Asking Effective Questions
Awareness of Bias in Designerly Thinking

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Asking Effective Questions: Awareness of Bias in Designerly Thinking

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Abstract

The formulation of questions in processes of design is an activity affected by cognitive biases inherent to humans. Cognitive biases, developed through gaining experience, influence how decisions are made during problem solving. When an outcome is predictable, experience provides mental shortcuts or heuristics to enable the problem solver to act effectively. When an outcome is uncertain, cognitive biases can wrongfully project preconceptions, elevate self-interest, and undermine the problem solver's greater ambitions for positive impact. Mitigating cognitive bias is thus vital for design problem solving under conditions of uncertainty. Designers explore uncertainty through an approach typified by human empathy, problem framing, and creativity. This chapter reveals the nature of asking effective questions within designerly thinking. This means understanding nuances of context, surfacing novel insights about how a system performs, and crucially working out how people within systems experience the world around them.

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Introduction

Asking effective questions allows engineering system designers to uncover constraints and clarify the nature of parameters, probing for deeper human insights from actors within systems. Asking effective questions allows the curious mind to learn about the environment around them – the environment which they have tasked themselves to improve. Yet the formulation of questions asked is often affected by cognitive biases and preconceptions. These preconceptions are inherent to human knowledge. Based on lived experiences, cultural frameworks, and beliefs, people grow and learn accepted ways of behaving and communicating. These experiences provide heuristics for decision-making when the outcome is likely or predictable.

However, when the outcome is uncertain, these biases can influence judgments and undermine the problem solver's greater ambitions for positive impact. Lloyd and Scott (1994) showed how, as engineering system designers develop expertise, they also move from a "first principles" approach to design, one where the best-fit solution is the starting point, a more efficient way to design, but one that may bring unquestioned assumptions. In the design of complex systems, for example, improving the effectiveness of a public health system, a problem begins in an ill-defined state, "we are not sure where to begin, let alone a next step," the system designer might ask themselves. What usually follows is an exploration through uncertainty where the designerly thinker confronts their own preconceptions about how best to improve the environment around them. It is the ability to be aware of, and reflexive to, these known preconceptions that offers designerly thinkers an ability to detach from the current situation and question *what can be*.

This chapter will clarify the nature of designerly thinking and explain why engineers must embrace the approach in light of the systemic nature of engineering problems encountered. We touch on the social requirements for engineers designing for complex engineering systems. New challenges to practice regarding negotiating individual and collective biases are presented and discussed in lieu of the central theme of this chapter, the awareness of biases. The chapter closes with a summary and points to future research pathways.

Technical Problems, System Problems

Popular rhetoric holds that design and engineering use distinctive methodological pathways and principles to progress from problem to solution. The engineer investigates and defines utility functions and subsequent parameters and then undertakes a process of optimisation. The designer explores through an approach typified by human empathy, problem framing, and creativity. A closer look at the motivations of the two fields reveals clear similarities. Designers attempt to solve problems in the best possible way. Engineers seek to arrive at optimal solutions. Designers can learn much from how engineers undertake optimisation. Engineers can learn from designers too, particularly how to work with ill-defined problems. Exploring synergies between these traditionally distinct disciplines is a valuable activity given the hybrid specialisations of systems engineer and systems designer.

How a problem is framed greatly informs the pathway to a solution. Jakobsen and Bucciarelli (2007) illustrate this with two examples shown in Figs. 1 and 2. In Fig. 1 a mechanical problem is shown, and with Fig. 2 this problem is reframed to introduce the wider societal context. These two examples are pertinent in this chapter in relation to the way problems are framed and the subsequent inquiry of the problem solver. The first example is a mechanical problem calling the engineer to calculate the force required to move a wheel (lawn roller) over an uneven surface. The problem is presented mathematically, using trigonometry and statics. Aside from the lawn roller reference, the wider context of this problem is excluded. Thus, questions such as the following are not relevant to the problem frame and subsequent solution pairing: *Whom or what will pull the wheel? What are the consequences of "bumps" to the quality of the lawn roller or any load being carried?* In this problem frame, there is one correlating solution to identify, *F (force)*. The engineer's

