CHAPTER

15

Mental Models and Conceptual Design

Highlights

- Mental models:
  - What is a mental model?
  - The ideal mental model.
  - The designer's mental model.
  - The user's mental model.
  - The conceptual design as a mapping between mental models.
- Making the conceptual design:
  - Start with a conceptual design for the ecology.
  - Conceptual design for interaction.
  - Conceptual design for emotional impact.
  - Leveraging design patterns in conceptual design.
  - Leveraging metaphors in conceptual design.
  - Conceptual design for subsystems by work role.

15.1 INTRODUCTION

15.1.1 You Are Here

We begin each process chapter with a "you are here" picture of the chapter topic in the context of The Wheel, the overall UX design lifecycle template (Fig. 15-1). In this chapter, we continue the UX design process with conceptual design to communicate the designer's mental model to users.

15.1.2 Mental Models

A mental model is a description, understanding, or explanation of someone's thought process about how something works. As applied in UX, a mental model is how someone (e.g., designer or user) thinks a product or system works.

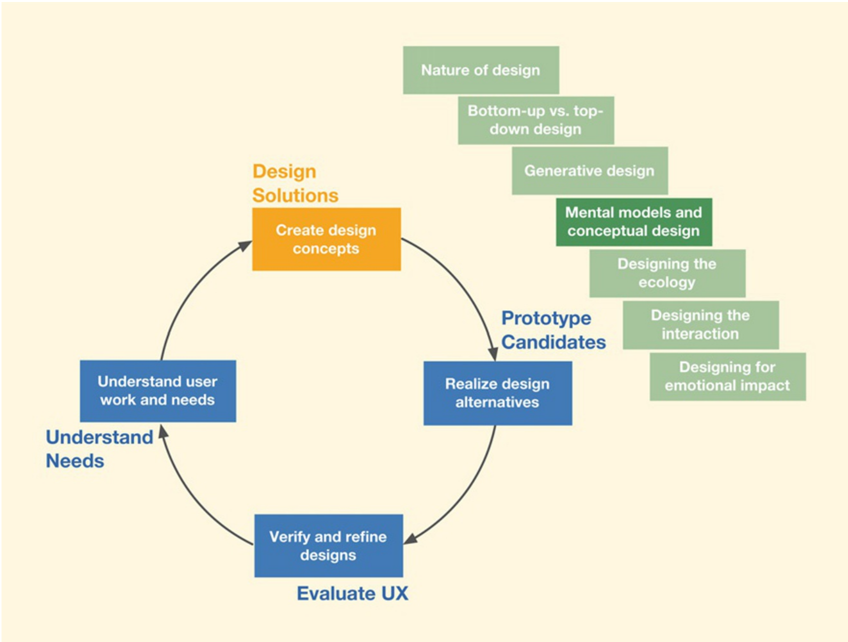

Fig. 15-1

You are here in the chapter describing the role of mental models and conceptual design within the Design Solutions lifecycle activity, in the context of the overall Wheel UX lifecycle.

Designers have mental models that, hopefully, are correct. Users, who may not completely understand a system, will have their own mental models, correct or not, of how a product or system works. If the user's mental model is correct, the user will know how to use the system. It is up to the designer to create a conceptual design capable of conveying a correct mental model to users.

For an example of how a mistaken mental model can make for entertainment, see Section 19.3.

15.2 HOW A CONCEPTUAL DESIGN WORKS AS A CONNECTION OF MENTAL MODELS

Fig. 15-2 shows how the conceptual design (in the center of the figure) is a kind of mapping from the designer's mental model (near the top) to the user's mental model (near the bottom).

