Designing for Complex, Interactive Architectural Ecosystems: Developing the Ecological Niche Construction Design Checklist

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Abstract

This paper presents the rationale for and ongoing development of the Design Project Ecological Niche Construction Checklist (DPENCC) [1], a designer's/researcher's checklist for assessing the usefulness of potential environmental design features on cognitive and task performance during the conceptual phase of environmental design. The rationale for developing such a tool stems from a comparative integration of concepts from ecological niche construction [2], systems science [3], embodied cognition theories of mind [4,5], and Kirsh's writings on pragmatic action [6], activity spaces [7], and performance design [8]. The checklist is developed and tested via three case studies that entail designing interactive building environments. This mixed methods case study research is organized and evaluated using the Design Science Research Method [9] and the Validation Square research method [10]. Findings, lessons learned, and next steps are discussed, especially the strengths, weaknesses, and likely preferred use cases for such a method and tool.

This research contributes to the fields of architecture and neuroscience by: (a) developing a designer's method and tool that represents possible impacts on cognition of environmental features during early conceptual design; (b) demonstrating a research framework for specifying, developing, and evaluating a cognitive method and tool; (c) and addressing a significant, emerging set of design challenges. These emerging design challenges entail degrees of complexity and interactivity that make them orders of magnitude more difficult to represent during design than traditional static environmental design challenges.

This research primarily addresses the following aspect of the Conference Mission:
-"...use of insights from neuroscience to develop new approaches to the design of intelligent buildings."

This research addresses the following ANFA BridgeSynapses Conference themes:
- role of action and interaction in the user's experience of buildings;
- learning from animal research: key findings, translational research, research-based architectural applications.

Study Design

This study used Pedersen's Validation Square [10] as an evaluation framework in order to assess usefulness of DPENCC with respect to the purpose of assess the usefulness of potential environmental design features on cognitive and task performance during the conceptual phase of environmental design. Method develop is guided by the Design Science Research Method [9] as described by Peffers et al.

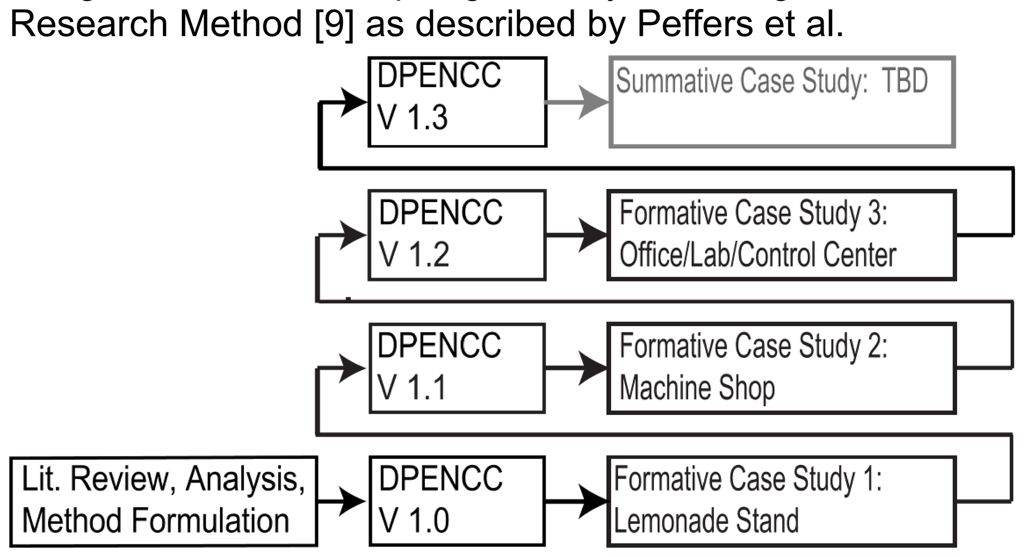

Figure 1: Method development through formative case studies based upon the Design Science Research Method [9].

