Chapter 3
Design Thinking: From Empathy to Evaluation

Fanke Peng

3.1 Learning Objectives

This chapter introduces methods and approaches for design thinking as the main drivers in developing the ability to identify critical problems in a given situation. This problem identification represents the opportunities for design intervention and creative solutions to a range of possible scenarios and practical applications. The chapter also develops the students' understanding of design as an iterative process involving empathy, ideation and prototypes to test and evaluate concepts and solutions to a wide variety of identified problems.

By the end of this chapter, you will be able to:

- Discover the history of the "designerly way of thinking" as the origin of design thinking
- Understand what design thinking is and why it is so important
- Reflect on a human-centred design (HCD) process through empathy, collaboration and creative thinking
- Select and assemble suitable design thinking models and tools for self-directed learning and problem-based learning.

3.2 Introduction

The need for design thinking in robotics is becoming the catalyst for digital transformation (Autome me, n.d.). Design thinking applies from the origin of a robotic system for industry through interactive robotic art and ongoing research. It helps

F. Peng (✉)
UniSA Creative, University of South Australia, Canberra, Australia
e-mail: Fanke.Peng@unisa.edu.au

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designers and non-designers empathise, learn, develop and deliver creative possibilities. To understand the importance of design thinking in robotics, we need first to understand what design thinking is and why it is so important?

3.2.1 What Is Design Thinking

Design thinking was introduced in the 1960s to the "design science decade" (Cross, 2001, 62). The theories evolved from the understanding that wicked problems are at the centre of design thinking. Buchanan's (1992) article about "wicked problems" in design has become a foundational reference for the discourse about design thinking and the whole design area. When designers engage in design processes, Buchanan (1992) stated that they face wicked and indeterminate problems. The designer is not merely discovering, uncovering and explaining the phenomenon in question (which is undeterminate) but is also suggesting other possibilities and creating and transforming the matter. Dewey (1938) defined the process of inquiry as a transformation process beginning from an indeterminate problem. Inquiry is a process that begins with doubt and ends with knowledge and a set of beliefs so concrete that they can be acted upon, either overtly or in one's imagination (Dewey, 1938). To engage in this process, one must ask questions and seek answers to eliminate the initial doubt.

'These complex and multidimensional problems require a collaborative methodology that involves gaining a deep understanding of humans' (Dam & Siang, 2020, par 7). Nonetheless, the main strength of this design process is that it can introduce novel approaches that the key stakeholders directly inform.

3.2.2 Design Thinking Models (Double Diamond Model, IDEO Design Thinking and d.school Methods)

The design thinking as a process model has an established ground for both divergent and convergent thinking. Various design thinking models divide the design process into different stages (see Table 3.1). According to Kueh and Thom's review, there are 15 design thinking models. For example, according to the Double Diamond design framework developed by the British Design Council, there are four steps in the creative process—Discover, Define, Develop and Deliver (Design Council, n.d.). Like this, the Hasso Plattner Institute of Design at Stanford d.school encourages empathising, defining, ideating, prototyping and testing in a completed design process. Ambrose and Harris (2009) divided the design process into seven stages: Define, Research, Ideate, Prototype, Select, Implement and Learn. IDEO Education (2012), a leader in design thinking techniques, breaks the design process into five steps: Discovery, Interpretation, Ideation, Experimentation and Evolution. Brown (2009) opined that design thinking covers three stages: inspiration-identifying

Table 3.1 Comparison of design thinking models (Kueh & Thom, 2018)

