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Interdisciplinary doctoral research supervision: A scoping review

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Abstract

This scoping literature review examines the topic of interdisciplinary doctoral research supervision. Interdisciplinary doctoral research programs are expanding in response to encouragement from funding agencies and enthusiasm from faculty and students. In an acknowledgement that the search for creative and innovative solutions to complex problems is best addressed through interdisciplinary collaborations, research-intensive universities are increasingly encouraging interdisciplinary projects and programs. The expansion of interdisciplinary research to the context of doctoral research may impact several core components of the doctorate: the enactment of the student–supervisor relationship, the process of forming and working with a supervisory committee, and the process and outcomes of doctoral research. In order to ensure that interdisciplinary doctoral supervision occurs in a positive and effective way, it is necessary to understand the distinct needs and challenges of interdisciplinary students and their supervisors, through scholarship about this phenomenon.

Résumé

Cet article retrace la recherche existante dans le domaine de l'interdisciplinarité ainsi que l'encadrement de recherches doctorales. Les programmes interdisciplinaires de recherches doctorales répondent à l'incitation des organismes de financement et à l'enthousiasme des professeurs et des étudiants et, de ce fait, deviennent de plus en plus nombreux. Les universités centrées sur la recherche encouragent la création de projets et de programmes interdisciplinaires, car elles sont convaincues que les solutions innovatrices et créatives aux problèmes complexes se réalisent par le truchement de collaborations interdisciplinaires. La demande croissante de recherche interdisciplinaire crée cependant un effet important sur plusieurs composantes centrales du doctorat : la mise en œuvre de la relation étudiant-superviseur; le processus de formation et de travail du comité de supervision; et les processus et résultats de la recherche doctorale. Pour que l'encadrement doctoral interdisciplinaire se déroule de façon positive et efficace, il est donc nécessaire de comprendre clairement quels sont les différents besoins et défis des étudiants et de leurs superviseurs, en fonction du savoir déjà existant dans le domaine.

Introduction

Interdisciplinary graduate supervision is an expanding phenomenon. Funding agencies are prioritizing interdisciplinary work at the doctoral level, as evidenced by programs such as the U.S. National Science Foundation's Integrative Graduate Education Research and Training Program (National Science Foundation, 2011) and the Canadian Institute of Health Research's Strategic Training Initiatives in Health Research (Canadian Institutes of Health Research, 2006). In response to encouragement from funding agencies, enthusiasm from faculty and students (Rhoten, 2004; Rhoten & Parker, 2004), and an acknowledgement that the search for creative and innovative solutions to complex problems is best addressed through interdisciplinary collaborations, research-intensive universities are increasingly encouraging interdisciplinary projects and programs (Gibney, Copeland, & Murie, 2009; Pinar, 2004). The expansion of interdisciplinarity to the context of doctoral research may impact the enactment of the student–supervisor relationship as well as the process and outcomes of graduate research. In order to ensure that interdisciplinary graduate supervision occurs in a positive and effective way, it is necessary to understand the distinct needs and challenges of interdisciplinary students and their supervisors, through scholarship about this phenomenon. This literature review examines the emerging body of literature on interdisciplinary doctoral (ID) supervision, using the guiding research question "what is known about interdisciplinary doctoral supervision?".

Although the supervisory relationship is the backbone of most graduate programs, theoretically grounded research about the dynamics of graduate supervision is still an emerging area of research (Deuchar, 2008; Grant, 2003; Grant, 2005; Halse & Malfroy, 2010; Lee, 2008; McCallin & Nayar, 2012; Sambrook, Stewart, Roberts, 2008). Empirical research on this topic may be constrained given that this relationship has been considered private and personal and traditionally conducted "behind closed doors" (Green & Lee, 1995; McWilliam

& Palmer, 1995). In addition, students may not be willing to share negative information about their supervisory experience due to concerns regarding anonymity and the need for a continued good relationship throughout their academic careers (Lee & McKenzie, 2011).

The recent emergence of interdisciplinary graduate education programs has the potential to further complicate the supervisory relationship, given that interdisciplinarity introduces factors such as cross-disciplinary co-supervision (Kiley, 2009), multiple theoretical orientations on supervisory committees (Nisselle & Duncan, 2008; Taylor, Beasley, & Ebrary, 2005), and different orientations to the process of doctoral research. Similar to its disciplinary counterpart, Spelt and colleagues argue that "while interdisciplinary higher education is commonly practiced, a surprisingly small body of theory has accumulated" (Spelt, Biemans, Tobi, Luning, & Mulder, 2009, p. 378). There is little, if any, available theoretical literature concerning the phenomenon of interdisciplinary graduate supervision; the majority of existing literature focuses on instrumental work, including practical tips for engaging in interdisciplinary doctoral research and supervision, as opposed to empirical and theoretical advances.

Methodology

A scoping approach to literature review is a systematic way of selecting, collecting, and summarizing a wide range of literature and applying an analytical reinterpretation of the data in order to show the breadth and depth of the topic (Levac, Colquhoun, & O'Brien, 2010). This approach is particularly useful when the topic to be reviewed is complex (Mays, Roberts, & Popay, 2001). Methodologically, we followed the approach outlined by Arksey and O'Malley (2005) who suggest that scoping reviews can be used to map fields of study where it is difficult to visualize the range and variation of literature, thereby identifying gaps and areas of saturation in existing literature. From this process, it is possible to contextualize the current state of knowledge and understanding (Anderson, Allen, Peckham, & Goodwin, 2008) and to draw conclusions regarding the overall state of literature in a particular research area. Scoping reviews include literature with varied study designs, including empirical and theoretical sources, but do not aim to assess the quality of the literature reviewed (Arksey & O'Malley, 2005).