Rationale & Initial Method Design

"Kirsh's constructs and strategies can be understood through and integrated with the construct of ecological niche construction to arrive at the constructs of physical niche construction, cognitive niche construction, and physical-cognitive-interaction niche construction as key aspects of environmental design and use. Kirsh's strategies and constructs may be interpreted with respect to each of the four tenets of ecological niche construction. First, Kirsh's construct of 'information objects' is subsumed into his constructs of 'passive objects, reactive objects, and active objects' [5]. That is, all things are information systems, or in Kirsh's language, 'information objects'. Second, whereas Kirsh's writings are human-centric, application of his ideas must be expanded to encompass all cognizing agents that use and participate in our computationally augmented environments, including software agents, robots, and other forms of perception and intelligence that act within the environment. Third, Kirsh's 'performance design' and 'activity space' constructs can be interpreted in light of the ecological niche construction constructs of ecosystem engineering, modification of selection pressures, ecological inheritance, and adaptation. [6] Doing so increases the power and usefulness of these constructs, especially if the aspects of ecological niche construction are split out into the following: the physical aspect, the cognitive aspect, the physical-cognitive-interaction aspect. In this way, designers can frame, plan, and execute their design work in order to design for both physical accommodation of occupants but also the cognitive performance and well-being of occupants (see Design Project Ecological Niche Construction Checklist image below).'[1]

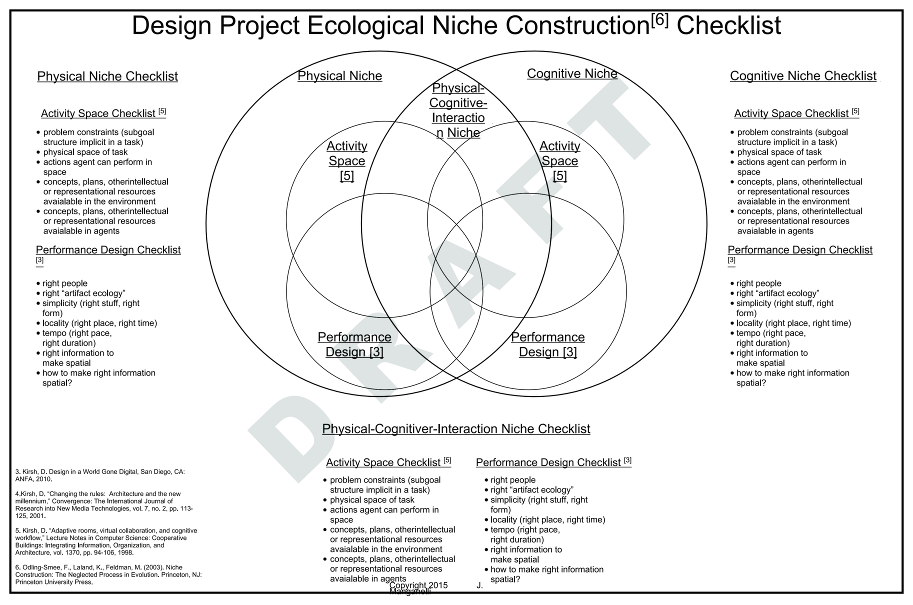

Figure 2: First iteration of the Design Project Ecological Niche Construction Checklist. [1]

Three Case Studies

The three formative case studies used to develop DPENCC incrementally increase in scale and complexity. The three formative case studies are:

Case Study 1: CIAE* Lemonade Stand

Case Study 2: CIAE* Machine Shop

Case Study 3: CIAE* State Healthcare Building

** NOTE: CIAE = complex, interactive architectural ecosystem [1]*

Methods

Each case study was completed in the following manner. First, the case study Owner's Project Requirements were reviewed and initial, traditional design brainstorming occurred. Next, annotated conceptual sketches were generated as a proposed design solution. Third, the DPENCC was used to assess the design concept and consider what modifications may be necessary to accommodate cognitive and physical task activities. Fourth, using the Validation Square [10], use of the DPENCC was evaluated with respect to three questions:

1. What knowledge does use of DPENCC add to an environmental design process?
2. Does this added knowledge seem to be useful? Why?
3. How can DPENCC be made more useful?

Lastly, DPENCC was iteratively revised in response to the question answers and the process was repeated.

Results

DPENCC went through 3 iterations. Figure 3 shows the final conceptual design iteration. Note that this diagram shows human work with technology in specific roles as being fundamentally a network design challenge. This realization shaped the development of DPENCC. Table 1 shows the insights gained from each iteration. Insights were gathered while pilot testing DPENCC and also through reflection on the standard set of questions presented in Table 1. Figure 4 shows the final iteration of DPENCC for this phase of method development. Note that additional information about the context, the role(s) of the agent, and the skills, rules, and knowledge [11] associated with that role are represented, as well as a framework for priortizing the most important roles/tasks to design space/technology usage around.

