STOPPING RULES FROM A MULTILEVEL PERSPECTIVE OF IS DESIGN

Susan Gasson, College of Information Science and Technology, Drexel University
email: sgasson@cis.drexel.edu

Traditionally, design is viewed as conforming to Simon's (1960; 1973; 1981) model of problem-solving, in which intelligence about the problem is gathered, alternatives are evaluated, and a solution is chosen and acted upon. But the persistence of this model of the design process imposes serious constraints on how we manage design. These constraints are discussed here, to understand how we may manage design more effectively if we view it as a multi-layered process.

Design As Goal-Directed Problem-Solving

Simon's (1960; 1973; 1981) model views design as goal-directed, individual problem-solving, in the sense that the designer aims to achieve solution-goals that are well-defined at the start of the process (Checkland and Holwell, 1998). Individuals structure a mental model of the problem-situation, to provide sub-goals that guide the decomposition and exploration of various problem-elements (Simon, 1981; Vera and Simon, 1993). Yet empirical studies of designers do not demonstrate such guided behavior. Organizational design goals and the structures associated with complex organizational problems and solutions appear highly subjective and subject to negotiation, rather than analysis, especially in situations, that require knowledge integration across multiple organizational groups (Checkland and Holwell, 1998; Markus et al., 2002; Walz et al., 1993). Organizational problems may be categorized as "wicked problems" (Rittel, 1972; Rittel and Webber, 1973). These are complex, interrelated, and subjective, with no definable solution rules. Problem boundary and definition are jointly constructed and negotiated, through argumentation between design participants and through an increasing familiarity with the design context (Rittel, 1972). Goals emerge through the *process* of design. The critical problem of design becomes one of distinguishing the significant from the insignificant (Turner, 1987).

Goal emergence can be seen in empirical studies of experienced software engineers. Rather than analyzing design problems according to a set of predetermined goals, designers appear to pursue a variety of sub-goals that emerge through the process of design. Such strategies have been described as "opportunistic", as they do not appear to follow a guided, decompositional strategy (Guindon, 1990; Khushalani et al., 1994). But such strategies may be considered exploratory, rather than opportunistic. Experienced designers extrapolate solutions from similar problems that they have encountered previously, incorporating implicit knowledge and implied requirements into the framing of new solutions (Curtis et al., 1988; Malhotra et al., 1980; Walz et al., 1993). If there are no available solutions to the problem as defined, *the problem may be reframed to fit available solutions* (Malhotra et al., 1980; Urquhart, 2001). A software 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 (Dorst and Cross, 2001; Maher and Poon, 1996). Thus, design appears to be driven by improvisation, indicating contingent, situated action (Suchman, 1987). The salient question becomes one of how we determine a "stopping rule" for this process of convergence between the problem-space and the solution-space. In the traditional model, the stopping-point is determined by the satisfaction of predetermined goals. If both solution *and* problem are redefined through the process of design exploration, how do we know when to stop? My own studies indicate that a critical part of group design is how we provide a group "mirror" in which an individual's understanding of design problems and solutions may be reflected and bounced around (critiqued). In my studies, design representations provided inadequate as a group mirror, as these captured only one level of decomposition, while design participants cycled between different levels of abstraction to understand an element of the design problem. I identified multiple decompositional levels that needed to be captured, to record the totality of design discussions: process definition (abstraction), proposed solution, work-exemplar, failure or success rationale, information requirements, work-outputs, process goals, process dependencies, process mechanisms, and responsibility-allocation. A failure to record these elements often lead to the group revisiting the same problems and issues repeatedly. But a formal process of modeling all aspects of the design rationale (Moran and Carroll, 1996) would have been inappropriate, as the design evolved so rapidly and these aspects often changed as the design became better understood. Instead, the group agreed that they could have usefully employed a "drill-down" modeling tool, where various levels of design-elements that had proven contentious could be recorded.

