MANAGING INTERDISCIPLINARITY: A DISCUSSION OF THE CONTEXTUAL REVIEW IN DESIGN RESEARCH

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ABSTRACT:

Design issues typically emerge from multifaceted social situations, making design research investigations ones of adequately contextualized application. Where this is the case the review of literature must navigate multiple research fields while also resolving relations between orthodox disciplinary and non-disciplinary sources of knowledge, including those emanating from design's strong vocational foundations. Managing multiple contextual frameworks to arrive at a creative fusion of methods and principles represents a significant practical and intellectual challenge for research students and supervisors. The literature on 'Mode 2' knowledge production in higher education can provide guidance here, describing research that is fundamentally applied, industry-oriented and interdisciplinary. The paper draws on theoretical discussion of the reflexive and situated nature of Mode 2 knowledge production to establish some parameters for the literature review in applied design research, complementing this with three narrative case studies of professional doctorate projects from an Australian university.

Key words: Applied design research; 'Mode 2' knowledge production; interdisciplinarity.

APPLIED RESEARCH AND INTERDISCIPLINARY KNOWLEDGE PRODUCTION

Although the debate about disciplinary status has not interrupted the production of innovative design research, as a relatively recent member of academia's 'tribes and territories' (Becher 1989) design is still establishing its disciplinary characteristics as a general research field and a set of specialist sub-fields. There is, for instance, some debate about whether design scholarship should include creative practice and reflection (for a sample of contrasting positions see Bayazit 2004; Downton 2001; Durling 2002; Roth 1999). Since a majority of design issues originate in everyday life individual design research questions are unlikely to fit specific disciplinary boundaries, the idea that design research definitively engages with multiple fields and literatures being widely acknowledged (Poggenpohl et al 2004). These considerations have contributed to the debate as to whether design research should conform to established models from the sciences and humanities or develop its own integral approaches. We suggest, however, that a greater focus on design's applied nature and inherent interdisciplinarity could profitably overtake the quest for disciplinary clarity.

Buchanan (2001), for example, describes applied design research as a process of induction where general theories and models for the design of a class of products are extrapolated from individual cases. On the other hand, he recognizes that the 'application of fundamental principles' is often unfeasible in design since 'many other factors, governed by other principles, may enter into the class of products or activities' under investigation (Buchanan 2001:18). Even where applied investigations are accepted as valid research activity there is an emerging consensus that industry practice does not in itself qualify as scholarly research (Buchanan 2001; Friedman 2003). Rather, innovation and useable knowledge must be framed within a set of explicit knowledge relations. Thus, a fundamental sign of scholarship in doctoral research is the extent and quality of a student's literature review, though the plurality of fields and disciplines that can converge in applied research projects offers an implicit challenge to students and supervisors.

There is broad recognition that knowledge production in higher education is shifting from traditional disciplinary questions to cross-disciplinary investigations grounded in industry, society and the environment. Gibbons (1994) gives a full account of the movement toward applied and industry oriented forms of knowledge production while Etkowitz (2003) suggests that the 'triple helix' of government-industry-university partnerships will become increasingly important in determining research agendas and funding. Such developments are significant for design, many design research investigations intersecting with larger questions about the nature of communications, consumption, cultures, environments, societies and technologies in the present. However, while border crossing in search of relevant knowledge, methods and theoretical frameworks can be a great strength of applied research it can also be a primary failing, especially for the practice of scholarship.

A basic condition of multimodal research is developing an understanding of the significance of appropriated ideas in the sphere from which they were derived (Lauer 1984). While accepting the danger of fixed definitions that do not correspond to the complexities of current research in higher education, like Gulbrandsen and Langfeldt (2004) we see Griffiths's scaffold of basic distinctions between Mode 1 and Mode 2 knowledge production (Table 1) as a useful heuristic model for framing applied research projects. In particular, it highlights how the dimension of application can make research more complicated while also introducing concrete objectives that direct the research process and validate knowledge.

