

# Designing Design Learning: A Case Study

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## Abstract

As 'designerly' ways of thinking and knowing are increasingly understood to be relevant in fields outside the traditional design disciplines, there is need to conceive of and design appropriate pedagogy. The challenge is to successfully negotiate disciplinary crossings in ways that simultaneously respect the discipline of design and provide a space for exploration and innovation, while at the same time produce results that satisfy individual disciplinary standards as well as the institutional standards of the university. The paper presents a case study of a novel graduate course in design research in the University of Toronto's Knowledge Media Design Institute (KMDI) – a multidisciplinary community in which the design has been largely grounded in models from human-computer interaction (HCI). The model of pedagogy that emerged out of this experience and reflection is then situated in terms of prior work on interdisciplinary pedagogy. We propose that our model of pedagogy grounded in what we call *disciplined transdisciplinarity* has the potential to generalise to other settings.

## Keywords

Pedagogy, interdisciplinarity, multi-disciplinarity, transdisciplinarity innovation, human-centred design

The complex and interconnected nature of many contemporary problems is increasingly recognised, and the need for more systemic approaches for addressing them increasingly understood. This understanding will resonate with designers and design scholars as this framing respects the now half century of scholarship on design research and design thinking. 'Designerly ways of knowing' (Cross, 1982) are increasingly part of the public conscience and being taken up by business schools, and in various ways by scholars in other fields.

In principle there is much to recommend increasing the knowledge flows across disciplines, and the value of disciplinary crossings has been recognised by bodies such as the National Academies of Science (*Facilitating interdisciplinary research*, 2005) and the US Council of Graduate Schools (2007). This is not, however, easy to do either intellectually or institutionally, and there is an ongoing debate on what constitutes interdisciplinarity; the term used to describe both disciplinary crossings in general and a specific form of practice (Moore, 2009). As well, the myriad challenges of engaging faculty and students from different disciplines in the traditional university have not yet been resolved (Moore, 2003). The Report of the US Council points specifically to the need for an increase in interdisciplinary training stating that: "interdisciplinary research preparation and education are central to future competitiveness, because knowledge creation and innovation frequently occur at the interface of disciplines" (2007, p.18).

This brings to the fore the importance of pedagogy, the need for experimentation and the development of innovative new approaches that foster the kind of productive collaborative outcomes that interdisciplinary engagement is argued to generate. Our paper is motivated by these concerns.

We set out to explore this complex set of relationships through reflection on the origins and development of a graduate course in design research. The process whereby the course emerged was highly informal, but on reflection and through the subsequent design of new course materials and the writing of research papers that came out of this engagement, we began to understand the potential of this case to inform a model of pedagogy for graduate education grounded in what we call *disciplined transdisciplinary*. Reviewing the literature with this framing in mind, we found others who have taken up the challenge around the design and delivery of 21st century graduate education to support interdisciplinarity.

The paper begins by situating our case study in its institutional context, and in the context of the intellectual ideas that informed the development of the institute. We next present the case and the model. Lastly, we situate the development of the model in the context of literature on interdisciplinary pedagogy.

## 2.0 The Institutional and Intellectual Context

The University of Toronto's Knowledge Media Design Institute (KMDI) was established in 1995, to foster tri-campus<sup>1</sup>, cross-divisional research and teaching in the emerging field of knowledge media<sup>2</sup> design (Moore & Baecker, 2003). Faculty and graduate students from 25 academic departments and faculties today engage in the scientific study of the ways in which media shape and are shaped by human activities and values; the design, development and evaluation of media applications and systems, and critical reflection on the implications of these developments in the broader social and cultural context.

This bold agenda challenged traditional university structures and existing practices as it required a broad base of collaboration across the disciplines. The University of Toronto, founded in 1827, is one of Canada's largest and most prestigious universities. It has a traditional organisation structure in which disciplinary and departmental boundaries tend to coincide, and departments and faculties are the site of scholarly legitimation, evaluation and reward for faculty and students. The ability to work across disciplinary boundaries is not readily accommodated, and it is especially difficult for untenured faculty and graduate students to engage in these practices. Second, knowledge media design is an emergent field and the potentially transformative nature of the internet and the associated cluster of technologies and applications emerging, was generally not appreciated in the mid 1990s. With limited funds, the institute was established as a virtual institute, a novel networked organisational form. Thus, despite the fact that interdisciplinary practices are not new, and had become re-invigorated in the 1960s (Klein, 1990,1996), the institutionalisation of these practices in universities can continue to be a challenge.

