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Abstract
Over the last half century, design education has diversified and developed considerably, in part in the arts academies, and increasingly in universities and vocational technical education. The TU Delft design program was founded in 1969, and has since grown quickly into a large, university-based, technology-aligned set of programs presently housing 2000 students and 100 academic staff. In the 50 years the Delft program changed due to: (1) changes in societal demand (from products, via services, to the systemic level of societal challenges), (2) the maturing of design as an academic discipline between science and engineering, and (3) international developments of the educational system (e.g., the Bologna agreement). In this paper we describe the development of this program within the broader disciplinary context of TU Delft, and how it brought together engineering, social sciences, and business studies in project-based education. We draw lessons from a unique position, made possible by this large scale and positioning next to engineering sciences. This position supported a large pool of in-house expertise; it fostered an intertwining of education, research, and practices in the industrial and wider societal context. And it also posed challenges of making design education work at a large scale.

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Introduction

Design education is changing rapidly in its content, its pedagogy, its students. Over the past decade or two, several developments have been at play. At the risk of oversimplifying matters, a caricature might best clarify these changes: fifty years ago, a designer was thought of as a professional who produced a specific product requested for by a client—"make me a metal chair that's stylish and will sell at a profit to an office market"—now, designers work collaboratively and, increasingly, with many others to address societal issues such as obesity, aging, and global warming. Every ingredient has broadened and deepened:

- the inputs (technologies such as artificial intelligence and digital connectivity),
- the outputs (from products to services and beyond; all realistic improvements are on the table),
- the methods (from intuitive through predictive to iterative),
- the actors (from professional designer and experts to facilitated users and other stakeholders),
- the values (from a focus on utilitarian values and functions for individual users to socio-cultural values and societal challenges such as obesity and global warming).

In this paper, we sketch developments at a large, university based design school over the past half century, and highlight some of the struggles and successes that have emerged. The sketch shows how design education and the profession for which it prepares students have both developed and diversified over the years. The Delft way is not the only way to do design, but the size and positioning of the Delft program helps to bring out some of these evolutions, and highlights some advantages and disadvantages of increased scale. In the discussion we try to draw lessons for design education in general.

History

The Delft program in Industrial Design Engineering (IDE) started in 1969 as *Tussenfaculteit Industriële Vormgeving* (Industrial Form Giving), an intermediate department between Architecture and Mechanical Engineering. Its mission was to educate engineers to support product development in industry. At its founding, three professors with complementary specialties in human factors, aesthetics, and construction were appointed. The founding director Joost van der Grinten also required that all design projects be taught by the professors together. Jointly instructed, integrative design projects have remained the hallmark of the school over the decades.

In the 50 years since then, IDE has grown from 2 students to 2000, from 3 professors to 100 academic staff. It currently hosts a variety of design programs at various levels, and maintains exchange programs with 70 design schools worldwide. 7000 alumni have found their way as designers—in jobs across industry and society, in research, and as founders of design education programs elsewhere in the world.

The Delft IDE program stood out from existing design education as taught at arts academies. It had been established at a university of technology, among other engineering disciplines ranging from architecture to physics, civil engineering, and aerospace. Delft University of Technology had strong connections to a variety of industries, and was looking to increase its emphasis on academic research alongside the training it provided in constructive engineering. Both these factors played an important role in the formation and development of the design school. Final degree graduation projects were typically carried out in industrial practice, guided by an interdisciplinary team of staff members—for a long time, three members from different disciplinary backgrounds was the norm—which meant new staff and students gained substantial and largely informal experience with the practical needs of industry, and saw first-hand how different disciplines contribute to design. The opportunity to grow academically gave us the means to turn our design work into sharable knowledge mostly in the shape of methods and consciously crafted competencies developed through our design courses.

Connections to research and society drove the development of the IDE program. In the 80s, faculty and administration noted that many of the alumni were finding jobs in marketing, and so business and management were added to the disciplinary mix; new staff had both education and research expertise. Likewise, when the new MSc in Design for Interaction was launched in 2003, its courses were filled with knowledge and methods for user experience research and participatory approaches, which had already been explored in dozens of individual MSc graduation projects over the preceding years.[1] And when service design became a prominent perspective around 2010, the faculty was able to build on the foundations it had established in experience design and innovation strategy, both of which had been part of its research and education for about a decade.[2]

The program progressed via formal revisions every 5–10 years, on average, and through continuous local improvements, often connected to both research and practice. One such mechanism was the graduation project in industry, under the guidance of researchers. Industry partners commissioned the projects, students applied recent research findings, and the researchers used the experience to further develop both research and education. The formal revision processes enabled the adaptation of spaces, facilities, and schedules. Such overarching strategic planning is usually quite difficult, given the many dependencies between courses, staff, and facilities that characterize large programs.

The success of the Delft IDE program brought with it more students and more staff, a substantial engagement with technology, a strong research orientation, and a wide-ranging curriculum. Dutch education policy precluded the faculty from implementing a selection process for its BSc program: any applicant who had earned high enough marks to pursue a technical education (typically high grades in maths and physics) had to be accepted. It wasn't until the 2010s that the school was allowed to implement an admissions policy based on design skills, and limit the number of students entering the program.

