Inventing the Future of Cognitive Work: Navigating the 'Northwest Passage'

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Abstract

Computer scientists, engineers, managers, and practitioners make claims about how new technologies will change cognitive work—how workers in various fields of practice solve problems in analysis, fault management, control, coordination, and replanning. When systems are built and fielded based on these beliefs, the actual effects on practice, including new forms of error, are quite different from what was envisioned as users workaround complexities or exploit new capabilities (Woods and Dekker, 2000). The gap between hopes and reality in changing the face of cognitive work arises for two factors: (1) because claims for new technology ignore the research findings of the field of Cognitive Systems Engineering on how people cope with complexity and (2) because advocates for new technology are trapped in a narrow range of possible expressions of the new capabilities relative to the demands of cognitive work. Since design methods have not had the desired impact of guiding designing in the context of cognitive work, the voyage of discovery that should follow from insight through research has been limited. Concepts were identified, but their implementation into the world of practice calls for an extended presence of design thinking in technology application —one that is human centered, not technology oriented (Winograd and Woods, 1997; Hoffman et al., 2002; Hoffman et al., 2004).

This research has examined how technologists envision the future of cognitive work and found a variety of oversimplifications that narrow the process of discovery (Feltovich et al., 2004). Based on these results, the paper proposes an integration of methods from Cognitive Systems Engineering and Design Innovation for finding promising directions (e.g., Winograd and

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Flores, 1986; Woods and Christoffersen, 2000; and Alexander, 1964; Jones, 1970 respectively). The integration, or de:cycle, coordinates three roles (and associated processes and artifacts produced through these design processes): practitioner—how they adapt to complexity, innovator—how they envision what would be useful, and technologist—how they bring the anticipated change into the world of practice.

Keywords: Cognitive Systems Engineering and Design, Design Methods, Human-Centered Design, Ideation Design, Envisioning, Broadening, Promisingness, Perspectives on Design, Design and Technology Development, Practice-Centered Design.

Introduction

Finding promising directions is like a voyage of discovery, such as the famous historical search for the Northwest Passage from Europe to Asia. In our case, the goal of discovery is to create potential leverage points and to chart the space of potential leverage points where technology change will support the changing face of cognitive work. This passage is the most intangible sequence in software, engineering and creative design in the ongoing search to establish affordances between future practitioners and the environment under design and to create design seeds that represent promising and reusable directions.

The integration uses storytelling concepts to forge a collaborative synthesis across pools of technological possibilities, pools of experience in the field, pools of patterns abstracted through observation. Since designs alter the very situation targeted by developers and the changed practices reshape the artifacts designed, a dynamic balance across these 3 pools of resources can guide the discovery process even when the ultimate target of "human-centeredness" is as elusive as the Northwest Passage.

To integrate discussions about design led by cognitive systems engineering specialists with the perspective of industrial design in part concerns the different forms of expertise across designers in different roles. This led us to examine how design work is conducted in the context of joint cognitive systems where the knowledge base consists of findings about how people cope with complexity. Cognitive systems are work environments that support practitioners in monitoring, controlling, or taking actions in the world (Hollnagel and Woods, 2005). Examples of such settings occur in flight decks, control rooms for power- or processing plants, and medical settings. All these settings have in common that the practitioners are highly trained, that significant investments are made to apply technology, and that failures have serious consequences.

Design work is conducted by many specialists and each one of them carries the label designer in one way or the other. Each of these specialists have experience and skills that function best in roles that cover portions of the full process, yet each claims to encompass the whole of design activity. Balancing across the perspectives on design from the point of view of practitioners, innovators, and technologists presents a rich structure of relationships that can encourage innovation that results in more useful products.

Design in technology intense development projects

Designing is concerned with change (Jones, 1970). Change can take the shape of technological innovation in order to provide practitioners with some notion of 'more' or 'better' support to interact with the world. Crucial to the question of 'better' is the point of view—does the point of the designers on 'better' correspond to the point of view of those who will interact with the new designs in the future. Participatory design techniques have been developed over the past three decades to involve practitioners as designers into the stages of defining what constitutes a desirable future as a target (Ehn, 1989).

Understanding the relationships between practitioners, technology, and the world has been the mission of work studies from the late 1960s on. Regardless of particular approach, one finding concerns the long term effect of innovations—the reverberations of change introduced by novelty usually are quite unexpected and diverge considerably from original design intent.

Technological innovation may lead to improvements on some aspects of work, but in a larger sense, leads to transformations in the way people engage in tasks, what tasks they perform and what they try to accomplish, as they adapt to and modify new technology (Carroll and Campbell, 1988).

Much of the discussion that accompanies investment on potential technological interventions is characterized by overconfidence in that technology will handle any new complexity encountered in the world (Roesler et al, 2001; Feltovich et al., 2004). While expecting performance and output measures to improve significantly, the usual expectation is that forms of problem solving by practitioners in analysis, fault management, control, coordination, and replanning remain unchanged (Woods and Dekker, 2000). The introduction of new technology, however will alter the world of practice, and may well have introduced new complexities (Winograd and Flores, 1986). Technological change may do more or less than was expected prior its release into the field of work.