Design As Collaborative Action

Information system design typically takes place in groups, or in interaction with other organizational actors. In managing the design process according to Simon's model of individual cognition, we assume shared understanding, which is far from the reality of collaborative design (Flor and Hutchins, 1991; Walz et al., 1993). Various design participants view the problem from multiple perspectives and worldviews (Checkland and Holwell, 1998). To produce a joint design, the members of a collaborative group must first realize that they define design problems and potential solutions in different, partial and non-congruent ways. This is not always obvious to members of a design group, especially when they derive from different disciplines (knowledge domains). So how does a collaborative group understand a design problem? A study of architectural design suggests that design framing in groups may be driven by the early definition of a "primary generator" concept (Darke, 1979): an *exemplar* for the form that a design will take, that permits designers to articulate goals and requirements for the design, in conversation with others. This would indicate a model for IS design that is very different from that for the goal-directed design of IT systems. In my own studies of the co-design of business and IT systems, I found that the group design process was driven by three levels of exemplar. At the highest level, a very high-level model of the system solution (a six-stage model of the target business-process) guided the process and did not change over the course of the design. At the next level, the design process was guided by a series of "mobilizing visions", that provided a structuring mechanism for analysis of the design problem over several weeks or months, until it proved insufficient to reflect newly-emergent understandings. It was then replaced by a new mobilizing vision, that included some aspects of the previous structure, but also included new aspects. For example, a mobilizing vision that structured the problem around the need for an *Electronic Document Library* was replaced by the mobilizing vision that structured the problem around the concept of a *Virtual Bid-Management Team*. But elements of the electronic library persisted in the way that the virtual team operation was defined. At the next level, group debate cycled between the discussion of suitable exemplars for the design, taken from existing organizational procedures, and solution-abstractions for the new system, based on process-generalizations of multiple exemplars. An increasing pattern of conflicts appeared to indicate that the mobilizing vision was proving inadequate as a way of matching individual solution-spaces to the group problem-space. It was at these points that the mobilizing vision tended to be replaced. This mechanism provided the group "mirror" discussed in the previous section, against which individual understanding was tested. Thus, an interrelated set of exemplars may guide design at different levels.

The distribution of design knowledge across participating actors is uneven, as actors from various knowledge-domains are sensitized to information that is most relevant to their own domain. Understanding within a collaborative group is distributed, or "stretched across" a set of individuals (Star, 1988). Collective understanding may be mediated by "boundary objects", such as maps and diagrammatic models, (Star, 1989). Boundary objects are incomplete, as they have to be sufficiently vague to represent different things to different people. External representations, such as design models, often contain a shared understanding that is not possessed individually by the people who produced them (Hutchins, 1991; Weick and Roberts, 1993). So the resulting knowledge is nomothetic (reduced and generalizable), rather than ideographic (specific to an individual knowledge-domain and context). Because of this, design representations do not provide a good basis for judging when the design is complete. Much of the design knowledge required to make this judgment is in the heads of individuals. Thus, we have the collective stopping-rule problem: how does a design group determine that the design is complete, when knowledge about the design is distributed between individuals and design artifacts? In my own studies, I have encountered some clues to the "stopping rule" problem at a group level. It would appear that the group determines that the design is complete when three conditions are met: (i) that the design problem can be sufficiently well-defined that its constituent sub-problem areas can be bounded, delineated and assigned to a specific group member, (ii) that individual group members are confident that they have a complete solution for a specific sub-problem, and (iii) that group members trust that they share a similar worldview to the extent that they can trust other group members to resolve a sub-problem area without further input from the group. When all three conditions are met, this appears to permit the cognitive division of labor necessary for the design to be considered complete. In this sense, the group "stopping rule" appears to be associated with the establishment of the design group as a coherent community of professional practice (Lave and Wenger, 1991).

Design As Contextually-Situated Action

Simon's (1973) description of bounded rationality views the design process as one of cognitively structuring and then decomposing a design-problem, to obtain solution requirements. But in Simon's description of this process, the structure pertains to the problem, not to the analyst. Yet, as Weick (2004) argues, a designer is thrown into a situation that is full of pre-existing interpretations of the problem and its context. Information system design project groups constitute a technology-centered community of practice, that coexists with other organizational groups, each of which has different and often competing worldviews (Brown and Duguid, 1994). Through the discourse and practices that constitute work, communities of practice create and improvise their local reality (Suchman, 1998). To uncover these interpretations – their own and those of others -- experienced designers engage in a process of *argumentation*, with users, stakeholders and each other (Rittel, 1972), or with "the situation" (Boland and Tenkasi, 1995; Weick, 2004). Wicked problems are interrelated, subjective and have no stopping-rule (Rittel, 1972). Thus, a critical part of the design process must be to bound and define an appropriate problem, from an organizational perspective. This involves negotiation across a much wider set of stakeholders than from the group perspective. Additionally, the definition of a consensus point at which the design can be considered complete also involves political negotiation, as the problem-definition emerges through the process of design (Weick, 2004). Thus, we have an "organizational" stopping-rule to add to the individual and group stopping rules discussed above. In my own studies, I found that organizational consensus depended more on the management of expectations, than upon complex political negotiation. A critical issue of design is how emergent problem-structures and their consequent design-goals are communicated to influential stakeholders. To frequent a change in design goals and the senior management perception is that the design is out of control. Too infrequent a communication and senior management definitions of the design problem are dissonant with the design group. The trick appeared to lie in communicating problem-structures, rather than solutions (the mobilizing visions discussed above). When design objectives were communicated in this way, a new problem-structure could be presented as a more developed vision. But when new solutions were presented, senior management perceived these as out of alignment with the previous problem-structure. Their stopping-rule appeared to be when the group could argue that all elements of the initial solution-structure (the primary generator) had been covered.