Model	Steps in the process						
Human Centred Design Toolkit (IDEO, n.d.)	Hear	Create	Deliver				
Acumen HCD Workshop (Acumen Fund, n.d.)	Discover	Ideate	Prototype				
Design thinking - Business Innovation (Vianna, Vianna, Adler, Lucena, & Russo, 2012)	Immersion	In-depth Immersion	Analysis and synthesis	Ideation	Prototyping		
Design thinking (Cross, 2011)	Quantify problem	Generate concepts	Refine concepts	Select a concept	Design	Present	
Design thinking for Educators (IDEO, 2012)	Discover	Interpretation	Ideation	Experimentations	Evolution		
Basics Design 08 Design Thinking (Ambrose, 2010)	Define	Research	Ideate	Prototype	Select	Implement	Learn
Double Diamond (Design Council, 2015)	Discover	Define	Develop	Deliver			
IDEO (Myerson, 2001)	Observations	Brainstorming	Rapid Prototyping	Refining	Implementation		
Leading Public Sector Innovation (Bason, 2010)	Knowing	Analysing	Synthesising	Creating			
Service Design (Stickdorn & Schneider, 2011)	Exploration	Creation	Reflection	Implementation			
Collective Action toolkit (Frog, 2013)	Seek	Imagine	Make	Plan	Build		
Bootleg Bootcamp (dschool, n.d.)	Empathise	Define	Ideate	Prototype	Test		
dSchool (dSchool, 2009)	Understand	Observe	Point of View	Ideate	Prototype	Test	
Designing for growth (Liedtka & Ogilvie, 2011)	What is?	What if?	What wows?	What works?			
Business Model Generation (Osterwalder, Pigneur, & Clark, 2010)	Mobilise	Understand	Design	Implement	Manage		

Context Framing Phase Ideation Phase Prototyping Phase Implementation Phase Reframing Phase

a problem/an opportunity; ideation-conceive general concepts and solutions; and implementing, producing and launching the final solutions (products or services). Kueh and Thom (2018) reviewed the design processes that are most commonly used and summarised that there are five main phases: 1. Context or problem framing phase; 2. Ideation generation phase; 3. Prototyping phase; 4. Implementation phase; 5. Reframing phase.

It is of value to point out that none of the design thinking models represents a linear process. "Cyclical icons" (as seen in Fig. 3.1) are always added to design thinking models, meaning that you could shift back and forth between these states, generating the new, analysing it, shifting and often, starting the whole process again. Our mode of thinking shifts among design stages and mental states: divergent and convergent thinking, and analysis and synthesis (Brown, 2008, 2009). No matter which model is adopted for the design practice, each step in the design process leads to a creative solution that addresses a known or otherwise unknown problem. For this chapter, we use the Double Diamond model (Fig. 3.1) as an example to demonstrate the process, from information extraction to decision-making.

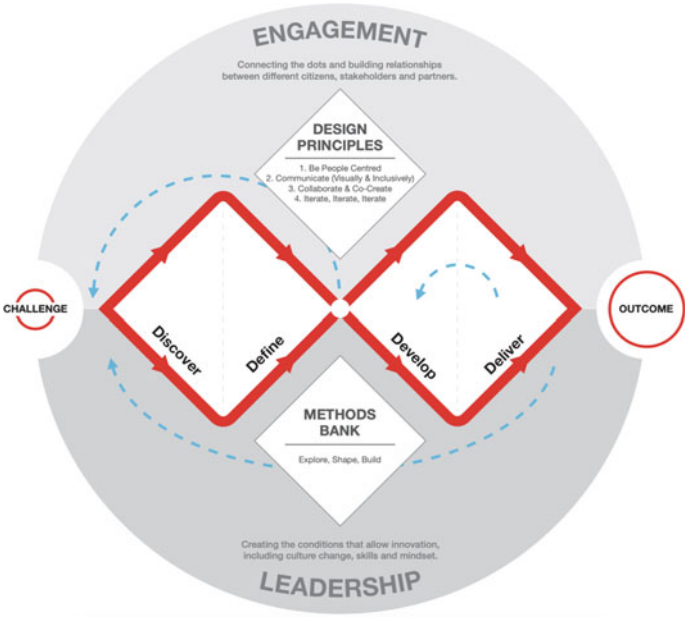

Fig. 3.1 Double Diamond model (Design Council, 2019)

3.2.3 Design 1.0–4.0 and Its Alignment with Robotics

A design approach and mindset to learning encourage understanding the complexity of a given situation. According to Jones (2013, 23–28) and Jones and VanPatter (2009), there are four levels of the design approach that are aligned with the levels of complexity in problems:

- **Design 1.0 Traditional "form-giving" Design**: This design approach focuses on creating design solutions in the form of websites, logos and posters. This deals mainly with a discrete problem that can be solved with an obvious solution. It aligns with embodied design in robotics and robotic product design.
- **Design 2.0 Service and Product Design**: This design approach seeks to explore complicated problems associated with human experiences through products and services. Designers often seek collaboration with stakeholders to explore possibilities in innovating experiences. Design 2.0 also aligns with embodied design in robotics and robotic product design.
- **Design 3.0 Organisational Transformation Design**: Commonly engaged in complex organisational challenges, designers engage in activities such as co-design of change processes for organisations and business systems. Challenges that are facing designers here are bounded by systems and strategies. Co-creation is the focus to achieve change-making processes in organisations.

