Resolving Wicked Problems In Information Systems Design

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ABSTRACT:
Wicked problems are subjective, interrelated and have no stopping rule. In a group that spans organizational boundaries, the resolution of wicked problems is especially problematic, as participants share minimal domain-knowledge. This paper discusses alternatives to current models of collaborative problem-solving, organizational innovation, and IS design, to understand how we may manage the processes of information system design in such conditions. A multilevel framework and an interrupted convergence model of design are presented, that focus on what elements drive design at various levels and how these elements interact and are mediated by boundary objects. The model suggests a new approach to boundary-spanning innovation that examines how interactions between levels of collaborative understanding reframe the negotiated order of design.

Introduction

In complex organizational settings, the problem of defining business requirements for organizational information systems (IS) requires input from stakeholders who belong to many different divisions, work-units and communities of practice. Sharing local knowledge across organizational boundaries is a complex problem that is not easy to negotiate. Many organizations now employ stakeholder participation in IS design, where managers from affected work-units co-design the required changes to business processes and IT systems. We lack good models to guide this type of design process. Collaboration often turns into political game-playing, as participants try to make sense of sparse and incomplete knowledge of how the organization works. This paper discusses why and how current models of problem-solving and design are inadequate, then presents an alternative model of boundary-spanning collaboration.

Design is closely related to organizational problem-solving (Schön, 1983; Simon, 1996). The assumption that problems may be clearly understood and defined in the context of IS design is a misapprehension. Curtis et al. (1988) quote a system engineer, from an empirical study of a large development team:

" Writing code isn't the problem, understanding the problem is the problem." *(Curtis et al., 1988, page 1271).*

This becomes especially relevant when design is viewed as IS support for emergent knowledge processes. It is nearly impossible to predict in advance who will participate in the design process and which tools they will use. Relevant knowledge is distributed, integrating both general expertise and local, contextual knowledge. So the design process itself is emergent (Markus, Majchrzak and Gasser, 2002). We cannot define goals and change-requirements early in the process, as we can with well-defined technical design. This challenge was addressed by Rittel (1972), who argues that organizational IS design problems are *wicked* problems, that involve the management of complexity and the negotiation of uncertainty. A wicked problem has the following characteristics (Rittel and Webber, 1973):

1. It is unique.
2. It has no definitive formulation or boundary.
3. There are no tests of solution correctness, as there are only 'better' or 'worse' solutions.
4. There are many, often incompatible potential solutions.
5. The problem is interrelated with many other problems: it can be seen as a symptom of another problem and its solution will formulate further problems.

Rittel resolves the collaborative nature of design by viewing design as *argumentation*, which he sees as "a counterplay of raising issues and dealing with them, which in turn raises new issues and so on" (Rittel, 1972). This may be contrasted with Simon's (1973) view of design as the resolution of "ill-structured" problems. A critical feature of the wicked problem perspective is that *each design problem is viewed as unique.* There is no objective structure to the problem: solutions cannot be analyzed, only subjectively interpreted. Simon, on the other hand, views design as a rational process, within the constraints of human cognitive limitations. The analyst achieves a satisficing solution by first bounding the problem-situation, then analyzing structures that are *properties of the situation*, guided by consensus goals (Simon, 1973, 1996) . Design from Simon's perspective is a gap-analysis, matching potential solutions to objective problem-structures defined at the start of the process, as shown in Figure 1.

Figure 1: IS Design as The Solution of Ill-Structured Problems

The implications of a goal-driven process are overlooked when formulating design methods. By applying a decompositional, goal-driven model of design to IS definition (as we do in software project management by pre-defining milestones and deliverables), we assume that Simon's

individual model of cognition is extensible to group or distributed collaboration. The notion that planned and predictable goals drive problem-solving and design has been questioned. Studies in the cognitive science literature focus on problem-solving, design and innovation processes as static, discrete tasks, performed by individuals or small groups who are isolated from organizational and occupational contingencies. This leads to inappropriate generalizations and models for real-world innovation (Drazin, Glynn and Kazanjian, 1999; Suchman, 1987). Goals are often a **post hoc** rationalization for action (Suchman, 1987; Weick, 1995). Goals do not drive design. Rather, they justify and legitimate design decisions after the event.