Compared to other design programs, IDE had several unique characteristics, including

1 Pieter Jan Stappers, Paul Hekkert, and David Keyson, "Design for Interaction: Consolidating the User-Centred Focus in Industrial Design Engineering," in *DS 43: Proceedings of E&PDE 2007, the 9th International Conference on Engineering and Product Design Education*, ed. E. Bohemia et al. (Newcastle: University of Northumbria, 2007), 69–74, available at https://www.designsociety.org/download-publication/28374/.

2 Stefan Holmlid, "Interaction Design and Service Design: Expanding a Comparison of Design Disciplines," *Nordes* 2 (2007): online, https://archive.nordes.org/index.php/n13/article/download/157/140; Froukje Sleeswijk Visser, *Service Design by Industrial Designers* (Delft: TU Delft, 2013), available at https://www.researchgate.net/publication/263133082.

- a critical mass of in-house expertise from the disciplinary mix;
- a large variety of contextual domains for skills application—rather than a single domain tied to a dominant industrial partner;
- an orientation toward client and user needs, rather than a focus on personal expression;
- an obligation to teach a diverse range of students who had above average general and scientific aptitudes, but not necessarily a salient capacity for design; and
- a university mandate that academic research feed into the education program.

These factors led to the program's rational focus on methodology, its orientation toward the needs of people (originally the client, then the user, then other stakeholders), and its emphasis on rational argumentation as opposed to the creation of aesthetically pleasing models.

The scale of the program brought challenges at a personal level. By dint of a system with large numbers of students and many study options, IDE students were forced to forge their own path and—crucially—build their own network. This was in contrast to the close-knit studio system common in smaller design schools. In such a model, the same small group of students stay together over the years, building familiarity.

The Changing Profession

The design profession and the context for design practice have both changed significantly over the past 50 years. Figure 1 depicts a loosely sequential evolution (bottom to top) of design approaches—including their associated outcomes, perspectives, models, methods, values, and

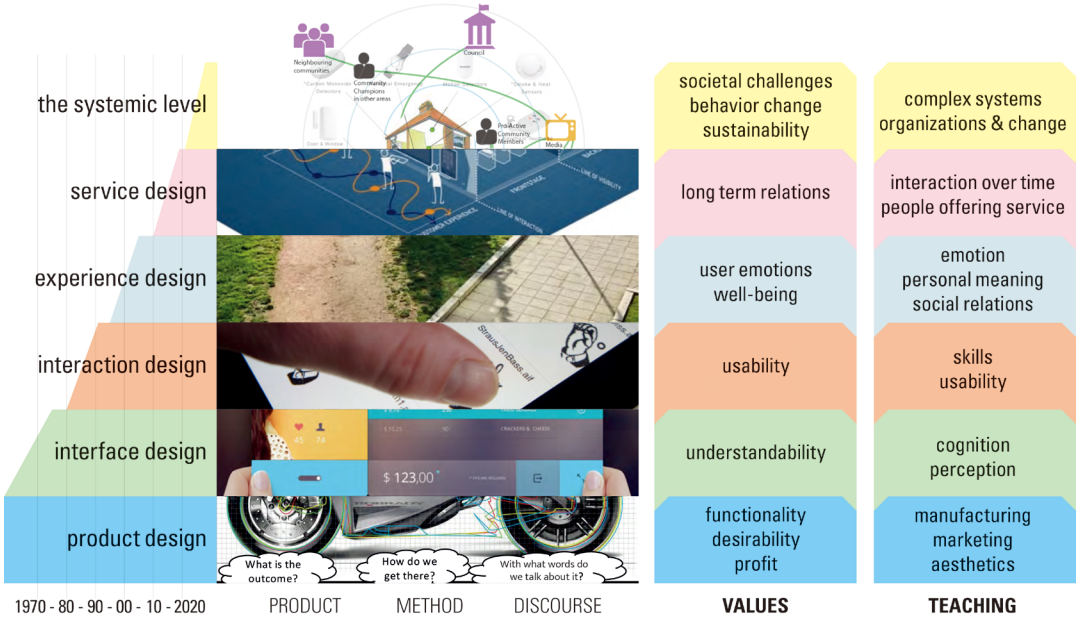

Figure 1
Broadening of design profession and education over the past 50 years (an earlier version of the figure was published in Sapna Singh, Nicole Lotz, and Elizabeth B.-N. Sanders, "Envisioning Futures of Design Education: An Exploratory Workshop with Design Educators," *Dialectic* 2, no. 1 (2018): 15–42). © 2020 by TU Delft.

knowledge elements—incorporated into Delft's IDE program curriculum. The model does not mention our greater emphasis on teamwork and the diversification of the clients and contexts we work with, but what you see serves to articulate the increasing complexity and scope of Delft's educational offering.

With each new level, different outcomes and values took center stage, new tools and jargon were developed, and new disciplinary knowledge was brought in. The sequence was one of broadening rather than replacing. Current IDE projects might still focus on products for mass production, but now more attention is paid to the effects a product will have within a larger context and over time. As a result, several more aspects must be taken into account: interaction, user experience, service organization, and sustainability for example. As the program has had to cover more and more aspects, some earlier exercises were dropped—design a typeface, design a hand-held device with a focus on ergonomics and form, design a way to indicate actions on a computer screen—and left to vocational education at universities of applied sciences. For 20 years, one first year group assignment had been to design a barbeque for a specific target group and then prototype and use it, to learn from burning one's own hands or having to beg for dinner if the group's barbeque overheated or collapsed. This project had four pillars: construction, form giving, ergonomics, and business management. After two decades, the assignment was scrapped. A contemporary barbeque assignment would now require more contextualisation, more framing and zooming in and out, more looking at the experience and cultural meaning of making food outdoors, and consideration of the role played by new technologies, and the barbeque's effect at wider scales, including the environment and related health issues.