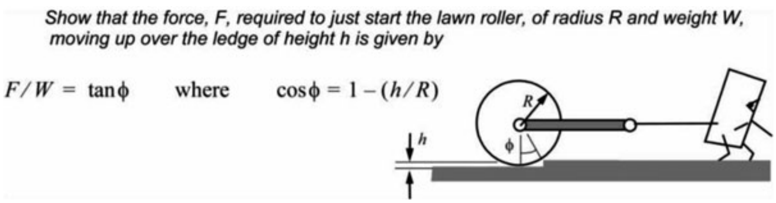

Fig. 1 Mechanics problem reduced to essential forces (Jakobsen and Bucciarelli 2007)

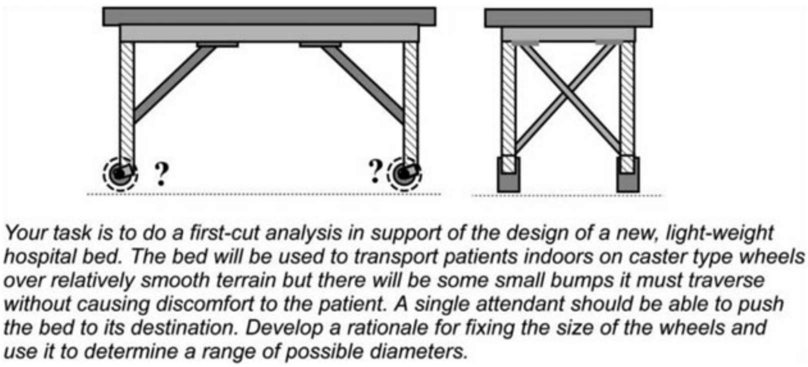

Fig. 2 Mechanics problem transformed to incorporate context: hospital bed wheel size (Jakobsen and Bucciarelli 2007)

heuristics kick into gear with the process of calculating force guided by a discernible pathway between theory and practice. Learnt heuristics provide effective reference points for judgment and decision-making in this controlled environment.

In Fig. 2, the mechanical problem set by Jakobsen and Bucciarelli (2007) is reframed. The problem now concerns designing a patient trolley for a hospital context. Question marks hover over the wheels of the trolley – calling upon the engineering student to focus attention *here*. Jakobsen and Bucciarelli (2007, p. 296) write:

> The first (disturbing) feature of the problem statement is the lack of information which might enable students to begin, none the less solve, the exercise. This is intentional. The student is meant to grapple with the question: What additional information do I need to respond? And a related question: Where might I obtain this needed information? What information is irrelevant?

The engineer must now undertake a process to establish the utility of the trolley. The context of the hospital will be mapped: *How high are the "bumps"? How wide are corridors and lifts? What is the friction co-efficient of various surfaces in the hospital in relation to possible wheel materials?* Once the parameters are identified, an optimisation process can begin. Yet in such a social-technical context, this approach also carries risk.

What is often overlooked in efforts to establish the parameters and begin a process of optimisation is exploration beyond essential utilities to the extended needs of users in the hospital system. Consider the effect of these *projection and egocentric biases* (Tversky and Kahneman 1974) on the project if left untreated:

- All patients and hospital staff are similar; they have similar experiences and needs.
- All hospitals are similar; they have similar layouts, conventions, and regulations.