Synthesis: A MultiLayered Model of Design

This paper has discussed how IS design operates at multiple levels, in complex organizational design environments. This type of design can be viewed as operating at multiple levels, which are summarized in Table 1.

Table 1. Research Framework for Study of Social Cognition in Boundary-Spanning Design.

Level	**Simon's Process Construct**	**Replacement Process Construct**	**Critical Research Questions**
Individual Problem-Solving	Goal-directed problem structuring and decomposition	Emergent co-evolution of problem and solution spaces	How to identify and define emergent design goals. Individual stopping rule – appears to be when individual understanding of solution for parts of design that are understood align with group mobilizing vision (emergent problem-structure).
Group	Shared cognition, equivalent to individual problem-solving	Distributed cognition	How collaborative design may be guided and coordinated through an interrelated set of exemplars that operate at different levels. Collective stopping rule – appears to be when three conditions are met that permit cognitive division of labor.
Organizational context	Problem-structures are inherent in the situation	Problems are interrelated, subjective & socially-constructed through interaction.	How to determine and a agree a consensus boundary and content for the problem. Organizational stopping rule – appears to be when senior management convinced that original high-level solution elements are explained by a coherent problem-structure.

The key issue in this discussion is the interrelationship between the three levels. Three different types of design "vision" were identified: (i) the high-level model of the system solution that provided a unifying primary generator for the group, (ii) the series of mobilizing visions, that provided a temporary, unifying problem-structure against which individuals could test their detailed understanding of the solution, (iii) the generation of consensus design through the use of existing organizational procedures as exemplars for partial solution-abstractions and the aggregation of these abstractions into sub-problem areas that could be assigned to individual group-members for detailed resolution. The stopping rules appear to be related to the various levels of design exemplar and also appear to depend on the coherency of problem-definitions, in conditions of organizational complexity. This is in contrast to Simon's model of design, where the stopping-rule is indicated by the satisfaction of pre-determined design goals.

References

Boland, R., J, and Tenkasi, R., V, "Perspective Making and Perspective Taking in Communities of Knowing," *Organization Science* (6:4) 1995, pp 350-372.

Brown, J.S., and Duguid, P. "Borderline issues: Social and material aspects of design," *Human-Computer Interaction* (9:1) 1994, pp 3-36.

Checkland, P., and Holwell, S. *Information, Systems and Information Systems: Making Sense of the Field* John Wiley & Sons, Chichester UK, 1998.

Curtis, B., Krasner, H., and Iscoe, N. "A Field Study Of The Software Design Process For Large Systems," *Communications of the ACM Nov 1988* (31:11) 1988, pp 1268-1287.

Darke, J. "The Primary Generator And The Design Process," *Design Studies* (1:1) 1979, pp Reprinted in N. Cross [Ed.] Developments In Design Methodology, 1984, J. Wiley & Sons Chichester, pp. 1175-1188.