The scoping approach to literature review goes beyond gathering and reporting data. A scoping review involves intellectual creativity in the analytical phase (Davis, Drey, & Gould, 2009); requiring "'sense-making' across fields of inquiry that are complex and lend themselves to interpretation through many academic and theoretical disciplines" (Anderson et al., 2008, p.6).

Methods

The guiding question for this review ("what is known about interdisciplinary doctoral supervision?") was formulated broadly to incorporate a wide range of existing scholarship in this area (Arksey & O'Malley, 2005). The aim of the review was to retrieve and critically analyze scholarly literature (empirically or theoretically driven), which contributes to knowledge about this phenomenon. This breadth includes scholarly articles that report on interdisciplinary research projects with attention to the perspectives of supervisors and doctoral students who engage in such projects, supervisor and doctoral student relationships and processes for working with each other, and supervisory committees, funding agencies, doctoral student colleagues, and disciplinary structures.

"Interdisciplinary" was defined broadly for this review, in order to incorporate as many sources as possible, and included alternate search terms such as multi-disciplinary, integrative, and transdisciplinary. While these terms are not synonyms (Klein, 1990; Klein, 2000; Klein, 2005), research in each of these areas speaks to the complexities of interdisciplinary supervision. These terms have been well defined elsewhere (Klein, 1990; Klein, 2000; Klein, 2005; Lattuca, 2003; Pohl et al 2008). Review was specifically interested in doctoral-level research. Doctoral research was chosen as the focus of the review because it was reasoned that the doctoral degree represents the process of "coming-to-be" a scholar (Green & Lee, 1995); bachelor's, master's, and professional degree students may not be pursuing an academic career, and post-doctoral fellows may have already formed their scholarly identities. The supervisory relationship was the crux of this study, and while there is ample work on interdisciplinary research and interdisciplinary curricula, there is little work with this specific focus.

Literature was searched via (a) education (ERIC, ProQuest Education, CBCA Education) and interdisciplinary research databases (Scholar's Portal, Google Scholar, IBSS), (b) the library catalogues of Western University and McMaster University, (c) hand searching the reference lists of key publications and key journals, and (d) by inquiring amongst the research team's networks for relevant sources. Table 1 shows the search strategy, which reflects an evolving depth of understanding of the topic as the review progressed (Arksey & O'Malley, 2005). As this is a relatively new phenomenon, the search strategy was not limited by year. The search tasks were completed in September 2011. The title and/or abstract of each retrieved paper was read to determine whether the source addressed doctoral supervision specifically, in relation to interdisciplinary doctoral research. If no abstract was available, the table of contents or introduction was used to determine relevance. See Table 1 for a list of search terms. When all the terms from the search categories were used together, there were very few sources available; when all the search terms except for one column were used, there was a profusion of irrelevant sources. Reference lists and lists of citing sources were hand searched, and inquiries were made to scholars working in this area for leads on additional relevant or seminal sources.

Table 1. Search Terms (columns combined with "and", rows combined with "or")

Type or Work	Type of Degree	Role
Interdisciplinary	Doctoral	Supervis*
Cross-disciplinary	PhD	Advis*
Multi-disciplinary	Graduate	
Trans-disciplinary	Postgraduate	
Integrative		

* indicates the use of the boolean operator for truncation, which expands a search term to include all forms of a root word.

Due to the paucity of literature (Spelt et al., 2009) addressing interdisciplinary doctoral supervision exclusively, a logic of inclusion rather than exclusion was adopted. Sources that addressed the topic of interdisciplinary doctoral supervision tangentially were included if the section that addressed the relevant area was grounded in scholarly literature. For instance, a source that was mainly about doctoral supervision but also addressed interdisciplinary complications would be included if the mention of interdisciplinary complications was related back to existing scholarly literature.

Eighty-nine sources, including journal articles (54), books (17), essays in edited anthologies (7), grey literature (6), conference proceedings (2) and dissertations (3), were reviewed for the final analysis. These sources were grouped as "primarily relevant" (18), that is, mainly focusing on interdisciplinary doctoral supervision, and as "secondarily relevant" (71), that is, mainly focusing on another topic, however addressing interdisciplinary doctoral supervision as a secondary topic of interest. The sources from the "primarily relevant" group are summarized in Table 2. Two additional relevant papers, published after the search was completed, are also included in Table 2 (Lyall & Meager, 2012; Parchoma & Keefer, 2012)

The literature in this area was found to be diverse in terms of discipline, study design, approach, and focus. Data were analyzed according to type: empirical, theoretical, program evaluation, instructional, and reflection on personal experience. The main points (relating to interdisciplinary graduate supervision) of each source were identified and summarized. A thematic analysis of the data was undertaken. Significant thematic overlap in the main points of different types of sources were found, and the data was organized thematically to determine areas of saturation and gaps in the literature. This thematic analysis was iterative, involving identification of themes, discussion amongst members of the research group who considered different ways of organizing the themes and clarified points of contention in thematic organization. The suggestions and critical commentary of the group refined the thematic analysis.