Research Question: **If goals are not the main driver for design, what elements of a design process drive an emergent model of collaborative, boundary-spanning design?**

An Emergent Model of IS Design

Early studies of IS design focused on relatively well-defined tasks, viewing design as the technology-specification stage of a linear systems development life-cycle. This led to methods that supported a rational, structured and plannable process which could be managed using hierarchical decomposition strategies (Ball and Ormerod, 1995). More recent studies have taken an integrative view, similar to that adopted in architecture or product design. Design from this perspective starts when a problem-situation is first identified and terminates with the implementation of an acceptable solution. IS design is more opportunistic than rational (Guindon, 1990). It proceeds as a process of convergence between a mental "space" of candidate problem-elements and a mental "space" of candidate solution elements (Maclean, Bellotti and Schum, 1993; Turner, 1987). Design is a cyclical process of learning about a situation, then planning short-term, **partial** goals (Suchman, 1987). Both design problems and partial, ill-defined design-goals **emerge** as partial solutions are explored in the context of how the problem is currently perceived (Schön, 1983; Suchman, 1987; Turner, 1987). The nature of the emerging "problem" becomes more complex and unbounded as the individual gains a better understanding of the organizational situation (Boland, Tenkasi and Te'eni, 1994). The critical task is differentiating between significant and insignificant knowledge (Turner, 1987).

In experimental studies of software designers, the designer's representation of the design problem and the way in which they structure the software solution appear to **co-evolve**, until these merge to provide a target system design. The focus of attention appears to alternate between individual's problem-space, the individual's mental representation of all relevant elements of the design problem, and solution-space, the individual's mental representation of the space of possibilities for a design solution (Dorst and Cross, 2001; Maher and Poon, 1996). Definitions of the potential problem- and solution-spaces emerge through interactions with the **context of inquiry**, which includes other design participants, stakeholders and users, as well as artifacts, documents, norms, goals and local practices (Boland et al., 1994; Dorst and Cross, 2001). This produces "surprising" information (Drazin et al., 1999), that leads to the reframing of the design problem in unpredictable ways, very different from the decompositional model of design (Markus et al., 2002).

A synthesized model is presented in Figure 2. The "gap analysis" in this model is very different from the gap analysis of Figure 1. On the "down" arrow, partial solutions known to the design participant are tested for their fit with the perceived design problem. On the "up" arrow, the problem is reframed in the participant's mind, to fit with new evidence or with a paucity of partial solutions (Malhotra, Thomas, Carroll and Miller, 1980). In the traditional model of design, a once-only gap analysis determines the solution and the tasks required to achieve a pre-defined set of goals (Simon, 1973). For the convergence model of Figure 2, the gap analysis is a continual process of evaluation, that assesses the fit between change goals and the process task-requirements indicated by the predicted solution-space, at any point in time. As problem- and solution-spaces emerge in tandem, change-goals and design-process-tasks are refined and redefined (Dorst and Cross, 2001; Maher and Poon, 1996).
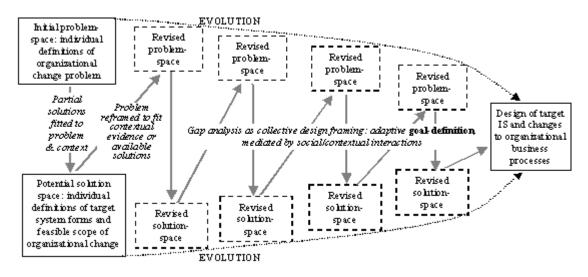

Figure 3: A Synthesis of the Design Process as Convergence Between Problem Space and Solution Space

Proposition 1: Design is a process of continual convergence between three emergent, intrasubjective "spaces", that form a design frame: the problem-space, the solution-space and a process-space that contains change goals and the process-tasks required to achieve these. All three spaces, including the process-space are defined and redefined adaptively, through social and contextual interactions.

