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Knowledge integration = knowledge diffusion? On impact and benefits of interdisciplinary research[1]

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Introduction

In this study, we conceive interdisciplinary research (IDR) in terms of knowledge integration and diffusion. Knowledge integration may manifest in different forms though, be it through the use and integration of published research results within the framework of or through the research collaboration of scientists with different disciplinary background, these forms are just different perspectives of how existing knowledge originated from different disciplines is exploited in new common contexts. Thus, who uses and which disciplines benefit from this kind of knowledge integration, would define and express a new quality of "impact". Hence some important, even crucial questions arise. The first one is quite obvious and has therefore already, at least partially, been studied, namely the question, of whether interdisciplinary research exhibits higher and possibly broader impact. Less obvious is the answer, which is certainly not a straightforward "yes" (Larivière and Gingras, 2010; Wang et al., 2015; Yegros-Yegros et al., 2015). Molas-Gallart et al. (2014) points out that increasing impact and increasing interdisciplinarity are not systematically positively correlated, a point already made in Larivière and Gingras. The question if articles that show a higher degree of knowledge integration are more cited remains a complex question indeed. This question also implies another one, namely that of the "broadness" of impact. And this will actually form the focus of our study: Is IDR relevant for and used in broader contexts, in the sense of, are interdisciplinary documents cited by documents from more disciplines than their monodisciplinary counterparts, and how interdisciplinarity of citing documents is related to that of the cited one?

To conduct this research, we apply the cognitive approach based on cited references, using the revised ECOOM-Budapest classification scheme at the level of 74 disciplines, measures of citation impact and interdisciplinarity (*variety* and *disparity*), and formulate three research questions on the basis of this methodological groundwork.

1. In how far are normalised measures of interdisciplinarity and citation impact intercorrelated?

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2. What is the relationship between knowledge integration in diffusion/dissemination as reflected by cited and citing documents, respectively?
3. How is interdisciplinarity of the papers under study related to the extent of interdisciplinarity and citation impact of citing papers?

Data sources and data processing

All papers of document type article/proceedings paper, letter and review published in journals indexed in the 2016–2018 volumes of the Web of Science Core Collection have been processed for three-year citation windows beginning with the publication year (i.e., for 2016–2018, 2017–2019 and 2018–2020). We have selected the following eleven subfields, i.e., disciplines (Table1) representing all major fields except the humanities, and drawn random samples from these fields representing 30% of all documents proportionally distributed of the selected discipline to keep the number of cited and citing papers within reasonable limits.

Table 1. Eleven disciplines selected for the study.

Code	Subfield (Discipline)
A1	agricultural science & technology
C3	organic & medicinal chemistry
E3	energy & fuels
G5	mineralogy & petrology
H2	pure mathematics
I2	endocrinology & metabolism
M2	dentistry
P2	atomic, molecular & chemical physics
R3	experimental/laboratory medicine
Y2	sociology & anthropology
Z4	plant sciences

For source papers and their citing and cited papers from general and multidisciplinary journals we have applied subject classification based on individual paper assignment procedure as described by Glänzel & Debackere (2021).

Methods

Measuring interdisciplinarity, its diffusion and impact

In order to measure interdisciplinarity, we used the *Inverse Simpson Index* (${}^2D$) for variety and the *Leinster-Cobbold* disparity (${}^2D^S$) with q=2 (see, e.g., Zhang et al., 2016). Adding citation impact as a third dimension, we ended up with measures that take differently structured values so that proper normalisation and application of the method of Characteristic Scores and Scales (CSS) resulted in the required set of commensurable measures (cf. Glänzel & Debackere, 2021). This way, we were able to distinguish between low (class1) and high (class 3&4) citation impact/interdisciplinarity scores in a triplet of document sets: the sampled publications under study and the documents either being cited by those and the publications citing the sample in the respective 3-year windows.

In order to answer the first research question, we have analysed the CSS classes of the three variables citation impact, variety and disparity. We have to note that although this part of the analysis relates to the source papers (2016–2018), impact already points to the future (i.e., the

use of information through citations), while the two IDR measures by definition points to the past (i.e., integrated knowledge through cited references).

The question of whether a higher degree of knowledge integration exhibits higher citation impact, proved complex, even if the underlying measures are properly normalised since communication behaviour may differ in the fields that are involved by knowledge integration. The necessity of using two measures of interdisciplinarity was shown, e.g., by Glänzel and Debackere (2021), where the two measures, variety and disparity, proved nearly uncorrelated. Therefore, Table 1 gives the relationship between the three indicators for the full sample[2] on the basis of the two IDR metrics separately. Indeed, the data in the table reveal a certain, however, not to strong effect, but this is reverse according to variety and disparity.

Table 1. Relationship between variety, disparity and citation impact by citation classes.