The Changing Landscape of Education

The above changes were happening in a worldwide development. In addition to the broadening of outcomes and means of arriving at them, the past few decades have also been accompanied by something Liz Sanders has described as the shift from design-of-outcome to design-for-criteria.[3] Increasingly, the core of design education—at Delft and elsewhere—has been focused on purposes, goals, and criteria. Electronic appliances design has become design for usability, or design for sustainability.

Over this period, the Dutch national education system has also evolved, in part due to its participation in the Bologna Process, a European Union initiative seeking to standardize and interconnect education across European countries and cultures.[4] Part of the process, which was initiated in 1999, entailed splitting up the traditional five year (engineering) degree into a BSc (three years) and an MSc (two years), plus a PhD. The traditional character of the PhD trajectory was a researcher in a master-apprentice relationship with a single full professor, with quality oversight carried out by the university. In the Bologna system, the PhD is now known as the third education cycle,[5] with BSc the first and MSc the second. Educating PhD students is also increasingly becoming the responsibility of departments and schools rather than individual academics, with a tendency toward formal specification of

3 Elizabeth B.-N. Sanders and Pieter Jan Stappers, "Co-creation and the New Landscapes of Design," *CoDesign* 4, no. 1 (2008): 5–18, DOI: https://doi.org/10.1080/15710880701875068.

4 For example, see Berndt Wächter, "The Bologna Process: Developments and Prospects," *European Journal of Education* 39, no. 3 (2004): 265–73, DOI: https://doi.org/10.1111/j.1465-3435.2004.00182.x.

5 "The Bologna Process and the European Higher Education Area," The European Commission, accessed January 30, 2020, https://ec.europa.eu/education/policies/higher-education/bologna-process-and-european-higher-education-area_en.

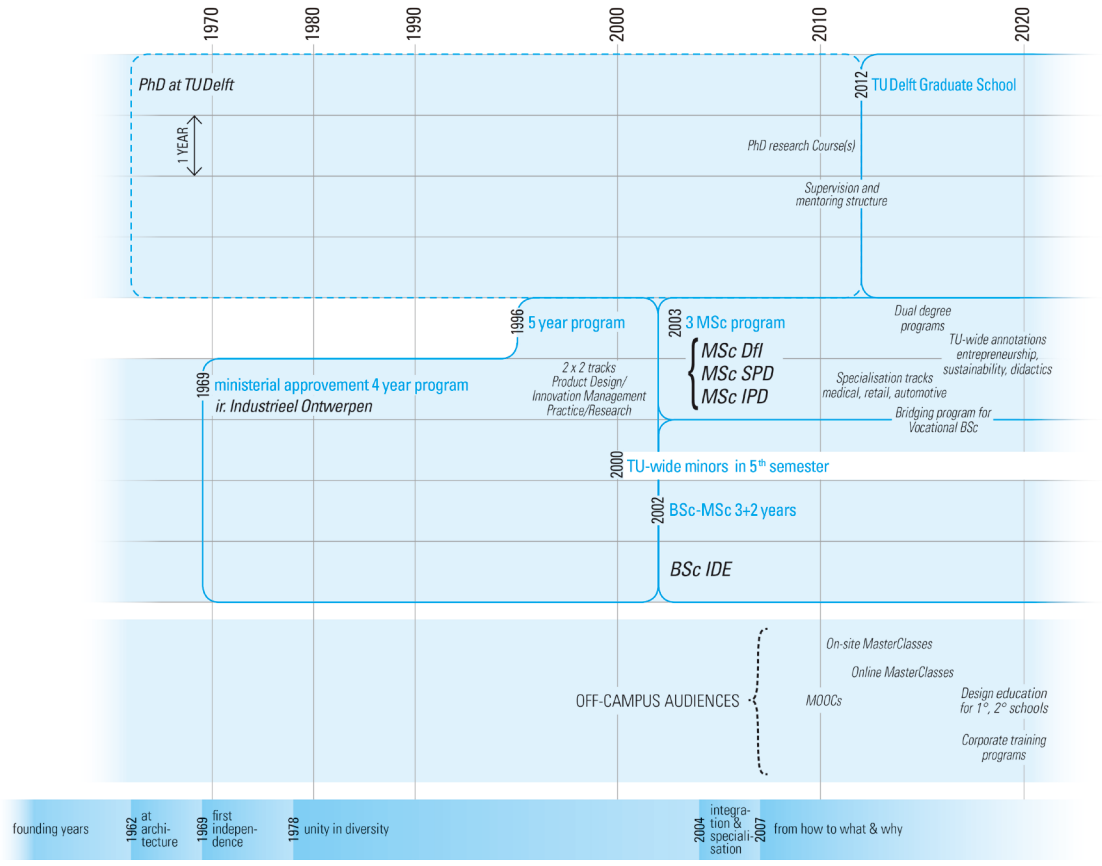

Figure 2
Development of IDE education programs. Text in italic roughly indicates which topics and formats were the focus of development. The vertical scale expresses the length of the programs: 3-year BSc, 2-year MSc, 4-year PhD. The phases at the bottom indicate the phases of IDE's history as described on https://www.tudelft.nl/en/ide/about-ide/history/delft-design-history/. © 2020 by TU Delft.

course components and education credits. Figure 2 sketches some of the changes in Delft IDE programs.

