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Multilevel exploration of the realities of interdisciplinary research centers for the management of knowledge integration

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ABSTRACT

The fostering of interdisciplinarity is increasingly requested of research organizations. However, conventional approaches to academic research management limit our understanding of the way interdisciplinary research (IDR) centers integrate multiple disciplines. This paper proposes a multilevel approach to explore the patterns of knowledge integration and the forms of research organization emerging from the practices and activities of IDR centers. Several bibliometric-based, network-oriented and visualization-rich approaches are used. The cases of two prominent IDR centers are considered: Harvard University's Wyss Institute and Kyoto University's WPI-iCeMS. At the macro level, our results show similarities in the scientific positioning of both IDR centers, which translate into differences in the nature, intensity and drivers of their knowledge interconnections at the meso-level. At the micro-level, we demonstrate that far from idealizations of full convergence, the realities of IDR centers are characterized by heterogeneous patchworks of multi-trajectory research domains—some of these enabling, others generating interdisciplinary knowledge. Differences in knowledge integration occur between but also, and more importantly, within IDR centers. Thus, tailored strategies tuned to the particularities of organizations and topic-based forms of research organization appear to cope better with interdisciplinary knowledge. The understanding of these inter- and intra-organizational differences proves crucial for effectively fostering knowledge integration. An integrated model relating levels of research management and visualization approaches is proposed for the management and assessment of knowledge integration in IDR centers.

1. Introduction

It is widely recognized that the production of knowledge and the various institutions involved in the science system are constantly transforming (Hessels and Van Lente, 2008). These changes are largely due to the increasingly complex scientific, technical, and societal problems facing research institutions (Anzai et al., 2012; Siedlok and Hibbert, 2014). Novel conceptions of and solutions to these challenges are believed to more likely arise from integrative or synthetic approaches cutting across multiple and disparate disciplines (NRC, 2014; Repko, 2008; Stehr and Weingart, 2000). Several labels are used to describe this phenomenon, such as "interdisciplinarity", "transdisciplinarity", "fusion", "convergence", "hybridization", "cross-disciplinarity", "anti-disciplinarity", and "cross-fertilization", among others (Battard, 2012; Islam and Miyazaki, 2010; Lauto and Sengoku, 2015; Moss, 2011). Despite their differences, these terms all imply the significance of the integration of different strands of expertise, theories, methods, or data (Repko, 2008; Wagner et al., 2011). To emphasize this common ground, the remainder of this paper uses the terms "knowledge integration" and "interdisciplinarity" interchangeably.

Knowledge integration is believed to lead to new knowledge (Huutoniemi et al., 2010). It has also been regarded as a potential source of competitive advantage and innovation (Siedlok and Hibbert, 2014; Siedlok et al., 2015). Several authors have expressed caution and skepticism about the promises of interdisciplinary approaches (Frodeman, 2011; Jacobs, 2013). Nevertheless, the increased interest in knowledge integration has led to its continuing and accelerating support in science and technology policy programs throughout the world (Anzai et al., 2012). New modes of production of integrative knowledge have emerged through the creation of research centers, programs, and courses with explicitly interdisciplinary aims (Hessels and Van Lente, 2008; Siedlok and Hibbert, 2014). These activities have embraced multiple fields of science and technology. Interdisciplinarity has been particularly influential on the life sciences (Burggren et al., 2010). Building on advances in molecular and cellular biology and genomics, interdisciplinary, high-impact life sciences research is ex-

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pected to lead to innovative solutions and sustainable new technologies (Sharp and Langer, 2011). Recent reports have proposed the *convergence* of life sciences with physical, mathematical, computational, engineering, and social sciences as a way to accelerate innovation (MIT, 2016; NRC, 2014). Examples of convergent, interdisciplinary initiatives in the US include the Brain Research through Advancing Innovative Neurotechnologies (BRAIN) Initiative, the Precision Medicine Initiative, and the National Cancer Moonshot Initiative (MIT, 2016).

Over the years, numerous research efforts have been undertaken to elucidate the determinants (Siedlok and Hibbert, 2014; Stokols et al., 2008; Su, 2014; Van Rijnsoever and Hessels, 2011), processes (Lee et al., 2015; Siedlok et al., 2015), outcomes (Anzai et al., 2012; Bishop et al., 2014; Gowanlock and Gazan, 2013; Jensen and Lutkouskaya, 2014), or combinations of these aspects (Wooten et al., 2014) of interdisciplinary research. Other studies have approached interdisciplinarity more theoretically, such as in definitions of typologies (Huutoniemi et al., 2010; Siedlok and Hibbert, 2014), or more practically, such as in studies of its barriers and facilitators (Aldrich, 2014; CFIR, 2005; NRC, 2014). Although no consensus on the definition of "interdisciplinarity" has yet been established, all these studies have clarified its characteristic features: its scientific domain-dependence (Sanz Menéndez et al., 2001; Van Rijnsoever and Hessels, 2011), the co-existence of multiple forms of interdisciplinarity (Huutoniemi et al., 2010; Klein, 2008; Siedlok and Hibbert, 2014), its close complementarity with disciplinary knowledge (Jacobs, 2013; Stehr and Weingart, 2000), and its cognitive and social duality (Klein, 2008; Wagner et al., 2011). As knowledge accumulates, the need becomes urgent for research stakeholders to facilitate and foster interdisciplinary research in their organizations. Despite these calls, we know little about how interdisciplinary research centers integrate multiple disciplines in practice. It is hypothesized that knowledge integration in IDR centers is likely influenced by the features of interdisciplinarity mentioned above. However, no empirical research has yet demonstrated pragmatically how these features translate into the patterns of integration emerging from the practices and activities of IDR centers. Several assessment and measurement approaches have been proposed for this purpose (Anzai et al., 2012; Bishop et al., 2014; Gowanlock and Gazan, 2013; Jensen and Lutkouskaya, 2014; Kaplan et al., 2014; Rafols, 2014), but they have not been able to properly address the multi-dimensionalities, complexities, multiple levels of aggregation and granularity, and different perspectives inherent in interdisciplinary research (Cambrosio et al., 2006; Klein, 2008; Rafols et al., 2012; Rafols and Meyer, 2010; Sanz Menéndez et al., 2001). There is thus a clear need for empirical approaches to study the practices of knowledge integration in interdisciplinary research centers in a holistic, integrated, and multilevel manner.