Individuals inhabit distinct "social worlds", that "provide the contextual conditions for action and its immediate meaning" (Strauss, 1983, p. 159). Interactions between the social worlds that individuals inhabit create a synthesis of problem and solution definitions. So a collaborative process model must provide the means for incorporating and negotiating a diverse set of problem-frames and solution-frames. There are problems of granularity in integrating diverse organizational worldviews and models held by stakeholders from different work-units and communities of practice, that can only be resolved by adopting a multi-level analysis (Drazin et al., 1999). This discussion adopts the three levels of analysis proposed by Drazin et al. (1999), which accord with the individual, group and organization levels of analysis commonly used in

the IS and organizational studies literature – for example (Curtis et al., 1988), but which are operationalized to examine collaboration from the perspective of sensemaking (Weick, 1995):

1. The intrasubjective level: the development of individual, cognitive sensemaking frames;
2. The intersubjective level: the construction of shared meaning within communities of practice at an implicit level;
3. The collective level: the negotiated order among differing communities of practice.

Design At The Individual Level

Most IS-relevant structures are human constructs, imposed on the situation by adopting specific points of view (Markus et al., 2002). People dynamically interpret the meaning of experiences, events, actions, and consequences by reference to an intrasubjective (in-the-head) map of how the world works (Drazin et al., 1999; Weick, 1995). Such maps may be referred to as "frames" (Goffman, 1974). Different frames of reference lead to individuals adopting distinct definitions of a relevant problem-space and solution-space. Frames derive from prior experience, such as the individual's disciplinary background, and their experience within specific communities of practice (Goffman, 1974; Lave and Wenger, 1991; Orlikowski and Gash, 1994). Experienced designers appear to circumvent the limitations imposed by goal-oriented design methods by adopting a contingency approach to problem solving. Observational studies show that expert IS designers appear to be *opportunistic* in their use of contextual information to structure a design problem (Guindon, 1990; Urquhart, 2001). They extrapolate solutions from similar problems that they have encountered, incorporating implicit knowledge and implied requirements into the framing of new solutions (Dorst and Cross, 2001; Malhotra et al., 1980; Urquhart, 2001).

Thus the designer is not acting as a *decision-maker* (as in Simon's rational planning model), but as a "*conversation-maker*" (Boland et al., 1994). "Conversations with the situation" are performed through reflective action and through interaction with other stakeholders in the design (Schön, 1983). The processes lead to refinement of the frames of reference by which the individual makes sense of the organization. A designer will not understand the organization in the same way at the end of the design process, as they did at the start of the design. Individuals' frames are also adapted through interactions with technology artifacts such as information systems (Winograd and Flores, 1986) and through participation in interactive work-practices (Suchman, 1987). Organizational knowledge is shared through participation in shared work-practices and organizational forms, rather than being understood through articulation (Weick, 1995) . We only explicitly understand the meaning of shared artifacts and practices when we experience a *breakdown*, during which an artifact, work-process, or organizational role does not function in the manner expected. We are then forced to reexamine the nature of the non-functioning element and to redefine its relationship to what we do, or to redefine our work-practices in relation to that element (Winograd and Flores, 1986) . We learn about design spaces through breakdowns that occur when we try – and fail – to fit our model of the organization to new evidence emerging from design inquiry. Breakdowns are by nature

unrealized and implicit (Guindon, 1990; Malhotra et al., 1980) . A design approach that utilizes breakdowns must provide a way of making these apparent to the designer.

In studies of designer problem-solving and of analyst-client interactions, a lack of fit between stated and implicit requirements appear to cause breakdowns in the design process. First the designer attempts to assemble a solution from previously encountered partial solutions, then they call on colleagues for solutions to elements that they cannot solve from their own experience (Malhotra et al., 1980; Urquhart, 2001). Design goals are often partial and assumptional - they are uncovered only when the user states a new system requirement which conflicts with the designer's implicit model of requirements. Malhotra et al. concluded that problem and solution-framing were interrelated: problems and solutions converge towards completeness. ***If there are no available solutions to the problem as defined, the problem may be reframed to fit available solutions***(Malhotra et al., 1980; Turner, 1987). During this process, inconsistencies between current solution-requirements and emerging details of the problem are exposed (Malhotra et al., 1980; Schön, 1983; Walz, Elam and Curtis, 1993). This process is illustrated in Figure 3.
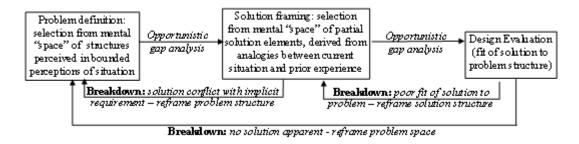

Figure 4: Individual Breakdowns In Convergence Between Problem and Solution "Spaces"

Proposition 2: At the individual (intrasubjective) level, design progress occurs through breakdowns in matching partial solution-spaces available to the individual with the generically-subjective (consensus) problem-space. A breakdown leads to problem-space or solution-space reframing.