The assumption that most hospitals are similar is relevant. Hospitals are governed by strict regulations and building codes to ensure safety. Certain wards, such as intensive care, emergency, neonatal, or oncology (and so on), will require unique equipment and processes of care. The hospital bed will come into contact with the various environments such as operating theatres or radiology. An engineer will ask: *What are the nuances of these environments and how will this influence the design of the hospital bed?* A designerly thinker considering the broader system might ask: *How might I undertake this project in an instrumental way to improve the hospital for the many different people who visit it?*

Many patients are also similar. They have illnesses or injuries and require treatment and care. They require a hospital trolley that supports their weight and any related equipment. Hospital staff by virtue of their occupation have similarities too. Yet in both cases, patients, doctors, nurses, technicians, training staff, family, cleaners, and many more stakeholders will interact with a hospital trolley in various and sometimes unexpected ways. Their experiences will be greatly informed by the mobility (and stability) of the hospital trolley. Consider how a patient is rushed around corridors and through tight doorways to an operating theatre by doctors and nurses, as their condition becomes critical. The manoeuvrability of the trolley is crucial. Consider how the child being wheeled to X-ray with a fractured leg feels every “bump” in the floor through their broken bone. The smooth ride is part of treatment and recovery. These experiences can be bettered through thoughtful *designerly systems engineering*.

Beyond the needs of users, the systems engineer will be tasked with resolving how the design of a hospital trolley interacts with the broader health system. The unit of the individual trolley is one small part within the health system. Yet an incremental improvement to the wheel design of a hospital trolley can be harnessed as an instrumental intervention with consequences across the wider health system. With improved trolleys, the designerly systems engineer might now ask: *How can increased patient mobility create capacity within a crowded health system? How might the trolley reduce complaints or associated costs of poor patient transport? How might those saved expenses now be reinvested to improve infrastructure or training? How might implementation of the trolley reveal the extent of doctor/nurses shortages?* These questions transform a simple mechanical improvement into a conduit for driving systemic reform. This can be reinforced when the benefits of a new design form the basis for new regulations. The widespread adoption of a superior hospital trolley across a healthcare system thus facilitates an accumulation of improvements. A strong measure of a country’s socio-economic status is the quality of its healthcare system, and innovation is a reflection of a dynamic and self-improving system. Just as a wheel redesign can be instrumental within one hospital, one hospital undertaking innovation to explore *what can be* becomes instrumental across the greater healthcare sector. Only when effective questions are asked and the designerly systems engineer mandates themselves with this greater task are such transformations possible.

When working with ill-defined problems, such as the hospital trolley in Fig. 2, exploration must precede optimisation. An optimisation process that is later disrupted by new insights, utility functions, and parameters will require costly backtracking. Discipline and patience is required to defer first ideas and undertake an investigation into the context of the hospital. In Fig. 1, the assumption was that the provider of the force was inexhaustible. In Fig. 2, the engineer must now confront the various types of loads and subsequent forces – physical and social – required to move the trolley.

Consider the physical, cognitive, and emotional condition of a nurse after a 12-hour shift and how intuitive use of the hospital trolley becomes paramount. Deeply considering the human condition at the end of 12-hour shift requires the engineer to activate empathy – to be designerly. Heylighen and Dong (2019) cite the seminal research of Pat Moore who transformed herself into an 85-year-old woman in order to understand the everyday life of elderly women in the absence of wealth (Moore and Conn 1985). While the designerly systems engineer might not undertake the same transformation, the essence of *walking in someone’s shoes* to understand phenomena provides a research approach that can be actioned through design methods such as journey mapping, scenarios, role-playing,and storytelling (Price and Wrigley 2016; Price et al. 2018).

The designerly systems engineer might now ask, *how many shoes must I walk in?* While it is inefficient to comprehensively identify and map the needs of all stakeholders, it is important to explore the context and empathise with people within a given system in order to develop principles and frameworks that initiative iterative prototyping. Expert designerly thinkers will sense *intuitively* an exhaustiveness to their exploration (Dorst 2017). All of the most essential utilities and needs of stakeholders are mapped. The mundane and surprising scenarios of use are anticipated. One feels ready to begin generating ideas. The phrase *paralysis by analysis* is pertinent here. Peter Lloyd writes, *design involves making it, then trying it out* (2020). Thus, prototyping concepts act as a safety net to evaluate first ideas. The designer can learn from the outputs of prototyping and take closer steps to a solution. To conclude, designerly thinking begins with questions that scaffold exploration and that making closely follows.