- **Design 4.0 Social Transformation Design**: This design approach focuses on ill-defined wicked problems and can be challenging to solve. Design activities include iteration of prototyping interventions, observing their impact on the community and reframing the design problem. Projects in this phase involve social and systemic challenges that are difficult to define. Design 3.0 and 4.0 seem to align with the broader question of robots transforming human lives outside of industrial environments, such as caregiving robots and hospital robots—these social robots might displace human workers. This helps to understand automation in its broader context—the impact of automation and loss of work, ethics in design and broad acceptance.

Design approaches and mindsets that focus on the levels of complexity allow people to cultivate the attitude of questioning challenging situations and experimentation with opportunities. This attitude is different from the "problem-solving" mindset that was appropriate in producing products. According to Medley and Kueh (2015), the "problem-solving" approach focuses on the simple and discrete problem that sees designers being detached from stakeholder's needs, while the "experimental approach" allows designers to emphasise on empathic and reflective exploration that would contribute to more complex problems in design levels 3.0 and 4.0. Therefore, an experimental design paradigm is an approach that encourages students to understand complexity in a holistic manner. An experimental design mindset encourages students to see outcomes as interventions applied in a more extensive system.

An Industry Perspective

Alexandre Picard
Mechanical Designer, Senior

Kinova Inc.

I have a technical degree in composite material transformation and a mechanical engineering bachelor's degree. I got into the robotic industry by total coincidence. I spent the first years of my career as a product designer for a design firm playing with anything ranging from airplane components to household products. Eventually moved on to designing patient simulators (aka manikins) for the healthcare industry. About three years later, and with a baby on the way, I got sick of spending three hours a day stuck in traffic so I decided it was time

for something new. I started looking for an opportunity that checked all the boxes in terms of my professional interests without the transportation hassle. I was lucky enough to stumble upon a small robotic company's job post, hi-tech designs, dynamic team, free coffee and robots! Why not? So yeah, I got the job and I've been there ever since … In short, I stumbled upon robotics because of a baby and traffic jams.

I think the most challenging portion of designing robots, and probably any product, is the constant "compromise negotiation" that is taking place between all the parties involved. It always starts with the idea of a product that can do anything at a budget price and, for fiscal reasons, that said product has to be completed and sold within a fixed timeframe. In a list of wishes and requirements, often the most rigid ones are linked to money and/or time. When designing you just have to deal with it and find ways of meeting the needs in a satisfactory manner without all the sparkles and refinements you initially had in mind. In my career, I think the most obvious example is when we designed a robot that needed to be dirt cheap compared to the competition but still at a professional quality grade. Of course, the initial drafts and requirements did not give a good perspective of achievability but, the "compromise negotiation" eventually led to what I believe was the first professional robot with a structure entirely made of plastic even with one-piece articulated fingers!

From what I see, with the design and prototyping tools expanding it will get much easier to iterate through ideas and concepts, especially for parts requiring complex or expensive production processes. It is already possible to test plastic components out of 3D printers prior to investing in tooling, and in some cases, it has become more cost-effective if the part remained printed. Also, in recent years, we have been using metal laser sintering (metal 3D printing) to produce entire robots out of aluminium to use as fully functional prototypes. I imagine that as these technologies continue to evolve and the materials offering expands, we will eventually be able to print robots using robots.

3.3 Design Thinking Process: Discover, Define, Develop and Deliver

Numerous design methods could be adopted and applied to the design thinking process to support this iterative process. This section will unfold the concept and definition of each design stage. Among the different design thinking models, we choose the Double Diamond model as a framework to demonstrate the critical concept and methods of design thinking. We will also introduce practical design methods for

each stage in the design thinking process. You should know what these models and stages are, why they are helpful, and how to implement these methods at each stage.