Table 2: Explicitly Relevant Sources

First Author	Year	National Context	(Inter)Disciplinary Context	Type of Work	Key Points
Adkins	2009	Australia	Published in an education journal; examples from humanities, arts, social sciences. Analytical framework from sociology.	Journal article, theoretical	• Conceptual and analytical focus on supervision as pedagogy; focus on relationship of learning context and knowledge process. • Acknowledges necessity to cross disciplinary boundaries both within academia and between academia and other fields. These changes necessitate different ways of producing, using, and transferring knowledge. • Uses analytical framework developed by sociologist Basil Bernstein to examine the connection between increasingly interdisciplinary knowledge requirements of universities and the implications for interdisciplinary doctoral research and supervision.
Blackmore & Nesbitt	2008	Australia	From proceedings of a conference on computing education. Authors affiliated with accounting, computer science, design, communication, and information technology.	Conference proceedings, theoretical, with reflection on authors' personal experience as ID student–supervisor pair.	• Describes a discipline-based supervisory model and the issues raised for interdisciplinary doctoral students. • Outlines potential issues and risks at different stages of the interdisciplinary PhD. • Draws analogies between software engineering and ID research projects.
Fry, Tress & Tress See also Tress, Tress & Fry, 2009	2006	Norway	Authors affiliated with Life Sciences, Environmental Sciences. Book addresses interdisciplinary study of landscape planning.	Book chapter, theoretical.	• Book chapter exploring the ways PhD students in different European countries cope with the dynamics of interdisciplinary studies. • Suggests several needs of interdisciplinary PhD students related to their supervisors and the wider institutional infrastructure. • Concludes that interdisciplinary research can be interesting but also threatening at the PhD level.

First Author	Year	National Context	(Inter)Disciplinary Context	Type of Work	Key Points
Golde & Gallagher	1999	USA	Authors affiliated with educational administration; journal related to ecology. Examples from science.	Journal article, theoretical.	• Examines the challenges facing American doctoral students in traditional programs who wish to undertake interdisciplinary research. • Highlights structural challenges, the need for support from advisor, program, and institution.
Golding	2010	Australia	Author is affiliated with Education; Journal is multidisciplinary.	Journal article, theoretical.	• Offers suggestions and tools for interdisciplinary graduate students to avoid misunderstandings with supervisor or committee. Most suggestions relate to ways of positioning work at the confluence of disciplines and articulating this positioning.
Green & Lee	1995	Australia	Journal and authors both affiliated with education.	Journal article, theoretical.	• Identifies a gap in theory existing around pedagogies of postgraduate supervision. • Concerned with disciplinary implications for postgraduate pedagogy, particularly when the role of advisor is reduced to supervision of research, without explicit acknowledgement of the ways in which supervision influences the formation of academic identity.
Kiley	2009	Australia	Journal and author both affiliated with Education.	Journal article, empirical (qualitative).	• Qualitative study exploring the selection of examiners for doctoral exams. • Choosing examiners is particularly challenging for interdisciplinary dissertations, finding someone who is open to the methodology and style of thesis, and also has content expertise. Additionally, the examiner should be accepting of an interdisciplinary approach and be able to see the work as a whole, rather than just focusing on their area of disciplinary expertise.

First Author	Year	National Context	(Inter)Disciplinary Context	Type of Work	Key Points
Lyall & Meagher[1]	2012	UK	Multidisciplinary journal. Authors work in biotechnology and social impact of genomics.	Journal article, theoretical. Draws on empirical study (mixed methods).	• Based on experience from an initiative to build interdisciplinary capacity of early and mid-career researchers; offers suggestion for improved supervision and mentoring of interdisciplinary graduate students. • Offers suggestions for developing and maintaining a committed supervisory team; building foundations and setting boundaries for the research, structuring and writing the thesis; building an interdisciplinary network; and developing a publication strategy.
Lyall et al.	2008/2011	UK	Authors work in biotechnology and social impact of genomics. Project sponsored by research institute related to science, technology, and innovation.	Briefing Note (2008); Report, Empirical study (2011) (mixed methods).	• 2008 is a short summary of findings related to interdisciplinary supervision from an empirical study aiming to build interdisciplinary capacity (2011). • Themes are similar to those in Lyall (2012), based on the same work.
Manathunga	2006	Australia	Journal and authors are affiliated with Education.	Journal article, theoretical.	• Imagines a new ID pedagogy after exploring examples of ID doctoral and undergraduate programs. • Proposes four major dimensions of an ID doctoral pedagogy relating to learning experiences, opportunities to develop knowledge and skills, metacognition, interdisciplinary understandings of epistemology.