Mode 1	Mode 2
segregated	Integrated
university based	socially distributed
discipline based	cross disciplinary and trans disciplinary
'pure'	sensitive to context of application
hypothesis led	social accountability and reflexivity
deductive	Messy
concerned with truth and predictability	

Table 1. Mode 1 and Mode 2 Knowledge (Griffiths 2004:718)

Other commentators on Mode 2 knowledge production support this understanding. For example, Boyer's explanation of the scholarship of application (1990), a discussion consistent with that of Mode 2 knowledge production, describes applied scholarship as 'oriented not towards knowledge and understanding for their own sake, but towards the use of knowledge and understanding in addressing conflicts, tackling problems and meeting the needs of client and other groupings' (Griffiths 2004:715). Horlick-Jones and Sime note that in contrast to conventional disciplinary work Mode 2 knowledge production makes 'connections not only across the boundaries between disciplines, but also between scholarly inquiry and the sphere of tacit and experiential knowledges' (2004:445).

Griffiths, however, cautions that it is 'intellectually dubious' to mix 'codified, discipline-based (explicit) knowledge' from outside an applied field with 'intuitive (implicit) knowledge' from within it (2004:716). This can be an issue in applied research projects conducted by students experienced primarily in design practice. Design research methods clearly need to develop in dialogue with the constantly evolving body of industry practices, however, practical command over design thinking can mask the need for reflexive engagement with the nature and application of methods, just as it can make the need for knowledge and approaches from outside design seem

superfluous to the act of problem solving. The same can hold for the need to develop a critical awareness of relations with bodies of extra-disciplinary knowledge that enter the research mix to address the framework of application. A conscious aspiration to transdiciplinarity in applied scholarship as it is conceived in Mode 2 knowledge production (Boyer 1990; Horlick-Jones and Sime 2004) could resolve many of the indeterminate dimensions of applied design research projects, introducing new ways of understanding and legitimating knowledge production in higher degrees in design.

DEFINING TRANSDISCIPLINARITY FOR APPLIED DESIGN RESEARCH

Nissani (1997) notes that resistance to interdisciplinary research and knowledge in higher education has recently shifted to broad interest. Yet ideas of interdisciplinarity often presume stable definitions of the disciplines themselves, an enterprise that Becher (1989) has shown to be both challenging and potentially undecidable. In an emerging academic field such as design, where disciplinarity is still in question and may never be resolved or achieved, an interdisciplinary approach to research questions cannot count on such a stable base. Moreover, the higher education literature contrasts three new categories of research—multidisciplinary, interdisciplinary and transdisciplinary—to conventional disciplinary studies. Each designates a different way of integrating knowledge, methods and outcomes and there is some concern in various fields to clarify their scope and meaning.

Choi and Pak (2006) suggest these categories can be partly distinguished by thinking of multidisciplinary research as additive; interdisciplinary research as interactive, and transdisciplinary research as holistic:

> Multidisciplinary, being the most basic level of involvement, refers to different (hence 'multi') disciplines that are working on a problem in parallel or sequentially, and without challenging their disciplinary boundaries. Interdisciplinary brings about the reciprocal interaction between (hence 'inter') disciplines, necessitating a blurring of disciplinary boundaries, in order to generate new common methodologies, perspectives, knowledge, or even new disciplines. Transdisciplinary involves scientists from different disciplines as well as nonscientists and other stakeholders and, through role release and role expansion, transcends (hence 'trans') the disciplinary boundaries to look at the dynamics of whole systems in a holistic way' (359).

A review by Aboelela et al. (2007) of the discussion on these three modes of inquiry arrives at a similar position while expanding on some of the ideas highlighted above. Other distinctions have been made. Aram (2004), for example, suggests that 'instrumental interdisciplinarity involves bridge building between fields, epistemological interdisciplinarity involves restructuring a former approach to defining a field, and transdisciplinarity seeks a movement toward coherence, unity, and simplicity of knowledge' (382). Instrumental interdisciplinarity is perhaps

that most commonly achieved in current postgraduate design research, since it involves the use of 'ideas or methods of another discipline to enhance problem solving within their home disciplines' (Aram:382).