Within this context, this paper addresses the following research questions: What patterns of knowledge integration emerge from the practices and activities of IDR centers? , and how do these patterns relate to their forms of research organization? To answer these questions, this paper uses the empirical cases of two convergent, life sciences-oriented research centers explicitly established with interdisciplinary aims: Kyoto University's Institute for Integrated Cell-Material Sciences (WPI-iCeMS) in Japan and Harvard University's Wyss Institute for Biologically-inspired Engineering (Wyss Institute) in the US. A three-level (macro, meso, and micro) analytical framework is proposed. Each level comprises a series of research activities that visually and quantitatively capture, from different degrees of granularity and perspectives, the cognitive structures underpinning research centers. For that purpose, this paper uses several bibliometric-based, network-oriented and visualization-rich approaches, including research landscape maps, science overlays (Leydesdorff and Rafols, 2009), density maps (Van Eck and Waltman, 2011), cluster mapping approaches, and heatmaps. The properties and dynamics of these cognitive structures are used as proxies for the patterns of knowledge integration and the forms of organization emerging in the practices of IDR centers. Knowledge integration is measured through the analysis of published scientific papers. The limitations of this method will be discussed in subsequent sections. Our results demonstrate that the realities of knowledge integration in IDR centers are far from their typical idealizations of full convergence. The similar scientific positionings of both IDR centers at the macro level translate into differences in the nature, intensity and drivers of their knowledge interconnections at the meso-level. At the micro level, IDR centers are characterized by heterogeneous patchworks of multi-trajectory research domains—some of these indirectly enabling, others directly generating interdisciplinary knowledge to different degrees. We argue that the exploration of the inter- and intra-organizational differences of IDR centers proves crucial for effectively fostering knowledge integration. An integrated model relating the levels of research management and visualization approaches is proposed for the management and assessment of knowledge integration in IDR centers.

The rest of this paper is structured as follows. Section 2 provides an overview of the relevant literature highlighting interdisciplinary research and approaches for its assessment in research centers. Section 3 continues with a description of the analytical framework and the case studies of this paper. Section 4 enumerates the data and research methods used. In Section 5, we report the findings of this study. Section 6 lists some of the main implications drawn from the study. Finally, Section 7 briefly concludes the paper.

2. Relevant literature

We first describe interdisciplinary research and knowledge integration, followed by a discussion of the roles of research centers established with explicitly interdisciplinary aims. This section finalizes with a review of studies assessing IDR centers, with a focus on studies using bibliometric approaches.

2.1. Interdisciplinary knowledge and research centers

The dynamics of science and technology are closely related to the generation, testing, and modification of knowledge (Loasby, 2002). Studies have described the evolution of knowledge as highly cumulative and path-dependent, featuring uncertain, open-ended, collective, and dynamically uneven processes (Consoli and Ramlogan, 2008; Nelson, 2003). The advancement of knowledge can take several routes; of these, knowledge that cuts across multiple and disparate disciplines has recently increased in importance (NRC, 2014; Repko, 2008). Such interdisciplinary knowledge is believed to be a potential source of competitive and innovative advantage (Huutoniemi et al., 2010; Siedlok and Hibbert, 2014; Siedlok et al., 2015), yet some researchers are skeptic (Frodeman, 2011; Jacobs, 2013). They plead for the dynamism, breadth, openness, and flexibility of disciplines, away from their prevailing view as isolated "silos" in the interdisciplinary studies literature (Jacobs, 2013; Repko, 2008).

Interdisciplinary research involves converging "data, techniques, tools, perspectives, concepts, and/or theories from two or more disciplines or bodies..." (CFIR, 2005). Integration is a defining characteristic of interdisciplinary research (Repko, 2008). It involves the (re-)combination of knowledge from disciplines, interdisciplines, and schools of thought through processes of knowledge transfer and creation (Repko, 2008; Siedlok and Hibbert, 2014). Knowledge integration has typically been characterized by its diversity (i.e. the disparity, variety, and (im)balance of given bodies of knowledge) and its coherence (i.e., the degree of interconnection between these bodies of knowledge) (Porter et al., 2007; Rafols, 2014).

There is still no clear consensus on the definition of "interdisciplinarity" (Wagner et al., 2011). However, a series of characteristics are repeatedly reported in the literature. Due to the intense context-dependence and multi-dimensionality of interdisciplinarity, we should