It is especially important to undertake exploration when dealing with ill-defined problems, as during uncertainty individual biases can falsely create an illusion of competence – *I know about this topic, so we will approach the problem in this way*. In short, even the most rational designer or engineer may be blinded to important details and information by their own sense of intuition. The designerly systems engineer of the hospital trolley should eventually arrive at a set of options that look much like the mechanical problem in Fig. 1. With a better understanding of the system context, heuristics can now be effective to progress the mechanical problem and improve the hospital bed for all those who interact with it.

Problem Framing in Designerly Thinking

Kees Dorst and Nigel Cross' design experiment (2001) sheds light on the nuances of designerly thinking and the importance of asking effective questions. Dorst and Cross tasked nine experienced designers to design a new railway train rubbish bin for passengers. Over 2.5 hours they observed the designers undertaking this task. Their findings are insightful to the processes of designing. Some designers questioned the purpose of the brief, *is a rubbish bin required at all? What if*.... Some designers manipulated the scope, *I should consider how the bin is emptied, hence I am designing a system too*.... This ability to question is essential to unlocking creativity and exploring possible solutions. Dorst and Cross (2001, p. 435) identify that creativity rests within the design process as an imaginative *bridge*:

> Our observations confirm that creative design involves a period of exploration in which problem and solution spaces are evolving and are unstable until (temporarily) fixed by an emergent bridge which identifies a problem-solution pairing.

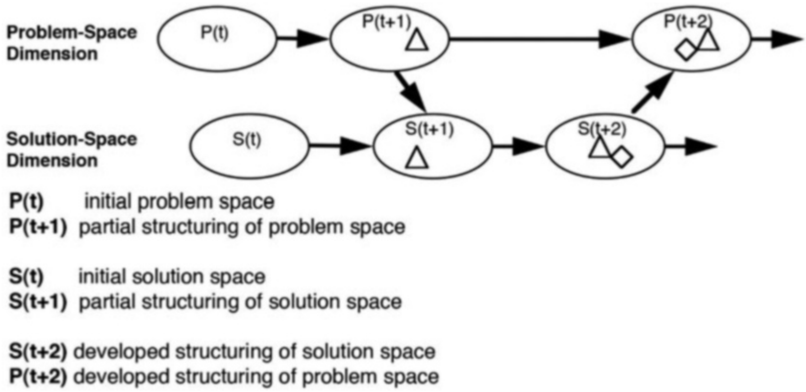

Fig. 3 Co-evolution of problem and solution (Dorst and Cross 2001)

Designers search for problem and solution pairs, often termed *frames* (Schön 1983; Dorst 2011). The activity of framing results in the co-evolution of problem and solution, a fundamental aspect of the design activity (Maher et al. 1996; Dorst and Cross 2001). This activity is visualised in Fig. 3. An initial problem is identified and framed; *P(t)*. This is often referred to as the *problem given*. A paired solution space to this problem given is also present; S(t). One of the key principles in designerly thinking is not to fixate on the first and obvious solution, but to explore the problem more thoroughly in order to arrive at a deeper understanding of phenomena – which may well be to design a mobile (yet stable) hospital trolley. Design exploration allows the designer to discover new insights and, in turn, allows for a reframed problem to emerge; *P*(*t* + *1*). A new subsequent solution space then also opens up; S(t + 1). This process of problem-solution co-evolution typifies the designerly approach to problem solving, yet requires a reflexive relationship to the subject matter at hand via continual questioning and making.

Dorst (2017, p. 57) describes framing in the design process as vital:

> When you 'frame' a problem, you impose a view on the problem that implies a solution, or at least a direction to follow. This is often the only way to achieve a design solution, design problems can be so ill-structured and difficult that you must propose a framework (impose some kind of order) and experiment with it.

