Eliciting unknown unknowns with prototypes: Introducing prototrials and prototrial-driven cultures

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This paper maps and describes how prototypes are used to elicit requirements of unknown unknowns in industry. Eight engineering design companies serve as a dataset for a multi-case investigation. By semi-quantitatively analysing 19 prototypes in terms of functionality, timing, stakeholder involvement and requirement elicitation, we present a wide spectrum of prototype utilizations. However, this broad span leads to misunderstandings of what the term 'prototype' encompasses, hindering exploitation of its full potential. Hence, we introduce the term 'prototrial' that covers functional prototypes utilized in the early stages of the design process, prototypes that effectively elicit unknown unknowns. With this contribution, we encourage introducing mind-sets and behaviours that aim at exploration and learning rather than lean implementation – a prototrial-driven culture.

Keywords: product design, prototypes, design process, unknown unknowns, product development

In recent research on radical innovation, development prototypes are given a considerable role as tangible rapid learning cycles representing the mind-set necessary when developing innovative solutions (Haines-Gadd et al., 2015; Leifer & Steinert, 2012; Marion & Simpson, 2009). IDEO-founder David Kelley asserts he can tell almost anything about a company's new-product-development (NPD) efforts by simply sampling a few prototypes – from the care of the models to the quality of the thinking of the designers (Schrage, 2006).

Research has described prototypes as objects in a design process with designated characteristics and details (Blackler, 2009; Houde & Hill, 1997; Lim, Stolterman, & Tenenberg, 2008; Sefelin, Tscheligi, & Giller, 2003). These sources are describing the prototypes from the designer's perspective and their active considerations when using and creating the prototype.

However, Elverum and Welo (2014) state that this does not explain how organisations currently utilize prototypes. How does the prototype support the

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existing NPD process and what is characteristic for companies that manage to implement rapid prototyping in the early fuzzy front end and not only use prototypes as physical iterations on already well-understood products?

This paper aims to address these questions by analysing eight case studies conducted in different companies representing very different industries, but all fitting into the classical engineering design process (Ulrich & Eppinger, 2008). With this we provide the community with a much-needed industrial perspective on the process of prototyping. Inspired by Tracey and Hutchinson (2016) focussing on uncertainty in the design solutions space, we utilize the framework of requirement elicitation Sutcliffe and Sawyer (2013) describing *known knowns*, *known unknowns*, *unknown knowns* and *unknown unknowns*. We evaluate the performance of nineteen different prototypes used in the eight companies and ask to what degree the prototypes help the companies elicit the different types of requirements.

In the theoretical section, we describe parameters defined by previous researchers as affecting the outcome and role of prototypes. These cover three overall topics: functionality and timing in the design process, stakeholder involvement and requirement elicitation. Followed is a description of the research methodology and the eight case studies.

The analysis presents the evaluation of the nineteen prototypes from the eight case studies and maps their performance regarding the three theoretical topics.

In the Results section, we answer our stated research questions and introduce the new term *prototrial*. This term covers high-functional prototypes utilized in the very early stages of the concept development process yet having low fidelity when it comes to comparing the prototype with the final product. These are nurtured not only by the designers themselves, but also the companies' attitude towards conscious targeting of *unknown unknowns,* and the degree of freedom accorded the designer's stated task. We define such company cultures as *prototrial-driven* cultures.

Our main contribution is a detailed mapping of the various utilizations of prototypes in engineering industries today. Further a call for a narrowing of this broad usage, starting by introducing *prototrials* and *prototrial-driven* cultures.

1 Theoretical framework

1.1 Prototypes and their functionality

A prototype is an initial model built to test a design idea; it is widely used in engineering design, from simple paper prototypes to foam models that closely resemble the final product (Blackler, 2009; Lim, Pangam, Periyasama, &