According to Alexander's analysis of the role of design in traditional environments (Alexander, 1964 and 1976), broader fields of technology demand a wider spectrum of specialists, and will re-define design work. Software designers, interaction designers, and information architects have entered the arena of the classic design fields to respond to the new complexities and freedoms provided by computerized systems. Technology intense design work can only be conducted with the support of specialists from the engineering fields. Designers trained outside technology programs may be pushed out or relegated to the periphery of technology intense development projects.

As a result, development centered on what is needed to utilize or realize technological possibilities increase the danger of not addressing the practitioner's position in the future operational setting. At one level, practitioners usually have little choice in regard to which designed artifacts to utilize, but in other ways they modify, work around or even reject the artifacts provided to them when these poorly fit the demands of practice (e.g., Cook and Woods, 1996 for a case of technology change in the operating room). Practitioners are not just users. The gap between hopes of design intent and reality of actual impact in context becomes apparent as claims for new technology ignore the research findings of the field of Cognitive Systems Engineering on how people cope with complexity.

The key for our purposes, is that advocates for new technology become trapped in a narrow range of possible expressions in regard to how novelty will play out, as they are unable to cast the effects of unconventional possibilities into the future (Feltovich et al., 2004). In part this occurs because standard prescriptive approaches to technology development models minimize or ignore the creative stages in design where the design space is explored, possibilities are envisioned, and promising directions are scouted. On the hand, design perspectives that include the creative steps that generate promising directions tend to mystify the process or treat it as a unique capability reserved to those with special aptitude (for a counter example of a model of the search for what is promising see Perkins, 2001).

The de:cycle as an integrative model of coordinated design expertise

Design activity, to be able to respond to the challenges provided by the call for novelty, needs to seek for an organizational structure that coordinates experts at three core stages in design—observe, explore, create—to provide linkage points between traditionally divergent areas of innovation—between the separated pools of research patterns, technological possibilities, and experience in the field. We propose the de:cycle as an integrative model. Three design roles provide their perspectives, associated processes and artifacts in regard to the future under design: practitioner—how they adapt to complexity, innovator—how they envision what would be useful, and technologist—how they bring the anticipated change into the world of practice. Three design stages intersect, and design activity within them is conducted in parallel—which provides for numerous interactions across the de:cycle's center where the future of the design is located.

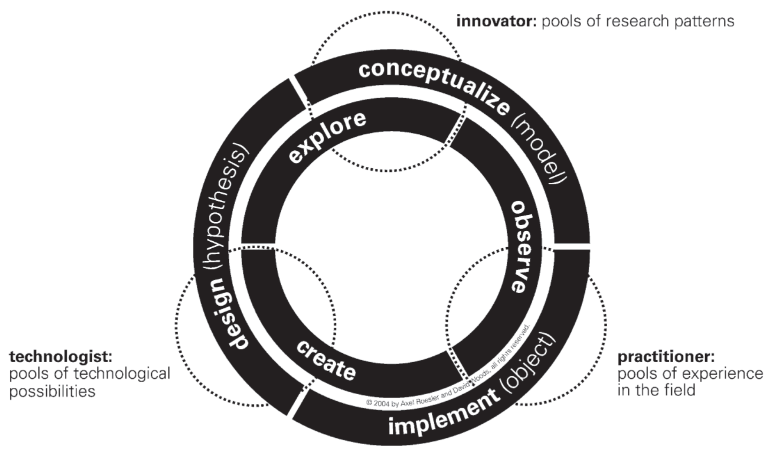

Figure 1: The de:cycle–The three roles in design and their respective interests and expertise in a cycle of analysis and synthesis. Alternating between counterclockwise rotation which moves design toward object creation and clockwise rotation which captures design intent stimulates broadening in the search for what will prove useful.

One perspective within the de:cycle is that of the practitioner who will eventually integrate envisioned technology with the real pressures and demands in the field of practice. The human centered perspective in design reminds us that technology provided by design is a shared representation or a negotiation across practitioners, innovators, and technologists. Such a design provides the appropriate kind of functionality as it reflects demands and capabilities in the world and it takes into account the skills, knowledge, and expertise of those who work with the provided technology. It represents the utilization of the full scope of possible change. The new design adapts to the context of a world that has previously existed and is now changed by innovation (Winograd and Flores, 1986).