Here's how it works:

1. The ideal mental model represents the reality of how something like a thermostat works "out there" in the world.

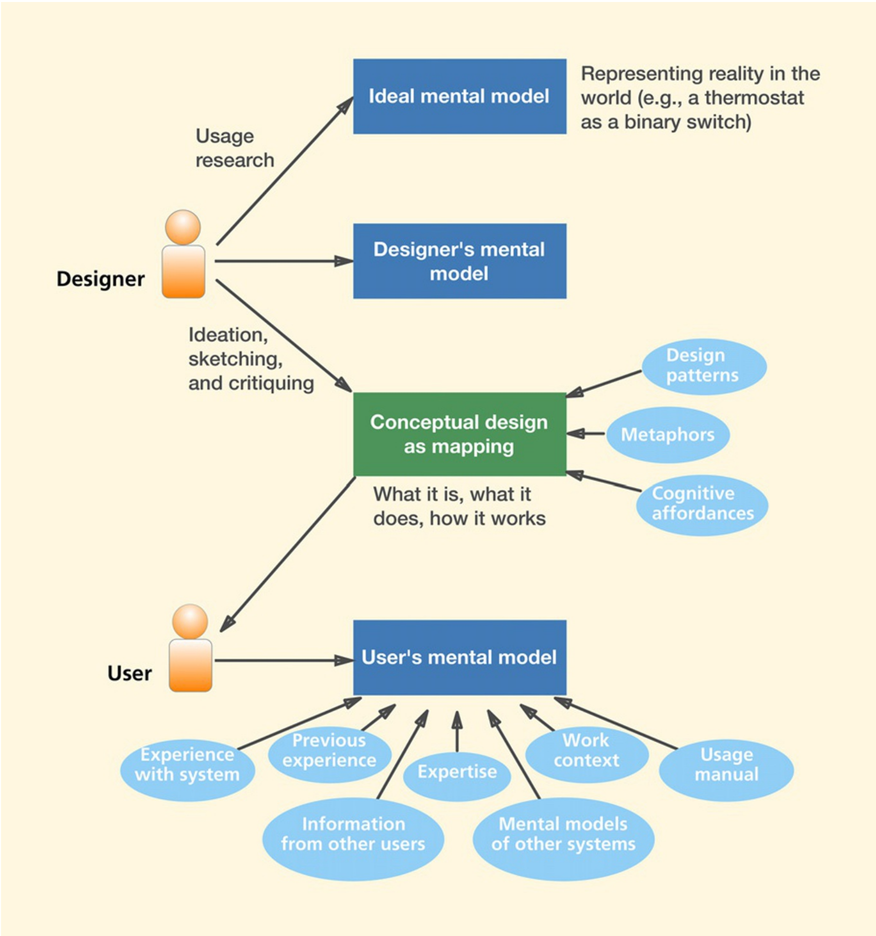

Fig. 15-2

The conceptual design as a mapping of the designer's mental model to the user's mental model.

2. The designer studies this reality via usage research, interactions with subject matter experts (SMEs), analysis, etc.
3. The designer develops a (possibly partial and/or not quite correct) mental model based on understanding of the reality thus captured.
4. The designer builds this mental model into the conceptual design.
5. The conceptual design conveys that knowledge of the designer's understanding to users.
6. If users had some a priori understanding of the reality, the conceptual design can either affirm or challenge that understanding. Otherwise, the user (hopefully) learns how this system or product works from the conceptual design.

We will explain the parts of this diagram in the sections that follow.

15.2.1 The Ideal Mental Model in Context

An ideal mental model is a theoretically correct description of the reality of a given design and a given implementation of a given system or product and how it works. The ideal mental model is a hypothetical abstraction of knowledge in the world and includes subject matter expertise and complete knowledge about the work domain. This complete knowledge will be held by a backend system designer or shared among the system design team, and for most domain simple systems, the UX designer may have this knowledge too.

Continuing with a common house thermostat as an example, the user's manual would probably say something to the effect that you turn it up and down to make it warmer or cooler, but would probably fall short of the full explanation of how a thermostat works. But the service manual will contain documentation about the complete knowledge about thermostat internals, including what type of thermally sensitive material is used, what its expansion profile is, what the material tolerances are, etc.

