# A Comparative Study of Interdisciplinarity in Sciences in South Korea, Turkey, and USA

Nazlı Yurdakul[1] and A. Nihat Berker[2,3]
[1] *Robert College, Arnavutköy 34345, Istanbul, Turkey*
[2] *Faculty of Engineering and Natural Sciences, Sabancı University, Tuzla 34956, Istanbul, Turkey and*
[3] *Department of Physics, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, U.S.A.*

A comparative study is done of interdisciplinary citations in 2013 between physics, chemistry, and molecular biology, in South Korea, Turkey, and USA. Several surprising conclusions emerge from our tabular and graphical analysis: The interscience citation rates are in general strikingly similar, between South Korea, Turkey, and USA. One apparent exception is the comparatively more tenuous relation between molecular biology and physics in the USA. Other slight exceptions are the higher amount of citing of physicists by chemists in South Korea, of chemists by molecular biologists in Turkey, and of molecular biologists by chemists in USA. Chemists are, by a sizable margin, the most interscience citing scientists in this group of three sciences. Physicist are, again by a sizable margin, the least interscience citing scientists in this group of three sciences. The strongest interscience citation is from chemistry to physics. The weakest interscience citation is from physics to molecular biology. Our findings are consistent with a V-shaped backbone connectivity, as opposed to a $\Delta$ connectivity, as also found in a previous study of earlier citation years.

## I. INTRODUCTION

While interdisciplinarity is currently much vaunted as the scientific mode of operation, intense specialization in any one field or, in fact, topic may run counter to cross-disciplinary efforts. Another characteristic of current science is the burgeoning of a multicontinental multicenter research environment, which brings the question of whether different regional, historical and current, academic traditions affect the conduct of scientific research. We have investigated simultaneously both of these issues, by conducting a comparative study between the South Korea, Turkey, and USA, as to the cross-referencing between published research papers in chemistry, molecular biology, and physics. Our interdisciplinary and academic intercultural findings, based on collected data, are surprising on both of the mentioned issues.

Our study involves cross-disciplinary citations between fields A and B, where A and B are chemistry, molecular biology, and physics, a priori deemed derivatively connected basic sciences, in articles published in a set of major journals (Tables I-III) in each field in the year 2013. The study is repeated for South Korea, USA, and Turkey. These countries were chosen because of the dominance in scientific research of the USA, and the rapid development of the transcontinentally and mutually distant South Korea and Turkey. Our study was inspired by Ref.[1], where the cross-citation network between fields is studied for earlier years, without distinguishing with respect to country. Similar studies have been made for the citation network between different journals in the same field [2] and on the relevance of cross-citations [3]. Detailed intercultural comparative studies are in Refs.[4–7].

## II. METHODOLOGY

In our study, 71, 33, 22 journals (Tables I-III) respectively in chemistry, molecular biology, physics, determined as described below, were searched for cross-science publications as described below. Of these, 46, 8, 17 journals (emphasized in Tables I-III) yielded 746, 23, 131 cross-science citing publications as described below. From these publications, 684, 2000, 4197 cross-science citations in 110, 193, 147 journals respectively in chemistry, molecular biology, physics, given by authors with institutional addresses in Turkey, South Korea, or USA, were extracted. In these, publications with author addresses from any two or all three of our studied countries were not included. Thus, a total of 6881 interdisciplinary citations entered our study.

In order to effectively compare the citation practices from each country, the pool of sample publications in each science must be as similar as possible between the countries. The number of publications by South Korean and USA scientists in 2013 exceeds those by Turkish scientists in most, but not all, of the selected chemistry, molecular biology, and physics journals (Tables I-III). Therefore, the sample size of South Korean and USA papers was equalized to the number of Turkish papers published in 2013: The South Korean and USA publications in each journal were ordered chronologically. Then, in each journal, the used pool of publications was expanded equally both ways starting from the median publication until the number of publication was equalized to that of Turkish publications in the same journal in 2013. For example, there are 18 papers published by Turkish physicists in the Physical Review A in 2013. Thus, the chronologically median publications in Physical Review A in 2013 by South Korean and USA physicists were found and the pool was expanded equally in both chronological direction until there were 18 papers in the pool from each