Office/Lab/Control Center

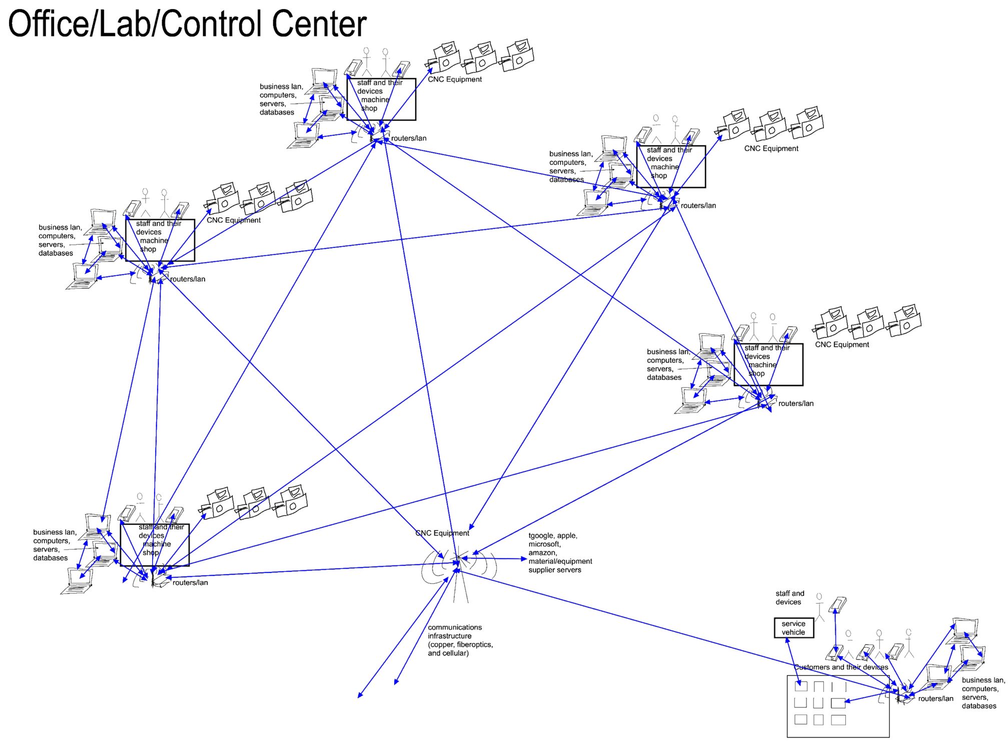

Figure 3: Final case study design diagram.

Questions		Case 2: Machine Shop	Case 3: Office/Lab/Control Center
What knowledge does use of DPENCC add to an environmental design process?	semantic knowledge and associated tasks relate to the physical context of the activities	way to integrate and operationalize SKR knowledge with design processes while also taking a more holistic view of the socio-technical context	mapping roles and tasks and prioritizing roles and tasks in order to find a critical subset of roles and tasks around which to organize the environment
Does this added knowledge seem to be useful? Why?	yes, it is useful as a way to document how a space will actually be used during early conceptual design --- this could be incorporated into the OPR process to help owners be more explicit about what human and machine systems exist and how they relate to space	potentially yes --- if all primary roles are documented and the 'citizenship' of the roles is established without an socio-technical information ecosystem, then humans or other agents can move in and out of these roles and be assured certain functionality	yes, it does seem to be useful for contexts in which the roles and tasks should be relatively stable over time
How can DPENCC be made more useful?	the individual and the social should be represented in the analysis to differentiate between procedural and semantic knowledge and associated tasks that are driven by individual action, social dynamics, or a mix of both	a deeper development of the SKR and roles components and developing a database of roles and SKR's	procedures must be developed to operationalize the idea of developing prioritized lists of roles and tasks to use as the basis for design
Negative case analysis: What is a use case in which it would not be appropriate to use DPENCC?	this approach may be less useful for much larger, more complex systems, because it would be overwhelming to document all activities --- a refined DPENCC and a DPENCC database would be required	roles and/or skr's are not clearly defined or are unknowable	again, using this method if the roles/tasks are not clearly understood would entail additional complications that may require trial and error to address, or perhaps use of a panel of experts (Delphi method)
Optimal case analysis: What is a use case that may be optimal for using DPENCC?	spaces used to perform a standard set of tasks over a long duration by many people, because the usefulness over time would make up for the fact that this is a time-intensive effort up front	an organization that relies on people performing ritualized / routinized behaviors	military, healthcare, education, construction, industrial, and any other context with strong, clearly defined roles and tasks
Method/tool analysis: Are there any methods/tools with which DPENCC would integrate well?	a relational database and a diagramming program and perhaps as an online SaaS tool	need to look into whether there are tools/databases for SKR and roles	there are prioritization methods and algorithms --- i'll have to look into them --- I used to know of one or two but cannot remember anything about it/them now

Table 1: Insights gained from iteratively pilot testing DPENCC.