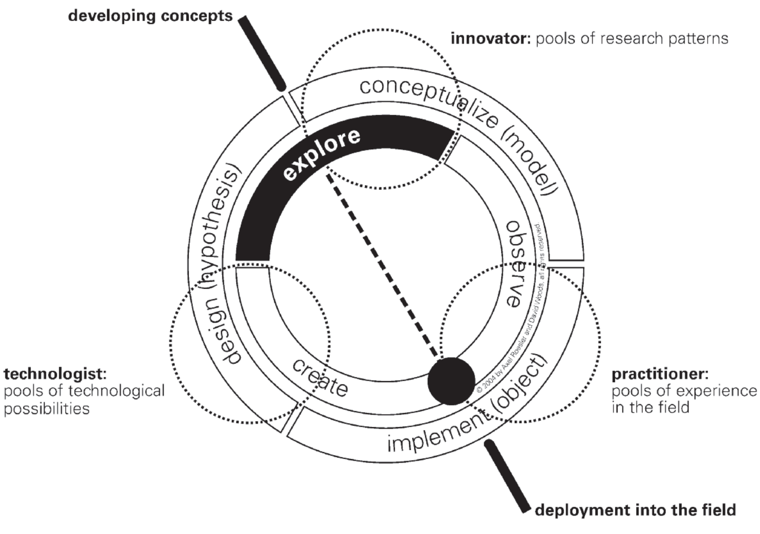

Figure 2: Human centered design: Designers develop concepts focusing on the potential effects of design change for practitioners in the field

Envisioning the future of cognitive work

Designing formulates hypotheses about change. Its basis rests on insights about the situation at hand, and its realization depends on the provision of means to bring the anticipated change about (Jones, 1970). Designers start with envisioning the future in making assumptions, estimates, and claims about the effects of various approaches to change. To be grounded in the specifics of the situation under design, the claims need to be in correspondence to an abstract model that represents how the situation under design works and sometimes does not work well, and how it is anticipated to react to changes made within it. Oversimplifications at the foundation of claims and assumptions are a design necessity and may sometimes turn out as designer-error. They can be found in the stories that are told to represent the design-to-be realized to others. Developers, for example prefer to tell god's eye view stories of their designs in best-case scenarios. Practitioners, in contrast, refer to expected performance based on their experience with past systems from an in-scene point of view—a perspective that cannot access all options provided, since the entire performance range of the new system is partially obscured.

Woods and Dekker (2000) have identified four classes of oversimplifications that pose the envisioned world problem: plurality, underspecification, ungroundedness, and miscalibration. In order to avoid and recover from oversimplification fellacies, designers need to have access to corresponding resources in order to verify assumptions about the nature of practice (Feltovich et al., 2004). Design across the full cycle of innovation requires integration of designing as analysis where designers move from concrete to generalized cases, and designing as synthesis where generalized insight gets channeled back into a concrete world. Covering the entire process of understanding and intervention, designing is the progressive definition of intent. Intent states the opportunity for action to successfully respond to challenges identified through insight study of the situations in the world. Insight about the essential nature of the situation under design lies at the core.

A series of techniques, carried out in the appropriate contexts, form a tentative design process, although the term process is problematic since design may have no beginning or end (Hoffmann et al., 2004).

Stage 1: Observations made at the intersection of past implementation and future conceptualizations

Innovators as design researchers plan observational studies, collect data records from protocols, cognitive task analyses, and other process tracing techniques.

Functional decomposition in the analysis of observations leads to an abstract model of conditions and relationships behind the observed concrete situations and allows designers to recognize patterns, provide explanations, and propose alternative scenarios.

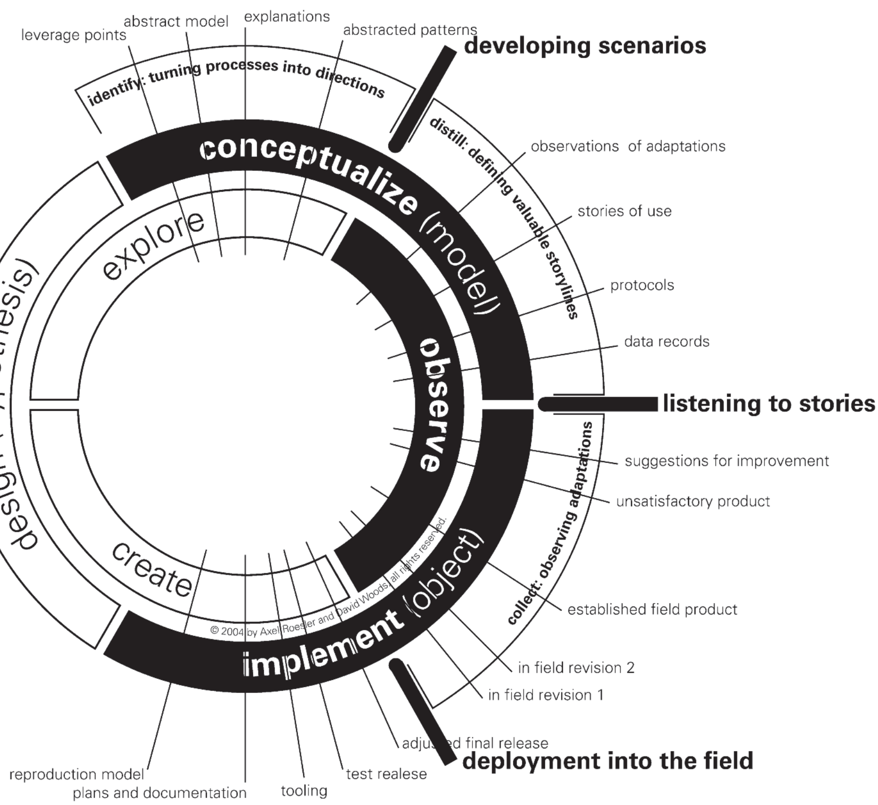

Figure 3: Practitioners tell stories about the realities of past designs in their field of work. Innovators as researchers trace the effects of past innovation with respect to how practitioners adapted to change.