3.3.1 What Is the Discover Mode, Why Empathise and How

According to the Double Diamond model, the discover mode is the first step in the design thinking process. The first step helps designers and non-designers understand and empathise, rather than simply assume, what the problem is (Design Council, n.d.). Empathy is the foundation of the discover stage and the core for a human-centred design (HCD) process. HCD is a systematic approach to problem-solving that focuses on empathy and encourages its practitioners to explore and understand the key stakeholders' emotions, needs and desires for which they are developing their solutions (Matheson et al., 2015). In order to empathise, you can observe, engage and immerse (d.school, n.d.).

- Observe: Observe your users and understand their behaviour in the context of their daily lives.
- Engage: Interact with your users through scheduled and short "intercept" encounters, such as interviews, focus groups and co-design workshops.
- Immerse: Put yourself into the shoes of your users and gain an "immersive" experience of what your users experience.

In order to design for the users, human-centred designers need to build empathy for who they are and what is important to them. The design tools help remove bias from the design process and help the team build a shared understanding of the users.

HCD denotes that the professionals involved consider the users' needs when designing a product. HCD is a form of innovation occasioned by developing a knowledge of people and then creating a product specifically for them, with the designer driving the process involved (Desmet & Pohlmeyer, 2013). In addition, HCD has much evidence in providing a solid approach to robotics.

Good HCD is generated from deep insights into human behaviour and a solid understanding of the users' beliefs and values. However, learning to recognise those insights, beliefs and values isn't easy. This is partly due to our minds automatically filtering out much information in ways we aren't even aware of (d.school, n.d.). To achieve this "enlightenment", you need to learn to put yourself into the users' shoes and see things "with a fresh set of eyes". Design tools for empathy, along with a human-centred mindset, could help you to tackle the problems with those fresh eyes (d.school).

Through discovering and empathise, you could engage others to

- uncover needs that people have which they may or may not be aware of
- guide innovative efforts
- identify the right users to design for

- discover the emotions that guide behaviours.

As you learn more and more about our users and their needs, ideas or possible solutions would then spring to mind. You document these ideas to make the process more tangible and generate conversation with users and stakeholders about solutions (DHW Lab, 2017).

3.3.1.1 Design Tools and Methods for Discover Mode: To Translate Ideas into Action

As identified in the framework of "Design tools and methods in the design thinking process" (Table 3.2), there are many design tools to guide innovative mind at the discover stage, including Empathy Mapping, Personas, Cultural Probes, Feedback Stations and Photo Boards. Due to the length of this chapter, we selected two essential design tools and methods for this section, they are 1. Visualising empathy and 2. Persona.

Visualising empathy

Brown (2009) and Vianna et al. (2012) identified a key element of design as having empathy and understanding for those affected by the problem. To tackle complex challenges, designers must identify, understand, reflect upon, challenge and possibly change their frame of reference, and habits of thinking. There are various empathy mapping canvases you can use, such as d.school's four-quadrant layout "Say, Do, Think and Feel" (d.school, n.d.) and Grey's "empathy mapping template" (Gray, 2017) (Table 3.3).

A simple "traditional" empathy map has a four-quadrant layout (Say, Do, Feel and Think). Table 3.1 gives a detailed explanation of the four traits. It's also an analysis

Table 3.2 Design tools and methods in the design thinking process (Double Diamond model)

Discover	Define	Develop	Deliver
Project brief	How might we?	Tomorrow's narratives	Decision matrix
Empathy mapping	Theming and coding	Science fiction prototypes	Low volume production
Personas	Design principles	Low-fi prototypes	Feedback station
Visual probes	Journey mapping	Hi-fi prototypes	Beta testing
Cultural probes	User goals	Role-play	Quantitative evaluation
Feedback stations	Rose, bud, thorn	CAD models	Full-scale testing
Photo boards	Comparing notes	Review survey	Role-play

Table 3.3 A traditional empathy mapping tool (adapted from d.school, n.d.)

SAY What are some quotes and defining words your user said?	*DO* What actions and behaviours did you notice?
FEEL What might your user be thinking? What does this tell you about his or her beliefs?	*THINK* What emotions might your subject be feeling?

tool to review your primary data from your user workshop, interview and fieldwork (Fig. 3.2).