The literature on interdisciplinarity has less to say about the integration of disciplinary and experiential knowledge, however, in a valuable review of models of 'integrative' landscape research, Tress, Tress and Fry (2004) identify six different forms of synthesis between disciplinary and real world knowledge production, including collaboration between academics and non-academics. They argue only interdisciplinary and transdisciplinary research achieve integration, transdisciplinary research being the most complex in crossing disciplinary and academic boundaries while incorporating non-academic participants to develop an integrated theory on science and society. Tress, Tress and Fry support the contention that policy guidelines and funding bodies increasingly expect interdisciplinary studies to be the norm for research in higher education, their idea that multilateral knowledge will be rapidly fed back into the problem context while encompassing the views of stakeholders in determining research questions and methods extending the nature of Mode 2 knowledge production even beyond the challenge of disciplinary boundary crossing. This view, however, is consistent with the idea of contemporary knowledge as a key economic input *and* output (Usher 2002).

Similarly, the trend for designers to work as members of interdisciplinary and transdisciplinary teams confronts design thinking with other disciplinary perspectives. In fact, design research could model this for industry through applied projects that explore relationships between knowledge and disciplinary 'situatedness', demonstrating how design is constituted through a multiplicity of context-specific iterations rather than universal principles. However, although the inclusion of design researchers in mixed teams of academics and industry experts at work on complex, real world problems is becoming more common, this model may not reflect applied design research in the context of a higher degree. Research conducted through government-industry-university partnerships brings designers into direct contact with other disciplinary knowledge and methods in action. Design research students working on self-determined projects are unlikely to have access to diversely informed supervisors and other experts or even the concrete problem context or relevant user groups, being obliged to address epistemological and methodological diversity in the context of a traditional supervisor-student relationship.

Some scholars see the appropriation of methods and concepts as relatively unproblematic and part of the unique character of design knowledge and thinking. Downton (2003), for example, characterises the designer not just as a bricoleur who employs knowledge from inside and outside the discipline but as one who explicitly 'reshapes these knowledges, discards parts, augments parts and juxtaposes elements on the way to proposing a design' (2003:95). We would argue that design research students and their supervisors need strong awareness and specific strategies for dealing with the range of perspectives that can converge in design research projects. Without this projects risk descent into a state of intellectual scavenging and naïvity while students can easily

become overwhelmed by the extent of relevant views and information. In the following discussion we consider how the management of the contextual review of discipline-based literature and other sources is crucial to candidates' ability to achieve transdisciplinary scholarship.

THE CONTEXTUAL (LITERATURE) REVIEW AS BOUNDARY CROSSING

The term 'boundary crossing' is often used in the context of interdisciplinary and transdisciplinary studies (e.g. Horlick-Jones and Sime 2004; Klein 1996). It is a particularly appropriate image for design, which can be seen as deeply embedded in the social world of human action and interaction while incorporating important technical aspects. Pierce (1999) observes that boundary-crossing interdisciplinary writing is relatively common in some fields, but the challenges of boundary crossing in respect of the practicalities of postgraduate research are rarely treated in sufficient detail. Golde and Gallagher (1999) suggest that conducting interdisciplinary research in traditional doctoral programs involves four challenges for students: finding advisors who are sympathetic and competent; mastering the knowledge and potential conflict between methods; finding an intellectual community sympathetic to such work; and overcoming justified fears about work being recognized. The 'struggle' of becoming competent in multiple disciplines can lead to breadth not depth. Working between 'disciplines means conceptualizing and undertaking research in the absence of proven frameworks and models … [and] often means resolving conflicts between paradigms and methods' (Golde and Gallagher:283). These are concerns that affect the production of the literature review in design research.