First Author	Year	National Context	(Inter)Disciplinary Context	Type of Work	Key Points
McGee & DeLong	2007	USA	Biomedical and life sciences	Journal article, empirical (qualitative).	• Formative evaluation of an NIH program which partners PhD students with two or more mentors; many students choose mentors from different disciplines and the formative evaluation specifically addressed these interdisciplinary supervision experiences. • The inclusion of interdisciplinary mentors prepared students for working within different disciplines, bringing insights from one to the other and readied students for collaborative research.
Mitchell	2009	Australia	Funded by an education council. Author affiliated with interdisciplinary research unit, researches corporate sustainability, international development, water, and sanitation.	Report relating to a three-year fellowship completed by the author.	• Discusses challenges of doing interdisciplinary research and supervising interdisciplinary students. • Provides summative quality criteria that might be helpful for evaluating the outputs of research and formative processes students might use to meet these goals. • Also includes workshop resources and ideas for good practice in ID research supervision.
Mitrany & Stokols	2005	USA	Journal and authors are affiliated with urban planning, policy and design, social ecology. Assessed dissertations from ID programs related to planning, environmental health science, psychology, and criminology.	Journal article, empirical (quantitative).	• Analyzed 144 doctoral dissertations with the aim of developing reproducible criteria to assess the inter/transdisciplinary qualities of doctoral dissertations and training programs. • Examined attributes of dissertations as well as personal and situational factors associated with level of transdisciplinarity. Departmental affiliation of supervisor was most significant factor influencing the transdisciplinary qualities of the research. Number of fields represented among thesis committee members was also significant.

First Author	Year	National Context	(Inter)Disciplinary Context	Type of Work	Key Points
Nisselle & Duncan	2008	Australia	Journal is interdisciplinary. Authors are affiliated with paediatrics, genetics education, bioethics.	Journal article, theoretical.	• Outlines key advantages and challenges associated with multidisciplinary supervision, especially when multiple supervisors are involved. • Introduces practical, academic, and epistemological challenges and provides potential strategies for amelioration.
Parchoma & Keefer[2]	2012	UK, USA + five unnamed countries where participating supervisors worked.	From proceedings of a conference on Networked Learning. Authors affiliated with education and communication departments. Participants work in the area of educational research and/or technology enhanced learning.	Conference proceedings, empirical (qualitative).	• Constructivist grounded theory study that posits a conceptual framework for examining interdisciplinarity. • Interdisciplinary supervision challenges often linked to supporting students to overcome knowledge gaps, develop methodological expertise, bridge loose ties between supervisor–student interests.
Petersen	2007	Australia	Education journal; author affiliated with humanities, communication, and social sciences.	Journal article, theoretical.	• Theorizes doctoral education as a process of subjectification and doctoral supervision as "category boundary work," wherein boundaries are negotiated about the meaning and identity of being an academic. • Discusses the ways in which constructions of academicity are closely tied to constructions of disciplinary acceptability, Providing a useful lens for understanding some of the tensions that may present when supervisor and student are not working within one discipline.

First Author	Year	National Context	(Inter)Disciplinary Context	Type of Work	Key Points
Rhoten	2003	USA	Principal authors affiliated with education and an interdisciplinary research institute. Report published by the same institute.	Report, empirical (mixed methods).	• Report detailing the social and technical conditions for interdisciplinary collaboration. Details networks of six interdisciplinary research centres. • While graduate students were often the most enthusiastic about the need and potential for ID research, they perceived/experienced fewer positive effects. • Graduate students often centrally located within ID networks, acting as connectors between other members.
Smith, S.	1997	USA	Author reflects on experience working with political philosophy and social policy analysis. Book is from politics.	Book chapter, personal reflection.	• The author reflects on his experience completing an interdisciplinary PhD with co-supervisors in different disciplines. • Discusses advantages and challenges of this approach, offers suggestions for other students embarking on an interdisciplinary thesis.
Spelt et al.	2009	The Netherlands	Journal is related to educational psychology; authors are associated with various social scientific disciplines.	Journal article, literature review and critical analysis.	• Reviews and analyzing literature related to interdisciplinary higher education; search terms relevant to but not specific to interdisciplinary doctoral research or supervision. • Analysis groups answers regarding the context of interdisciplinary higher education and interdisciplinary thinking, student conditions, learning environment conditions, learning process conditions and the relationship between these items.
Wall & Shankar	2008	Canada	Education journal; authors discuss experiences related to studies in sociology and nursing.	Journal article, narrative analysis of authors' experiences as interdisciplinary doctoral	• Through narrative analysis, highlights the features of a transdisciplinary doctoral training program which contributed to success, including mentorship and relationship with non-supervising faculty members and the program director, who provided alternative areas of expertise and different perspectives.

Notes.

1. Not included in review paper, due to date of publication
2. Not included in review paper due to date of publication

Findings

There is sparse literature on the specific topic of interdisciplinary doctoral supervision. A recent literature review on the area of teaching and learning in interdisciplinary higher education identified only 13 relevant empirical works on this topic (Spelt et al., 2009). Areas of saturation and gaps in the literature related to interdisciplinary doctoral research supervision will be discussed, and then an integrated analysis of the findings from the literature will be presented.

Mapping Existing Literature: Gaps and Areas of Saturation

As literature was collected, it was grouped thematically to determine gaps in existing research and areas of saturation. The three identified categories are: (i) descriptions of interdisciplinary doctoral (ID) research, (ii) challenges of ID research, (iii) approaches to successful ID research supervision. Each of the identified categories represent areas of saturation in the current literature and opportunities for future research.