TU Delft and the Dutch educational system both require uniform standards across disciplines. When the university declared the instatement of degree minors in 2007, the fifth semester of regular study was dropped from all Delft BSc programs and replaced by a minor, elective-subject semester. To fulfil this, students select from a set of interdisciplinary programs offered by TU Delft schools or schools abroad, or do internships in industry. When that change was implemented, it meant that one-sixth of the BSc program was left up to the individual responsibility of the student, with each school in the university expected to provide cross-disciplinary minors open to other students. Increasingly, education delivery itself has taken the form of networked connections of opportunity and choice, rather than the one-on-one, signature training offered by a master to an apprentice.

In 2003, student graduation projects had become so diverse that the MSc in Industrial Design Engineering was divided into three types: Integrated Product Design, Strategic Product Design, and Design for Interaction. While the BSc program remained partly Dutch-language, the MSc programs were taught in English. IDE saw rapid growth in the number of its international

students, and more systematic exchange opportunities with other universities worldwide. On top of that, enrolment in the three master's degree programs—with an annual intake of roughly 100 students each—was a very clear demonstration that not all design students shared the same grounding in their BSc. One interesting development was that students in the three MSc programs came to regard each other as "different." Each community started to establish its own (slightly) different identity while working with the others to complete joint projects combining diverse areas of interest, design methods, roles, and responsibilities. These projects improved students' capacity to operate in a multidisciplinary environment. Before then, IDE had always included a teamwork dimension in its design projects, but every member of the team had taken the same courses and completed the same exercises, including the iconic barbeque exercise. Quickly, the differences between the specialized MSc programs became quite apparent.

Keeping the scale manageable did require some specific architectural choices across programs, however. Courses required by one program became electives for others, which promoted further program content crossover beyond the 40% that was already shared among them.

The Shift to a Research Discipline

At its inception, most of the teaching staff was teaching based on their industrial experience and design practice, but research has since become an important component of staff expertise. In the past, engineering schools had traditionally placed emphasis on problem-solving and solution-building in industry and society, rather than on writing academic papers. But since the 80s, a growing body of research has emerged, first on design methods, and then on supporting disciplines such as perception, management and manufacturing, and human factors. The number of people pursuing a PhD at the school grew. Most of the candidates in those early years had already gained research experience in other disciplines—in psychology, marketing, mechanical engineering, or physics, for example—but rarely in design. From around 2000, there was a steep rise in the number of candidates who had a design degree. This had an influence on research topics, journal types and other research dissemination platforms, and also on the way research was carried out. Research varied from designers in industry reflecting on their practice to researchers building on other disciplines relevant to design, and in between, there was the developing field of Research through Design, where design activities are part of the research method.[6]

The PhD in Design—Disciplinary or Beyond?

Finally, a word on doctoral education. With the maturing of design as an academic discipline, establishing PhD programs has become the focus worldwide, but where these programs are going is far from clear. In the European Union, the Bologna process brought BSc and MSc education into a uniform framework and supported exchange, flow through, and other connections. But the PhD remains highly varied in form and content, as we learned over the course of our exchange programs with other universities that have established PhD programs, including Politecnico di Milano, Aalto University

6 Imre Horváth, "Comparison of Three Methodological Approaches of Design Research," in *DS 42: Proceedings of ICED 2007, the 16th International Conference on Engineering Design*, ed. Jean Claude Bocquet (2007), online, available at https://www.designsociety.org/publication/25512/; Pieter Jan Stappers and Elisa Giaccardi, "Research through Design," in *The Encyclopedia of Human-Computer Interaction*, 2nd edition, ed. Mads Soegaard and Rikke Friis-Dam (online, 2017), 1–94, available at https://www.interaction-design.org/literature/book/the-encyclopedia-of-human-computer-interaction-2nd-ed/research-through-design.

in Helsinki, Imperial College London, Carnegie Mellon in Pittsburgh, and the Illinois Institute of Technology in Chicago. At some places, there is a structured curriculum and a cohort of students starts simultaneously. At others, students begin individual projects, and some course elements are available. All of the schools named have a formal PhD in Design, which suggests a third, design-specific phase of education. At TU Delft, PhD students typically work for four years on a research project that fits into the IDE faculty research agenda. The students come from a variety of backgrounds, and aim to achieve the university-wide standard of independent researcher.[7] Specific education elements are provided by faculty. The PhD students at IDE are a community with a different culture than at other faculties, but the policy, rules, and support structure are uniform across the university. In an increasingly interdisciplinary world of cross-disciplinary research, we see this transdisciplinarity—some might call it post-disciplinarity—as a potential advantage.

The Importance of Infrastructure

The history of our school was also influenced by its location. For several decades it occupied different locations across the old town of Delft, but around 1990, the school moved to the main TU Delft campus. Its departments were situated in two separate wings, its workshop located half a mile from these, and lecture halls and project studios scattered around the campus. As of December 2001, IDE was housed in the refurbished former university central workshop, with a large, dedicated central hall, workshop spaces, a ring of open studios on the first floor, and departmental labs and offices in close proximity. Much of the teaching—except for some large-scale lectures—is delivered on site. The central hall is used as study space and for exhibitions and events, and it's a place where staff and students can see what's going on elsewhere in the school (Figure 3).

