Interdisciplinarity Patterns of Highly-Cited Papers: A Cross-Disciplinary Analysis

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ABSTRACT

This study analyzes the level of interdisciplinarity and interspecialty of highly cited papers. We distinguish research referring to different *disciplines* (referred to as "interdisciplinarity") and research referring to different *specialties* of the same discipline (referred to as "interspecialty"). The results indicate that: (1) interspecialty research, has a greater impact on science development than intradisciplinary (or intraspecialty) research for most specialties and disciplines; (2) interdisciplinary research plays a more important role in Natural Sciences and Engineering than in Social Sciences and Humanities; and (3) interdisciplinary research is becoming more important in science either at the specialty or discipline level.

Keywords

interdisciplinarity, bibliometrics, research, scholarly communication

INTRODUCTION

Interdisciplinary research is seen as a way of sparking creativity, supporting innovation and addressing pressing social needs. In recent years, cross-disciplinary research centers and multidisciplinary research projects have been encouraged in science policy (Rafols et al., 2012). Recent studies try to provide quantitative evidence of the importance of interdisciplinary research in science but until now there are few substantial results and there is no clear correlation between interdisciplinary research and citation rates (Braun & Schubert, 2003; Jacobs & Frickel, 2009; Larivière & Gingras, 2010, 2014; Levitt & Thelwall, 2008, 2009; Porter & Rafols, 2009; Rafols et al., 2012; Rinia et al., 2002; Steele & Stier, 2000). Interdisciplinary research is often praised for contributing scientific breakthroughs and for fostering innovation. The goal of this article is to explore the importance of interdisciplinary research for the advancement of science, using the subset of top 1% most cited papers. Since highly cited papers are typically considered as high quality science, studying interdisciplinarity in this subset of paper could reveal its importance in the creation of scientific breakthroughs.

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METHODS

Data

We selected highly cited papers (the top most cited 1%) of all disciplines from Thomson Reuters' databases over the 1900–2012 period. First we extracted the top 1% most cited papers regardless of disciplines. This set of papers is called HCPA (highly cited papers over all disciplines). Since there are important differences in citation practices between disciplines, we extracted another set, which included the top 1% most cited papers of each discipline. This set is called HCPD (highly cited papers by discipline). HCPA includes 316,705 papers while HCPD includes 315,050 papers. We also retrieved the reference sets of these highly cited papers (14,315,579 references for HCPA and 10,174,267 references for HCPD respectively). Papers with no traceable references made to other source items found in Thomson Reuters'

databases were dropped from the sets and, in the end, we were left with 310,989 in papers in HCPA and 282,623 papers in HCPD.

Interdisciplinarity vs Interspecialty

The disciplinary classification of journals used in this study is that of the U.S. National Science Foundation (NSF) which categorizes each journal into one discipline and one specialty. This classification includes 143 specialties and 14 disciplines. Rinia (2007) introduced two types of interdisciplinarity: "big" and "small." Big interdisciplinarity refers to interdisciplinarity occurring amongst disciplines (e.g., chemistry vs physics) while small interdisciplinarity refers to interdisciplinarity amongst specialties within the same discipline (e.g., organic chemistry vs applied chemistry). In this article, to stay closer to the distinctions in sociology of science between discipline and specialty, we refer to "big interdisciplinarity" as *interdisciplinarity* and "small interdisciplinarity" as *interspecialty*.

Interdisciplinarity Indicator

Several indicators can be used to measure interdisciplinarity in research (Bornmann, 2010; Bornmann & Mutz, 2011; Carley & Porter, 2012; Leydesdorff & Bornmann, 2011; Porter & Chubin, 1985). Stirling (2007) proposed a general diversity heuristic to combine the three basic properties of diversity: variety, balance and similarity (Stirling, 1994). He showed that classic indices of diversity, such as Shannon's or Simpson's, measure a combination of variety and balance, but fail to account for the distances or similarities between categories. The Rao-Stirling Index, a simple variant of the Stirling general diversity index, has been used by Rafols and Meyer (2010). They constructed an interdisciplinary framework based on the Rao-Stirling Index and network coherence. Porter and Rafols (2009) investigated inter-disciplinarity evolution over a 30-year period over six research domains with the Rao-Stirling Index. Carley and Porter (2012) also applied the Rao-Stirling model to explore knowledge diffusion in interdisciplinary evolution for the perspective of citing documents. In this study we are not concerned with discipline components and their distance or similarity in interdisciplinary research and we consider inter-disciplinary research among distant disciplines just as important as among close disciplines. Based on these needs, the Simpson diversity index appears to be the best adaptable interdisciplinarity indicator. We define the Disciplinary Interdisciplinary Indicator (DII) based on the Percentile Rank Score (PRS), a distribution-based indicator used to describe the distribution of citation counts (Bornmann, 2010; Bornmann & Mutz, 2011). By substituting interdisciplinarity for the citation counts we constructed a DII to describe the interdisciplinarity distribution characteristic of our set of papers. PRS generally uses six or one hundred rank classes but we divide interdisciplinarity into ten even rank classes. The DII formula is as follows, where K denotes the number of percentiles rank classes, x is a discrete random variable and p(x) the relative frequency (or proportion) of each rank (from 1 to 10):