In established disciplines the literature review is the recognized vehicle for the evaluation of existing sources relevant to postgraduate research projects. Numerous texts provide useful guides to the critical review of textual sources but tend to emphasize (mono) disciplinary scholarship (see Cooper 1998). Hart (1998) provides a more in-depth analysis of the rhetorical issues of argumentation and warranting in the social sciences. Granello (2001) shows how the cognitive complexity of the literature review increases with the levels of sophistication expected of scholarly work. All students can bring limited conceptions of the literature review to their research. Bruce, for example, (1994) finds that scholarly outcomes are limited when postgraduate students see a literature review as a listing of sources. More recently, Bruce (2001) has observed that student's fundamental grasp of the scope or coverage of their project can be equally problematic and inadequate. Montuori's (2005) recent contribution to the limited discussion on student literature reviews adds to existing observations in arguing that the literature review should be seen as a creative dialogue with the primary assumptions of the community of inquiry one is in the process of joining. The idea of the contextual review as an active engagement with a community of practice (Lave and Wenger 1991) is perhaps under-represented in the existing literature on the subject.

In an analysis of literature reviews in social work and nursing where interdisciplinary collaboration is the aim, Couturier and Dumas-Lavardiere (2006) conclude that the different conventions of the two disciplines make a merged homology difficult. Samraj and Swales (2000) observe that establishing an interdisciplinary rhetoric in emergent disciplines is especially challenging for students. However, they note that biology students working in conservation achieve this through one of two means; producing new knowledge from the synthesis of different fields but without discussing disciplinary relativities and contradictions or by common references to problems in the real world. The second observation is perhaps the most pertinent to applied design research, suggesting that the grounding of research investigations in a specific problem context is useful to the effective integration of cross-disciplinary perspectives.

In design research invoking disciplinary and non-disciplinary sources is sometimes referred to as a contextual review (see Gray and Malins 2004). The term has its critics. Durling (2002), for example, is scathing of its 'fashionable' use in practice-based design research, noting that 'context' is typically defined by the practitioner's subjective interests and limits, the 'loosely structured survey' usually 'not intended to be exhaustive.' (82). Durling argues that a piece of research can only be judged as an original contribution to knowledge 'if such a contribution can be compared with the state of knowledge in the field in the period preceding the study.'(82). His critique seems well placed but his reference to 'the field' assumes that design is a stable disciplinary field and that design research operates according to a traditional disciplinary model. Both suppositions are contestable and disregard the difficulty in complete recourse to 'the literature' in respect of applied research questions that are only be adequately investigated through multiple sources.

Chief among these issues is identifying relevant literature and resources when both student and supervisor are searching in unfamiliar territory. Boote and Beile (2005), building on Hart's approach (1998), offer a rubric (Table 2) for evaluating literature reviews that is adaptable for interdisciplinary design research projects. Reference is made to its various criteria in the case studies below.