Further, Dorst identifies *experimentation* as key. The initial problem frames allow the designerly thinker to question assumptions through experiments and prototyping. When a problem and solution space are prematurely fixed, for example, the designer decides *P(t)* is the problem to solve, the creative potential of designerly thinking to realise novel solutions is stifled. Consider the following scenario:

> A design team is tasked to reduce alcohol-related crime in a city's night entertainment district. The team begin with brainstorming ideas in relation to the set task. Designer A gravitates toward ideas for greater police presence on the streets. Designer B explores ways

to reduce alcohol consumption in bars, *what about a ban on sales after a certain time?* Designer C considers how to transport people away from the area to reduce crowding on the streets. In the end, the ideas are evaluated and the concept B wins. To reduce alcohol-related crime, reduce the antecedent- alcohol.

There are three problems with this type of approach to design. First, Seidel and Fixson (2013) identify that brainstorming is ill-suited to unexplored problem statements. To ideate freely before a problem is thoroughly defined projects bias in an uncontrolled way. This is a trap for design and multidisciplinary teams. Second, the design team members would have faced difficulty detaching from their own individual concepts. Nikander et al. (2014) describe this as the "preference effect" noting that designers show a systematic preference for self-generated concepts during evaluation tasks (p. 473). Third, Dorst and Cross (2001) state this is not how designerly thinking works, "the creative design is not a matter of first fixing the problem and then searching for a satisfactory solution concept" (p. 434). As the problem has been presupposed as stable, *reduce alcohol-related crime,* there is no opportunity to allow for surprising new directions for problem-solution evolution.

This was the challenge facing the University of Technology Sydney's Research Centre, *Designing Out Crime* (reported on by Camacho Duarte et al. 2011). The research team explored the nightlife context and reframed the issue of violence as a result of a "void" created when large numbers of intoxicated patrons leave bars and clubs and enter the street at the same time. This sudden influx of people on the street pushes public infrastructure to the edge of capacity and causes tensions that can spark anti-social behavior and ultimately violence. Based on insights from exploration, the design team designed a set of system interventions; such as a night-rider *bus* to move people to a transport hub, allow them to charge phones, use Wi-Fi to connect with lost party-goers, and hydrate with water; public urinals to allow those that cannot re-enter bars and clubs after "lockout" to relieve themselves cleanly thus freeing up police officers to focus on preventing violent offences; and new lighting and seating to attract people away from bar and club entrances thus clearing sidewalks. The team's interventions thus developed from the dominant engineering systems of transport and communication to a more generally defined problem: distract the public and promote social behavior.

The design team did not constrain themselves to certain types of solutions such as *we must design new communications or new transport solutions*. Rather the team asked effective questions to probe into the peculiarities of people and stakeholders within the local environment. The team revealed unique insights like *people would like to catch the bus and ride around the route in circles, using Wi-Fi and phone charging until they could reconnect with lost friends*. Thus, the night-rider bus became more than a public transport vehicle; it became a *mobile safe house* for people who were vulnerable without realising it. This approach flipped the notion of reducing crime on its head and instead focused the team to the task of increasing public safety.

In exercising empathy and framing over optimisation, the interventions were effective in reducing crime and have survived for the most part - although the nightlife industry has been crippled by Covid-19 regulations. They illustrate that approaching a system with a restricted problem frame can be unnecessarily limiting – and can even be counterproductive. For the *Designing out Crime* team, asking effective questions was not just about uncovering needs. Asking effective questions allowed the team to detach from accepted ways of thinking about crime, public infrastructure, and engineering systems to develop meaningful interventions that did not restrict the elements that made the system valuable in the first place.

Problem-solution framing is also critical in determining different kinds of design reasoning within a design approach (Dorst 2011). Previous experiences as a designer inevitably play a role here. Lloyd and Scott (1994), in a study of engineering system design in the area of process control, showed how increased levels of experience led to progressive case-based reasoning in solving problems. This has the benefit of efficiency, in quickly transferring what has been learnt in past projects, but carries with it a danger that any previous errors may be unconsciously repeated without new questions being asked.