Personas: composite character profile

The information you collected through the empathy mapping will help to create personas. What are personas? Personas are reference models, representing a subgroup of users. Technically, they can be called behavioural archetypes when they focus on capturing the different behaviours (e.g. "the conscious chooser") without expressing a defined personality or socio-demographics. The more the archetypes assume a realistic feeling (e.g. name, age, household composition, etc.), the more they become real personas, fully expressing the needs, desires, habits and cultural backgrounds of specific groups of users. Creating personas help designers to get inspired by their specific life and challenges (sdt, 2021) (Fig. 3.3).

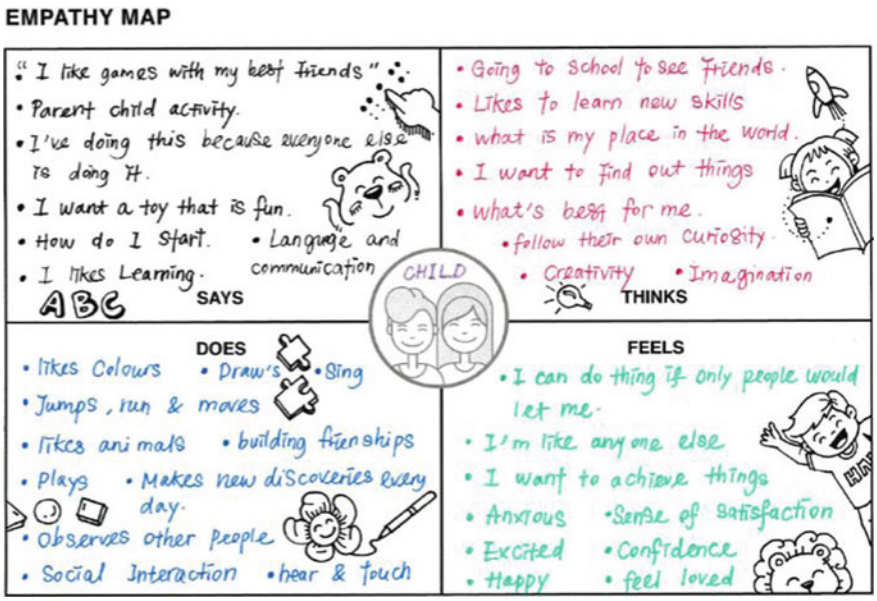

Fig. 3.2 Empathy map example (Master of Design Strategies student's coursework by Boon Khun Ooi)

Exploration of Service Design Solutions

Persona Profile 1

MAX

Max was born blind due to genetic mutations. He is an only child. His parents want a braille learning toy, for parent-child activity at home. At the same time they can improve Max's spelling and communication skills.

Age : 6 years old
Gender: Male
Living Condition:
Lives with parents
School: Kindergarten
Hobbies:
Loves animals and Learning

SOCIAL
- Socially active
- Loves family
- Loves new discoveries

GOALS
- Building friendships
- Be independent
- Having fun with friends and parents
- Wants a fun learning toy

PERSONALITY & FEELINGS
- Likes animals
- Loves stories
- Loves toys and drawing
- Likes to learn new skills

FRUSTRATIONS
- Want to achieve things
- Struggles with socialising with new people
- Very dependent on his parents
- Sensory sensitive
- Not enough braille toys in the market
- Complicated and expensive learning toys

CLINICAL
- Born blind due to genetic
- mutations
- Regular practitioner visit

Persona Profile 2

EMELIA

Emelia was around two years when she was diagnosed as having Retinopathy of Prematurity. She lives in a regional city with both parents and two older siblings. She interacts well with her siblings but is uncomfortable in social situations outside the family unit.

Age : 5 years old
Gender: Female
Living Condition:
Lives with parents
School: Kindergarten
Hobbies:
Loves School and Learning

SOCIAL
- Loves family
- Likes colouring outlines
- Loves new discoveries

GOALS
- Having fun with friends and parents
- Want a fun learning toy
- Want to achieve things
- Opportunity to develop learning abilities

PERSONALITY & FEELINGS
- Likes bright colours
- Likes to dance around
- Loves toys and drawing
- Likes social interaction

FRUSTRATIONS
- Struggles with socialising with new people
- Very dependent on her parents
- Avoidant personality disorder
- Can see only light and dark
- Not confident with technology
- Complicated and expensive learning toys

CLINICAL
- Regular practitioner visit

Fig. 3.3 Personas examples (Master of Design Strategies student's coursework by Boon Khun Ooi)

Quiz: key questions to ask for reflective designers at this stage

- What problem are you solving? What solutions already exist?
- What are your assumptions about the problem?
- Whom are you designing for? What types of users are involved?
- What are the constraints of the project?
- Who are the stakeholders could be involved?
- What are the needs, pain points and desires of different users?
- How might this idea solve problems or pain points for different users?