category	criterion	1	2	3	4
1. Coverage	A. Justified criteria for inclusion and exclusion from review	Did not discuss the criteria for inclusion or exclusion.	Discussed the literature included and excluded.	Justified inclusion or exclusion	
2. Synthesis	B. Distinguished what had been done in the field from what needs to be done. C. Placed the topic or problem in the broad scholarly literature D. Placed the research in the historical context of the field. E. Acquired and enhanced the subject vocabulary. F. Articulated important variables and phenomena relevant to the topic. G. Synthesized and gained a new perspective on the literature.	Did not distinguish what has been and has not been done. Topic not discussed in broader scholarly literature. History of topic not discussed. Key vocabulary discussed. Key variables and phenomena not discussed. Accepted literature at face value.	Discussed what has been and has not been done. Some discussion of broader scholarly literature. Some mention of history of the topic. Key vocabulary defined. Reviewed relationships among key variables and phenomena.. Some critique of literature.	Critically examined the state of the field. Topic clearly situated in broader scholarly literature. Critically examined history of the topic. Discussed and resolved ambiguities in definitions. Noted ambiguities in literature and proposed new relationships. Offered new perspective.	
3. Methodology	H. Identified the main methodologies and research techniques that have been used in the field, and their advantages and disadvantages. I. Rationalized ideas and theories in the field to research methodologies.	Research methods not discussed. Research methods not discussed.	Some discussion of research methods used to produce claims. Some discussion of research methods used to warrant claims.	Critiqued research methods Critiqued appropriateness of research methods to warrant claims.	Introduced new methods to address problems with predominant methods.
4. Significance	J. Rationalized the practical significance of the research. K. Rationalized the scholalry significance of the research.	Practical significance of research not discussed. Scholarly significance of research not discussed.	Practical significance discussed. Scholarly significance discussed.	Critiqued scholarly significance of research Critiqued scholarly significance of research	
5. Rhetoric	L. Was written with a coherent, clear struct-ure that supported the review.	Poorly conceptualized, haphazard.	Some coherent structure.	Well developed, coherent.	

Table 2: Boote and Beile (2005) Criteria for Literature Review

STUDENT CASE STUDIES: REFLECTIONS ON THE CHALLENGE OF INTERDISCIPLINARY RESEARCH CONTEXTS AND SUPERVISION

The remaining discussion examines various challenges in developing an interdisciplinary perspective on the literature review. The three case studies show students and supervisors (the authors) grappling with the demands of the review of prior knowledge in multimodal applied research projects. Professional doctorates are a relevant example of the value of grounding higher education research in the frameworks of Mode 2 knowledge production (McWilliam et al. 2002; Winter, Griffiths and Green 2000). The origin, rationale and broad curriculum

structure of the doctorate have been previously discussed (see Barron, Anderson and Jackson 2005). As a model of knowledge production in higher education the professional doctorate sees knowledge as 'performative' and knowledge relations as emanating from the problem context (Tennant 2004). This characterization is valid for the three case studies which follow. To exemplify and 'ground' some of the principles identified above the student case studies are described from the perspective of the authors. Such narrative case studies have been recognized in the literature on research supervision as a valuable complement to theoretical discussion, particularly where students are from second language backgrounds (Mercer 2001; Ryan and Zuber-Skerritt 1999; Taylor & Beasley 2005; Wisker 2004).

CASE STUDY 1

A professional doctorate exploring flexible interior design for Taiwanese cluster housing developments exemplifies how the effort to understand the wider problem context in applied research projects introduces widely dispersed bodies of literature. The recently completed project demonstrates that although multidisciplinary sources can significantly inform an investigation, an overarching sense of the research purpose is crucial to focusing the contextual review and establishing meaningful knowledge relations in research outcomes. The student, an experienced interior designer and design educator, sought to address an issue routinely encountered in practice; the difficulty and expense of remodeling domestic interiors to suit owner's needs and preferences as a result of the dominance of concrete construction.

The student's intention was to contribute new approaches and practical knowledge to Taiwanese interior design and society through the cyclical process of problem identification, reflection and conception common to design practice. The need to identify relevant knowledge and precedent studies in respect of a complex problem context deferred the framing of a design response to the topic while taking the investigation into a diversity of fields, many unfamiliar. These ranged across user-centered and participatory design, supply chain management, customization principles from product design and manufacturing, urban design and theories of Open Building and Open Source Building. The multifaceted literature review supported the student's intuitive sense that a new system of flexible interior design was needed. It established that while this idea had been addressed in areas of engineering, housing studies and architecture little had been attempted from a user-centered, interior design perspective and there was no specific study for Taiwan. The literature challenged design's tendency to propose abstract responses to real world issues. For example, studies in housing and supply chain management showed that altering design characteristics across a category of buildings required wide-ranging intervention and cooperation at many levels of industry and government. Housing studies and urban design identified diverse implications for societies of poor housing, including Taiwan. Such information enabled the student to raise both sharper and broader arguments about the impact of current interior design practices in Taiwan.

