Report	Service, process, and interaction	Airline	Y: Project fully implemented in industry partner
	*PhD Completion: Comfortable Passenger Seats: Recommendations for Design and Research	Integrated product	Independent	Y: Candidate employed and project continued
2016	Time Flies ... When Your Bag Was In The Skies! Designing Individual Tracking Events for Incoming Baggage and its Applications towards the Passenger and Airline	Service, process, and interaction	Airline	N
	The Design of a Future Apron for the New a Pier	Systems and organizations	Airline	Y: Project continued with implications for terminal design at major airport
	Designing a Seamless Passenger Journey: Picking up Luggage from Origin to Destination and Back	Service, process, and interaction	Airline	N
	Bag Checker: How Hand Luggage Overload Disrupts Transavia Processes & Experience	Service, process, and interaction	Airline	Y: Project continued with recommendations guiding industry partner
	The Future of Air Cargo: Design of a Solution to Use Sensor-Based Data to Improve Efficiency, Transparency and Communication for Airline Cargo's Employees and Customers	Service, process, and interaction	Airline	N
	Hand Baggage: A Passenger-Centric Approach to Decrease the Amount of Hand Luggage	Service, process, and interaction	Airline	Y: Project continued and fed into PASSME deliverables

(*Continued on next page…*)

	The Optimization of Airline's Hand Luggage Checking Process	Integrated product	Airline	Y: Project continued and fed into PASSME deliverables
	Design of a Seamless Shower Service Experience for the New Airline Lounge	Service, process, and interaction	Airline	N
	Future Baggage Reclaim: Innovating Around the Passenger in the A Area	Service, process, and interaction	Airline	N
	Empowering Idea Owners to Innovate: Implementing an Innovation Toolkit at Airline	Systems and organizations	Airline	Y: Project implemented in full
	Improving the Ergonomic Experience of the Service Trolleys Handled by Flight Attendants	Integrated product	Aircraft Manufacturer	Y: Project continued
	Improving Passenger Experience in Airports through Redesign of the Jet Bridge Environment	Service, process, and interaction	Airport	N
	Improving Boarding Efficiency and Experience	Service, process, and interaction	Aircraft Manufacturer	Y: Project continued and fed into PASSME deliverables
2017	On Demand – A Premium Service for Premium Customers	Service, process, and interaction	Airline	N
	Creating Customer Intimacy and Increasing Employee Engagement	Systems and organizations	Airline	Y: Project continued and fed into PhD on employee engagement
	Airport Security Scanner: A Revision of the Security Scanner. Restoring the Balance between Pax, Agent and Scanner	Service, process, and interaction	Airport	N
	Rediscovering the Romance of Flying	Integrated product	Seat Designer	Y: Project continued and implemented at regional airport
	Deep Personalization	Service, process, and interaction	Airline	Y: Project continued
	Voluntary Hand Luggage Check-In Solutions: Changing the Passenger's Hand Luggage Handling Experience and Behavior	Service, process, and interaction	Airline	Y: Project continued with recommendations guiding industry partner
	Intuitive Wayfinding: Defining Wayfinding Design Principles for the New Airport Pier & Terminal, through Conceptual Design as a Case Study	Service, process, and interaction	Airport	N
	Designerly Organization as Supplier	Systems and organizations	Aircraft Part Manufacturer	Y: Project continued and fed into PhD
	Designing a Crew Seat With a Sleep Opportunity	Integrated product	Aircraft Seat Designer	Y: Project continued and under Embargo
	A Design Concept and Vision on Airport's Seamless Connection to the Netherlands Based on the Passenger's Point of View	Service, process, and interaction	Airport	Y: Project continued and fed into PASSME deliverables
	Optimizing Flow in the Gate Areas to Improve Air Travel Passenger Experience	Service, process, and interaction	Airport	Y: Project continued and fed into PASSME deliverables
	A New Proposition for Skyteam Airline Alliance	Service, process, and interaction	Airline Alliance	Y: Student employed
	*PhD Completion: Design Considerations for Airplane Passenger Comfort	Service, process, and interaction	Independent	Y: Recommendations presented to industry

(*Continued on next page…*)

*PhD in Progress: Designing Organizational Infrastructure	Systems and organizations	Anonymous	In progress
*PhD in Progress: Improving Employee Engagement	Systems and organizations	Anonymous	In progress
*PhD in Progress: Designing Servitization of an Airport Manufacturer	Service, process, and interaction	Airport Manufacturer	In progress
*PhD in Progress: Designing the Interorganizational Innovation Process	Systems and organizations	Airport Manufacturer	In progress
*PhD in Progress: Engineering the Perfect Inflight Experience	Systems and organizations	Aircraft Part Manufacturer	In progress

References

Beckman, Sara L., and Michael Barry. "Innovation as a Learning Process: Embedding Design Thinking." *California Management Review* 50, no. 1 (2007): 25–56. DOI: https://doi.org/10.2307/41166415.