I. Descriptions of interdisciplinary doctoral research. Descriptions of interdisciplinary doctoral (ID) research, defined as definitions of ID research and descriptions of ID programs, is a well-saturated area of research. Within the literature on ID research, there is widespread acceptance of Klein's taxonomy of interdisciplinarity (Klein, 2010; Klein, 1990), with some authors using more nuanced definitions combining the ideas of several scholars, often including Klein. Beyond this approach to defining interdisciplinarity, some authors choose to work with their own definitions, or without defining their particular version of interdisciplinarity. Among those working with their own definitions, there is little consistency or precision in these definitions, perhaps reflecting that despite a growing body of literature, "interdisciplinarity is not a unified and clearly defined phenomenon" (Manathunga, Lant, & Mellick, 2006, p. 366).

There is a significant amount of literature describing particular interdisciplinary doctoral programs (Copenheaver, Nelson, & Goldbeck, 2009; Coryn, Stufflebeam, Davidson, & Scriven, 2010; da Sousa Correa, Chornik, & Samuels, 2009; McGee & DeLong, 2007; Mcvicar et al., 2006; Rhoten, 2003; Rhoten & Parker, 2004; Skarakis-Doyle & Doyle, 2008; Stufflebeam, 2001; Sugimoto, 2010). This literature is focused on articulating current practices with varying degrees of description, reflection, and use of empirical data. The phenomenon of supervision in these programs is mostly a tangential topic in the description of current practices. With the exception of Rhoten and colleagues' study of five interdisciplinary research programs (Rhoten, 2003; Rhoten & Parker, 2004; Rhoten, 2004) and Enders' (2005) examination of different modes of doctoral research training (Enders, 2005), this literature concerns single-site studies with various levels of empirical data. Empirical research in this area includes formative evaluation (McGee & DeLong, 2007) surveys, interviews (Sugimoto, 2010), bibliometric approaches (Sugimoto, 2010), and academic genealogical analysis (Copenheaver et al., 2009). Generally the literature in this area is descriptive, offering a historical account of how the program came to be, the disciplines involved, a characterization of the areas of expertise of the faculty members and students, and a justification for why interdisciplinary work is necessary in this topic area. These articles rarely comment on how their specific programs relate to other interdisciplinary programs or interdisciplinary scholarship on a broader scale; there is little theoretical development in this body of literature.

There is a gap in research concerning multi-site comparisons of interdisciplinary doctoral programs. Rhoten and colleagues (Rhoten, 2003; Rhoten & Parker, 2004) have undertaken a multisite comparison of interdisciplinary research centres, however they do not focus on graduate supervision. There is also little literature that examines institutional barriers and facilitators of ID supervision. Sá's work investigating institutional barriers and facilitators to interdisciplinary research conducted by faculty suggests that this may be a rich area of study in the context of doctoral research and supervision (Sá, 2006; Sá, 2008a; Sá, 2008b). There have been suggestions of institutional constraints that may challenge interdisciplinary supervisors and students who work in traditional research programs (Golde & Gallagher, 1999; Mitrany & Stokols, 2005) and an examination of the institutional conditions that create a learning environment that encourages interdisciplinary doctoral work (Spelt et al., 2009); however empirical comparative work in this area is sparse. In addition to a lack of empirical work in this area, there is a paucity of theoretical work, a gap that will be further discussed as an opportunity for future scholarship.

II. Challenges of ID research. By far the most saturated area of literature is reflective papers that combine reflection on personal experience of ID research with a survey of selected literature. The literature in this category tends to focus on challenges of ID research, from the perspective of the author (Golding, 2010; Hagoel & Kalekin-Fishman, 2002; Martin, 2011; Nisselle & Duncan, 2008; Robinson, 1997; Smith, 2001; Smith, 1997; Wall & Shankar, 2008). There is little work on the potential strengths of ID research, although most authors mention why they were drawn to work in an interdisciplinary way, commonly for reasons of interest in the topic or a desire to produce information that was applicable to real world problems.

In addition to the sources related to personal experience as an interdisciplinary doctoral student or supervisor, there are a few sources that address the challenges of ID research from theoretical or empirical perspectives rather than descriptive or experiential perspectives. Such work is well grounded in existing literature on supervisory pedagogy and interdisciplinary research (Fry, Tress & Tress, 2006; Pole, 1998; Sampson & Comer, 2010; Tress, Tress, & Fry, 2009). Also addressing the challenges of ID research are a number of instructional books that mention interdisciplinary doctorates in a passing way, on the topics of supervising doctoral students (Bartlett & Mercer, 2001; Delamont, Atkinson, & Parry, 2004; Eley & Jennings 2007; Gordon & Habley, 2000; Nightingale & Higher Education Research and Development Society of Australasia, 2005; Taylor et al., 2005; Wisker, 2005) or completing a doctorate (Bartlett & Mercer, 2001; Burnham, 1997; Finn, 2005; Phillips & Pugh, 2005; Semenza, 2005).

III. Approaches to successful ID research supervision. Category (iii) describes potential tools or approaches for successful supervision of ID research. It is the least developed area of literature, with most work falling into two categories: (a) theoretical considerations for interdisciplinary pedagogies for doctoral supervision and (b) work regarding the development and use of evaluation tools for ID research, both empirical and theoretical.