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<sup>1</sup> The University of Toronto is comprised of three campus; the St. George campus in the City of Toronto and two satellite campuses located 25 km to the east and west.

<sup>2</sup> KMDI defines knowledge media (KM) as a specific class of media and media technologies designed to enhance human thinking, creativity, learning, communication, and collaboration.

In 2002, KMDI's Collaborative Masters and Doctoral Program in Knowledge Media Design proposal was approved by the Ontario Council on Graduate Studies thereby providing a specialisation for graduate students from a variety of academic backgrounds to engage in this emerging field. The Collaborative Program model<sup>3</sup> administered by the School of Graduate Studies at the University of Toronto was one institutional process that supported the ambitions of KMDI to offer graduate education in which students from more than one discipline could participate. Today there are ten academic units<sup>4</sup> participating in the program, and 57 masters' students and 30 doctoral students have been enrolled. Four specialised courses have been offered in addition to two core courses that provide the fundamentals of knowledge media design. On average two courses are offered per term. The potential for disciplinary mixing of students, already the norm for faculty participating in the institute, was thereby established.

## **2.1 The Role of Design in KMDI**

Questions about how to engage with design and design practice have been a central concern in KMDI from the outset. The focus was a specific form of design; one that came primarily from the field of human computer interaction (HCI). This orientation reflected the origins of the institute in research on collaboration technologies as well as the physical location of a number of the faculty and the institute administrator in the department of computer science – also the home department of the first Director. KMDI's orientation to human-centred design (Moore & Timmerman, 1996), however, differentiated it from other North American computer science departments, in which the notion of user-centred design proposed by Norman & Draper (1983) was the norm at that time. As well, a number of the faculty founding KMDI had been associated with the Ontario Telepresence Project and worked with researchers from Xerox PARC and EuroPARC on media space. Many had been active in the field of CSCW: Computer Supported Cooperative Work, and associated with the Scandinavian model of participatory design (PD) since the 1990s. Thus, from the outset, a wide range of theoretical and methodological approaches informed the research carried out in the Institute. A diverse array of epistemological foundations do not necessarily co-exist comfortably and part of the research of the institute has been to explore this issue (Moore, 2003; Lottridge and Moore, 2009), and to develop strategies to negotiate these differences in ways that are both productive and creative.

Collectively, the faculty were less aware of the research in design that came from the design disciplines; architecture, industrial design, graphic design. However, with the emergence of the field of interaction design in the late 1990s with roots in both communities, this began to change (*Being Human*, 2008; Fallman, 2003; Leblanc, 2009). The question that began to emerge for us was how, and in what ways, might this scholarship inform our design practice? Would viewing knowledge media design through the lens of scholarship on design research be a source of new insights?

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<sup>3</sup> The University of Toronto through its graduate departments, centres, and institutes offers unique, non-degree granting, collaborative programs. These emerge from cooperation between two or more graduate units, providing students with a broader base from which to explore a novel interdisciplinary area or a special development in a particular discipline, to complement their degree studies. Source: <http://www.gradschool.utoronto.ca/programs/collaborative.htm>

<sup>4</sup> These include Computer Science, Sociology, Information Studies, Mechanical and Industrial Engineering, Architecture & Landscape Architecture, Medical Science, Urban Design, Visual Studies and two departments in the Ontario Institute for Studies in Education, Curriculum Studies and Teacher Development and History and Philosophy of Education.

Following Cross, we understand design “as a coherent discipline of study in its own right, based on the view that design has its own things to know and its own ways of knowing them” (2007, p. 4-5). It was our goal to explore how this way of knowing with its focus on ‘making’ as well as thinking, on the elaboration of the relationship between practice and research, and on the need for collaboration and integrative thinking could help advance design research in the emergent field of knowledge media design. Buchanan has written: “Some see no need for design research, and some see in the problems of design the need for research that is modeled on the natural sciences or the behavioural and social sciences as we have known them in the past ... others see in the problems of design the need for new kinds of research for which there may not be entirely useful models in the past – the possibility of a new kind of knowledge, design knowledge, for which we have no immediate precedents” (2001, p. 6-7). To achieve the objectives to which KMDI aspires, a deeper understanding of design research and the epistemic communities involved in the production of design knowledge appeared to offer promise.