Thermostats are very simple devices, and their ideal mental model is widely known and understood. Most thermostats, as Norman explains in his famous book, *The Design of Everyday Things* (Norman, 1990, pp. 38–39), are binary switches that are simply either on or off. When the sensed ambient temperature is below the target value, the heating system switch closes and the thermostat turns the heat on. When the temperature then climbs to the target value, the switch opens and the thermostat turns the heat source off. It is, therefore, an incorrect mental model to believe (taken just as an example) that you can make a room warm up faster by turning the thermostat up higher than the target temperature.

15.2.2 The Designer's Mental Model in Context

The designer's mental model, sometimes called a conceptual model (Johnson & Henderson, 2002, p. 26), is the designer's understanding of the how the envisioned system is organized, what it does, and how it works. If anyone should know these things, it is the designer who is creating the system. But it is not uncommon for systems to get built without a clear mental model upfront.

The results can be a poorly focused design that fails as a mapping (middle of Fig. 15-2), causing users frustration.

15.2.3 The User's Mental Model in Context

Veer and Melguizo (2003), citing Carroll and Olson (1987), define a user's mental model as the "mental representation that reflects the user's understanding of the system." It's an internal explanation a user has built about how a particular system works. As Norman (1990) says, it is a natural human response to an unfamiliar situation to begin building an explanatory model a piece at a time. We look for cause-and-effect relationships and form theories to explain what we observe and why, which then helps guide our behavior and actions in task performance.

As shown in Fig. 15-2, each user's mental model is a product of many different inputs, including, as Norman has often said, knowledge in the head and knowledge in the world. Knowledge in the head comes from mental models of other systems, user expertise, and previous experience. Knowledge in the world comes from other users, work context, shared cultural conventions, documentation, and the conceptual design of the system itself. This latter source of user knowledge is the responsibility of the UX designer.

15.2.4 The Conceptual Design as Mapping Between Mental Models

A conceptual design is the part of a design containing a theme, metaphor, notion, or idea with the purpose of communicating a design vision about a system or product, corresponding to what Norman calls the "system image" of the designer's mental model (Norman, 1990, pp. 16, 189–190). The goal of a conceptual design (second box from the bottom in Fig. 15-2) is to communicate the designer's mental model to users.

A conceptual design must convey the designer's mental model in a way that the user can acquire or form a similar mental model and, thereby, know how to use the system. Without an effective conceptual design, users cannot leverage any experience they gain from interacting with one part of the system while interacting with another.

Metaphor

An analogy used in design to communicate and explain unfamiliar concepts using familiar conventional knowledge. A central metaphor often becomes the theme of a product, the motif behind the conceptual design (Section 15.3.6).

Example: The Washington, DC, Metro Ticket Kiosk

The Washington, DC, Metro ticket kiosk (Fig. 15-3) is an example of a system that lacks a good conceptual design, and it does not look like any other kiosk. It is what we call a "show up and throw up" user interface. This type of design is also sometimes called "information flooding." The designers didn't determine what information users needed and when, so they show everything at once and let the users take it from there.

A bewildering array of buttons and displays meets the user who walks up to this kiosk. Remember the context of interaction here: the users are in a hurry to purchase a fare to get on the train. Add to that the fact that a significant portion of these users are tourists having no prior experience with this system to rely

Fig. 15-3

A Washington, DC, Metro ticket kiosk.

upon. And finally, there is usually a line of people waiting behind the current user, so the pressure is on to get the fare and not hold up the line.

