Inquiring Materials for Tangible Prototyping

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ABSTRACT
As TUI research moves from technical to empirical studies which explore theoretical claims, it is important for researchers to be able to quickly and easily build low fidelity (lo-fi) prototypes to explore the unique features of interaction that TUIs offer. Currently, the best practices for choosing prototyping materials are vague at best. In this paper, I present an analysis of the role of materials in inquiry and propose a set of criteria for evaluating the suitability of lo-fi prototyping materials.

Author Keywords
Tangibles, low fidelity prototyping.

INTRODUCTION
The development of interfaces which augment tangible objects with computation is a current and growing theme in the human computer interaction research community. Tangible and physical user interfaces can be constrained to include augmentation of physical objects with computation. Specifically, tangible user interfaces utilize everyday physical objects to control, organize and manipulate digital representations. Similarly, physical computing involves augmentation of everyday physical objects, typically with sensor technology. Tangibles and physical interfaces provide us with ways to leave behind the flatland of personal computers.

However, as Greenberg pointed out in 2002 and others continue to point out, building these systems involves considerable knowledge and skill in electronics, circuits, sensors, camera vision and multimedia programming [5,6,8]. There are only a few available toolkits for constructing high fidelity (hi-fi) prototypes. A literature review revealed little scholarly discussion on low or mixed [9] fidelity prototyping for tangible or physical interfaces (see [1] for an exception). It is no wonder that the field is still immersed in a phase focusing on demonstrations of technical development and creations of descriptive taxonomies. As a result, many of the claims of potential benefits to human interaction of these systems remain unexplored. The investigation of theoretical concepts through empirical studies requires simply and easy to use lo-fi approaches and hi-fi toolkits. This paper presents the first known scholarly discussion of the suitability of *inquiring materials* for lo-fi prototyping of tangible and physical user interfaces. This paper builds on a model of design inquiry through prototyping seen through the lens of interactive or embodied cognition. In this context, I present a set of criteria suitable for the evaluation and selection of prototyping materials.

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PROTOTYPING: THE ROLE OF INQUIRING MATERIALS
Henrik Gedenryd made a well articulated case for "interactive cognition" as model for both action-based cognition in general and design in particular in his Ph.D. dissertation [4]. Interactive cognition is grounded in the pragmatist view of knowledge and built on Dewey's theory of inquiry [3]. It is influenced by the real time planning aspects of Hutchin's description of navigation via distributed cognition [7]. As well, it is influenced by Schön's concepts of design as a conversation with the working materials, and integrated problem setting (specification) and solving (performance) in his account of reflective design practice [11]. The core idea is that cognition is organized to carry out cognitive activities that leverage the mind, action and world, working together. Cognition is not organized around a mind working in isolation. That is, inquiry (e.g., design) is an aggregate process with several component functions, one of which is action and another of which is accessibility to the world through relevant physical materials.

Inquiring action can be categorized as exploration or experimentation. During exploration, designers manipulate some aspect of the world in order to "shake loose" some property that is not readily apparent [4]. Designers use exploration to "evoke what the specifications do not mention, and to make out what consequences follow from them" [4]. Experimentation is a more powerful tool. During experimentation, designers test out their ideas in the world instead of imagining what will happen.

Traditionally, what are viewed as design artifacts are the end products of the design process. These materials have a productive purpose. However, if artifacts are created in the design process not as an end product but instead to serve the purpose of inquiry (as in design research), then these artifacts have an inquiring purpose. Inquiring materials are then working materials with a cognitive purpose. The success of cognition (and design) relies on the presence of those physical materials with which it is concerned. Clark states: "Any given project will often rely on the use of multiple kinds of surrogate situations, each of which highlights or makes available some specific dimension of what Gedenryd calls the future situation of use"[2].

In design research, the goal of inquiring materials is to create opportunities to explore and experiment with theoretical concepts embedded in future situations of use. Surrogate situations are not simply miniature versions of the end product in use. Rather, they are selected to allow us to engage specific, and often quite abstract, aspects of the future situation of use. In early stage tangible research, materials of inquiry can be developed, explored and experimented with in order to better understand if specific theoretical concepts can have an informing role in design. In this way, it is possible to generate knowledge about the utility and importance of these concepts. Materials of inquiry can include just about any physical objects and many researchers suggest using a variety of craft or art supplies. But how to choose? Are some materials better than others are at supporting inquiry?

EVALUATING THE QUALITY OF INQUIRING MATERIALS

In order to be effective for design, inquiring materials must allow the designer to solve a problem by performing actions in the world rather than in the head [4]. That is, inquiring materials must have a cognitive purpose. Materials are created in response to incremental questions that arise during design research. They allow action based inquiry into simplified, approximations of future situations of use.

Gedenryd, based on Rettig, proposes four features of a prototyping medium which make it a good inquiring material for design: workability, relevance, goodness and fun [4,10]. A prototyping medium is *workable* if it can be quickly built and is easy to work with. It facilitates concentration on inquiry, rather than on the realization of features in a prototype. A medium is robust if it is insensitive to technical details. And it can be easily changed. A prototype is *relevant* if it leaves out details that are not important to the inquiring purposes. It is relevant if the focus of the prototype is on essential elements in the inquiry. Rough and unfinished prototypes facilitate focus on the aspects of interest rather than superficial details. *Vertical relevance* is when an inquiring material focuses on one aspect in detail. It serves to provide understanding of a particular aspect of the topic of inquiry. For example, a rough sketch supports experimentation with a specific aspect in detail. *Horizontal relevance* is when an inquiring material focuses on several aspects of interest with little detail. It serves to provide insight, discussion and development of ideas. For example, a thumbnail in sketching supports exploration without detail. *Goodness* refers to the quality of insight gained, discussion allowed, and inquiry supported. Prototypes are concrete materials that allow us to test out our conceptions. Gedenryd reminds us that we enjoy interacting with concrete materials in a physical world. Abstract reasoning during design is not as much *fun* as working with concrete materials.

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CONCLUSION

This paper addressed the need for a scholarly and systematic understanding of the properties of materials that are effective for lo-fi tangible prototyping. A set of criteria based on an understanding of the desirable qualities of materials of inquiry in interactive cognition was described.

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