Dorst, C.H., and Cross, N.G. "Creativity in the design process: co-evolution of problem–solution," *Design Studies* (22:5) 2001, pp 425-437.
Flor, N.V., and Hutchins, E.L. "Analyzing distributed cognition in software teams: a case study of team programming during perfective software maintenance," Empirical Studies of Programmers - Fourth Workshop Norwood NJ: Ablex, 1991, pp. 36-59.
Guindon, R. "Designing the design process: Exploiting opportunistic thoughts," *Human-Computer Interaction* (5) 1990, pp 305-344.
Hutchins, E. "The Social Organization of Distributed Cognition," in: *Perspectives on Socially Shared Cognition*, L.B. Resnick, J.M. Levine and S.D. Teasley (eds.), American Psychological Association., Washington DC, 1991.
Khushalani, A., Smith, R., and Howard, S. "What Happens When Designers Don't Play By The Rules: Towards a Model of Opportunistic Behaviour In Design," *Australian Journal of Information Systems* (1:2), May 1994 1994, pp 13-31.
Lave, J., and Wenger, E. *Situated Learning: Legitimate Peripheral Participation* Cambridge University Press, Cambridge UK, 1991.
Maher, M.L., and Poon, J. "Modelling design exploration as co-evolution," *Microcomputers in Civil Engineering* (11:3) 1996, pp 195-210.
Malhotra, A., Thomas, J., Carroll, J., and Miller, L. "Cognitive Processes In Design," *International Journal of Man-Machine Studies* (12) 1980, pp 119-140.
Markus, M.L., Majchrzak, A., and Gasser, L. "A Design Theory For Systems That Support Emergent Knowledge Processes," *MIS Quarterly* (26:3) 2002, pp 179-212.
Moran, T.P., and Carroll, J.M. "Overview of Design Rationale," in: *Design Rationale: Concepts Techniques and Use,* T.P. Moran and J.M. Carroll (eds.), Lawrence Erlbaum Associates, Mahwah NJ, 1996.
Rittel, H.W.J. "Second Generation Design Methods," Reprinted in N. Cross (ed.), *Developments in Design Methodology*, J. Wiley & Sons, Chichester, 1984, pp. 317-327., Interview in: Design Methods Group 5th Anniversary Report, DMG Occasional Paper, 1, pp. 5-10.
Rittel, H.W.J., and Webber, M.M. "Dilemmas in a General Theory of Planning," *Policy Sciences* (4:155-169) 1973.
Simon, H.A. *The New Science of Management Decision* Harper & Row, New York, NY, 1960.
Simon, H.A. "The Structure of Ill-Structured Problems," *Artificial Intelligence* (4) 1973, pp 145-180.
Simon, H.A. *Sciences of The Artificial,* (Second ed.) MIT Press, Cambridge MA, 1981.
Star, S.L. "The Structure of Ill-Structured Solutions: Boundary Objects and Heterogeneous Distributed Problem Solving," Proceedings of the 8th AAAI Workshop on Distributed Artificial Intelligence, Department of Computer Science, University of Southern California, Reprinted in M. Huhns and L. Gasser (Eds.), Distributed Artificial Intelligence Vol. II, Menlo Park: Morgan Kauffmann, 1989, pp. 37-54., 1988.
Star, S.L. "The Structure of Ill-Structured Solutions: Boundary Objects and Heterogeneous Distributed Problem Solving," in: *Distributed Artificial Intelligence, Vol. II.,* L. Gasser and M.N. Huhns (eds.), Morgan Kaufmann Publishers Inc., San Mateo CA, 1989, pp. pp. 37-54.
Suchman, L. *Plans And Situated Action* Cambridge University Press, Cambridge MA, 1987.
Suchman, L. "Constituting shared workspaces," in: *Cognition and Communication at Work,* Y. Engestrom and D. Middleton (eds.), Cambridge University Press, New York, 1998, p. 350.
Turner, J.A. "Understanding The Elements Of Systems Design," in: *Critical Issues In Information Systems Research,* B. R.J. and H. R.A. (eds.), Wiley, New York, NY, 1987, pp. 97-111.

Urquhart, C. "Analysts and clients in organisational contexts: a conversational perspective," *The Journal of Strategic Information Systems 10* (3:243-262.) 2001.
Vera, A.H., and Simon, H.A. "Situated Action: A Symbolic Interpretation," *Cognitive Science* (17:1) 1993, pp 7-48.
Walz, D., Elam, J., and Curtis, B. "Inside A Design Team: Knowledge Acquisition Sharing and Integration," *Communications of the ACM October 1993* (36:10) 1993, pp 63-77.
Weick, K.E. "Designing For Throwness," in: *Managing as Designing*, R. Boland, J and F. Collopy (eds.), Stanford Uniersity Press, Stanford CA, 2004, pp. 74-78.
Weick, K.E., and Roberts, K.H. "Collective Mind In Organizations: Heedful Interrelating on Flight Decks," *Administrative Science Quarterly* (38) 1993.