If the user is trying to purchase a one-time fare card, they have to first figure out how much the fare is by reading the small text at the top of the kiosk. If they are successful, they have to select one of the three options next to the "Select Purchase" section at the top to get started with the type of card they are purchasing. This option, thankfully, is at the top of the screen, a reasonable location the user will look for to get started. However, if the user already has a rechargeable "Smartrip" fare card, they have to start first by tapping their card on the circular widget in the bottom center part of the kiosk, to the lower right of the "Insert Payment" label. Then, they have to select an option from the "Select Purchase" step at the top. Then, they pay using one of the available options in the center and then touch the circular card again in the center. It is an arbitrary sequence of steps that is only explained through small text in the center of the kiosk.

Even if designers had a clear mental model, they didn't articulate it in an effective conceptual design, and, consequently, the users have no way of forming a mental model of how the system works. The three steps of the workflow are not supported consistently for all types of transactions. For example, the Smartrip users or users trying to combine their existing fare card balances into a single card do not start in the "Select Purchase" step. Similarly, not all payment steps are organized in the payment section in the middle (note the "coin return" at the bottom). Because people struggle with this so much, the Metro system had to post (and pay for) Metro employees onsite to help, but this defeats the purpose of having a kiosk in the first place.

Compare this to the NYC ticket kiosk where the user is guided through a task flow using a touch screen user interface and not overwhelmed with all options at once.

15.3 DESIGN STARTS WITH CONCEPTUAL DESIGN

A clear and consistent conceptual design assures that the rest of the product or system design presents a unified and coherent appearance to the user.

After doing usage research, many designers jump right into sketching out screens, menu structures, and widgets. But Johnson and Henderson (2002) will tell you to start with conceptual design before sketching any screen or user interface objects. As they put it, screen sketches are designs of "how the system presents itself to users. It is better to start by designing what the system is to them." Screen designs and widgets will come, but time and effort spent on interaction details can be wasted without a well-defined underlying conceptual structure. Norman (2008) puts it this way: "What people want is usable devices, *which translates into understandable ones*" (final emphasis ours).

Conceptual design is where you innovate and brainstorm to plant and first nurture the user experience seed to build this understanding. Without an effective conceptual design upfront, you can never iterate the design later to yield a good user experience. Conceptual design is where you establish the metaphor or the theme of the product—in a word, the concept.

It's a general rule in creating a conceptual design that the designer's mental model must be articulated clearly, precisely, and completely in the conceptual design. To paraphrase Johnson and Henderson's rule for the conceptual design: *If something is not in the conceptual design, which represents the designer's mental model, the system should not require users to be aware of it.*

15.3.1 Need for a Conceptual Design Component at Every Level in the User Needs Pyramid

Ecology

In the setting of UX design, the ecology is the entire set of surrounding parts of the world, including networks, other users, devices, and information structures, with which a user, product, or system interacts (Section 16.2.1).

Before we start to design for the ecology, interaction, and emotional impact, we must create a component of the conceptual design for each layer in the user needs pyramid (Section 12.3.1); see Fig. 15-4:

- An ecological component that helps users understand how the product or system fits into its ecology and works together with other products and systems in that ecology.
- An interaction component that helps users understand how to use the product or system.
- An emotional component that conveys the intended emotional impact.

The components of the conceptual design that address these three layers are described in the following sections.

Emotional impact

An affective component of user experience that influences user feelings. Includes such effects as enjoyment, pleasure, fun, satisfaction, aesthetics, coolness, engagement, and novelty and can involve deeper emotional factors such as self-expression, self-identity, a feeling of contribution to the world, and pride of ownership (Section 1.4.4).

15.3.2 Conceptual Design for Work Practice Ecology: Describing Full Usage Context

The mental model for the system ecology helps users understand how the product or system fits into its ecology and works together with other products and systems in that ecology. Let us expand the explanation of thermostats to include their ecological setting.