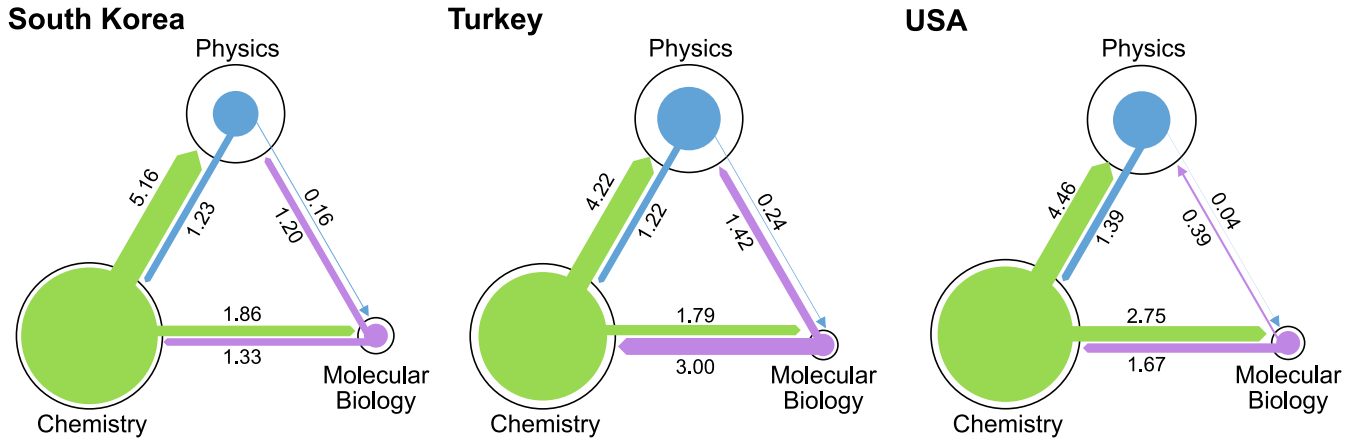


FIG. 1: Interdisciplinary citations given in 2013, as described in the text, between chemistry, molecular biology, and physics, in South Korea, Turkey, and USA. The direction of each arrow is from the field giving citations towards the field being cited. The width of each arrow is proportional to the average number of such citations per publication. In a given field, approximately the same number of publications is used for each country. Thus, the area inside the drawn circle is proportional to the total number of publications in the pool. For each country and each field, the area of the colored circle is proportional to the total number of papers giving such interscience citations.

country. In several cases, the number of Turkish publications in a given journal exceeded the number of South Korean or USA publications. In these instances, the pool of Turkish publications was not decreased and all of the South Korean or USA publications were included.

The same pool of publications, for each country and each science, was used for determining the citation flow from this science to each of the two other sciences. For instance, there were 161 physics publications by Turkish authors in the selected journals. This same set of 161 papers was used to determine the average number, per publication, of citations to chemistry and to molecular biology. The standard deviation was also determined. When calculating the average and the standard deviation, citations to all publications in the other science are of course included, regardless of the country of the publication receiving the citation. The results are given in Fig. 1 and Tables IV-VI.

## III. RESULTS AND DISCUSSION

In Fig. 1, for each country and each science, the area of the colored circles is proportional to the total number of publications giving interscience citations to the two other sciences. The area inside the drawn circles is proportional to the total number of publications considered. Therefore, as explained above, for each field the latter areas are similar, but not strictly equal, between the countries. The widths of the arrows are in turn proportional to the average number of citations, per publication, from the field they originate to the field they are pointing. The corresponding numerical data are given in next to the arrows and in Tables IV-V.

Several surprising conclusions emerge from these data: 1) The interscience citation rates are in general strikingly similar, between South Korea, Turkey, and USA. Thus, the common problems, methodology, instant communications and personal mobility in a given science appears to have transcended regional cultures. 2) One apparent exception to the above is the comparatively more tenuous relation between molecular biology and physics in the USA. Other slight exceptions are the higher amount of citing of physicists by chemists in South Korea, of chemists by molecular biologists in Turkey, and of molecular biologists by chemists in USA. 3) Chemists are, by a sizable margin, the most interscience citing scientists in this group of three sciences. Physicist, although reputed to be more generalists, are, again by a sizable margin, the least interscience citing scientists in this group of three sciences. (Fig.1 and Table VI) 4) The strongest interscience citation is from chemistry to physics. The weakest interscience citation is from physics to molecular biology. 5) Our findings are consistent with a V-shaped backbone connectivity, as opposed to a $\Delta$ connectivity, consistently with what was found for earlier years in Ref.[1].

### Acknowledgments

We are grateful to Behlül Üsdiken for a careful reading of our manuscript and many useful remarks. We thank Asuman Akyüz, Tolga Çağlar, Bedia Erim, and Zehra Sayers for advice and assistance. Support by the Academy of Sciences of Turkey (TÜBA) is gratefully acknowledged.