We were also aware that not all aspects of design research theory, methodology and practice would be relevant to the evolution of knowledge media design. We asked: how does one explore an unfamiliar field with a group of people from different disciplines, none of whom are experts in the field? How should we learn, and how might what is learned be mobilised going forward? And finally, how does one actually do the work of exploring the relevance of a field of scholarship to an emerging area such as KMD from several perspectives while simultaneously accommodating the formal requirements of students for academic credit?

Our approach was pragmatic and initially informal. We simply started to meet and a process began to evolve. Methodologically, this approach is closest to Schon’s idea of ‘reflection in action’ which is in a complex relationship with ‘knowing in practice’. As Schon notes: “A practitioners’ reflection can serve as a corrective to over-learning. Through reflection, he can surface and criticize the tacit understandings that have grown up around the repetitive experiences of specialized practice, and can make new sense of the situations of uncertainty or uniqueness which he may allow himself to experience” (Schon, 1983, p. 61). Reflecting on the outcomes months later we began to formalise this as a model of pedagogy; a model to which we will return after describing the case.

### **3.0 The Case Study**

#### **3.1 From reading group to reading course**

In the fall of 2007 an informal reading group was organised to explore the literature on design research. This began a process that would unfold over the next four months in a ‘designerly’ way – open, engaged, and iterative. The inspiration for the reading group can be traced to growing awareness of the potential that traditional design theories and practices might offer. A visit to a studio in landscape architecture was part of a KMDI core course, and a seminar on *Research design: Design research*, in the other core course led a number of doctoral students to take up the instructor’s invitation to engage in further explorations of the field of design research. In the summer of 2007, the faculty member sent out a brief prospectus that included an excerpt from an earlier design project which she had led, and a number of questions that might be explored. Students were asked to contribute their expectations in terms of content and focus and to commit to attending a reading group in the fall if interested.

The challenges were two-fold. First, to look deeply into the scholarly literature on design research to consider what of this corpus might be relevant to a graduate research program in knowledge media design, and second, to consider how this might be taken up in the context of the institute and the university. The four doctoral students who participated were members of the KMDI Collaborative Program, and enrolled in faculties of engineering, education research and information, and had backgrounds in computer science, engineering, and media and communications. The faculty member was a sociologist.

The group shared common ground in that all were familiar to some degree with the design literature in the fields of HCI and human factors. Each was interested in reading more broadly to explore how, and in what ways, other disciplines contributed to the literature of design research. The group met regularly, more or less biweekly, and agreed upon a set of readings co-identified by the group members. At times these seemed random and almost disconnected, but in the process of sorting, sharing and reflecting, certain patterns began to emerge. We looked across the fields of engineering, architecture and industrial design, and saw how these fields mapped to the dominant intellectual history of each period. Not surprisingly, points of tension and transition generally aligned – for example, the challenge to the rationalist perspective and the impulse to participatory practices. Yet, despite similarities in periodisation there appeared to be little cross-fertilization across the fields with the exception of the classics such as Simon's *The Sciences of the Artificial* (1970). The field of interaction design<sup>5</sup> that began to emerge over a decade ago is now one bridge linking traditional design disciplines and HCI.

With the richness of the material uncovered and the quality of the conversations, the group decided to continue into the second term. However, the instructor felt these efforts should be formally acknowledged. The only formal university course structure that could accommodate this style of work was a reading course. Traditionally, reading courses involve a single professor and a student, and there is no procedure for a group to work in this way. The solution was that each student had a separate reading course, a specific research paper they negotiated with the faculty member, and they continued to meet as a group.<sup>6</sup> (See Figure 1.)

The group met more or less weekly through the 2008 winter term, and, a seminar series was developed to complement the course. (See Figure 2.)

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<sup>5</sup> While there is still “no commonly agreed definition of interaction design, its core can be found in an orientation toward shaping digital artifacts – products, services, and spaces – with particular attention paid to the qualities of the user experience” (Fallman, 2003, p. 4).

<sup>6</sup> This constraint is a barrier to collaborative practice, as is the fact that reading courses don't ‘count’ toward faculty course load requirements.