Beyond the physical infrastructure, IT services have become important assets. To foster its participation in the EdX consortium, TU Delft invested in software, equipment, facilities, training, and support staff for designing, creating, and running online courses. This has enabled faculty to develop introductory Massive Open Online Courses (MOOCs) on design methods and sustainability, plus a series of online and blended courses connecting professionals to recent methods and knowledge.[8] Complementing face-to-face experience, these platforms allow staff and students to teach to and learn from students at various levels across the world.

The Broadening Appeal of Design

For a long time after Bauhaus, design practice was reserved for professionals in agencies and company departments, and taught to future professionals in design schools. But the last two decades have shown both a broader recognition in business and in society that design matters—not only because it makes products appealing or useable, but also as a way of thinking, working, and addressing problems. Designers have entered the boardroom, and are called upon not only by industry but by various societal partners. This design thinking wave comes with mixed blessings: there is a wider appreciation of design skills, methods, and tools, but also superficial, management-led

7 Maaike S. Kleinsmann, Pieter Jan Stappers, and Cees de Bont, "Nurturing Designers in PhD Research," in *Proceedings of the IASDR 2011, the 4th World Conference on Design Research*, ed. Norbert Roozenburg, Lin Lin Chen, and Pieter Jan Stappers (Delft: IASDR 2011), 1–8, available at https://pure.tudelft.nl/portal/en/publications/nurturing-designers-in-phd-research(b3ea5307-3e8f-4af2-82be-a3abe8848280).html.

8 IDE's courses can be found on TU Delft's site https://online-learning.tudelft.nl/courses/. Important examples are the flagship Delft Design Approach course, running since 2015, https://online-learning.tudelft.nl/courses/delft-design-approach/ (100,000 enrolments; over 1000 finishing with a certificate) and the Circular Design course, https://online-learning.tudelft.nl/courses/circular-economy-design-and-technology/ (50,000 enrolments; over 2000 certificates).

Figure 3
In the IDE building, workshops and studios surround the central hall. © 2013 by TU Delft.

oversimplification.[9] On the upside, it has made it easier for designers to explain and sell their contributions. On the downside, it has given the impression to many that design can be done in an afternoon session in the management boardroom, as long as you have post-its, crayons, and templates.

At Delft, we have seen this in our alumni going to ever more varied jobs. Design has become a prominent part of product and service development, has moved from back-end gloss, through usability testing and concept development, all the way up to the fuzzy front end of strategic foresight. In the Netherlands alone, two other research universities of technology (TU Eindhoven and Twente University) and a range of vocational universities of applied sciences (*Hoger Beroeps Onderwijs*/HBO) later developed integrated, technology-oriented, design programs like the one at TU Delft.[10]

University-based design programs in the Netherlands have joined forces to form Design United, and together with the professional association CLICKNL, have become key players in the Dutch development and research network. This broader establishment of what had before then sometimes been regarded in Dutch academic circles as "a Delft hobby" has helped its visibility and impact, and connected design to the national top sector policy[11] for development of industry (in this case the creative industry). Two design-focused calls for research (CRISP, 2016; NWO/RTD, 2015)[12] became the foundation for two successful research programs that explicitly investigated the value of design as a component of research.

9 For example, see Benedict Sheppard et al., "The Business Value of Design," *McKinsey Insights*, (October, 2018): 1–17, available at https://www.mckinsey.com/business-functions/mckinsey-design/our-insights/the-business-value-of-design; Jon Kolko, "The Divisiveness of Design Thinking," *interactions* 25, no. 3 (2018): 28–34, DOI: https://doi.org/10.1145/3194313.

10 Ruth Graham, *The Global State-of-the-Art in Engineering Education* (Cambridge, MA: MIT, 2018), available at https://www.cti-commission.fr/wp-content/uploads/2017/10/Phase-1-engineering-education-benchmarking-study-2017.pdf; Dirk Schaefer, Graham Coates, and Claudia Eckert, eds., *Design Education Today: Technical Contexts, Programs, and Best Practices* (Springer, 2019).

With these developments, IDE was systematically addressing audiences beyond its in-house students. One reason for this was that international MSc students were going back to their home countries, raising awareness about integrated design among their peers and in their circles, and asking for materials for their students, partners, and clients. Another was repeated requests from alumni who, after a decade in practice, wanted to learn which new methods had come out, often learning about these developments through interns and projects.

To deal with this demand, the school developed a popular methods book, *The Delft Design Guide*,[13] MOOCs on the EdX platform, including "Product Design: The Delft Design Approach,"[14] a series of on-site and online master classes, and corporate collaborative research and training programs for industry research partners, such as Schiphol airport, Dutch airline KLM, and Ford Motors.[15]

A third motivator is the recognition of design skills such as creativity, empathic understanding, and collaboration as a general need. The OECD's 21st century skills for general education consist for half of such design skills, meaning that design, like many disciplines before it, is expected to deliver measured ingredients for primary and secondary education.[16]

These developments are here described from a local perspective, but have been happening across the planet, especially in the UK, Scandinavia, China, South America, and the USA.