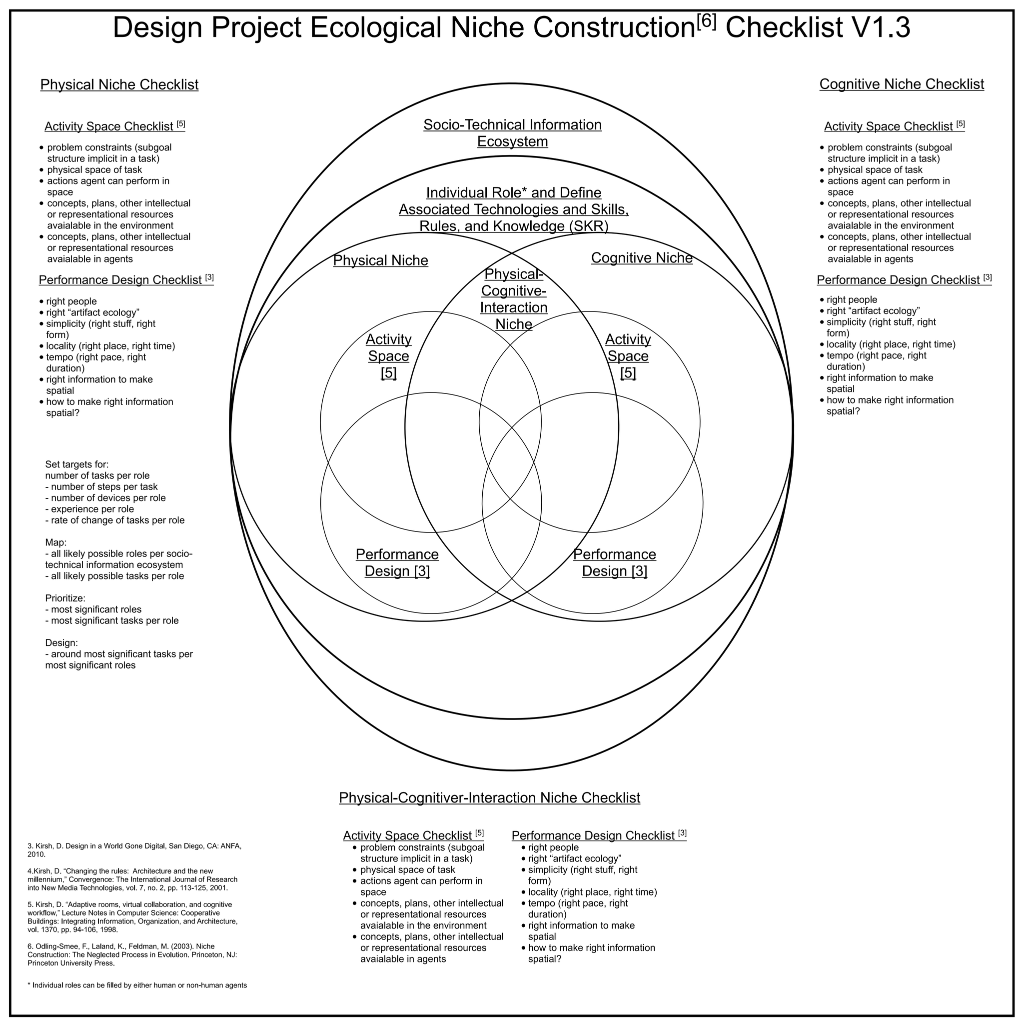

Figure 4: DPENCC V1.3 accounts for the socio-technical information systems context, as well as the roles of agents and the skills, rules, and knowledge used in those roles.

Likely Use Cases

Likely use cases are space programs that house well-defined roles that perform well-defined tasks, including: military, healthcare, some educational environments, and industrial environments. Environments that house poorly understood roles and tasks woulld require additional work in order to implement DPENCC.

Strengths & Weaknesses

The strengths of DPENCC are that it makes visible to the designer the relationships between the space being designed and the roles, tasks, skills, rules, and knowledge required of the agents performing in the space. The weaknesses of DPENCC are that it is labor-intensive and requires adequate access to information abou tthe roles and tasks to be performed in an environment.

Next Steps

The next step is to develop the roles, tasks, skills, rules, and knowledge mapping protocols, and research the prioritization protocols. Then iterate development again and ultimately perform a sumative evaluation.

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