The failures and successes of the past encourage fixation on perceived positive directions within a design project (Crilly 2015). For example, a designer who faced difficulty integrating smart materials within a previous project may altogether avoid the prospect of experimenting with the feasibility of those materials in a new project. Further, designers have a tendency to fixate on fine details in concept stages of the design process when working beyond wireframe or sketches (Damle and Smith 2009), for example, the way in which considering the colour of the vehicle distracts the designer from deeper questions about why designing an internal combustion vehicle is the appropriate direction in the first instance.

Designerly Thinking Involves Experiential Learning

Central within the design process is learning. Beckman and Barry (2007) argue that the learning process in design is experiential. Experiential learning involves the bridging of two axes: *action and reflection* and *analysis and synthesis*. Beckman and Barry point to the theoretical developments of Kolb (1984) and Owen (1998) as lineages of experiential learning theory pertinent to designerly thinking. Kolb (1984) develops a matrix of learning styles underpinning problem solving that identifies the boundaries of experiential learning. Owen (1998) develops an understanding of how knowledge acts as a bridge between the realms of theory and practice. Where a problem is well defined, such as the mechanical lawn roller challenge (Fig. 1), a set of heuristics allow the problem solver to deduce one optimal solution. The bridge between theory and practice is accessible. When the problem is ill-defined, such as the hospital bed challenge (Fig. 2), the application of theory to practice requires experiential learning with users, stakeholders, and the system itself. The system engineer must step out of their office (and perhaps out of their comfort zone) to engage with the people and environments around them.

Jakobsen and Bucciarelli (2007) reflect on the nature of engineering education and the need for hospital bed problems as a means for authentic learning that reflects the often difficult pathway between theory and practice:

> We ought to train students in discerning concepts or laws by varying the assignments we give over contexts of much broader scope – i.e. the hospital bed compared to the roller – challenging students to discern the concept, laws or principles to be learned in more authentic as well as more varied situations. And in that way we give them the possibility for obtaining an understanding which is detached from specific contexts and thus prepare them to discern what is essential in the professional assignments they will meet (p. 299).

Within experiential learning lies an emphasis on *reflection*. Reflection is a crucial skill of the design thinker that can be undervalued within engineering fields. Designers are reflective practitioners who employ reflection-in-action in order to remain reflexive to their own work (Schön 1983). The designer steps back from their work to evaluate relevancy and build expertise.

Experiential learning is much more than individual reflection however. In group settings, surprise and reflexivity occur in social settings and are thus influenced by the norms of the environment. This has implications in innovation processes that integrate design. Dong et al. (2015) propose that concept selection in new product development involves two phases: first, evaluating the merits of a design concept through deductive analysis. In an organisational environment, deductive analysis of design concepts to assess feasibility and viability are commonplace. Second, a stage where the concept is placed into a future context to assess, "'what might be', rather than 'what is'" (p. 39). The latter stage requires innovative abduction to generate new plausible hypotheses capable of being tested. Importantly, when a deductive frame of reasoning is imposed during the evaluation of design concepts, the likelihood of that a new concept passing into later stages of the new product development process decreases. The implication is that designers must be proactive in creating environments where their concepts are evaluated in an open-minded way to anticipate biases carried by others. When decision-making is informed by designerly cognition (abduction), the merits of concepts are more likely to be appreciated. Consequently, an innovative project concept is more likely to be accepted.

An example of this relates to thinking about how an engineering system becomes optimised over time, discounting other social factors that may prove key in determining system performance. In *Car: A Drama of the American Workplace*, Mary Walton (1997) observes the design and development of the Ford Taurus, describing an episode where the position of the external rearview mirrors is determined. The problem is of a technical nature where many factors are to be considered – utility of course, but also aesthetics, noise, impact on other car systems (internal audio, air conditioning), materials, functionality, weight, etc. Should the mirror be positioned on the "sail" – the triangular area bounded by the doorframe – or on the door itself? A team of engineers test out different configurations in a wind tunnel. Walton writes of the Ford project (1997, p. 92):

> Having proved the advantages of the door location, Ehlert turned to the shape of the mirror, employing a sophisticated method of testing called a design of experiments that was useful in situations with many variables. He and a colleague spent three, twelve-hour days running wind tunnel tests on seventeen different mirror heads. With those results in hand, they worked with the studio to style a mirror that had the optimal characteristics. [. . .] The team spent a half a million dollars but at least they had the satisfaction of knowing their efforts had paid off with what could well be the quietist outside rearview mirror in the history of mankind.