Stage 2: Explorations at the intersection between conceptualizations about the future and the building of hypotheses about what would be useful

Innovators as ideation designers, synthesize between insight and possibility in the envisioning stage of designing – the Northwest Passage in the de:cycle. They are proficient in interpreting formulated insight into design seeds—concepts that capture and reveal promising directions. They are trained in an established set of generation and selection techniques to turn promising concepts into committed design responses. Their focus is in mediating between field studies and technological capacity to expand the possibilities for change.

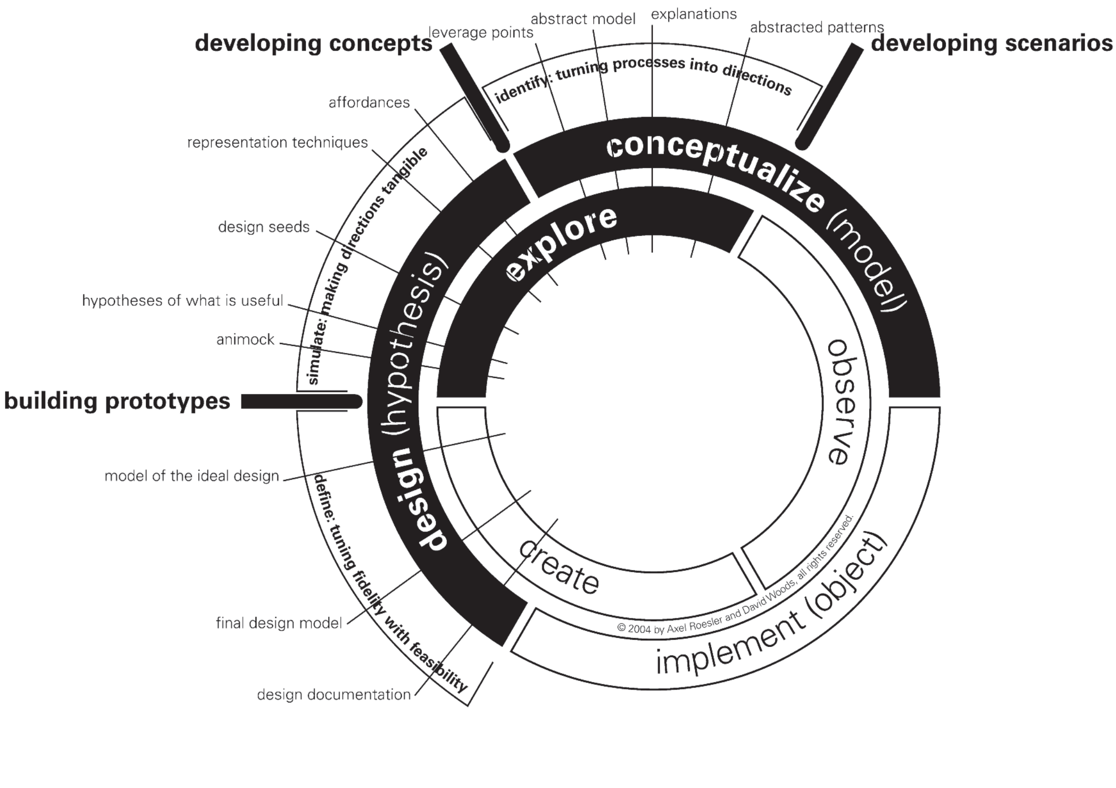

Figure 4: The Northwest Passage of design. Design exploration generates hypotheses about what would be useful though the methods and markers for this passage are thought erroneously to be purely personal and highly idiosyncratic.

Stage 3: Creating objects at the intersection of formulating hypotheses and implementation

Having to translate conceptual design directions into working realities, technologists choose from a pool of available technologies those that are appropriate for the design task at hand. The appropriateness of applied technologies is evaluated against factors of functionality, reliability, feasibility, safety, and economic feasibility–and how necessary modifications will reflect on the original design program.