Design At The Intersubjective Level

We have little evidence about how intersubjective (cognitively-shared) design proceeds. Most empirical studies of IS design are experimental or involve talking-aloud protocols for solving relatively well-defined problems. These fail to account for the interactions of collaborative design inquiry (Curtis et al., 1988; Walz et al., 1993). In a rare observational study, Walz et al. (1993) concluded that their design group appeared to have no common understanding of requirements, even when the requirements specification was frozen for system implementation. New knowledge was constantly acquired, reframed and integrated into a shared model, throughout the project lifecycle. So this study may support a design emergence model such as that shown in Figure 3. Davidson (2002), studying collaboration in system

development, found that the use of group metaphors shifted the discussion into different framing-domains that provided a unifying way of viewing the design problem. The adoption of specific framing domains appeared to be ad hoc, driven by the contingencies of inquiry. Analogical reasoning appears to be critical. MacKenzie and Wajcman (1985) argue that exemplars form expectations of a design and that these may constrain innovation by driving design in a certain direction. For example, refrigerators only hum because everyone ***knows*** that refrigerators hum and so designers do not think to innovate. Exemplars derive not only from technical artifacts, but also from shared experience of work-processes, organizational routines and structures. Through shared practice, we create and re-create meaning within the organizational "world" (Strauss, 1983; Weick, 1995). Shared experience creates intersubjective domain knowledge – also considered a critical success factor in design. A study of the extent to which IS development team members shared a mental model of the design emphasized the importance of common prior domain knowledge. Teams with members who had similar prior experience designed and implemented their system in a significantly shorter timeframe. The authors concluded that sharing and integrating diverse domain knowledge is a critical design activity (Espinosa, Kraut, Slaughter, Lerch, Herbsleb and Mockus, 2002).

Drazin et al. (1999) observe that organizational problem-solving and innovation appear to be driven by periodic crises. This accords with Gersick's (1988) view of group collaboration as interrupted equilibrium. Relatively calm, coordinated episodes of collaborative design activity are punctuated by short, disruptive periods of crisis and revolution – a collective breakdown, leading to problem reframing. Such crises may shift the negotiated order to favor the perspectives of those capable of resolving the crisis. Crises may result from events that were manipulated to resolve a power struggle, or from meanings attributed to external contingencies (Drazin et al., 1999). Newman and Robey (1992) view punctuated equilibrium as a progression of phases, separated by discontinuities during which group goals and activities are realigned, while Gersick (1988) proposes that group problem-solving and design is punctuated by a disruption only at the midpoint. Sarker and Sahay (2003) found evidence for a two-phase punctuated equilibrium model in only some of the virtual teams that they studied, but it is possible that these teams were too short-lived, or not provided with sufficient triggers for a disruption or breakdown in their problem-solving collaboration. Chang et al. argue that these apparent discrepancies between findings may stem from the multiple levels at which group framing operates. Developments that affect surface levels of understanding lead to incremental group process changes, while developments that affect deep understanding lead to revolutionary changes in how the group works on their tasks over time (Chang, Bordia and Duck, 2003). We need to examine events leading to disruptive changes in deep-level, collective understanding to understand how groups may operate through punctuated equilibrium.

Proposition 3: At the shared (intersubjective) level, design progress takes place through breakdowns in agreement around joint exemplars and metaphors, that provide a structure around which both the problem and the solution can be understood. The breakdown leads to rapid redefinition of a new problem-structure analogy (metaphor or exemplar).