But senior management weren't happy, and a "looks versus quality" debate continued until finally the two Vice Presidents intervened during a "theme decision" meeting and told the team to put the mirror on the sail. The engineers had worked hard to objectify the problem and show clearly that there was an optimal solution (deduction), but all judgments in the design process are not equal, whatever their basis. The biases of others, especially of those with seniority and power in decision-making, can often determine the final outcome of a system-related problem, despite evidence that a particular part of the system could function more efficiently.

Remedying Bias in Designerly Thinking

> "I think that. . .," "chances are. . .," "it is unlikely that. . . ."

These three phrases begin Amos Tversky and Daniel Kahneman's 1974 seminal article, *Judgment under Uncertainty: Heuristics and Biases* (p. 1124). These simple pathways to biases prompt even the most rational mind to drift toward predictable and systematic judgment errors. Key design advocate and scholar Jeanne Liedtka (2015) translates the work of Tversky and Kahneman to the benefit of designers and design(erly) thinkers. It is Liedtka's contention that design offers a way for problem solvers and organisations to identify and remedy biases that plague innovation processes. These biases can be costly, risking the firm's reputation through poor products – or even solvency through poor business choices.

Table 1 (below) shows the cognitive biases identified by Tversky and Kahneman. A short description is provided with consequences for innovation listed. This collection of biases is not exhaustive, but rather representative of relevant biases experienced by designers. An example illustrates the thought processes of whoever is affected by these cognitive biases is added by the authors of this chapter – of which you might have experienced one if not several in your engineering studies or career. These tendencies are part of human nature, for example, to project a bias based on the past may be a simple mistake that leads to larger consequences for the client and firm. What is important is knowing how these biases exist, and they can be remedied. Designerly thinking and the subsequent tool kit of design offer ways do so.

Asking effective questions is a critical activity within engineering systems design to steer away from these tabulated examples. When ineffective questions are asked, or no questioning takes place at all, the problem solver limits their access to

Table 1 (Liedtka 2015, p. 930), modified to merge remedies for cognitive bias reduction (p. 932)

Cognitive bias	Description	Innovation consequences	Symptomatic thoughts/ statements of bias	Mitigating thoughts/ statements to bias	Mitigating actions
Projection bias	Projection of past into the future	Failure to generate novel ideas	"In the past, this worked well..."	"Times have changed, let's approach this from a new perspective"	Collect deep data on others; improve ability to imagine experience of others; work in cross-disciplinary or dynamic teams; value naïve questions and challenges from less experienced people
Egocentric empathy gap	Projection of own preferences onto others	Failure to generate value-creating ideas	"I know this topic, so I will take the lead. . ."	"Please take the lead so we can explore new opportunities"	
Focusing illusion	Overemphasis on particular elements	Failure to generate a broad range of ideas	"I like the function as it is, let's focus on the color now. . ."	"Best we zoom in and out from detail to the bigger picture to make sure we do not get fixated"	
Hot/cold gap	Current state colours assessment of future state	Undervaluing or overvaluing ideas	"There is no hope trying. . ."	"Tomorrow is a new day. . ."	
Say/do gap	Inability to accurately describe own preferences	Inability to accurately articulate and assess future wants and needs	"The user told me these are the functions required, but when I observe them, I notice several more. . ."	"Let's triangulate our research to make sure we integrate as many perspectives as possible"	Improve users' ability to identify and assess their own needs; use methods that do not rely on users imagining their own needs and solutions