$$DII = \sum_{r=1}^{K} x \cdot p(x)$$

RESULTS

Global Interdisciplinary Research Impact

First we analyzed the interdisciplinary research in the HCPA set by computing the DII values of all NSF specialties and disciplines. Our analysis shows that interspecialty research accounts for the largest proportion of references made in the set. These results reveal the importance of interspecialty research for the development of science as it provides most of the references of these high quality papers, while the interdisciplinarity of highly cited papers is much smaller.

The same analysis on the HCPD set shows that the distribution of highly cited papers differs greatly amongst disciplines. At the interspecialty level, 82% of papers in Natural Sciences and Engineering (NSE) have a DII greater or equal to 5, while for papers in Social Sciences and Humanities (SSH) this proportion only reaches 55%. Interestingly, at the interdisciplinarity level there is no marked difference between the two sets of papers (39% for NSE and 38% or SSH). Based on these results, we can infer that interspecialty research is very important for the development of highly cited science, especially in NSE while the impact of interdisciplinary research is less marked.

Evolution of Interdisciplinary Research Impact over the Past 30 Years

Even though previous studies have confirmed that science is becoming more interdisciplinary (Larivière & Gingras, 2014) we do not have a clear understanding of the level of importance of interdisciplinary research for the development of most cited science. DII values reveal the impact of interdisciplinary research. Figure 1 displays DII value evolution for all scientific disciplines (HCPA set) from 1981 to 2010. We can see that both interdisciplinary research and interspecialty research follow an upward trend, indicating that interdisciplinary research in general is becoming more important in the top 1% most cited papers.

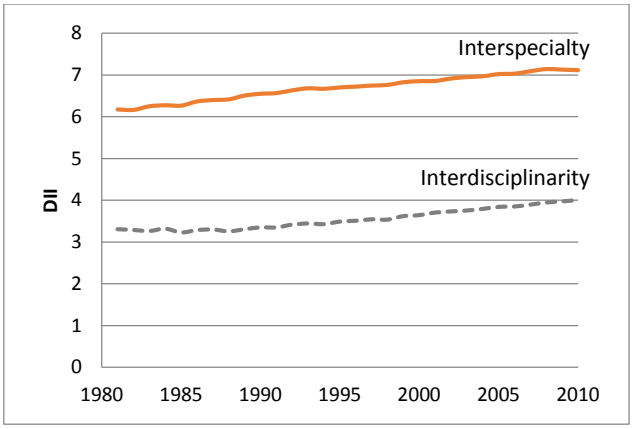

Figure 1. Evolution of interdisciplinary research from 1981–2010 for the HCPA set.

Similar analysis on the HCPD set reveals that, at the interspecialty level, all of the 14 NSF disciplines follow the same upward trend, with minor variations between disciplines. We note that six disciplines (Health, Biomedical Research, Psychology, Biology, Chemistry and Clinical Medicine) always obtain high DII interspecialty values over time. Two disciplines (Engineering & Technology and Mathematics) rise rapidly over the period, while two disciplines (Arts and Humanities) exhibit more modest increases. We can conclude that interspecialty research is increasingly important in the top cited research of each discipline albeit at a different rate. As for interdisciplinarity research, the same upward trend is observed for all disciplines, with two disciplines (Engineering & Technology and Arts) showing the greatest increases. These results also illustrate that interdisciplinary research is becoming more important in the core of the most cited papers of each scientific disciplines.

CONCLUSION

Our study shows that interdisciplinary research is becoming increasingly important, especially at the interspecialty level. The reason may be that interdisciplinary research is more difficult to achieve than interspecialty research which in turn impedes the impact level of these papers globally at the interdisciplinarity level.

By examining the importance of interdisciplinary over disciplinary research, we observe that disciplines and specialties from the Natural Sciences are more inter-disciplinary while disciplines such as Arts and Humanities are more disciplinary.

In further research it would be useful to compare trends in interdisciplinary research among highly cited papers with trends observed for all papers as established in Larivière & Gingras (2014) using the same indicators.

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