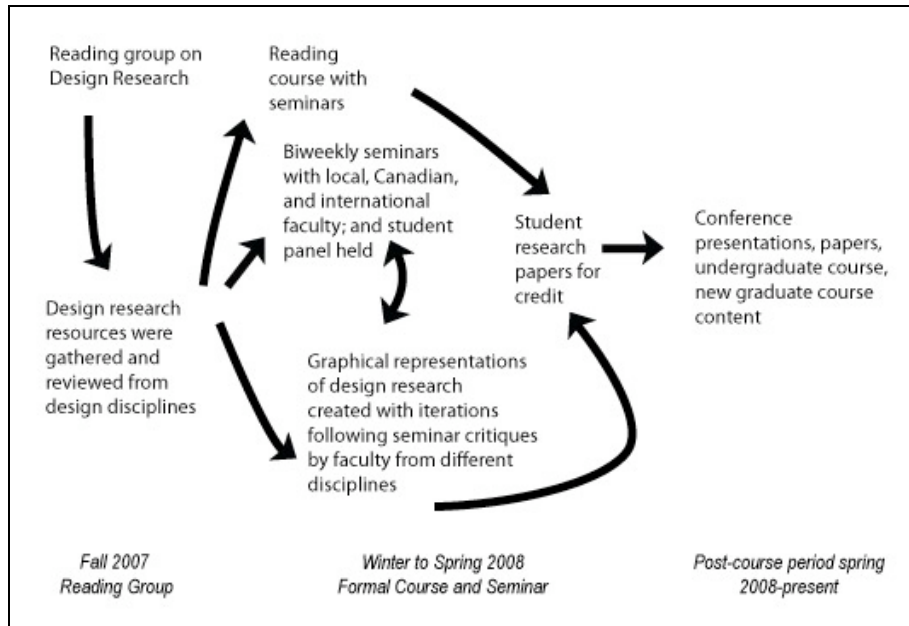


Figure 1 Design Research Reading Group, Course and Outcomes

The first seminars were given by local faculty from different departments teaching design, followed by Canadian experts with design expertise not available at the university. The students presented their research in one session and the series closed with two international scholars who participated in the seminar series and in addition gave a public lecture. These lectures were widely advertised in the university community and webcast. Overall, the series brought together design researchers from industrial design, information visualization, architecture, biomimetics, and critical design, and explored theories ranging from actor-network theory to critical design, and practices that included sketching and the use of design probes.

**Design Research: Views from Across the Disciplines**  
 2-4 pm at Bahen Centre for Information Technology, BA 7256 (7th floor) 40 St. George St.

Epistemologically, what do designers 'know'? Are there 'designerly ways of knowing' distinct from the recognised scientific and other scholarly ways of knowing? Speakers from different disciplines will take these questions as their point of departure to explore what, for them, constitutes a legitimate knowledge claim. And, since research in knowledge media design is typically trans-disciplinary, we will also explore ways of fostering communication across disciplinary boundaries and bridging traditional epistemological divides.

1. Cross, R. (2004). *Designing ways of knowing*. London: Springer.  
 2. Woodbridge, N. (2004). *Designing ways of knowing*. London: Springer.  
 3. Cross, R. (2004). *Designing ways of knowing*. London: Springer.

March 6: **Nick Woodbridge**, Professor, Biomedical Communications & KMOL, U of T  
 March 13: **Michael Langford**, Professor, Dept. of Design, York University & **Barbara Cross**, Professor & Director, Joint Graduate Programme in Communication & Culture York University  
 March 20: **Rodney Hoekes**, PhD in Design (Harvard) & Creator of Parallel Worlds Lab  
 March 27: **Li Shu**, Professor, Biomimetics for Innovation & Design Laboratory, Dept. of Mechanical & Industrial Engineering, U of T  
 April 3: **Tomas Dorta**, Professor adjoint, Ecole de design industriel, Université du Montréal  
 April TBA: **Bill Gaver**, Professor of Design, Goldsmiths, University of London.  
 April 24: **Bill Buxton**, Principal Researcher, Microsoft Research & author of award winning book, *Designing User Experiences*.  
 May 1: **Design Research & KMOL: A Panel Discussion**  
 Daniela Lombardi, PhD candidate, MEd, KMOL; Kate Sellen, PhD candidate, ME & KMOL; Karen Smith, PhD candidate, FIS & KMOL & Joan Touzet, PhD candidate & KMOL. Moderated by Gale Moore, Professor & Director, KMOL  
 May 20: **Nigel Cross**, Professor of Design Studies, Faculty of Technology, The Open University & Editor-in-Chief of Design Studies