Current Situation and Ongoing Actions

Design has come a long way since the Bauhaus started a century ago, and over the last fifty years we've seen it fan out into a diverse spectrum of education ranging from arts to engineering. In the Netherlands, design began as tentative bridge between architecture and mechanical engineering at Delft. It has grown into a solidly established discipline at several Dutch universities, is now tied to the academic research structure, and has become well-connected with industry and other societal partners, dealing with society's most up-to-date challenges.

We have described how these developments fit within the context of wider, ongoing developments in society, industry, education management, human wellbeing, and the welfare of the planet. Here we focus more narrowly on what design education should bring to the design professionals it trains in the BSc and MSc programs.

The job of a designer has evolved from that a lifelong employee in an industrial company to a more diverse professional, who will have a succession of jobs, and needs to learn continuously as the challenges, earning models, and solution ingredients change rapidly. The users for whom they design will likewise experience similar dynamics.

Designers need exploratory mindsets and skills—economic, environmental, social, and technical—to shape new solutions in a rapidly changing world. More than before, design students need to acquire a solid, critical understanding of design methodology rather than proficiency using a few tools for a specific application. Design education needs to foster that critical

11 "Encouraging Innovation," Government of the Netherlands, accessed January 30, 2020, https://www.government.nl/topics/enterprise-and-innovation/encouraging-innovation.

12 The outcomes of the Creative Industries Research Programme (CRISP) were reported in a series of magazines, available at http://www.crisprepository.nl/about/crisp-magazines. The call for the Research through Design program of the Dutch Research Council NWO can be found at https://www.nwo.nl/onderzoek-en-resultaten/programmas/research+through+design.

13 Annemiek van Boeijen et al., eds., *Delft Design Guide: Design Strategies and Methods* (Amsterdam: BIS Publishers, 2013); Annemiek van Boeijen et al., eds., *Delft Design Guide: Perspectives-Models-Approaches-Methods*, rev. ed. (Amsterdam: BIS Publishers, 2020).

14 "Product Design: The Delft Design Approach," *TU Delft*, accessed January 31, 2020, https://online-learning.tudelft.nl/courses/delft-design-approach/.

15 A recent example of such a collaboration covering 75 MSc and 7 PhD projects is described in Rebecca Anne Price, Christine de Lille, and Katinka Bergama, "Advancing Industry through Design: A Longitudinal Case Study of the Aviation Industry," *She Ji: The Journal of Design, Economics, and Innovation* 5, no. 4 (2019): 304–26, DOI: https://doi.org/10.1016/j.sheji.2019.07.003.

16 Joke Voogt and Natalie Pareja Roblin, "A Comparative Analysis of International Frameworks for 21st Century Competences: Implications for National Curriculum Policies," *Journal of Curriculum Studies* 44, no. 3 (2012): 299–321, DOI: https://doi.org/10.1080/00220272.2012.668938; Alex Gray, "The 10 Skills You Need to Thrive in the Fourth Industrial Revolution," *World Economic Forum*, January 19, 2016, https://www.weforum.org/agenda/2016/01/the-10-skills-you-need-to-thrive-in-the-fourth-industrial-revolution/; OECD, *The Future of Education and Skills: Education 2030* (Paris: OECD, 2018), available at https://www.oecd.org/education/2030/E2030%20Position%20Paper%20(05.04.2018).pdf.

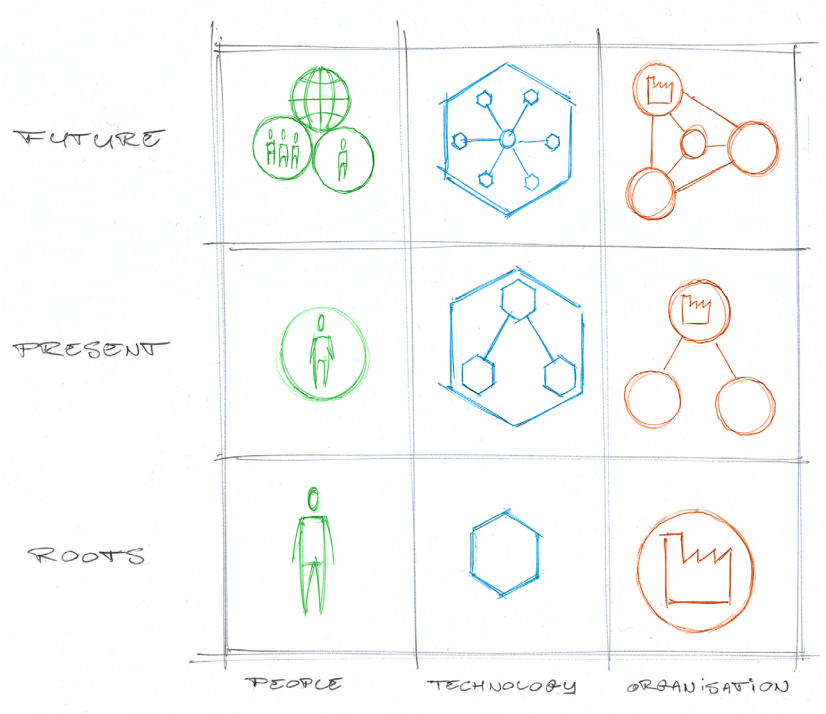

Figure 4
Basic diagram of current design position (BSc revision 2019). © 2019 by TU Delft.

ability, and provide instruction in skills that enable students to flourish in a collaborative context. Figure 4 is a diagram expressing our view of the past and current challenges for design, expressed in three perspectives: the people affected by design, the technology enabling it, and the organization needed to get it out into the world. In terms of people affected, the designer's view is widening from the single user to include context and societal issues. For technology, there is a shift from single mass-produced products to product-service systems, and toward systems with many components and actors. For organization, the shift has been from the single manufacturer, to service constellations, and on to highly connected, multi-actor and multi-stakeholder processes.