A thermostat ecology includes a heating (and/or cooling) system consisting of three major parts: a heating source or cooling unit, a heating or cooling distribution network, and a control unit, the latter being the thermostat and some other hidden circuitry. The heat source could be gas, electric, or wood burning, for example. The cooling unit might use electric power to run a

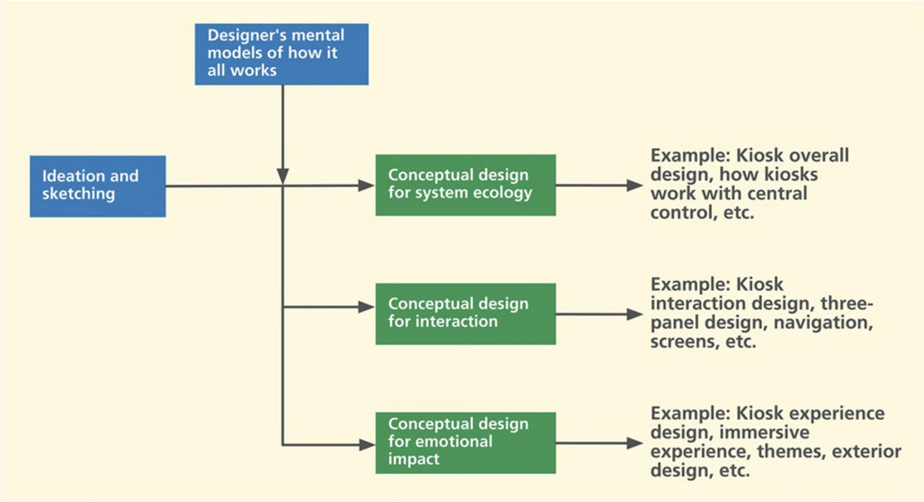

Fig. 15-4

Designer workflow and connections among the three layers of the user needs pyramid.

compressor. The heating or cooling distribution network would use fans or air blowers to send heated or cooled air through hot air ducts, or a pump would send heated or cooled water through subfloor pipes. Finally, there is a living space being heated or cooled, and its ambient temperature.

Next, we address what a thermostat does within its ecology by noting that it is for controlling the temperature in a room or other space. It does this by turning on the heating or cooling source until the temperature in the living space stays near a user-settable value to keep people comfortable. In other words, the model for a thermostat design is a controller that checks the ambient temperature and keeps a thermal or cooling source on or off until a desired value is detected.

If the designers are planning to create a smart thermostat, their mental model will also include a way to sense users in the house to ascertain occupancy, conserving energy when the house is unoccupied. This includes sensor locations, how the data from those sensors will be communicated to the thermostat, and how users will be able to control the system when they are away from the house. Thus, the conceptual design will expand to include connectivity with the Internet, whether the data are saved over a period of time for trend analysis, and whether the system provides other types of feedback such as comparing with energy consumption averages in the neighborhood or of friends and family.

Ecology

In the setting of UX design, the ecology is the entire set of surrounding parts of the world, including networks, other users, devices, and information structures, with which a user, product, or system interacts (Section 16.2.1).

15.3.3 Conceptual Design for Interaction: Describing How Users Will Operate It

For interaction, a conceptual design is a task-oriented view about how a user operates the system or product. There will need to be a different model for the different platforms and different devices for interacting with the system. For example, the thermostat could be a traditional physical device on the wall or it could be a smartphone app that interfaces with the physical device via the Internet.

In the physical device case, a user can see two numerical temperature displays, either analog or digital. One value is for the current ambient temperature, and the other is the setting for the target temperature. There will be a rotatable knob, slider, or other value-setting mechanism to set the desired target temperature. This covers the sensory and physical user actions for operating a thermostat. User cognition and proper formation of intentions with respect to user actions during thermostat operation, however, depend on understanding the mental model of its behavior.

A second possible interaction design, one that reveals the conceptual design, might have a display unit that provides feedback messages such as “checking ambient temperature,” “temperature lower than target; turning heat on,” and “temperature at desired level; shutting off.” This latter design might suffer from being unnecessarily complex to produce, and the added display is likely to be a distraction to experienced users (i.e., most users). However, this does illustrate a design that helps project the designer’s mental model to the user through the conceptual design in the interaction perspective.