Several authors agree that ID research requires a different pedagogy of supervision than single disciplinary doctoral research (Bauer, 1990; Delamont et al., 2004; Green & Lee, 1995; Hodge, 1995; Manathunga et al., 2006; Mitrany & Stokols, 2005; Mitchell, 2009a; Mitchell & Willetts, 2009). Petersen (2007) has developed an analytical tool based on the concept of category boundary work to examine the ways in which the su-

pervisory relationship shapes graduate students as academics. This conceptualization is explicitly context sensitive and provides a useful lens with which to consider the unique challenges that may be encountered by those in ID supervisory relationships, as well as the differences between "becoming" an interdisciplinary scholar versus a disciplinary scholar (Petersen, 2007). Some pedagogical literature remains a theoretical or philosophical reflection on the phenomena (Bauer, 1990; Green & Lee, 1995; Hodge, 1995), while others move beyond the broader scholarship on supervision pedagogy to generate pedagogical elements that may be specifically relevant to interdisciplinary supervision. Common proposed pedagogical elements include epistemological and methodological coherence, flexibility when working with a wide variety of literature and methodologies. a self-reflexive disposition, a reflexive orientation towards different bodies of knowledge, emphasis on contribution, and communication to multiple types of audiences (Green & Lee, 1995; Manathunga et al., 2006; Mitchell, 2009a; Mitchell & Willetts, 2009; Mitrany & Stokols, 2005; Smith, 2001)

The literature on ID evaluation is divided into two different types: theoretical and empirical. The theoretical literature on evaluation of ID research is congruent with the pedagogical literature, sometimes co-existing in a single text (e.g. Adkins, 2009; Boix-Mansilla & Duraising, 2007; Mitchell, 2009a; Mitchell & Willetts, 2009). Common themes in theoretical approaches to evaluation of interdisciplinary literature include an emphasis on responsive and reflexive goals; broad preparation and mastery of process; evolution of epistemology, methodology, and methods so as to achieve coherency and alignment; critical reflection and reflexivity; effective communication to diverse groups; critical and pluralistic engagement with the literature (Hodge, 1995; Mitchell, 2009a; Wickson, Carew, & Russell, 2006)

Empirical research concerning evaluation of interdisciplinary student work is a small but growing body of literature. Harvard's Interdisciplinary Studies Project has contributed insights of faculty who participate in evaluation of interdisciplinary work (Boix Mansilla, 2006; Boix-Mansilla & Duraising, 2007; Rhoten, Boix-Mansilla, Chun, & Klein, 2006) and the project reports on the results of an exercise in interdisciplinary collaborative evaluation of student work (Boix-Mansilla, 2005). Others developed quality criteria by examining student work such as successful graduate scholarship applications and dissertations (Borrego & Newswander, 2010; Mitrany & Stokols, 2005).

Thematic Analysis

The thematic analysis is organized into two parts: an analysis of the themes in the existing literature (Existing Knowledge about Interdisciplinary Doctoral Supervision) and a secondary analysis (Gaps in Knowledge) that asks what the next steps are, where opportunities exist for more research, and what needs to be explored further.

1. Existing Knowledge about Interdisciplinary Doctoral Supervision

There are several key themes frequently occurring in the literature that we have conceptualized as challenges (1a) and suggestions for overcoming challenges (1b).

1a. Challenges of Intellectual and Physical Diffusion. Interdisciplinary work necessitates a move outside of the disciplinary–departmental format that structures most

doctoral research. Without the traditional structure of disciplinary departments or programs, interdisciplinary students may find that the physical and intellectual resources they wish to access are not necessarily available in a single format, location, or cohesive package. In this section of the paper, the challenges of intellectual and physical diffusion, the possible barriers students may encounter as they pursue interdisciplinary research are identified from the literature.

The phrase "intellectual diffusion" refers to ideas that may not commonly occur together and may have to be sought out, reconciled, explained, or justified as a package. This may include institutional factors such as different departmental or disciplinary expectations for the elements of the Ph.D., for instance the format and content of a research proposal or comprehensive exams (Blackmore & Nesbitt, 2008). An interdisciplinary student may need to contend with different visions of the purpose of the Ph.D. Do the different disciplines involved consider the PhD a vocational goal or a vehicle for student development (Nisselle & Duncan, 2008)? As in single disciplinary doctoral degrees, students may grapple with different supervisory conceptions of whether the content or the act of learning is of primary importance (Franke & Arvidsson, 2011), or encounter different ideas of what a PhD *is* and how it is *done,* both of which may also affect relationships with supervisors (Pole, 1998). The student and supervisor or co-supervisors may have distinct ideas about the supervisory role. Does the supervisor act as a project leader or supervisor (Franke & Arvidsson, 2011)? Is supervision an administrative or pedagogical task (B. Smith, 2001)? This misunderstanding of roles may be complicated by the propensity for interdisciplinary students to have co-supervisors (Kiley, 2009). Inconsistent views of the nature of supervision may affect the academic success and identity of the student (Smith, 2001). Green and Lee contend that "supervision is not just coming to know, it is also coming to be" (Green & Lee, 1995), a formation of the academic self (Manathunga, 2007; Petersen, 2007). Peterson (2007) suggests that through the supervisory relationship, individuals "come to embody insidious and tacit knowledges re: how to express recognition of competence, how to express our recognition that what someone does or says falls outside the domain of the appropriately academic," (Smith, B., 2001, p.30) and that we learn this through multiple social and discursive sites. Reconciling conflicting messages may be challenging, as models of supervision are a product of "deeply entrenched cultural norms that we may not even be aware of" (Smith, B., 2001, p.30).