Figure 2 Design Research Series Poster<sup>7</sup>

<sup>7</sup> This poster includes an image from flickr.com under Creative Commons license by viagallery.com

To foster discussion regarding epistemology and Cross' concept of 'designerly ways of knowing', a number of steps were taken. First, each of the presenters was asked to provide a reading or two that was illustrative of their research perspective. This was distributed to the local community one week in advance as part of the seminar promotion with the request that anyone attending the seminar have read it. Second, the seminar series was not advertised outside the KMDI community, nor with the exception of the final public lectures were they webcast as is customary. The goal was to keep the seminars small enough for active engagement. Third, each presenter was asked to engage and reflect upon a graphical representation of design research that was being created in the course, and iteratively modified in response to the seminar discussions. The graphical representations became a set of shared artifacts around which the attendees, course participants, and presenters could orient, allowing us to consider what aspects of their epistemology, methods and practice might be relevant to the field of knowledge media design. These creative activities were one way in which our growing understanding and appreciation of design thinking could be put into practice.

### **3.2 Outcomes**

The outcomes of the Design Research seminar surpassed expectation.

The curriculum and readings were co-constructed by the students and faculty. Each student worked throughout the term on a paper inspired by the course readings, bringing literature from their home discipline into the discussion as part of an exploration of disciplinary assumptions and perspectives. This led to deep enquiry that was reflected in the writing. Two term papers were expanded; one was published in a high-ranked peer-reviewed journal (Lottridge & Moore, 2009) and the other was presented at peer-reviewed technical conference (Smith, 2009). The ideas are being taken up in doctoral theses, and mobilising awareness of design research in the students' home departments.

The director of an undergraduate program in new media approached one of the doctoral students from engineering to develop a design-oriented course. In collaboration with a social science doctoral candidate they revised and updated an undergraduate course that drew on their experiences in the reading course. This course has been run twice and is being considered for addition to the core requirements for the undergraduate program. The students in the course have also brought this material into other undergraduate and graduate courses in which they participate. For example, in 2009, the course project in the core KMDI course *Fundamentals of KMD* was changed from a traditionally HCI three-step process of user-centred design (user requirements, prototyping, evaluation) to a four-step process that introduced the concept of ideation and included a sketching requirement.

Another significant outcome was the adoption of this approach for the newly established KMDI annual pro-seminar. Two doctoral students, inspired by their participation in the Design Research Seminar Series and the level of engagement and interaction, proposed a course and complementary seminar on the topic of Visual Thinking to the Collaborative Program director. This was taken up as the pro-seminar, and a faculty member who had contributed to the design research seminar agreed to serve as the course instructor. The students and faculty met to create a curriculum and to design a seminar series. While this course was inspired by the earlier model, the approach was modified to fit the specific needs and constraints of the group and the subject. For example, the major assignment was more visual and focused on the creation of an artifact, while continuing to integrate literature from the students' disciplinary backgrounds. This course and series

was a success, and KMDI is now encouraging another group of students to articulate their choice for an emerging topic for the next pro-seminar. In the summer of 2009 the authors approached the 2009 course leaders to present a poster on the model and its evolution for the KMDI@13 Research Showcase (Lessard et al, 2009).

#### 4.0 The Emergence of a Model of Pedagogy

A key observation from the case was that students were learning to think across disciplinary boundaries and to understand the ways in which epistemology, methodologies and values shape disciplinary knowledge and knowing. As well they were developing ways to negotiate cultures constructively even where epistemological differences were irreconcilable. This went beyond the disciplinary crossings normative in KMDI's research and collaborative program that have been primarily multi-disciplinary. The generative nature of these interactions is characteristic of transdisciplinarity.

Interdisciplinarity as a field of scholarly enquiry has long been part of KMDI's agenda (Moore & Timmerman, 1996; Moore, 2003, 2009). In transdisciplinarity the primary focus is not on the discipline per se but on the transformative potential of the interaction of individuals from different disciplines working together in a context of application. The process is dynamic, flexible, and generative. Figure 3 illustrates the various forms. It is the transdisciplinary form that we feel holds the greatest promise for addressing complex problems.