3.3.2 What Is the Define Mode, Why Ideate and How

Data collected through research and investigation during the discover phase helps us build a clearer picture of the problem. The design team group, theme and distil qualitative and quantitative findings into insights that will guide the development of design solutions.

The define mode is "convergent thinking" rather than "divergent thinking". Two goals of the define mode are 1. To develop a deep understanding of your users and the design space and 2. Based on those deep insights into human behaviour and a solid understanding of their beliefs and values, to develop an actionable problem statement. The problem statement focuses on targeted users, insights and needs uncovered during the discover mode.

At this mode, you understand the "why" is the key to addressing the "wicked problems" and provide the insights that be leveraged in design concepts to create a "how" towards a successful solution.

3.3.2.1 Design Tools and Methods for Define: To Translate Ideas into Action

Possible design tools at this stage include: Design Principles, User Journey Mapping, Theming and Coding; How Might We? Card Sorting; Hypothesis Generation.

Design principles

Design principles are fundamental laws, guidelines and strategies to solve a design challenge independent of a specific solution (d.school, n.d.). You can articulate these principles, translating your findings into design directives, such as needs and insights. These principles represent the accumulated wisdom and knowledge in design and related disciplines, including behavioural science, sociology, physics, occupational therapy and ergonomics. Many well-established design principles are critical to defining your problem-based learning. From simple to complicated, Common Principles of Design & Global Health (Design for Health, n.d.) are principles where the Bill & Melinda Gates foundation attempts to build a shared understanding, language and a shared sense of purpose between designers and global health practitioners.

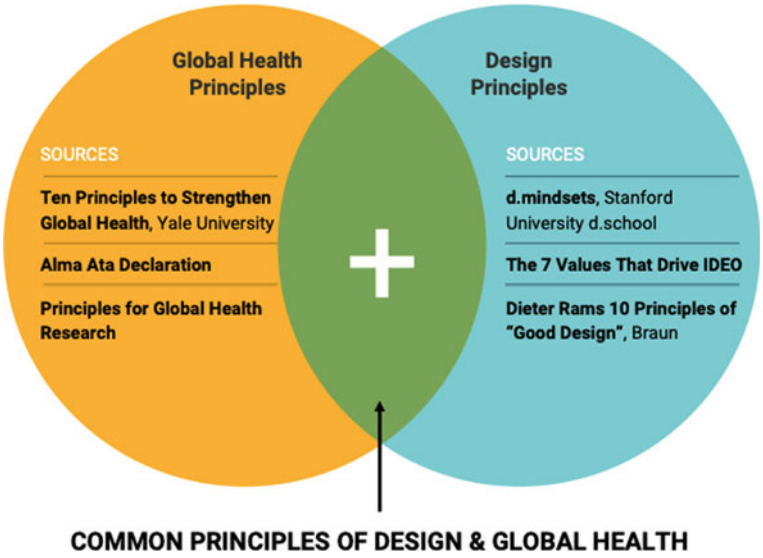

Fig. 3.4 Common principles of design & global health (Design for Health, n.d.)

This set of simple statements, some more aspirational than others, demonstrates the alignment and commitment by designers to longstanding global health principles and values. This resource outlines a code of practice for design in global health (Fig. 3.4).

User journey mapping

The journey map is a synthetic representation that describes step-by-step how a user interacts with a service. The process is mapped from the user perspective, describing what happens at each stage of the interaction, what touchpoints are involved, what obstacles and barriers they may encounter. The journey map is often integrated with additional layers representing the level of positive/negative emotions experienced throughout the interaction (sdt, 2021) (Fig. 3.5).