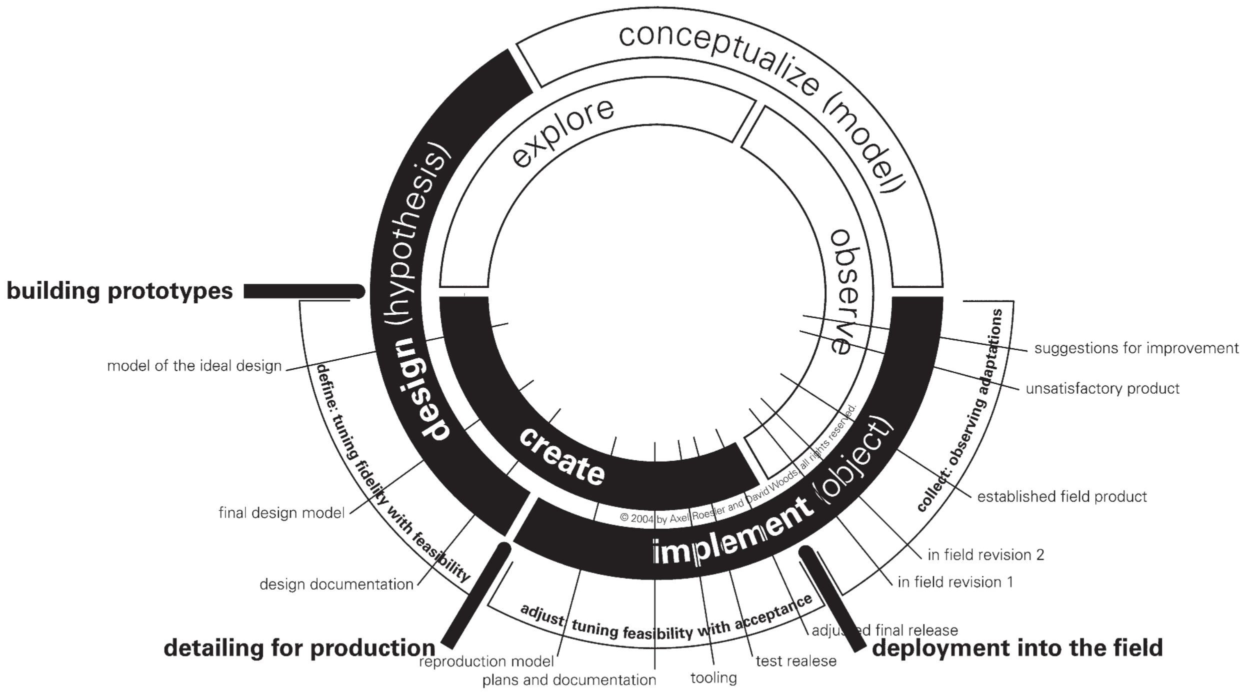

Figure 5: The implementation passage of the de:cycle as prototypes are detailed to create field-able objects.

Coordinating the various roles in the design process requires a shared understanding between all participants. Collaboration between the various facets of design skill also occurs through handover procedures where knowledge collected by one group can be communicated to the neighboring ones. Researchers, innovators, technologists, and practitioners work differently, and it is of little merit to force them into one cultural template. Differences are necessary, provide opportunities, and emphasize the need for a means of exchange at the intersection of different expertise.

Handover products take the shape of specific knowledge representations and mark deadlines. Examining and tracing these artifacts allow tracing the flow and structure of designing. The handover marks in the de:cycle are points of overlap across roles and represent points of closure for one design function and the increasing role of another design function. The choice of labels for the handover marks reference different landmarks in design process along the circumference of the de:cycle:

- Listening to stories is the handover mark between observing adaptations as collecting and defining valuable storylines and processes of distilling essential patterns.
- Developing scenarios at the intersection of turning identified patterns into promising directions.
- Developing concepts is a transfer to the envisioning stage, or Northwest Passage of design, which makes promising directions tangible.
- Building prototypes opens the stage for design definition, or the activity of tuning fidelity with feasibility.
- Detailing for production marks the transition to an adjustment process where feasibility gets tuned with acceptance.

Deployment into the field marks the release of the design and begins the process of adaptation through use which then are observed and collected in field studies of the design in operation, and stories of use provide the material for the handover mark at the beginning of this list—the de:cycle reaches back on itself.

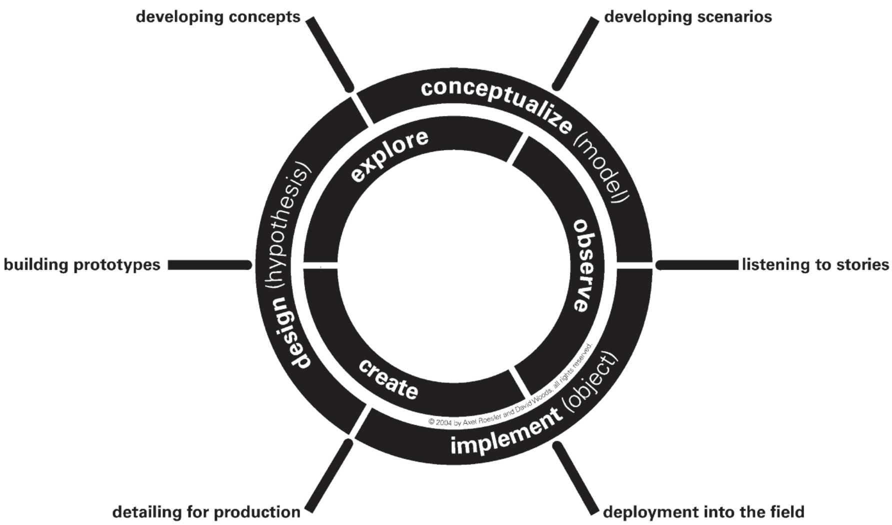

Figure 6: Handover marks in the de:cycle mark transition points between several specialized design stages