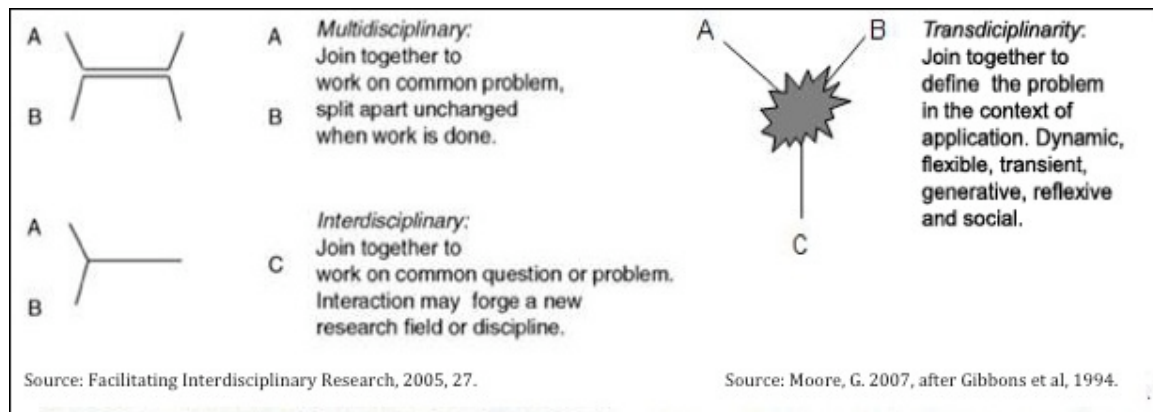


Figure 3 Inter-, Multi- and Trans-disciplinarity

Our model is summarized in Figure 4 below. Reflecting on the success of our case, we discuss three contributions beyond the activities that took place: the 'designerly' progression; the disciplined transdisciplinary nature of the engagement; and knowledge mobilisation. The model is then reviewed in terms of the literature on innovations in interdisciplinary pedagogy.

First, we position the visual model of design research by Sanders and Stappers (2008) at the base of our model to indicate the 'designerly' way the process unfolded. This references the transition from the 'messy' and informal practices at the origin to the more refined and formal outcomes at the end.

Second, by initially moving outside the boundaries of formal course requirements, we experienced the generative potential of the interaction of individuals from different disciplines working together in the context of a specific application, or what Michael



Gibbons (1994) refers to as transdisciplinarity. However, we continue to value the expertise gained through disciplinary training, and success in our case was in enabling a specific form of transdisciplinarity that we call *disciplined transdisciplinarity*. The notion is that by making disciplinary assumptions and values explicit, it is possible to co-create the bridges required to negotiate disciplinary divides and to appreciate the different epistemologies and perspectives revealed. KMDI students are frequently engaged in the design of digital media projects and have their own experiences to draw upon. The introduction of design thinking and ideas from the design disciplines engages them intellectually with how this is similar and different from design coming from a computer science or human factors perspective, The understanding and knowledge that results from this process can then be taken back to the disciplinary home unit.

Knowledge mobilisation is the third element in the model. Over the period of the course there was movement across what we are calling the *continuum of access* as the ideas moved outward from the students in the course, to the open seminar, and to their home departments and faculties. Finally these are disseminated in the university through public lectures, and via webcasting and publications, to the world.

