Inferential reasoning in design: Relations between material product and specialised disciplinary knowledge

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This study investigated how students use *knowledge in a mechanical engineering design course. The findings suggest that the structural relations that students construct between the designed artefact and the knowledge recruited are more important than just the content knowledge. Using the semantics dimension of Legitimation Code Theory, LCT (Semantics), as the analytical lens, the findings suggests that students need to be able to shift fluently up and down a range of relative abstraction and concretisation, but always rooted in the concrete. In design, when the evaluation often lies in the performance of the artefact, an increase in the technical and functional requirements of the artefact drive the requirement for a more abstract and integrated use of the knowledge recruited.*

Keywords: design knowledge, disciplinary knowledge, logic of design, reasoning

Attempts to characterise the nature of design, and consequently what should be taught and learned in design courses has been a consistent challenge to the design research community. What has generally become evident from this broad ranging, but potentially fragmented research is the complexity of what it means to design (Dorst & van Overveld, 2009). As the design research community grapples with design processes, creativity, design thinking and the skills needed to design, underlying concepts of 'reflective practice' (Schon, 1984) and the notion of 'being' or 'becoming' (see for example Adams, Daly, Mann & Dall'Alba, 2011), have tended to dominate the research. In this collection of papers that analyse design review conversations between students and instructors from a range of perspectives, the general focus is on understanding the nature of reasoning as it is articulated throughout the design process.

The contribution of this paper is a study of the nature of reasoning using specialised disciplinary knowledge to design, specifically the way in which students mobilise disciplinary knowledge to design a material artefact in a simulated professional context. Where many design education researchers propose mimicking authentic practice in order to better develop design skills (see for example Bucciarelli, 2003), sociology of education theorists in the social realist

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tradition (Moore, 2012) after Bernstein (2000) have argued that the context of education sets up particular knowledge and social relations that change or 're-contextualise' the discourse itself. The ambiguity that arises as a result of these conflicting social relations, and implications for assessment are developed in a companion paper to this one, based on the same empirical data (Wolmarans, in press). In this paper, the focus is on the structural relations that students construct as they work with specialised knowledge to design. While social realists have raised the importance of *knowledge* as an object of study, they have tended to focus on abstract generalisable knowledge. Design offers an interesting addition to that research because it requires the specialisation and concretisation of knowledge.

In taking a knowledge perspective on design this paper perhaps represents one extreme, very different than the more constructivist perspective taken by Adams, Forin, Chua, and Radcliffe (2016) at the other. However, there are traces of specialised disciplinary knowledge in the other papers, for example as the basis of deep reasoning (Adams et al., 2016), developing a balance between a "command of technical matters and the norms of practice" and "their own sensibilities" (McDonnell, 2016); and within the evaluative logic of functional originality (Christensen & Ball, 2016). The papers by Dong, Garbuio, and Lovallo (2016) and (Yilmaz & Dally, 2016) in this volume also look at how instructors influence shifts in the nature of reasoning, as cycles of abductive and deductive reasoning in the former and between convergent and divergent reasoning in the latter.

As part of the DTRS10 symposium, this paper draws on the shared data set generated for the symposium (Adams & Siddique, 2015) and develops an aspect of a paper presented at the symposium (Wolmarans, 2014). This study follows three mechanical engineering design teams through their Preliminary Design Review, Critical Design Review and into their Final Design Review and evaluation as they design and build a prototype device. The analysis uses one of the five dimensions of Legitimation Code Theory (LCT), LCT (Semantics) (Maton, 2014), to investigate the way in which students need to work with multiple disciplinary traditions while simultaneously moving between abstract theoretical knowledge and the material context of its application. The findings suggest that some students are less successful than others, not because of the knowledge they use, but because of how they use it.

1 Literature

1.1 Engineering design: science, design and professional skills

For many engineers, design is the defining feature of engineering practice. Even when engineers are not formally design engineers, there is a sense in which they always *design* solutions to practical problems. For this reason