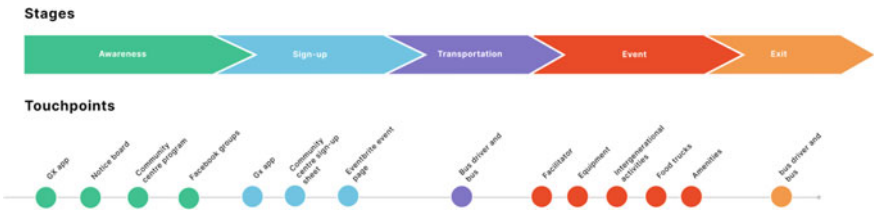

Fig. 3.5 A touchpoint diagram is a graphical representation of how the user interacts with the service (Master of Design Strategies student's coursework by Jordan Mckibbin)

Recap: key questions to ask for reflective practitioners at this stage

- What are the common needs or pain points for users?
- Where in the journey are they experienced or desired?
- How did users or stakeholders respond to ideas presented?
- Who might benefit most from the ideas presented?

3.3.3 What Is the Develop Mode, Why Ideate and Prototype and How

Once you've defined your insights and identified areas to improve the user experience, you begin developing design concepts explored during discover mode or generate further ideas in response to our insights. There are two key concepts in the develop mode: 1. Ideate and 2. Prototype.

Ideation is a mode of divergent thinking rather than convergent thinking. You ideate to generate radical design ideas, concepts and alternatives. The goal of ideation is to explore both a large number of ideas and a diversity among those ideas (d.school).

To further develop the diverse and large quantity of ideas during ideation, prototypes are built to test with users from this vast depository of ideas. Prototypes are "any representation of a design idea, regardless of the medium" (Houde & Hill, 1997, 369). Prototyping is a process of "building, visualising and translating a rough concept into collectively understandable, defined and defendable ideas" (Kocsis, 2020, 61).

> Prototypes traverse from low-fidelity representations in the initial stages (discover and define) of designing to high-fidelity realisations when design outcomes near finalisation (develop and deliver) and can include haptic, oral, digital, spatial, virtual, visual, graphical and also modes beyond a purely technical functional scope through embodied representations of communication such as art, dance and performance. (Kocsis, 2020, 61)

Prototyping facilitates an iterative, interactive communication process. A prototype tests if parts work together for the intended design. This allows further exploration of risks, opportunities and refining of the iterative prototype into the next phase (deliver). "Practices oscillate between creation and feedback: creative hypotheses lead to prototypes, leading to open questions, leading to observations of failures, leading to new ideas and so on" (Dow et al., 2009, 26).

3.3.3.1 Design Tools and Methods for Develop Mode: To Translate Ideas into Action

There are various prototyping tools for this stage, including the low-fi prototype, high-fi prototype, desktop walkthrough, role-play, science fiction prototype and 3D printed prototype. (Chapter 2.7 in the Embodied Design section will discuss 3D Printed Prototypes and CAD in more detail.)

Role-playing

Role-play is a representation tool often used during co-design sessions; it explains a service or product idea by acting out an exemplificatory scenario. Role-playing could be applied at different stages of the design thinking process, not limited to develop mode. Role-playing is a popular technique for building empathy in the discover mode and demonstrating the user experience in the develop mode. It typically requires defining some roles or personas (e.g. Max and Emelia in Fig. 3.3, the service provider, etc.) and preparing rough prototypes (e.g. paper prototypes) or other materials that can facilitate the performance. While a team is acting out their story with given scenarios, the rest of the participants learn about the idea, understand the high-level sequence of actions required, and gain an immersive experience of the actual user experience (sdt, 2021 and Stickdorn & Schneider 2011) (Fig. 3.6).

Fig. 3.6 Role-playing from the co-design for healthy ageing workshop at Nanyang Polytechnic 2019

Recap: key questions to ask for reflective practitioners at this stage

- How do users respond or interact with solutions?
- What do users find easy or difficult about our solutions?
- What can we do to improve the prototype?