Artifacts created through design activity

The functional roles captured in the de:cycle can be seen through the artifacts that are created and shared as part of that aspect of design activity. As Figure 7 shows, there are many and regular forms of design artifacts produced in 2/3rds of the de:cycle. To the northeast, researchers, as they listen to stories of adaptation, use, and failure in the field of practice and as they abstract patterns from these studies, produce systematic artifacts that mark the methods used and results obtained.

To the south, processes associated with creating fieldable objects are well documented to achieve goals of reliable and reproducible systems. However, the Northwest Passage is the most intangible sequence in designing. Fewer, more informal, and more idiosyncratic artifacts accompany design through the envisioning stage.

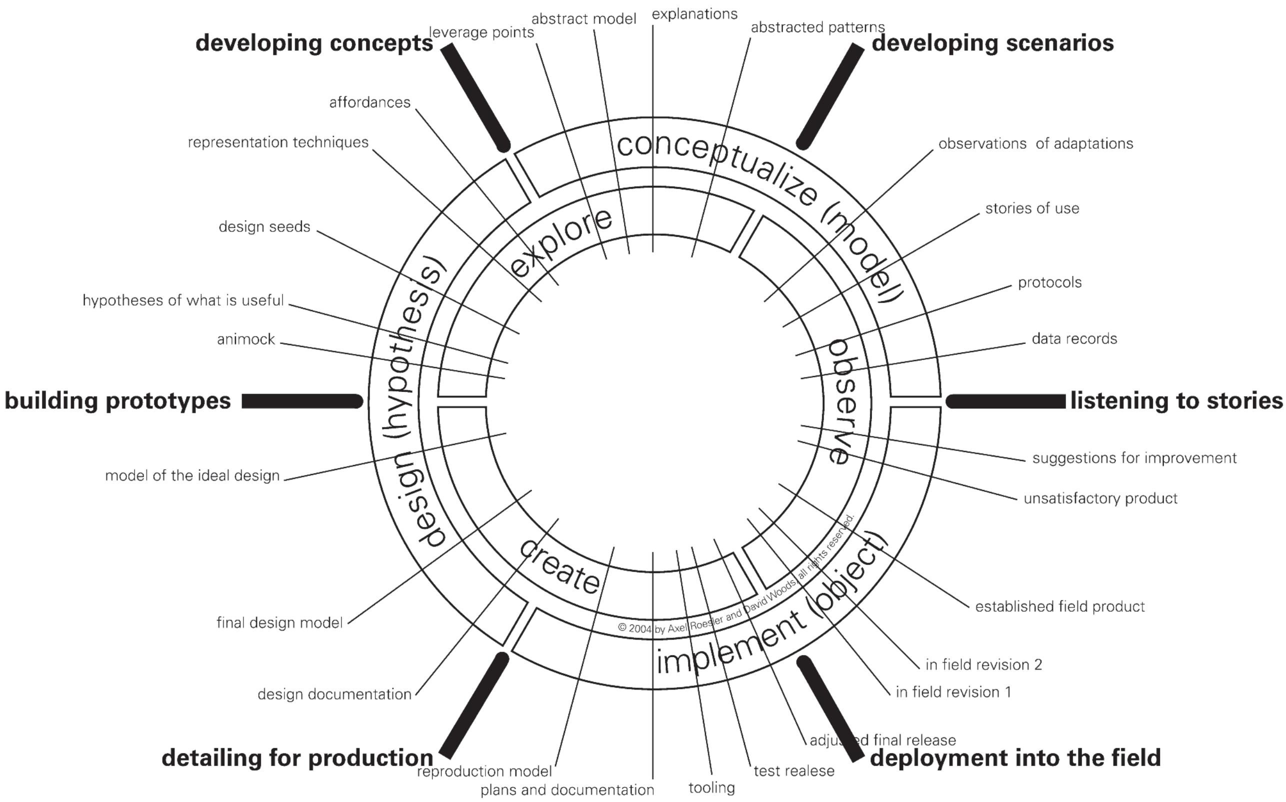

Figure 7: Handover products and artifacts created during design mark the design process

The Northwest Passage

To the northeast in the de:cycle, researchers listen in various ways to stories of practice and trace processes of adaptation as fields of practice change over new demands and new resources. At the north pole of the de:cycle, insight about the situation under design is formulated and structured to explain observed behaviors (Woods and Christoffersen, 2002). The result is an abstract model that represents the innovator's understanding of the essential character of the field of practice (Woods, 2003). This functional model generalizing situated observations into more universal patterns is a necessary step to build a research base that can be relevant across similar design situations. The de:cycle itself is an example for an abstract model that represents the activity of designing.