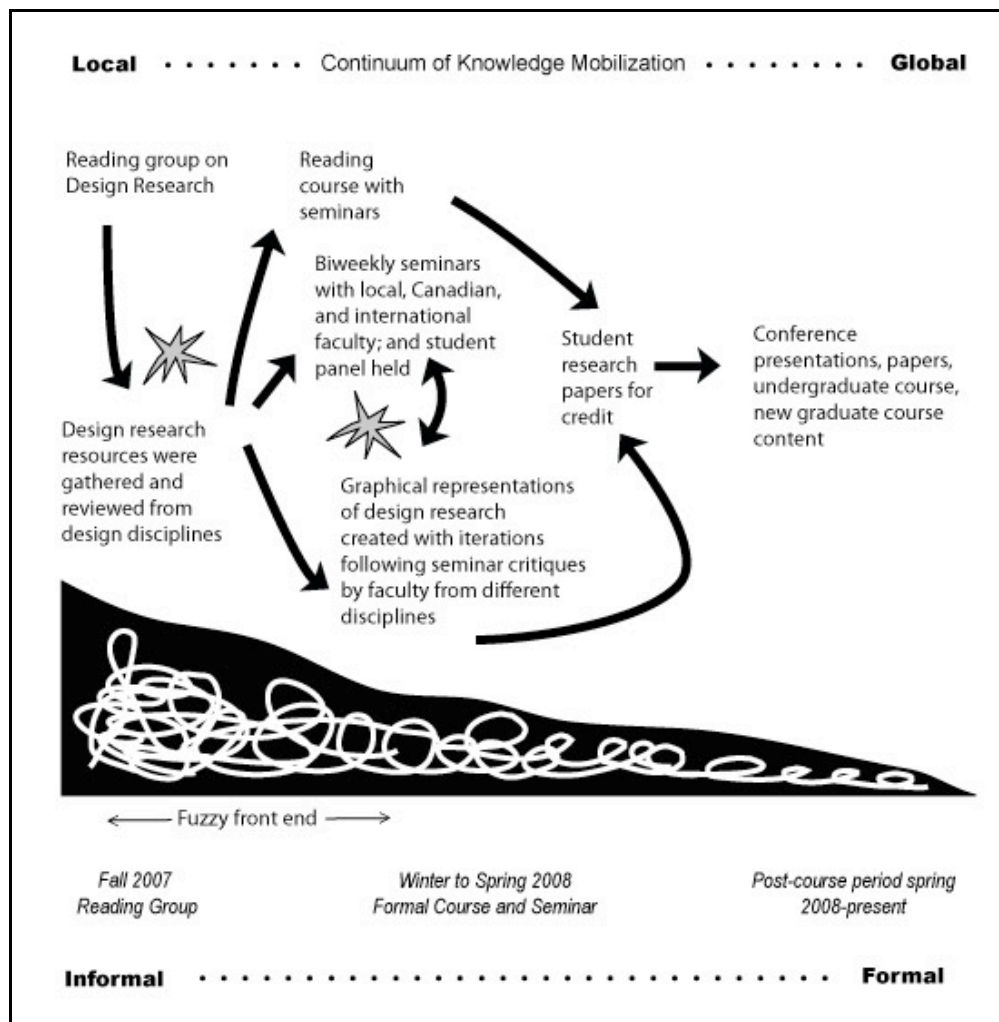


Figure 4 Pedagogical Model

## 5.0 Discussion and related work

A review of the literature illustrates the timeliness of this topic as educators from many disciplines consider how to prepare students for the challenges and complexity of the 21st century. In situating our work in relation to this corpus we focus specifically on pedagogy for interdisciplinary graduate education. We draw in particular on the work of Gerhard Fischer (2008) and Simon Penny (2009). Fischer's focus is on education for IT; and Penny's is on interdisciplinary education in the emergent field of media-arts and digital cultural practices, both highly relevant to knowledge media design. As one of our goals in reviewing the literature of design research was to identify the ways in which this field could be taken up and become part of graduate education in our field, we were encouraged to find scholars engaged in questions of pedagogy.

Fischer, a member of the Center for LifeLong Learning & Design, the Institute of Cognitive Science and the Dept. of Computer Science at the University of Colorado, Boulder, argues that there is a need to develop transdisciplinarity competencies which "refer to knowledge and skills required to identify, frame and address important scientific and practical problems that cut across disciplinary boundaries" (2008, p.3). The conceptual framework required to deliver these competencies, he suggests are derived from the learning sciences, Human-Computer Interaction (HCI) and Computer Support for Collaborative Learning (CSCL). Fischer's framing of transdisciplinarity is similar to ours in that it recognises the innovative and creative potential inherent in this form while also recognising the possibility of failure if there is an inability to find common ground (2008, p. 8).

The educational model of 'courses-as-seeds' (dePaula, Fischer, Ostwald, 2001) "explores meta-design and social creativity in the context of fundamentally changing the nature of courses taught in universities. Its goal is to create a culture of informed participation" (cited in Fischer, 2008, p. 5). Instructors provide the initial seed, rather than a final product and students actively co-create the course. While unaware of this research during the course, it describes our process well. However, while Fischer's approach to transdisciplinary education highlights the advantages of diversity and is aware of the complexity of achieving it, we suggest that an important aspect of transdisciplinarity – discipline – remains masked. We argue that it is critical to foreground discipline and the significance of disciplinary differences in norms, values and ways of knowing in order to fully release the innovative and creative potential of transdisciplinary interaction. For this reason we prefer the term *disciplined transdisciplinarity*.