[1] Maps of random walks on complex networks reveal community structure, M. Rosvall and C. T. Bergstrom, Proc. Nat. Acad. Sci. **105** (4) 1118-1123 (2008).

[2] Exploring the astronomy literature landscape, E. A. Henneken, A. Accomazzi, M. J. Kurtz, C. S. Grant, D. Thompson, E. Bohlen, S. S. Murray, M. Rosvall, and C. Bergstrom, in Astronomical Data Analysis Software and Systems XVIII, Eds. D. A. Bohlender, D. Durand, and P. Dowler, **411**, 384-387 (2009).

[3] The transmission sense of information, C. T. Bergstrom and R. Rosvall, Biol. Philos. **26**, 159176 (2011).

[4] Centres and Peripheries: Research Styles and Publication Patterns in 'Top' US Journals and their European Alternatives, 1960-2010, B. Üsdiken, J. Management Studies **51**, 764-789 (2014).

[5] International influence in science: beyond center and periphery, T. Schott, Social Science Research **17**, 21938 (1988).

[6] Ties between center and periphery in the scientific world-system: accumulation of rewards, dominance and self-reliance in the center, T. Schott, J. World-Systems Research **4**, 112144 (1988).

[7] International Collaboration in Multilayered Center-Periphery in the Globalization of Science and Technology, K. Hwang, Science Technology Human Values **33**, 101-133 (2008).

| Analytical Chemistry | |
|---|---|
| ***Analyst*** | ***J. American Society for Mass Spectrometry*** |
| ***Analytica Chimica Acta*** | ***Journal of Chromatography A*** |
| Analytical and Bioanalytical Chemistry | ***Sensors and Actuators B - Chemical*** |
| ***Analytical Chemistry*** | ***Talanta*** |
| Electroanalytical Chemistry | |
| **Applied Chemistry** | |
| ACS Combinatorial Science | ***Food Hydrocolloids*** |
| Advanced Synthesis and Catalysis | ***Journal of Agricultural and Food Chemistry*** |
| ***Carbohydrate Polymers*** | Journal of Combinatorial Chemistry |
| ***Dyes and Pigments*** | ***Microporous and Mesoporous Materials*** |
| ***Food Chemistry*** | Molecular Diversity |
| **Inorganic Chemistry** | |
| Advances in Inorganic Chemistry | ***Journal of Inorganic Biochemistry*** |
| ***Dalton Transactions*** | Journal of Solid State Chemistry |
| ***European Journal of Inorganic Chemistry*** | Organo Metallics |
| ***Journal of Biological Inorganic Chemistry*** | Structure and Bonding |
| **Multidisciplinary Chemistry** | |
| ***ACS Nano*** | Journal of Controlled Release |
| ***Angewandte Chemie - International Edition*** | ***Journal of the American Chemical Society*** |
| ***Chemical Science*** | ***Tetrahedron - Asymmetry*** |
| Energy and Environmental Science | |
| **Organic Chemistry** | |
| Advanced Synthesis and Catalysis | ***European Journal of Organic Chemistry*** |
| Bioconjugate Chemistry | ***Journal of Organic Chemistry*** |
| ***Biomacromolecules*** | ***Organic and Biomolecular Chemistry*** |
| ***Carbohydrate Polymers*** | ***Organic Letters*** |
| Current Organic Chemistry | Organometallics |
| **Physical Chemistry** | |
| ACS Catalysis | ***Faraday Discussions*** |
| ***Advanced Energy Materials*** | ***Journal of Catalysis*** |
| ***Advanced Functional Materials*** | ***Journal of Chemical Theory and Computation*** |
| Advanced Materials | ***Journal of Physical Chemistry B*** |
| Advances in Colloid and Interface Science | ***Journal of Physical Chemistry C*** |
| Catalysis Science and Technology | ***Journal of Physical Chemistry Letters*** |
| ***ChemCatChem*** | ***Langmuir*** |
| ***Chemistry of Materials*** | ***Physical Chemistry Chemical Physics*** |
| ***Colloids and Surfaces B - Biointerfaces*** | Structure and Bonding |
| **Polymer Science** | |
| Advances in Polymer Science | ***Macromolecules*** |
| ***Journal of Membrane Science*** | Plasma Processes and Polymers |
| Journal of Polymer Science A - Polymer Chemistry | ***Polymer Chemistry UK*** |
| ***Macromolecular Bioscience*** | ***Soft Matter*** |
| Macromolecular Rapid Commnications | |