Design At The Collective Level

Group coordination is critical in achieving design consensus and progress. Stakeholders must collaborate to assemble a disparate set of partial understandings of how the organization works to transfer local knowledge across domain boundaries (Carlile, 2004). In boundary-spanning collaboration, collective knowledge is not so much shared between people as distributed across, or "stretched over" these individuals (Star, 1989). Consensus is difficult across multiple communities of practice, with differing domain knowledge. Subordination of individual views to a systemic view ensures a coherent design. Individuals subordinate when they trust other group members to work towards a common good, to provide needed information, and to make decisions based on the needs of the system (Crowston and Kammerer, 1998). Subordination is achieved through employing design representations that ensure a common view of the design domain. Such models produce a coherent worldview that group members espouse to external stakeholders. But deriving a shared vision of the design requires a consensus model of the problem situation. Darke (1979), in a study of architectural design, observed that the form of a design appeared to be driven by a "primary generator" – an overarching concept that provided an exemplar for the form and function of the designed artifact. For example, one of her groups agreed early on that the design would follow a "ranch house" concept. This enabled them to coordinate design activity without checking to see if they were designing compatible elements. Again, analogical reasoning appears significant, but at an "architectural" level. What is being modeled is not the solution (as in defining system requirements), but a problem-structure that allows group members to make sense of new information. Much organizational knowledge is contained in shared procedures, work-practices, and genres of communication. This knowledge cannot be shared easily between communities (Lave and Wenger, 1991). So consensus design proceeds through argumentation and negotiation around a high-level problem-structure, rather than through the decomposition of shared solution-goals.

Breakdowns appear to be critical in driving a collective design forward. But this level of breakdown occurs between the design group and external stakeholders. Reframing appears to be triggered when shared problem-definitions are challenged by external evidence or constraints imposed by influential decision-makers (Gasson, 1999). The management of external perceptions of the design process, particularly those of the informal network of influential managers who sponsor or constrain the design initiative -- is a critical element in success.

Proposition 4: At the collective level, the main driver for design is a high-level, exemplar problem-structure – a "primary generator" that provides a structure for the design as a whole. Design progress takes place through *collective* breakdowns, that occur when evidence, framing perspectives, or constraints presented by external stakeholders conflict with the group model of design.

Synthesis: Design, Sensemaking, and Levels of Analysis

The research question that drove this discussion was **:*If goals are not the main driver for design, what elements of a design process drive an emergent model of collaborative, boundary-spanning design?***

The research propositions emphasized the emergent, interactional nature of design at three levels of analysis: individual, intersubjectively-shared, and consensus-distributed. To test these propositions, we need to understand how the various elements of collaborative design proceed and interact, in an organizational or simulated group setting. Wicked problems are not amenable to structuring or even definition. It is therefore not possible to simulate a wicked problem context in an experimental study. From the literature on collaborative design, problem-solving and innovation discussed above, I present the framework shown in Table 1, to summarize the various elements that drive design.

Level of analysis	Process enablers	Process drivers	Typical artifacts used to manage process	Processes used to manage inquiry and learning	Artifacts used to test fit with other levels of understanding
Individual	Prior experience of knowledge domain.	*Individual breakdown:* Conflict between implicit understanding and articulated solution requirements.	Design specs, written process definitions and models, and lists of issues or requirements.	Interactions with the problem-context and with design stakeholders.	Diagrammatic models that communicate relationships between elements of design solution or problem space.
Shared	Use of *detailed* design exemplars and metaphors to mediate shared understanding. Common prior experience.	*Group breakdown:* Conflict between various individual definitions of the three design-spaces (problem, solution, and process).	High-level diagrammatic models that communicate relationships between elements of design solution or problem space.	Debate and argumentation. Group interactions with external stakeholders enable additions to 3 design-spaces..	Written requirements specifications force breakdowns at individual level. Project (process) planning forces a breakdown at the collective level.
Consensus (distributed)	*High-level* design exemplars provide a unifying framework for the designed solution form and function.	*Collective breakdown:* Conflict between individual and collective definitions of the three design-spaces.	Shared artifacts that provide a group transactive memory. E.G. formal process specs, detailed models, or project plans.	Obtaining approval and buy-in from influential stakeholders may enable the process but constrain collective inquiry.	Consensus specifications and models enable group to obtain buy-in from influential stakeholders, but may also force breakdowns at shared or individual level of design understanding.