However, the incorporation of diverse research sources challenged the student's critical skills, requiring high level organizing principles. Values and assumptions from business, engineering and manufacturing especially threatened to overwhelm the user centered design perspectives that inspired the project. The former typically applied quantitative models to the proposition of flexible design and construction, stressing the delivery of cost savings, time efficiencies and competitive market advantage to business. The adaptable interior design system outlined in the student's research proposal explicitly opposed the inflexible, developer-driven approaches entrenched in Taiwan's cluster housing market where short-term profitability impels housing development. Strong fiscal or rationalistic principles and validation methods from outside design stressed efficiency and improvement in industry practice over the project's interest in empowering homebuyers and designers to achieve housing outcomes responsive to human and social needs.

The student was determined to maintain his insider status in relation to the research issue and to validate the professional knowledge of the interior designer in a social context where developers hold power. Framing the problem around knowledge and methods from outside design risked transforming the research into a process of disengaged observation and commentary. The time and intellectual effort required to synthesize material from relevant studies significantly reduced the scope for simulated design work. Rigorous engagement with abundant multidisciplinary knowledge made the research more theory-driven than practice-based but gave a much fuller diagnosis of the issues facing Taiwan's housing sector and their potential solutions, adding weight to the research recommendations and providing a basis for the student to embark on a multilateral stream of funded research on completion of his degree.

CASE STUDY 2

An ongoing project involving the development of a media TV campaign for anti-smoking education aimed at primary school age children in Malaysia is a second example of a project integrating multiple fields. The project is linked to WHO funding of a larger project and requires the student to position his research within the literatures and fields of public health education, the epidemiology, economics and politics of smoking in South East Asia, and multimedia design and development. Engaging with these diverse literatures and finding a scholarly balance complementing the professional competence of the designer and his understanding of the sociocultural context of Malaysia has placed a significant burden on student and supervisors.

As in the previous case example, the student project could be swamped by the public health sources and discourse on smoking, which are multiple. However, to adequately position the research to meet scholarly standards it was especially important to ground the significance of the issue in empirical and statistical accounts of the prevalence of smoking and economic costs and benefits. This involved accessing publicly available WHO statistics and locating the medical and health literature addressing the Malaysian environment. These international

scholarly perspectives were needed to complement the student's knowledge of Malaysian-based projects, and help justify the significance of the study. Fortunately, the public and scholarly literature had only begun to engage with relevant issues in Malaysia, allowing an almost complete synthesis of existing published studies where this would not have been possible for a country with more developed research programs.

Complementing this synthesis of sources in establishing the significance of the research problem was a potentially vast body of work on health communication and education. The practical solution to tackling this material was to employ the frameworks and models in three widely cited textbooks, complementing this with the much smaller number of studies addressing the specific needs and characteristics of programs addressing primary school age children in developing countries. Thus, having established the significance of the issue and the need for public health interventions the literature review moved on to the problem context, considering health communication and education frameworks relevant to the target group, primary school age children in Malaysia. Childhood development, culture and education were relevant to understanding this group. Here, the design student was able to connect his personal knowledge of this context to data and frameworks from the larger WHO project from which the study was drawn. Currently, multimedia design work is a priority in the project. It remains to be seen how the synthesis of sources and project work will achieve the literary balance required for the text output. Compared to the student's high design competence he has not yet mastered academic scholarship and writing, which means extra time must be dedicated to text work and coherence. This, however, is a challenge for all practitioner researchers not an issue specific to an international student.