TABLE I: The 71 chemistry journals listed in this Table were searched, for 2013, in our study. Cross-disciplinary citations between chemistry, molecular biology, and physics, from South Korea, Turkey, and USA, were used from the 46 journals emphasized by bold italics, as described in Sec.II.

| General Molecular Biology | |
|---|---|
| Biochimica Biophysica Acta: Molecular Cell Research | Molecular and Cellular Biology |
| Cell | ***Molecular and Cellular Proteomics*** |
| ***Journal of Molecular Biology*** | Molecular Biology of the Cell |
| Molecular Microbiology | Molecular Plant |
| Molecular Cell | ***Oncogene*** |
| Molecular Biology and Evolution | ***PLoS Computational Biology*** |
| Molecular Aspects of Medicine | ***PLoS Genetics*** |
| EMBO Journal | Structure |
| EMBO Reports | |
| **Biochemistry and Biophysics** | |
| ACS Chemical Biology | ***Journal of Biological Chemistry*** |
| Acta Crystallographica D: Biological Crystallography | J. Proteins: Structure, Function, Genetics |
| ***Biochemical Journal*** | Journal of Structural Biology |
| Biophysical Journal | Nature Chemical Biology |
| FASEB Journal | Nature Structural and Molecular Biology |
| Journal of Applied Crystallography | New Phytologist |
| **Biotechnology and Biomaterials** | |
| ***Bio Materials*** | Nature Biotechnology |
| Biotechnology Advances | Nature Methods |

TABLE II: The 33 molecular biology journals listed in this Table were searched, for 2013, in our study. Cross-disciplinary citations between chemistry, molecular biology, and physics, from South Korea, Turkey, and USA, were used from the 8 journals emphasized by bold italics, as described in Sec.II.

| Journal | Topic |
|---|---|
| ***European Physical Journal A*** | Hadrons and Nuclei |
| ***European Physical Journal B*** | Condensed Matter and Complex Systems |
| ***European Physical Journal C*** | Particles and Fields |
| European Physical Journal D | Atomic, Molecular, Optical and Plasma Physics |
| European Physical Journal E | Soft Matter and Biological Physics |
| European Physical Journal H | Historical Perspectives on Contemporary Physics |
| ***European Physical Journal AP*** | Applied Physics |
| ***European Physical Journal ST*** | Special Topics |
| ***European Physical Journal PLUS*** | Archiving and Documentation |
| Europhysics Letters | General Interest Impact |
| ***Physica A*** | Statistical Mechanics and its Applications |
| ***Physica B*** | Condensed Matter |
| ***Physica C*** | Superconductivity and its Applications |
| ***Physica D*** | Nonlinear Phenomena |
| ***Physica E*** | Low-dimensional Systems and Nanostructures |
| ***Physical Review A*** | Atomic, Molecular, and Optical Physics |
| ***Physical Review B*** | Condensed Matter and Materials Physics |
| ***Physical Review C*** | Nuclear Physics |
| ***Physical Review D*** | Particles, Fields, Gravitation, and Cosmology |
| ***Physical Review E*** | Statistical, Nonlinear, and Soft Matter Physics |
| Physical Review X | Cross-Topic, Cross-Field, Cross-Disciplinary |
| ***Physical Review Letters*** | General Interest Impact |

TABLE III: The 22 physics journals listed in this Table were searched, for 2013, in our study. Cross-disciplinary citations between chemistry, molecular biology, and physics, from South Korea, Turkey, and USA, were used from the 17 journals emphasized by bold italics, as described in Sec.II.