The conceptual design must also include descriptions of interactions required for users to set up the ecology by connecting the thermostat to the Internet, accessing it via a smartphone app, logging into any required accounts, etc.

15.3.4 Conceptual Design in the Emotional Perspective: Describing Intended Emotional Impact

For emotional aspects, the conceptual design is a description of the expected overarching emotional response. Regarding the thermostat example, this could be about the emotional effect of a modern and sleek aesthetic with steel and glass components in contrast to traditional designs made with plastic materials. The conceptual design for emotion will also include physical design, how it fits in with the house décor, and the craftsmanship of its construction. The designers may also have specific plans for the visual design of the display on the device, including the type of LED to use and whether there will be color options available. A traditional

Fig. 15-5

The appearance of an old thermostat versus that of a Nest.

plain appearance gives up emotional ground to the sophisticated look of a Nest thermostat (Fig. 15-5), especially when that stylish exterior carries with it the knowledge that the Nest is really cool because of what it can do inside.

15.3.5 Leveraging Design Patterns in Conceptual Design

A design pattern is a repeatable solution to a common design problem that emerges as a best practice, encouraging sharing, reuse, and consistency (Sections 14.2.8.5, 17.3.4, and 15.3.5). Design patterns are design styles that entail reuse of interaction structures, color schemes, fonts, physical layout, look and feel, and locations of interaction objects. They help with consistency and ease of learning. As an example of designers leveraging the design patterns of conceptual designs from known applications to new ones, consider a well-known application such as Microsoft Outlook. People are familiar with the navigation bar on the left side, the list view at the top right side, and a preview of the selected item below the list. When designers use that same idea in the conceptual design of a new mail application, the familiarity carries over.

15.3.6 Leveraging Metaphors in Conceptual Design

A metaphor is an analogy used in design to communicate and explain unfamiliar concepts using familiar conventional knowledge. A central metaphor often becomes the theme of a product, the concept behind the conceptual design. Metaphors control complexity by allowing users to adapt what they already know in learning how to use new system features.

Metaphors are analogies for communication and explanations of the unfamiliar using familiar conventional knowledge. This familiarity becomes the foundation underlying and pervading the rest of the design.

What users already know about an existing system or existing phenomena can be adapted in learning how to use a new system (Carroll & Thomas, 1982). We use metaphors to control design complexity, making it easier to learn and easier to use instead of trying to reduce the overall complexity (Carroll, Mack, & Kellogg, 1988).

A good example is the now-pervasive desktop metaphor. When the idea of graphical user interfaces in personal computers became an economic feasibility, the designers at Xerox Parc were faced with an interesting UX design challenge: how to communicate to the users, most of whom were going to see this kind of computer for the first time, how the interaction design works.

Physicality

Referring to real direct physical interaction with real physical (hardware) devices like in the grasping and moving of knobs and levers (Section 30.3.2.4).

In response, they created the powerful "desktop" metaphor. The design leveraged the familiarity people had with how a desktop works; it has files, folders, a space where current work documents are placed, and a "trash can" where documents can be discarded (and later recovered, until the trash can itself is emptied). This analogy of a simple everyday desk was brilliant in its simplicity and made it possible to communicate the complexity of a brand-new technology.

Another great example of a metaphor for interaction conceptual design can be found in the Time Machine feature on the Macintosh operating system. It is a backup feature where the user can take a "time machine" to go back to older backups—by flying through time as guided by the user interface—to retrieve lost or accidentally deleted files.

The designers of this feature use animation to represent traveling back through time to points where the user made backups. Any files from that backup can be selected and brought back to the present to recover lost files. This conceptual design is effective because it uses a familiar metaphor to simplify and explain the complexity of data backup. Other backup products provide similar capabilities but are more difficult to interact with because they lack a similar metaphor to reflect how it works.