In today's connected society, with AI becoming part of the material of the world, and the limits of a liveable world in sight in many directions (from global warming to demographic shifts to depleting resources), designers need to play their part. That part is not just offering up their personal creativity for a given task, or designing an experience that pleases an individual. It involves collaboration, co-creation, connecting disciplinary input, and deepening and strengthening bridges where needed.

The competencies needed to navigate through all these demands are different from what is currently often taught. Table 1, developed in 2020 during the IDE BSc program renewal process, presents our current view on the basic competencies that new designers need.[17] These competencies

17 Our approach updates Chris Conley's design competencies for the present day. Chris Conley, "Leveraging Design's Core Competencies," *Design Management Review* 15, no. 3 (2004): 45–51, DOI: https://doi.org/10.1111/j.1948-7169.2004.tb00171.x; Chris Conley, "The Core Competencies of Design: The Basis of a Broadly Applicable Discipline," IDSA, 2011, 1–7, available at https://www.idsa.org/sites/default/files/Chris%20Conley.pdf.

Table 1 **Design competencies in the IDE BSc 2020 curriculum renewal.**

framing & reframing the design challenge in its emerging future context	By finding the question behind the question, designers explore the real challenge at hand and obtain an understanding of the future context in which this challenge will likely play out, given the developments we can already foresee.
creating & evaluating iteratively to converge towards a desired impact	Complex challenges require iteration, repeated divergent exploration, synthesis, and evaluation. The space of possibilities needs to be discovered and created. In developing solutions, designers often need to pursue different options in parallel, only to find out later which one has the most promise. When it comes to complex problems, a great deal of the solution only comes into view as plans move into implementation.
integrating an increasing amount of relevant perspectives into a working whole	Design is driven by values, taking on the original perspectives of desirability for people, feasibility of technology, and viability of the organization. Increasingly, these values explicitly include human-centered concerns for care and sustainability, and a consideration of the ethical implications of the outcomes and processes of design. This includes taking note of the changes at the core of these perspectives inspired on increased knowledge or a changing context. For example, the recent emergence of human centered values in industry (design thinking) and in society (need for purpose, safety, security) calls for empathic designers that are able to put themselves in the shoes of all those affected by the design, and argue, where possible, with facts, knowledge and empirical validation of their ideas.
meaningfully steering the design and stakeholder process	This needs a carefully crafted design process that, in its context, involves and supports key stakeholders. It requires critical thinking among designers and the ability to perform and leverage critique from various others, leading to a skillful introduction and integration of the intervention into stakeholders' status quo. This means working in a multidisciplinary setting, and managing collaborative and participatory processes with many others, who may or may not have design skills themselves.
working and communicating at varying and multiple levels of abstraction, and across disciplinary perspectives	Designers need to be able to work at different levels of abstraction at the same time, and fluently move from abstract to concrete, and between disciplinary perspectives. Abstraction means eliminating details, and focusing on a strategic issue. The details, however, are necessary to make a design work in reality. Ways of analysis that need to be mastered will vary at the different abstraction levels. Beyond this, communication at all these levels is key and involves a whole array of skills varying from visualization of abstract ideas, to storytelling and roleplaying, to modelling and prototyping to envision and rehearse new futures in a multidisciplinary setting and with multiple stakeholders.

should be available broadly across an organization as well as down the ranks so that organizations can navigate change and achieve innovative progress.

It would go too far here to specify how these principles should work out at the BSc and MSc level. The competencies listed in Table 1 are currently being used to renew our BSc and MSc programs, and also to shape our growing offering toward current professionals, and outreach toward general education (21st century skills).

Discussion and Conclusion

The previous sections described the trajectory that design education at TU Delft has followed. In this section we carry over some themes of that journey, to indicate what is happening in the broader field of design education.

Design Is Becoming a Mature Research Discipline

Design at universities has become accepted as an academic discipline. We see a strengthening of the journals[18] and a budding acceptance of design in some national research programs. At the same time, the popularity of management-style quick-solutions that emerge during so-called "design thinking workshops" requires that we do a better job in positioning what exactly the design profession is offering. Part of that is the development of PhD programs, but largely it is stating what design is through historical, contextual, and critical work.

Occupying the space in between other academic disciplines—which include psychology, anthropology, engineering, and management, among others—has not been easy. It is obvious design can use the insight from those disciplines, but their core theories are often too specialized for designers, who need to engage with many other aspects of a problem in concert. There is also a need for boundary theories and boundary spanners, similar to the need for boundary objects. These are already needed to bridge different design specializations.