| Cross-Science (CS) Citation from Science A to Science B | No. of Sci. A Papers Considered | No. of CS Citing Sci. A Papers | Ratio Sci. A CS Citing/ Considered | CS Cit. per Sci. A Paper | CS Cit. Standard Deviation | No. of CS Cited Sci. B Papers |
|---|---|---|---|---|---|---|
| South Korea | | | | | | |
| Chemistry to M. Biology | 297 | 139 | 0.4680 | 1.8620 | 3.2356 | 553 |
| Chemistry to Physics | 297 | 181 | 0.6094 | 5.1582 | 7.8186 | 1532 |
| M. Biology to Chemistry | 15 | 6 | 0.4000 | 1.3333 | 3.6998 | 20 |
| M. Biology to Physics | 15 | 4 | 0.2667 | 1.2000 | 2.6128 | 18 |
| Physics to Chemistry | 133 | 27 | 0.2030 | 1.2406 | 3.2378 | 165 |
| Physics to M. Biology | 133 | 4 | 0.0300 | 0.1654 | 1.3161 | 22 |
| Turkey | | | | | | |
| Chemistry to M. Biology | 294 | 152 | 0.5170 | 1.7925 | 2.9198 | 527 |
| Chemistry to Physics | 294 | 147 | 0.5000 | 4.2177 | 8.1211 | 1240 |
| M. Biology to Chemistry | 12 | 7 | 0.5833 | 3.0000 | 3.5355 | 36 |
| M. Biology to Physics | 12 | 4 | 0.3333 | 1.4167 | 2.4650 | 17 |
| Physics to Chemistry | 161 | 56 | 0.3478 | 1.2298 | 2.5152 | 198 |
| Physics to M. Biology | 161 | 1 | 0.0062 | 0.2422 | 3.0641 | 39 |
| USA | | | | | | |
| Chemistry to M. Biology | 310 | 160 | 0.5161 | 2.7516 | 4.9637 | 853 |
| Chemistry to Physics | 310 | 176 | 0.5677 | 4.4613 | 8.4244 | 1383 |
| M. Biology to Chemistry | 18 | 7 | 0.3889 | 1.6667 | 2.5197 | 30 |
| M. Biology to Physics | 18 | 4 | 0.2222 | 0.3889 | 0.8085 | 7 |
| Physics to Chemistry | 168 | 44 | 0.2619 | 1.3988 | 3.4643 | 235 |
| Physics to M. Biology | 168 | 3 | 0.0179 | 0.0357 | 0.2413 | 6 |

TABLE IV: Cross-science citations between chemistry, molecular biology, and physics, grouped by country.

| Cross-Science (CS) Citation from Science A to Science B | No. of Sci. A Papers Considered | No. of CS Citing Sci. A Papers | Ratio Sci. A CS Citing/ Considered | CS Cit. per Sci. A Paper | CS Cit. Standard Deviation | No. of CS Cited Sci. B Papers |
|---|---|---|---|---|---|---|
| | Chemistry | to M. Biology, | M. Biology to | Chemistry | | |
| South Korea | 297, 15 | 139, 6 | 0.4680, 0.4000 | 1.8620, 1.3333 | 3.2356, 3.6998 | 553, 20 |
| Turkey | 294, 12 | 152, 7 | 0.5170, 0.5833 | 1.7925, 3.0000 | 2.9198, 3.5355 | 527, 36 |
| USA | 310,18 | 160, 7 | 0.5161, 0.3889 | 2.7516, 1.6667 | 4.9637, 2.5197 | 853, 30 |
| | M. Biology | to Physics, | Physics to | M. Biology | | |
| South Korea | 15, 133 | 4, 4 | 0.2667, 0.0300 | 1.2000, 0,1654 | 2.6128, 1.3161 | 18, 22 |
| Turkey | 12, 161 | 4, 1 | 0.3333, 0.0062 | 1.4167, 0.2422 | 2.4650, 3.0641 | 17, 39 |
| USA | 18, 168 | 4, 3 | 0.2222, 0.0179 | 0.3889, 0.0357 | 0.8085, 0.2413 | 7, 6 |
| | Physics | to Chemistry, | Chemistry to | Physics | | |
| South Korea | 133, 297 | 27, 181 | 0.2030, 0.6094 | 1.2406, 5.1582 | 3.2378, 7.8186 | 165, 1532 |
| Turkey | 161, 294 | 56, 147 | 0.3478, 0.5000 | 1.2298, 4.2177 | 2.5152, 8.1211 | 198, 1240 |
| USA | 168, 310 | 44, 176 | 0.2619, 0.5677 | 1.3988, 4.4613 | 3.4643, 8.4244 | 235, 1383 |

TABLE V: Cross-science citations from South Korea, Turkey, and USA, grouped by sciences.

| Cross-Science Citation Ratios | South Korea | Turkey | USA |
|---|---|---|---|
| Chemistry | 0.8754 | 0.7823 | 0.8258 |
| M. Biology | 0.5333 | 0.5833 | 0.4444 |
| Physics | 0.2164 | 0.3457 | 0.2722 |

TABLE VI: Fraction of publications giving cross-science citations from chemistry (to molecular biology and/or physics), molecular biology (physics and/or chemistry), and physics (to chemistry and /or molecular biology).