Penny addresses the question of the development of effective interdisciplinary pedagogy for the ACE project at University of California, Irvine; a project in the emergent field of media-arts and digital cultural practices. "The key components of such a project are: deep technical training and understanding; deep training in artmaking and cultural practice; deep theoretical and historical contextualization, and an open and rigorous interdisciplinary context which maximally facilitates the negotiation of these often divergent ways of thinking and making." (2009, p. 31). The disciplinary crossings are generally broader than in knowledge media design as ACE includes the experimental and conceptual plastic arts. While our goal is disciplined transdisciplinarity, Penny is reaching for interdisciplinarity and the creation of a new discipline. The goal of ACE is the "formation of practitioners who are neither artists nor engineers, or who are equal parts both" (2009, p. 31). And, he suggests that "there is a fair argument that, as of around 2005, the descriptor 'new media' has become an anachronism, and the 'field' has moved into a post-interdisciplinary transition phase; it is actively undergoing the

transition to disciplinary status...” (2009, p. 37). Both agendas require extensive work in negotiating disciplinary or epistemic cultures, and the awareness that the exploration of the epistemological foundations of individual disciplines may prove uncomfortable (Lottridge & Moore, 2009). The ACE project, however, goes further as their slogan – “danger of permanent damage to axiomatic assumptions” (2009, p. 37) makes explicit.

While ACE and KMDI differ in their goals in terms of the desired outcomes of disciplinary border crossings, there are interests in common and two of these are questions asked in the discipline of design. First, what is the relationship between theory and practice and second, what is the relationship between problem setting and problem solving? The work of Rittel & Webber (1973) on problem setting is framed by Penny as “asking the right question” (2009, p. 46). He contrasts this with the analytical intelligence required for problem solving, and we are sympathetic to this view. We also agree with Penny’s observation that “such broad integrative inquiry often demands the negotiation of world views and epistemologies that may appear quite immiscible” (2009, p. 46). However, from the perspective of knowledge media design it is important to continue to problematise the theory/practice space, as efforts toward developing a model that represents this field continue to benefit from exploring this tension. For Penny, “the reconciliation of theory and practice is a central dimension of the interdisciplinarity of ACE” (2009, p. 34). From our perspective, transdisciplinarity rather than interdisciplinarity, continues to be preferred for reasons that are critical. It keeps the future open, and does not risk falling into the trap of disciplinary rigidity and institutionalisation, precisely what a project of interdisciplinarity risks if it succeeds. Furthermore, there is value in disciplinary depth; a goal with which our notion of disciplined transdisciplinarity is not incompatible. The challenge is to find those disciplinary experts willing to engage in intellectual conversations of this nature. We concur with Penny that this requires humility, courage and intellectual rigour (2009, p. 39-40).

## 6.0 Conclusion

“Interdisciplinary thinking is becoming an integral feature of research as a result of four powerful ‘drivers’: the inherent complexity of nature and society, the desire to explore problems and questions that are not confined to a single discipline, the need to solve societal problems, and the power of new technologies” (*Facilitating interdisciplinary research*, 2005,p.40). Support for this kind of thinking requires innovative approaches to education and training, and nowhere is this more important than in our universities where future researchers and scholars are trained. We will continue to require the specialised knowledge and expertise that disciplinary training produces. But while this is still necessary, it is no longer sufficient. To succeed in the 21<sup>st</sup> century graduates will need to have learned how to be self-directed learners, how to negotiate across cultures, including disciplinary ones, and how to work collaboratively in environments from the material to the virtual. Innovations in pedagogy and in our universities are required, and much we have argued can be learned from the discipline of design. This paper represents our first steps in an ongoing process of exploration to understand how best to prepare students to take a human-centred approach to the design of knowledge media as well as to be able to engage in constructive criticism of these media, technologies and related policies. A model of pedagogy grounded in disciplined transdisciplinarity we propose is one approach to preparing students for the uncertainties of a complex world.

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