Example: Physics as a Metaphor in UX Conceptual Designs

Scrolling through lists on an iOS device such as an iPad, done by swiping the finger up or down, demonstrates a phenomenon called physics in interaction. The scrolling is done as though the display was on a large wheel that you spin with your finger. This display *exhibits* significant mass, so it has inertia that keeps it spinning after you release your finger. But it also exhibits friction that soon slows it down and stops it.

So, this display involves mass, inertia, and friction, all parameters of physics. The way the mass and inertia are exhibited is so real that it actually *feels* like a real wheel to the finger. It's a kind of artificial physicality. And if the users spin it past where they want to be, that is technically considered an "error" by most definitions, but it doesn't feel like an error. It feels normal for a wheel with mass, and they just *naturally* spin it back a bit.

See how natural that interaction is when the "physics" work as the user expects? Other examples include rubber-banding when reaching the end of a list and tactile feedback on buttons.

15.3.6.1 Metaphors can cause confusion if not used properly

As critical components of a conceptual design, metaphors set the theme of how the design works, establishing an agreement between the designer's vision and the user's expectations. But metaphors, like any analogy, can break down when the existing knowledge and the new design do not match.

When a metaphor breaks down, it is a violation of the agreement implicit in a conceptual design. The famous criticism of the Macintosh platform's design of ejecting an external disk by dragging its icon into the trash can is a well-known illustration of how a metaphor breakdown attracts attention. It might have been more faithful to the desktop metaphor if the system would discard an external disk, or at least delete its contents, when it is dragged and dropped onto the trash can, instead of ejecting it. However, that would be too dangerous. Maybe ejection could have been better portrayed by pulling a device symbol out of a computer symbol.

15.3.7 Conceptual Design for Subsystems by Work Role

In Section 8.7.3, we discussed how an overall product or system can be divided into subpieces by work role. Each such subsystem will have its own user needs within the pyramid: ecology, interaction, and emotional. That is, for each work role that corresponds to a subsystem, we must think of ecological, interaction, and emotional conceptual designs (Fig. 15-6).

We cover designing (including creating conceptual designs) for each of the layers of the pyramid in the following three chapters.

Exercise 15.1: Conceptual Design for Your System

Goal: Get a little practice in initial conceptual design.

Activities: Think about your system and usage research data and envision a conceptual design, including any metaphors, for how your overall system works.

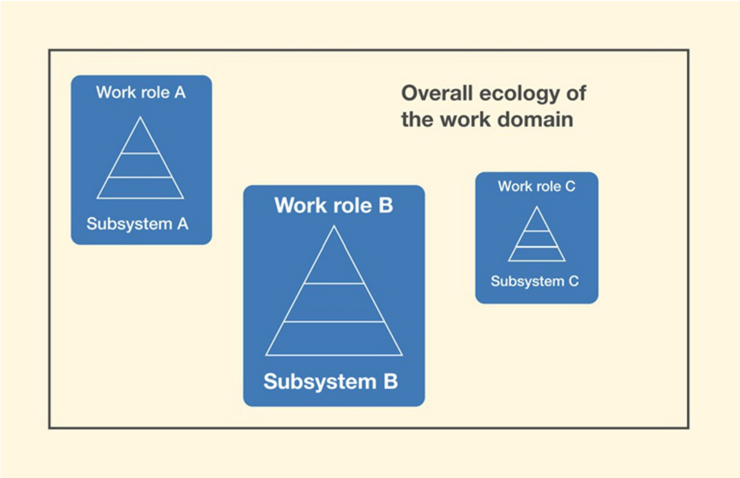

Fig. 15-6

Two dimensions of conceptual design: subsystems defined by different work roles and addressing the layers of the user needs pyramid.

Try to communicate the designer's mental model, or a design vision, of how the system works.

Deliverables: Brief written descriptions of your conceptual design and/or a few presentation slides of the same to share with others.

Schedule: You decide how much time you can afford to give this.