3.3.4 What Is the Deliver Mode, Why and How

The final stage is delivering the design solutions. Following design development/prototyping, concept testing and review sessions, potential solutions are narrowed down based on assessment criteria. "The process of designing, building and testing continues to go through iterations until you achieve the final solution" (Autometa, n.d.). The process of prototype testing and looping in feedback also provides continuity to create a seamless way forward in the HCD. The final solution (e.g. robot) delivered should be created to empathise with the customer requirements and concerns. The validation and evaluation process is crucial so organisations spend a good chunk of time testing the prototype against business objectives and metrics. Upon completion of detailed design and production, the realised solution will be physically installed or digitally implemented into the business environment, depending on the type of project.

3.3.4.1 Design Tools and Methods for Deliver Mode: To Translate Ideas into Action

Possible design tools and methods at this step: decision matrix, full-scale testing, system map and feedback stations.

Decision matrix

A decision matrix is an analysis tool to compare and evaluate to select the best option between different options. Through the develop mode, you developed several design prototypes and there are several factors you need to consider. Decision matrix can help you to make your final decision. Between more than one option in order to make your final decision.

There are various formats and styles that you can adopt. Using the sample decision matrix as an example, you can list each of the criteria/metrics you evaluate against in the left column of the table. You then place the options available to you across the top row of your table. For the scoring system, you can choose different systems. Table 3.4 chooses the scale of 1–5, with 5 being a good score and 1 being a very poor score. In the bottom row, you can sum all the scores for each option for your decision-making.

Recap: key questions to ask for reflective practitioners at this stage

- What will it cost to manufacture a high-fidelity prototype?

Table 3.4 Simple decision matrix

Criteria	Options		
	Option 1	Option 2	Option 3
Criteria 1	x	x	x
Criteria 2	x	x	x
Criteria 3	x	x	x
Criteria 4	x	x	x
Criteria 5	x	x	x
Total	x	x	x

x: choose the scale of 1–5, with 5 being a good score and 1 being a very poor score

- What additional capability might you need to deliver the design?
- What existing channels can you leverage to implement our solution?
- What is change management required to implement our solution?
- What criteria are you evaluating against?
- What is the best way to measure the success of this solution?

3.4 Conclusion

This chapter provides valuable and practical guidance on design thinking models and tools for people interested in applying design thinking in their projects. Design thinking is an iterative process, which encourages people to empathise, collaborate and prototype. Doing so helps to generate user-centred design to tackle wicked problems in our society.

This chapter covered the history of the "designerly way of thinking" to introduce the origin of design thinking. The development of Design 1.0–4.0, in comparison to the field of robotic, helped provide a context for the past, present and future.

The design thinking process was then deconstructed into different stages to provide a practical toolkit for people from non-design backgrounds to adopt. Many existing design methods can be used for different stages in the design thinking process. Some of them would be applied from the start to the end, such as service blueprint and prototyping. Due to the length of the chapter, we could not include all the existing design methods. However, the key design methods included in this chapter provided a solid ground for the entry level of design thinking. Design thinking in robotics allows practitioners and researchers to seek opportunities through which they can discover, define, develop and deliver value to their stakeholders and additionally, get them engaged, and create ripples of change.

3.5 Quiz

- What is the difference between divergent and convergent thinking?
- What are some key stages in the design thinking process?
- Name some design tools incorporated in achieving iterative processes in design thinking.
- What design methods can you adopt to advance your empath in the discover stage?
- What methods can you employ to test your concepts in the second diamond stages?

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Fanke Peng is an Associate Professor and Enterprise Fellow at the University of South Australia. She is an award-winning educator, designer and researcher in design-led innovation, design for health, digital fashion and cross-cultural design. She has been heavily involved in extensive research projects in the UK and Australia, including Australian Council for the Arts project: Home Economix, ACT Government Seniors Grants Programme project: ACT Intergenerational Pen Pal Service, Economic and Social Research Council (ESRC) project: E-Size, Technology Strategy Board (TSB) project: Monetising Fashion Metadata and Fashioning Metadata Production Tools, Engineering and Physical Science Research Council (EPSRC) project: Body Shape Recognition for Online Fashion, and an Arts & Humanities Research Council (AHRC) project: Past Present and Future Craft Practice.

Fanke is passionate about design-led innovation and design for health and wellbeing. To share this passion with students and inspire them. She has developed new courses and units, established innovative work-integrated learning opportunities and international faculty-led programmes (FLP). In 2020, she was awarded Senior Fellow of the Higher Education Academy (SFHEA).