From the abstract model, a structured set of alternative scenarios samples the difficulties, challenges, and demands of a field of practice. This forms the basis for creating authentic scenarios from which innovators are able to make claims about the future. Developing scenarios marks the begin of an exploration into the uncharted terrain of the Northwest Passage.

The Northwest Passage of the de:cycle is located across from the point at which the designed product is deployed into the field of practice (Figure 8). Between the most abstract and concrete representation of design intent/designed objects, the Northwest Passage spans the formative, discovery sequences in designing—the mysterious area in which ideas are born.

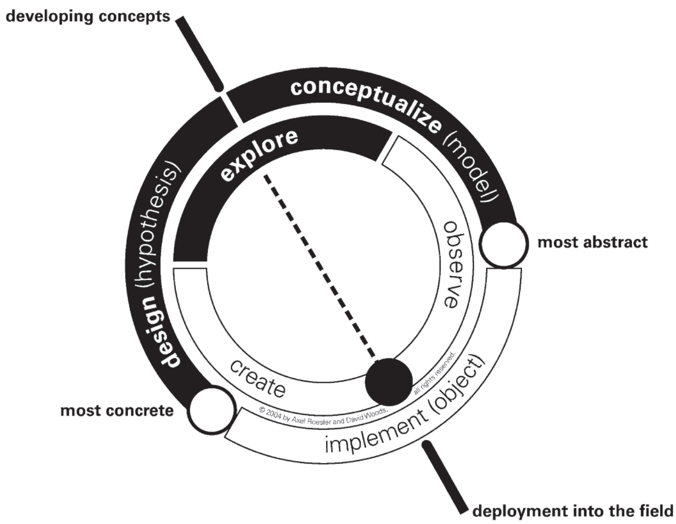

Figure 8: The Northwest Passage as the movement between abstract and concrete.

The Northwest Passage is the search for leverage points in the field of practice. Leverage points indicate opportunities where changes in the fabric of the field of practice can be triggers for progressive adaptive cycles. Identifying affordances lays out a program for design. The term affordance goes back to James J. Gibson (Gibson, 1979) as a label for the relationship between people and their environment. Affordances are engagement opportunities that are provided by the dynamics and structure of the physical world that surrounds us. Hypotheses of what will be useful are represented as design seeds that begin to define promising directions and designs-to-come. They are commitments towards design directions that mark the transition where analytical activity in design turns toward synthesis to transform insight into action.

A variety of design hypotheses get formulated, some necessarily contrasting with others. In this passage, effectiveness is judged by developing many possibilities—broadening (Perkins, 2001). The possibilities and seeds define views of the future that have the status of tentative hypotheses. As such it is critical to remain open to revision and subject these hypotheses to empirical jeopardy in the face of feedback about actual patterns of change and adaptation (Woods and Dekker, 2000; Roesler et al., 2001).

To support divergent thinking, prognoses about the future design are playfully set loose in envisioning situations that instantiate stories of the future of operations and allow many stakeholders in that future to provide input to enrich the storyline. For example, one study created realistic artifacts of future incidents as a game board and invited multiple representatives from the field of practice to play out their future roles and expectations in concert. The struggles to do so and the disconnects between roles provided the key information and feedback about design concepts as hypotheses about what is useful in distributed cognitive work in general and in this domain in particular (Dekker and Woods, 1999).

As in this sample study, storytelling provides the framework to share and develop simulated futures as a synthesis across diverse perspectives. For many years, designers have used static images and physical models in various degrees of detail. While their mock-ups and rough concept sketches invite modification, designers tell stories about the future of operations around theses artifacts (storyboarding). With the capabilities of current computerized design tools, new design representations can support exploring and observing design concepts in time and space. One such technique is the animock or animated mock-up that uses techniques for narrative and that re-represents research findings as general story lines to create a digital visual narrative for sharing and revising stories of the future (Roesler et al., 2001).

Balancing the roles in designing

The de:cycle provides a series of relationships that help to achieve a dynamic balance across the different perspectives held by experts in the three roles in designing. Coordinating the various roles in the design process requires a shared understanding between all participants about what designing entails. In the Northwest Passage tension over hypotheses about what would be useful are resolved based on claims and evidence with respect to the potential impact on the nature of practice (Fig. 9).