Design Is Entering the Systemic Level

As the history section indicated, design is now being called upon to contribute to complex problems, in a highly decentralized and heterogeneous contexts, and within development processes that are increasingly connected.[19] This shows itself in a necessary broadening of focus, with complications involving teamwork and specialization. This broadening works at least in three ways:

- the work and teams build on contributions from multiple disciplines;
- the complexity of these problems require that teams work simultaneously at different scales, continuously jumping back and forth between the big picture and various levels of detail and implementation;
- the problems increasingly are inter-sectoral—they involve both public and private stakeholders, or different industries that were not traditionally connected (such as healthcare and insurance, as an example).

This has led to a struggle in the profession in dealing with scaling and meaning. We wonder whether everybody needs some skill at, and role in, creating a design that affects them,[20] about when it is important for designers to get involved in the wider system,[21] or when designers should focus on exploiting and serving local variations.[22] The diagram in Figure 1, which depicts a succession of product categories as defining design, is likely too simple to catch where the field is going. But the field of design is diverse, and does not have a compelling new narrative: each level of interaction/service/system was claimed by some to replace or embed "older forms," but overlooked how these other forms are still very much in existence, and have

18 For example, see Gerda Gemser and Cees de Bont, "Design-Related and Design-Focused Research: A Study of Publication Patterns in Design Journals," *She Ji: The Journal of Design, Economics, and Innovation* 2, no. 1 (2016): 46–58, DOI: https://doi.org/10.1016/j.sheji.2016.05.002.

19 Elisa Giaccardi and Johan Redström, "Technology and More-than-Human Design," *Design Issues* 36, no. 4 (2020), forthcoming, the accepted author manuscript available at https://pure.tudelft.nl/portal/files/69227577/TechnologyAndMoreThanHumanDesign_Preprint.pdf.

20 Ezio Manzini, *Design, When Everybody Designs: An Introduction to Design for Social Innovation* (Cambridge, MA: The MIT Press, 2015).

21 Donald A. Norman 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.

22 Jeremy Myerson, "Scaling Down: Why Designers Need to Reverse Their Thinking," *She Ji: The Journal of Design, Economics, and Innovation* 2, no. 4 (2016): 288–99, DOI: https://doi.org/10.1016/j.sheji.2017.06.001.

progressed. One century after Bauhaus, design has grown into a recognized set of professions with practice, research, and economic value, but has not yet created its new story as a field.

Designers Will Need (Even) More Collaborative Competencies

Given the shifts in problem content, collaboration will become even more important. Already, communication and collaboration with other designers and non-designer stakeholders is often claimed to take up at least 50% of modern design work. As design task complexity increases, we need to enable design students (and graduates, and others) to prepare themselves for these collaborations.

Navigating the trade-offs between design-as-serving and design-as-leading, and a spectrum of teaching that uses the same language but with nuanced differences in meaning, framing, and values, is a challenge for both students and staff. At Delft, one advantage of our program's size is that frictions between disciplinary views, complementary stakeholders, and varieties of societal partners are all nearby, often in-house. This offers a tremendous opportunity for rehearsing new competencies.

Nurturing Broader and Longer Connections among Different Types of Design

In the educational domains where designers must be equipped to handle collaborative outcome development, wider and longer-lasting connections with research and societal partners are needed. At Delft, this has become apparent in the need for postgraduate master classes that bring alumni up to date with new methods, in the successful outreach to non-professionals through MOOCs, and in the bringing of design elements to education in general (aka the 21st Century Skills for every citizen[23]). In the Netherlands, we have been part of a growing trend in research funding that brings different types of researchers—including different types of designers—from art, science, engineering, and practice, together. We believe it is of vital importance that academic design schools take responsibility for equipping different designers and stakeholders for collaborative development actions. The ways in which this can be achieved through schools of different sizes and orientations will be different.

Design Research, Education, and Practice Grow via Interaction to Achieve a New Balance of Roles

At a university, education and research should be linked. In our history, the interdisciplinary supervision of students in projects with societal partners has served to also connect them to the needs and opportunities of practice. We take these for granted, having various forms of expertise (and the corresponding tensions) in house, but experiences with other schools have shown that the links between education and research are often not easy to make, if design education does not have close interaction among different strands of design research as well as with design practice. We have experienced the difference it made when our departments were physically co-located,

23 **Voogt and Roblin, "A Comparative Analysis of International Frameworks for 21st Century Competences"; Gray, "The 10 Skills You Need to Thrive in the Fourth Industrial Revolution"; OECD, *The Future of Education and Skills*.**

and informal interactions became more frequent. Our next steps will be to explore the role of PhD programs in pushing the interdisciplinary and inter-sectoral boundaries of the field, connecting design research and design education across the world, and rehearsing new design competencies and practices.

Responding to the challenges of this changing landscape will require us to have the courage to revisit and innovate established education programs at every level. There will need to be a broadening and deepening of interdisciplinary collaborations, and at the same time a nurturing of new connections among different types of design and stakeholders. But our response also calls for pedagogically rehearsing new competencies and roles, and doing so programmatically, by addressing real problems and attempting to craft more sustainable futures. Most importantly, the steps we take must help to push the boundaries of the field and explore novel ways to align design education, research, and practice.

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Declaration of Interests

All five authors come from the Faculty of Industrial Design Engineering, TU Delft. Ena Voûte is its Dean. Pieter Jan Stappers coordinates the PhD program, Elisa Giaccardi the MSc program Design for Interaction, Sylvia Mooij the BSc program. And Annemiek van Boeijen edited *The Delft Design Guide* and Delft Design Approach MOOC.

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