Planning fallacy	Overoptimism	Overcommitment to inferior ideas	“This is the best idea yet. . .”	“There is always room for improvement”	Help decision-makers become better testers; work with multiple options; conduct reflection of results of real experiments
Confirmation bias	Look for confirmation of a working theory	Missing key data that would disprove the working theory	“I ran a small evaluation and my results were overwhelmingly positive. . .”	“Let’s test the results of this evaluation to check for reliability”	
Endowment effect	Attachment to first solutions	Reduction in options considered	“I immediately had a brilliant idea that we ran with. . .”	“Let’s step back from initial ideas, and see what else is possible”	
Availability bias	Preference for what can be easily imagined	Undervaluing of more novel ideas	“I did a quick brainstorm and these three ideas were obvious solutions. . .”	“Our earliest ideas are the starting point for prototyping”	

contextual information that can contribute to a richer understanding of phenomena as well as increased innovation (Busby and Lloyd 1999). Further, when ineffective questions are asked, or no questioning takes place at all, the problem solver limits their ability to disconnect from *what is to challenging what can be*.

Skills and Competences of the Designerly Systems Engineer

This chapter has portrayed the nature of asking effective question in designerly thinking as a means to surface and address bias. The chapter began by identifying how problem reframing can reveal alternative solution pathways. Technical problems, such as the mechanics challenge of Fig. 1, allow the system engineer to clearly relate theory and practice. When the constraints and parameters of a problem are clear and undisputed, the problem solver can confidently follow heuristics and begin engineering a solution. However, the vast majority, if not all, of systemic engineering problems don't follow this functional logic. They are based on a human context that plays a major role in the success of engineering solution and thus must be taken account of for a design to be considered a success.

When systematic problem frames are encountered, such as the hospital trolley challenge in Fig. 2 or the Sydney nightlife crime scenario, the designerly systems engineer must begin an exploration into how the systems operates, crucially including how people experience that system and the world around them. Effective questions probe how a problem can be solved in a way that benefits the greater system. For example, the widespread adoption of a superior hospital trolley across a healthcare system to create an accumulation of improvements. A designerly systems engineer might ask: *How might the hospital trolley reduce complaints or associated costs of poor patient transport? How might implementation of the hospital trolley reveal the extent of nurse shortages?* Effective questions probe the human experience which necessitates an empathic approach from the designerly systems engineer: *How can we protect young party-goers in the Sydney nightlife district who don't even realise they are vulnerable?* Together with empathy, exploration to define and reframe problems typifies a designerly approach.

The theoretical basis for design exploration is known as the co-evolution of problem and solution (Dorst and Cross 2001). Co-evolving problem and solution frames means asking effective questions to learn about complex environments around us and also suggests ways in which smaller experimental prototypes can unveil sub-problems to move the design process forward. Beckman and Barry (2007) argue that designerly thinking is experimental learning, where loops of action, insight, analysis, and synthesis occur. Reflection is thus another crucial skill of the designerly thinker that is often undervalued within engineering fields. The designer steps back from their work to consider its effect and evaluate relevancy and so builds expertise while avoiding fixation on certain patterns or concepts (Crilly 2015), thus lowering the risks of innovation (Liedtka 2015).

To conclude, the designerly systems engineer displays the following qualities in asking effective questions and mitigating bias:

- They reframe the given question to include more contextual elements.
- They show empathy with the human experience of any proposed solution.
- They think in systemic terms.
- They reflect on their own learning about the problem and how to improve it.
- They question their assumptions and draw carefully on past experience.

To learn from past experiences yet not be blinded to the biases that form as a practitioner progresses from novice to expert is a careful balancing act. Asking effective questions acknowledges that even experts do not know everything. Indeed, being able to ask effective questions, at the right time, is a sign of real expertise in designing.

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▶ Creating Effective Efforts: Managing Stakeholder Value
▶ Design Perspectives, Theories, and Processes for Engineering Systems Design
▶ Designing for Human Behaviour in a Systemic World
▶ Engineering Systems Design Goals and Stakeholder Needs
▶ Human Behaviour, Roles, and Processes
▶ Public Policy and Engineering Systems Synergy
▶ Roles and Skills of Engineering Systems Designers

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