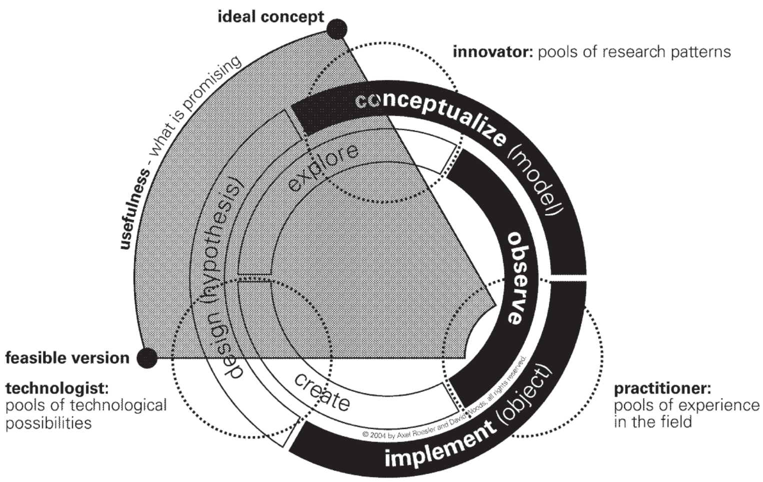

Figure 9: Usefulness as the relationship between technologist and innovator relative to the practitioner's perspective.

Usability is concerned with the passage from prototype to fieldable object based on assumptions about the validity of the insights about the essential nature of practice (Fig.10). Enhancing the usability of technology provided to practitioners by technologists helps complete this passage within the cycle. With respect to the technologist this passage requires a realistic design program that can be implemented. From the practitioner's perspective, usable artifacts fit into the details of the situations they experience.

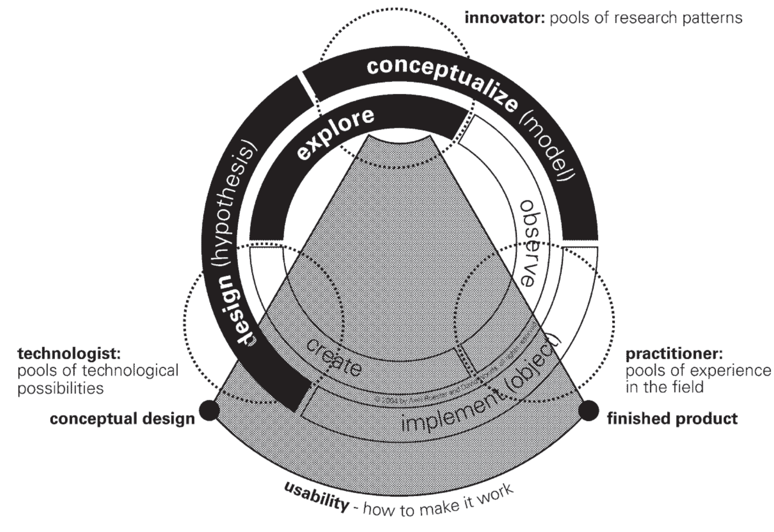

Figure 10: Usability as the relationship between practitioner and technologist relative to the innovator's perspective.

Understanding and modeling practice examines the impact of the introduction of new artifacts into ongoing fields of practice. Understanding is established in the relationship between innovators and practitioners (Fig. 11) and provides a basis for the discovery of promising possibilities.

Design projects are typically conducted as iterations on the bases of previously existing concepts. These iterations occur within each of the three passages. However as for all iterative processes they run the risk of premature narrowing or closure (Woods, 1998). The de:cycle illustrates how broadening can occur by interconnecting the processes in each with reference to the third pool of experience. Innovation rests not so much on the creative individual or team leader as stated in conventional accounts, rather innovation results from building collaboration connections across specialists with core skills in these three roles to link understanding from studies of practice, with hypotheses about what could be useful, with the technological possibilities and powers for realizing new fieldable artifacts.

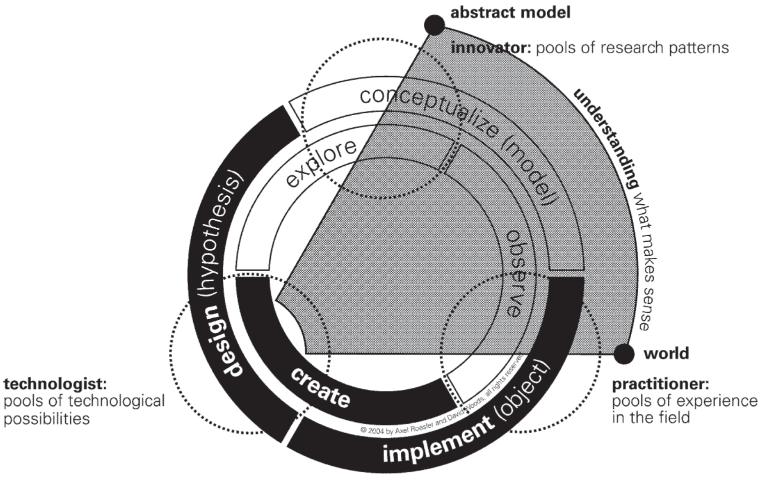

Figure 11: Understanding as the relationship between practitioner and innovator relative to the technologist's perspective.

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