Interdisciplinary supervisory committees bring intellectual diversity although single disciplinary students may also face these issues on their supervisory committees. Taylor suggests it is important for all members of a supervisory committee to have a common framework for understanding basic matters of research such as epistemology, relation of theory to practice, and ways of locating problems and finding solutions (Taylor et al., 2005). That is not to say that each member of the committee should agree or share the same theoretical lens, but that it is important for all members to have a way to discuss these issues in an explicit way and to negotiate how best to support the student. A few authors (Nisselle & Duncan, 2008; Taylor et al., 2005) suggest that without this discussion, there is a possibility for "disciplinary chauvinism" within the committee, undermining the concept of interdisciplinary work.

Beyond the supervisory relationship, interdisciplinary students may be challenged when working outside of disciplinary or departmental lines by a lack of a peer group who

can evaluate interdisciplinary research for funding (Hagoel & Kalekin-Fishman, 2002) or peer review publications (Wickson et al., 2006). Interdisciplinary students often struggle to find evaluators or examiners who can see the project from multiple angles rather than assessing it from a single disciplinary perspective (Kiley, 2009), which may be disadvantageous when work considered stylistically appropriate in one discipline may not be appropriate in another (Blackmore & Nesbitt, 2008). Interdisciplinary research initiatives may be educating strong scholars who struggle to fit into disciplinary frameworks for success.

Academic work is often rewarded or productivity assessed through disciplinary structures such as disciplinary publications, departmental promotions (Greybill & Shadas, 2010; Pfirman & Martin, 2010), or disciplinary funding mechanisms (Golde & Gallagher, 1999). In both external and internal assessment situations, disciplinary groups are the primary locus of control over doctoral education (Golde & Gallagher, 1999). Some authors suggest it is essential that ID students learn to work in a style acceptable to both and in a way that constitutes a contribution to both bodies of knowledge (Golde & Gallagher, 1999; Nisselle & Duncan, 2008). In this body of literature, the onus is on students to learn and work in ways that fit traditional academic structures with little emphasis on changing the way academic structures work with interdisciplinary scholars and no calls for interdisciplinary institutions or journals to accommodate the burgeoning amount of interdisciplinary work were found.

The challenges of intellectual diffusion may be exacerbated by physical diffusion. It may be difficult for students to find an advisor who is interested and capable of supervising an interdisciplinary project on the topic of interest at their institution (Golde & Gallagher, 1999). Depending on institutional arrangements, faculty members may not be recognized or rewarded for supervising students outside their home department; institutional structural arrangements can be instrumental in encouraging or discouraging interdisciplinary collaboration (Sá, 2006; Sá, 2008a; Sá, 2008b). In order to obtain the necessary supervisory expertise, interdisciplinary students may be more likely to have co-supervisors (Kiley, 2009), introducing a new set of advantages and complications. Co-supervisors located in different disciplines may be physically separate in the university and may not have worked together before, necessitating the need for the student to develop independence and communication skills (McGee & DeLong, 2007). Physical diffusion also raises issues of office space for interdisciplinary students or accommodation into an existing group of supervised students (Golde & Gallagher, 1999). Co-supervised doctoral students may also struggle with a diffusion of academic responsibility, where no single faculty member is responsible for the academic progress of the student (Phillips & Pugh, 2005).

1b. Ameliorating Challenges. One of the challenges of ID research is the establishment of expectations for achievement. Supervisors, examiners, and peer reviewers from different disciplines may have different ideas about quality criteria (Boix-Mansilla, 2005), about the expectations, purpose, and nature of interdisciplinary work (Boix Mansilla, 2006), and about the requirements of an interdisciplinary doctorate (Taylor et al., 2005). This may also be true of disciplinary doctoral students, but different perspectives are likely to be amplified in interdisciplinary situations (Golde & Walker, 2006).

We may currently be working at a time of epistemological evolution in academia in terms of evolving standards to accommodate ID work, evidenced by a shift in the humani-

ties to standards of reflexivity, situation/standpoint, means of production and re-presentation (Hodge, 1995), and a shift in the sciences towards research carried out in the context of application rather than in the context of a particular academic discipline (Enders, 2005). This shift is reflected in the quality criteria proposed by a number of authors (see Manathunga et al., 2006; Mitchell, 2009b; Mitchell & Willetts, 2009; Mitrany & Stokols, 2005; Wickson et al., 2006) who share a common emphasis on assessing ID work based on contribution to different knowledge domains, breadth versus depth considerations, reflexivity towards work, coherent theoretical perspectives, and effective communication (Manathunga et al., 2006; Mitchell, 2009a; Mitchell & Willetts, 2009; Wickson et al., 2006).