CASE STUDY 3

The third project grew from a student's concern for the expression of contextual specificity in the interior design of public buildings in an era of globalization. Questions of locality and culture in globalization are, of course, currently of broad scholarly concern, being considered from diverse empirical, theoretical and disciplinary perspectives. Scrutiny of the interior design literature found it to be mostly concerned with questions of disciplinary and professional status. Accordingly, recourse to other disciplinary perspectives, and particularly urban design theories, addressed the need to locate research questions in a broad scholarly framework. Seeking interdisciplinary input to develop methods and principles for interior design constituted an implicit critique of the state of methods and research in interior design. Nevertheless, identifying a relevant and manageable literature from abundant alternative sources was challenging, especially given the complex arguments within and between disciplines over the proper terms for considering issues of globalization. Expectations of scholarship required recognition of the variegated nature of globalization debates. A meaningful understanding of this was certainly needed to address the cursory appropriation of theories of globalization in much design writing but setting limits

here was vital to ensuring that design exploration was not marginalised by the effort to master theoretical perspectives and knowledge from other disciplines.

The decision to explore the expression of locality in interior design through a simulated redesign of an actual international air terminal in Taiwan linked the production and demonstration of knowledge to a capacity to recognize and resolve specific design issues. Awareness of theoretical perspectives on globalization encouraged the student's reflexive engagement with design practice, though it was important to recognize that critical theory in particular constructs issues according to its own operation as an intellectual institution, its internal debates not necessarily relevant to design. It was also crucial to avoid seeing the application of multidisciplinary knowledge as the 'solution' to interior design problems, the problem context being the primary framework for contingent learning and knowledge production.

Although it was not always clear at the time, by working outward from the simulated project as the need arose to other bodies of knowledge the research achieved a critical, transdisciplinary review of methods and principles in interior design. Literature on globalisation, tourism and Taiwanese national and cultural identity situated the project and shed light on the problem context. Literature on airport design, which was mostly engineering not design oriented, served a similar role in addition to supporting the nature of the project's innovation. Relevant methods and principles for expressing locality in built environments were identified in urban design. Their transposition to the context of application transformed an open-ended question about culture in globalization into the proposal of a set of highly specific methods for addressing space and place legibility in complex public interiors. Conducting the literature review in parallel with simulated design work challenged design thinking, leading to several major revisions of design strategy, the measure of a valid literature review becoming the identification of useful knowledge in the pursuit of design innovation. Identifying any significant contrary views to the main cross-disciplinary ideas in the research was the primary marker of scholarship in a model of knowledge production that was outcome focused and contextually defined.

DISCUSSION

This paper claims that applied design research in higher education requires students and supervisors to undertake a form of transdisciplinary contextual review that is distinct from the text-based disciplinary review of established academic disciplines. The multiple fields and multimodal sources of such a review both constitute and validate the scholarship of application exemplified in industry-oriented, Mode 2 knowledge production in higher education. The systematic contextual review is distinct from the manifestly outcome-driven and variable research that can characterize the industry-based practices of the design studio. The early phases of the doctoral experience involve institutions and supervisors complementing the industry competence that doctoral students bring to their projects with the academic literacies of the scholarship of application. However, the fact that

applied design research projects exceed disciplinary boundaries clearly changes the relationship between supervisors and students from that where research is conducted within the intellectual parameters of a specific discipline and research direction is defined by the coordinating supervisor. Here, supervisors become critical commentators on the integration of disparate methods and perspectives with the demands of the problem context and the student's design practices and beliefs.

The three case studies have provided some details about the practical challenges of achieving an interdisciplinary synthesis in the shadow of potential information overflow. The literature review, in particular, brings additional responsibilities and challenges to students and supervisors. In current debates about design research too little concrete attention is paid to justifying claims to the particular nature of such research and we believe that student case studies put this in perspective. We have suggested there can be no *one* design studies but only a multiplicity of context-specific design research investigations that create proliferating demands in the literature review stage of doctoral study. The authors propose that further student case studies and development of the definition and characteristics of transdisciplinarity in design be undertaken in the future.

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