Buchanan, Richard. "Wicked Problems in Design Thinking." *Design Issues* 8, no. 2 (1992): 5–21. DOI: https://doi.org/10.2307/1511637.

Buchanan, Richard. "Rhetoric, Humanism, and Design." In *Discovering Design: Explorations in Design Studies*, edited by Richard Buchanan and Victor Margolin, 23–66. Chicago: The University of Chicago Press, 1995.

Buchanan, Richard. "Worlds in the Making: Design, Management, and the Reform of Organizational Culture." *She Ji: The Journal of Design, Economics, and Innovation* 1, no. 1 (2015): 5–21. DOI: https://doi.org/10.1016/j.sheji.2015.09.003.

Bucolo, Sam. *Are We There Yet? Insights on How to Lead by Design*. Amsterdam: BIS, 2015.

Buede, Dennis M. *The Engineering Design of Systems: Models and Methods*, 2nd ed. Hoboken: John Wiley & Sons, Inc., 2009.

Cavalieri, Sergio, and Giuditta Pezzotta. "Product-Service Systems Engineering: State of the Art and Research Challenges." *Computers in Industry* 63, no. 4 (2012): 278–88. DOI: https://doi.org/10.1016/j.compind.2012.02.006.

Christensen, Clayton M. "Exploring the Limits of the Technology S-curve. Part I: Component Technologies." *Production and Operations Management* 1, no. 4 (1992): 334–57. DOI: https://doi.org/10.1111/j.1937-5956.1992.tb00001.x.

Cross, Nigel. *Designerly Ways of Knowing*. Basel: Birkhauser, 2007.

De Lille, Christine, Julia Debacker, and Manuel Pardo Maldonado. "Weight, Safety, and/or Services? An Aviation Manufacturer Tackling Challenges of Servitization through Design." In *Proceedings of the Spring Servitization Conference 2015*, edited by Tim Baines and David Harrison, 18–25. Birmingham: Aston Business School, 2015. https://pure.tudelft.nl/portal/en/publications/weight-safety-andor-services-an-aviation-manufacturer-tackling-challenges-of-servitization-through-design(87eff997-51d7-491e-b384-1191db83634c)/export.html.

Dong, Andy. "Design × Innovation: Perspective or Evidence-Based Practices." *Journal of Design Innovation and Creativity* 3, no. 3–4 (2015): 148–63. DOI: https://doi.org/10.1080/21650349.2014.943294.

Forlizzi, Jodi, Erik Stolterman, and John Zimmerman. "From Design Research to Theory: Evidence of a Maturing Field." *IASDR Proceedings 2009: Rigor and Relevance in Design*. Seoul: Korean Society of Design Science, 2009. http://www.iasdr2009.or.kr/.

Fraser, Heather M.A., *Design Works: How to Tackle Your Toughest Innovation Challenges Through Business Design*. Toronto: University of Toronto Press, 2012.

Friedman, Ken, Yongqi Lou, Don Norman, Pieter Jan Stappers, Ena Voûte, and Patrick Whitney. "DesignX: A Future Path for Design." *jnd.org*, December 2, 2014. http://www.jnd.org/dn.mss/designx_a_future_pa.html.

Frølund, Lars, Fiona Murray, and Max Riedel. "Developing Successful Strategic Partnerships with Universities." *MIT Sloan Management Review* 59, no. 2 (2018): 71–79. https://sloanreview.mit.edu/article/developing-successful-strategic-partnerships-with-universities/.

Fuad-Luke, Alastair. *Design Activism: Beautiful Strangeness for a Sustainable World*. London: Routledge, 2013.

Gaver, William W. "What Should We Expect From Research Through Design?" In *CHI '12: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 937–46. New York: ACM, 2012. DOI: https://doi.org/10.1145/2207676.2208538.

Giaccardi, Elisa, Chris Speed, Nazli Cila, and Melissa L. Caldwell. "Things as Co-ethnographers: Implications of a Thing Perspective for Design and Anthropology." In *Design Anthropological Futures*, edited by Rachel Charlotte Smith, Kasper Tang Vangkilde, Mette Gislev Kjaersgaard, Ton Otto, Joachim Halse, and Thomas Binder, 235–48. London: Bloomsbury Academic, 2016.

Ingold, Tim. *Making: Anthropology, Archaeology, Art and Architecture*. Abingdon: Routledge, 2013.

Irwin, Terry, Gideon Kossoff, and Cameron Tonkinwise. "Transition Design Provocation." *Design Philosophy Papers* 13, no. 1 (2015): 3–11. DOI: https://doi.org/10.1080/14487136.2015.1085688.

Jones, Peter. "The Systemic Turn: Leverage for World Changing." Editorial, *She Ji: The Journal of Design, Economics, and Innovation* 3, no. 3 (2017): 157–63. DOI: https://doi.org/10.1016/j.sheji.2017.11.001.

Joore, Peter, and Han Brezet. "A Multilevel Design Model: The Mutual Relationship between Product-Service System Development and Societal Change Processes." *Journal of Cleaner Production* 97 (2015): 92–105. DOI: https://doi.org/10.1016/j.jclepro.2014.06.043.