These types of quality criteria require a coherence between epistemological assumptions and methodologies, including understanding and communicating the limitations and values of chosen approaches (Mitrany & Stokols, 2005). There is also an emphasis on the thoughtful pairing of epistemologies and methodologies. Disciplinary knowledge cannot be isolated from its epistemology, methods, theories, and history (Bauer, 1990), but interdisciplinary students can use different bodies of knowledge to critically reflect upon other forms of knowledge in a transformative way, deconstructing and rebuilding a new body of knowledge (Adkins, 2009; Wickson et al., 2006). This type of deconstructive/generative work is an example of how interdisciplinary research may require more time and effort from a student, leaving that student potentially feeling overwhelmed (Golde & Gallagher, 1999). Interdisciplinary research may also require more investment from students in developing expertise in more than one area (Blackmore & Nesbitt, 2008; Golde & Gallagher, 1999; Mitrany & Stokols, 2005), working with supervisors who have different viewpoints and ameliorating their suggestions (Nisselle & Duncan, 2008), and working with a supervisor who does not share epistemological or paradigmatic foundations with the student (Robinson, 1997). However, these challenges may also make interdisciplinary doctoral work more theoretically rigourous.

Due to the requirement for more work than single disciplinary research (Tress et al., 2009), students embarking on interdisciplinary work should have a commitment to working in this way, a belief that the combination of two disciplines can produce better explanations or richer solutions than a single discipline (Smith, S., 1997), an interest in the topic, dedication to practical relevance, a desire for intellectual stimulation, or a wish to do innovative work (Fry et al, 2006; Tress et al., 2009).

2. Gaps in Knowledge

Much of the literature is focused on potential challenges for ID students. Challenges are discussed directly or through suggestions for amelioration; however there is scant literature that focuses on the positive aspects of ID research. One exception is Wall and Shankar (2008), who are explicit about their intent to focus on the positive potential of mentorship for ID researchers. Many authors address the topic with an introductory paragraph about the "importance" of interdisciplinary research or mention enthusiasm for this type of work from funding agencies or industry, yet there is little empirical work about the benefits or advantages to interdisciplinary students. This gap is an important one to explore in order to formulate best practice guidelines for supervision and to determine advantages or disadvantages faced by ID students when competing for jobs and funding in an institutional world that rewards disciplinarity (Rhoten & Parker, 2004; Rhoten, 2004). We

assume here, supported by previous research, that interdisciplinary researchers face many similar issues, regardless of what disciplines are being combined (Rhoten et al, 2006; Lyall & Meager, 2012) and it may be feasible to suggest broad guidelines for interdisciplinary supervision that would be helpful across different areas of research.

There is little empirical work on the advantages and disadvantages of interdisciplinary work during the doctorate, and that which does exist concerns evaluation standards, or is a single-site program evaluation or analysis of theses produced by a particular program. There is ample room for empirical research on ID work, particularly around processes and outcomes for these students. As previously mentioned, the area of definitions of interdisciplinarity is well saturated, with widespread commitment to the taxonomy of interdisciplinarity developed by Klein (Klein, 2010; Klein, 1990; Klein, 2000; Klein, 2006). Yet, it is still unknown whether these definitions have been adopted in practice. Do students and supervisors working on interdisciplinary projects adopt a specific definition of interdisciplinarity or work with individualized, idiosyncratic definitions of this approach?

The existing scholarship on ID research is primarily based on previous scholarship about single disciplinary doctoral research. There are two potential implications to this. First, it raises questions about the difference between single disciplinary and interdisciplinary doctoral research. Without empirical and theoretical work in this area it is impossible to draw any conclusions about the potential similarities and differences between single disciplinary and interdisciplinary doctoral supervision. Some of the literature on single disciplinary doctoral research appears consistent with the experiences of those working with ID students; other literature seems dissonant. While there are, no doubt, commonalities between the two approaches to research, the question arises – are the differences truly different? Or are the differences simply an amplification of challenges that single disciplinary doctoral students also face, such as the challenge of co-supervisors with different areas of expertise or the need to amalgamate different faculty member's expectations of quality? More research is needed to understand the relationship of these two approaches to doctoral research. Second, if we assume there are differences between single disciplinary and ID researchers, what are the implications for conducting research about the phenomenon of interdisciplinary research within the hegemony of the disciplinary frame in academia? If ID research is considered within the frame and structure of single disciplinary doctoral research, what opportunities are missing for further innovation and insight? Is there room for consideration of ID research in its own right, outside of the boundaries and expectations created by traditional disciplinary work? Researchers in this area might ask themselves if they are approaching their research from a disciplinary perspective, expecting the outcome to fit back into a disciplinary frame. They may wish to ask what kind of scholars are we creating through ID study? Where will they fit in the academic world? What kind of opportunities are there for interdisciplinary scholars and how can doctoral education best prepare them to capitalize on these opportunities? When considering the literature on ID supervision in this light, it is clear there is a need for creative, generative research that will provide theory and evidence to encourage excellence in ID research. There is opportunity for this body of research to move beyond existing research that has mapped the surface of the phenomenon to explore the cultural, structural, institutional, and epistemological depths of possibility.

Conclusion

There is little literature specific to ID research although it is a topic commonly addressed in a tangential way by scholars concerned with doctoral research in general or interdisciplinary research in general. The literature that exists in this area is concentrated in accounts of personal experience, descriptions and evaluations of particular doctoral programs, and theoretical work on supervision pedagogy. Many authors claim that interdisciplinary work is becoming more prevalent at the doctoral level, but that has yet to be established on a national or international level. If true, as suggested by single-site studies and anecdotal evidence, the body of knowledge in this area would benefit from more empirical and theoretical exploration of barriers to and facilitators of ID research, exploration of outcomes for students who study in this way, and an examination of processes that lead to success.

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