Table 1: Collaborative Design Process Elements At Multiple Levels of Analysis

This framework suggests an approach to boundary-spanning innovation that examines how interactions between levels of sensemaking reframe the negotiated order of design. Synthesizing across the three levels of analysis results in the model presented in Figure 4 . In addressing whether a convergence model could be applied to a multi-level analysis of the design process, the answer appears to be that it depends … The degree of convergence appears to differ, depending on whether problem- and solution-spaces are analyzed at the collective or the individual level. Multiple empirical studies of group-design predict and then fail to find convergence between individuals' problem-spaces and the group solution-space over the course of a project. The model of Figure 4 turns this expectation on its head, suggesting instead that there is limited convergence between the shared (group) problem-space and individual, partial solution spaces over time. This model is supported by empirical findings that there is not

space here to discuss. When a degree of convergence has been achieved that enables the group to achieve a sufficiently shared understanding of common change-goals, the group adopts a subordination strategy (Crowston and Kammerer, 1998) that enables them to divide the labor of specifying a detailed design solution. Design proceeds through a recurrent pattern of consensus, followed by a breakdown in shared understanding, leading to a new consensus, and so on. A breakdown is terminated by the appearance of a new group problem-structure, that encapsulates an enhanced way of thinking about the structure of the design problem.
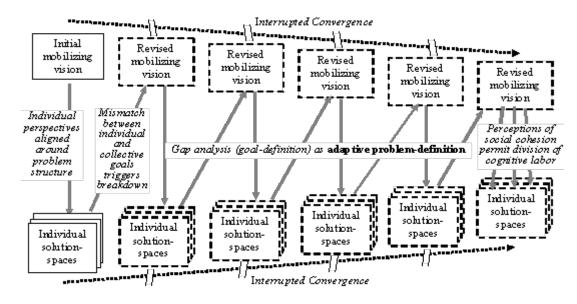

Figure 5: Interrupted Convergence Between Group Problem Space and Individual Solution Space

Implications And Limitations

The framework and the alternative model of design proposed here have significant implications for research and for practice. Existing models are inappropriate for cross-functional IS design that spans organizational boundaries, as these are focused on software design, rather than systems design. But we need more observational research studies of situated design, to refine or refute the model presented here. There are limitations to the interrupted convergence model. This discussion has focused on high-level, business-oriented design – this process is appropriate for the resolution of wicked problems in the design of organizational IS. It is not appropriate for the development of technology, where the problem-structure is already well-defined, as existing (decompositional) goal-driven design approaches are adequate in these circumstances.

By applying a wicked problem view of the design context (Rittel, 1972), we have a process model that is driven by collective problem-definitions, rather than solution-goals. The current view of design as boundedly-rational problem-solving (Simon, 1973, 1996) is replaced by a view of design as interrupted, evolutionary problem-definition. It should be emphasized that the

interrupted convergence model in Figure 4 does not represent a punctuated equilibrium model of group activity in the form described by Gersick (1988) , where a midpoint transition in consensus caused a revolution in an otherwise stable process. Instead, it represents an interrupted linear progression model, similar to that suggested for other types of innovation process by Newman and Robey (1992) or Chang et al. (2003) . But there is also a limited convergence between the problem-space (of situational elements and structures considered relevant to the design), and the solution-space (of available change-elements considered significant for problem-fit). This appears to be managed through periodically adapting the process-space (of goals and tasks salient to achieving design consensus).

For this model to be of use in managing the design process, we need to recognize how to bring about the conditions for collective breakdown. This occurs when there is conflict between individual solution-spaces and collective definitions of the problem-space. When the group needs to publish a document detailing their joint solution, this exposes individual differences that cause them to redefine their joint problem definition. By searching for suitable high-level design exemplars to represent these problem definitions, we may bring about a revolution in group understanding. As collective breakdowns needs to take place periodically for the design to progress, we might operationalize the model through a spiral process model with iterations driven by an evaluation of how far the system design satisfies a revised, detailed organizational problem-definition. With current design methods, the problem-statement remains implicit and unstated, which fails to provide the conditions for collective breakdown. New methods are required, that focus on making visible the complex problem structures that underlie consensus.

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