Kretzschmar, Anders. *The Economic Effects of Design*. Copenhagen: National Agency for Enterprise and Housing, 2003.

Kyffin, Steven, and Paul Gardien. "Navigating the Innovation Matrix: An Approach to Design-Led Innovation." *International Journal of Design* 3, no. 1 (2009): 57–69. http://www.ijdesign.org/index.php/IJDesign/article/view/305.

Liedtka, Jeanne. "Perspective: Linking Design Thinking with Innovation Outcomes through Cognitive Bias Reduction." *Journal of Product Innovation Management* 32, no. 6 (2015): 925–38. DOI: https://doi.org/10.1111/jpim.12163.

Liedtka, Jeanne. "Design Thinking as a Social Technology." Keynote speech, Design Management Academy Conference 2017, Hong Kong, June 7, 2017.

Lombard, Matthew, Jennifer Snyder-Duch, and Cheryl Campanella Bracken. "Content Analysis in Mass Communication: Assessment and Reporting of Intercoder Reliability." *Human Communication Research* 28, no. 4 (2002): 587–604. DOI: https://doi.org/10.1111/j.1468-2958.2002.tb00826.x.

Mayring, Philipp. "Qualitative Content Analysis." *Forum: Qualitative Social Research Sozialforschung* 1, no. 2 (2000): 1–7. DOI: https://doi.org/10.17169/fqs-1.2.1089.

Morelli, Nicola. "Designing Product/Service Systems: A Methodological Exploration." *Design Issues* 18, no. 3 (2002): 3–17, DOI: https://doi.org/10.1162/074793602320223253.

Muratovski, Gjoko. "Paradigm Shift: Report on the New Role of Design in Business and Society." *She Ji: The Journal of Design, Economics, and Innovation* 1, no. 2 (2015): 118–39. DOI: https://doi.org/10.1016/j.sheji.2015.11.002.

Nieminen, Johanna, and Tuuli Mattelmäki. "Navigating in the World of Services Visualizing a System of Systems." In *Proceedings of Nordes 2011, the 4th Nordic Design Research Conference*, edited by I. Koskinen, T. Härkäsalmi, R. Mazé, B. Matthews, and J-J. Lee, 263–68. Aalto: Aalto University, 2011. https://research.aalto.fi/en/publications/navigating-in-the-world-of-services-visualizing-a-system-of-systems(48d5d725-b691-41fe-999c-65bc35ad504a)/export.html.

Norman, Donald A., and Pieter Jan Stappers. "DesignX: Complex Sociotechnical Systems." *She Ji: The Journal of Design, Economics, and Innovation* 1, no. 2 (2015): 83–106. DOI: https://doi.org/10.1016/j.sheji.2016.01.002.

Peppou, George, Clementine Thurgood, and Sam Bucolo."Designing Competitive Industry Sectors." *Design Management Journal* 11, no. 1 (2016): 3–14, DOI: https://doi.org/10.1111/dmj.12029.

Peters, Jay. "Educating Designers to a *T*." *Design Management Review* 23, no. 4 (2012): 62–70. DOI: https://doi.org/10.1111/j.1948-7169.2012.00213.x.

Price, Rebecca, Cara Wrigley, and Judy Matthews. "Action Researcher to Design Innovation Catalyst: Building Design Capability from Within." *Action Research* (June 2018): 1–20. DOI: https://doi.org/10.1177/1476750318781221.

Rittel, Horst W. J., and Melvin M. Webber. "Dilemmas in a General Theory of Planning." *Policy Sciences* 4, no. 2 (1973): 155–69. DOI: https://doi.org/10.1007/BF01405730.

Schanz, Jonathan, and Christine De Lille. "Customer Experience Strategy Turned into Hands-on Actions through a Design Approach." *Design Management Journal* 12, no. 1 (2017): 28–39. DOI: https://doi.org/10.1111/dmj.12037;

Stoimenova, Niya, and Christine De Lille. "Building Design-Led Ambidexterity in Big Companies." *Conference Proceedings of the Design Management Academy*, vol. 4, edited by Erik Bohemia, Cees de Bont, and Lisbeth Svengren Holm, 1043–61. Loughborough: Design Research Society, 2017.

Storvang, Pia, Susanne Jensen, and Poul Rind Christensen. "Innovation through Design: A Framework for Design Capacity in a Danish Context." *Design Management Journal* 9, no. 1 (2014): 9–22. DOI: https://doi.org/10.1111/dmj.12006.

Van Rijn, Roxanne, Matthijs Netten, and Rebecca Price. "U and I: Insights from a University-Industry Design Collaboration." Paper presented at the *21st DMI: Academic Design Management Conference*, London, UK, August 2018. https://www.researchgate.net/publication/325782664.

Wrigley, Cara. "Design Innovation Catalysts: Education and Impact." *She Ji: The Journal of Design, Economics, and Innovation* 2, no. 2 (2016): 148–65. DOI: https://doi.org/10.1016/j.sheji.2016.10.001.