		Complete set	Disparity Classes				Variety Classes			
			1	2	3	4	1	2	3	4
Citation Classes	1	67.4%	65.3%	69.6%	77.4%	78.3%	72.9%	65.5%	64.2%	63.4%
	2	23.1%	24.6%	21.9%	16.3%	15.2%	19.6%	24.1%	25.2%	26.0%
	3	6.9%	7.4%	6.4%	4.8%	4.7%	5.6%	7.4%	7.8%	7.8%
	4	2.5%	2.8%	2.1%	1.6%	1.8%	1.9%	3.0%	2.8%	2.8%
Total		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Subject distance of cited and citing documents with respect to interdisciplinarity of the sources
A second question arising from knowledge integration and diffusion is the subject dispersion of cited and citing documents according to the different degrees of interdisciplinarity of the source papers. The unique feature of the cognitive approach offers studying this by following citation links. We consider the bibliographic-coupling based cosine similarity of the subfield of the source with those of the cited/ citing papers, analogously to that used for the disparity measure but by contrast here considering the similarity between subfields of source and target paper. The subfield of the source is excluded from the target side to avoid bias.

Table 2a. Mean similarity of subfield of cited documents with subfield of source document by variety (left) and disparity (right) classes.

Field	Class1	Class2	Class3	Class4
A1	0.28	0.25	0.24	0.22
C3	0.23	0.16	0.14	0.13
E3	0.27	0.31	0.29	0.25
G5	0.30	0.18	0.15	0.12
H2	0.37	0.33	0.25	0.18
I2	0.22	0.21	0.21	0.21
M2	0.11	0.09	0.08	0.07
P2	0.38	0.39	0.35	0.30
R3	0.33	0.37	0.37	0.36
Y2	0.22	0.22	0.21	0.18
Z4	0.35	0.33	0.27	0.23

Field	Class1	Class2	Class3	Class4
A1	0.27	0.22	0.18	0.19
C3	0.16	0.21	0.22	0.21
E3	0.34	0.19	0.12	0.09
G5	0.23	0.18	0.17	0.21
H2	0.32	0.31	0.18	0.02
I2	0.22	0.20	0.20	0.18
M2	0.09	0.11	0.10	0.07
P2	0.44	0.29	0.22	0.16
R3	0.39	0.29	0.25	0.20
Y2	0.23	0.16	0.14	0.12
Z4	0.34	0.26	0.24	0.21

Table 2a/b gives the similarity scores by disciplines and disparity/variety classes of the source paper. Two trends can be observed, firstly, both the variety and disparity affect the similarity, generally, in the same direction. Similarity of citing and cited documents with the source

[2] More detailed results with breakdown by disciplines can be found at STI2022_ECOOM.

document is decreasing with an increase of disparity and variety. This trend is to be expected in the cited publications by the disparity classes as the same similarity is used. Secondly, we observe a strong difference in effect amongst the disciplines. In M2, dentistry, the overall similarity is very low and stable, while E3, P2 and R3 exhibit large decreases. Thus, at the citing site, higher-score interdisciplinary papers are picked up by subfields that are more distant from the original one.

Table 2b. Mean similarity of subfield of citing documents with subfield of source document by variety (left) and disparity (right) classes.

Field	Class1	Class2	Class3	Class4
A1	0.29	0.27	0.26	0.25
C3	0.24	0.18	0.17	0.15
E3	0.30	0.33	0.32	0.28
G5	0.27	0.16	0.15	0.13
H2	0.37	0.33	0.28	0.24
I2	0.22	0.21	0.21	0.21
M2	0.09	0.08	0.08	0.08
P2	0.41	0.40	0.38	0.35
R3	0.34	0.37	0.37	0.37
Y2	0.22	0.22	0.21	0.18
Z4	0.35	0.34	0.29	0.25

Field	Class1	Class2	Class3	Class4
A1	0.28	0.24	0.22	0.22
C3	0.18	0.22	0.25	0.24
E3	0.35	0.23	0.18	0.19
G5	0.22	0.16	0.16	0.22
H2	0.33	0.32	0.30	0.26
I2	0.22	0.20	0.20	0.20
M2	0.08	0.09	0.08	0.08
P2	0.44	0.33	0.29	0.28
R3	0.39	0.31	0.27	0.24
Y2	0.22	0.16	0.16	0.17
Z4	0.34	0.27	0.26	0.25

Extent of interdisciplinarity and citation impact of literature citing documents with different IDR scores

The last question relates to the citation impact and the interdisciplinarity of the documents citing the sampled documents. Table 3 gives the comparision of citation impact of citing papers with respect to the extent of interdisciplinarity of source documents. Surprisingly, no general trend could be observed, neither with repect to variety nor to disparity. Papers citing IDR did not prove to achieve higher impact. By contrast, we observe clear increasing trends in terms of the interdisciplinarity scores (both variety and disparity), of course, with variations across the disciplines (see Table 4).

Table 3. Mean citation impact over citing documents by variety (left) and disparity (right) classes

Field	Class1	Class2	Class3	Class4
A1	6.66	10.14	10.24	9.41
C3	14.14	10.62	10.26	10.18
E3	12.20	16.69	16.11	12.52
G5	7.03	7.44	8.65	8.40
H2	3.01	4.33	5.08	6.80
I2	10.67	10.47	11.14	10.45
M2	5.36	6.03	6.34	6.97
P2	10.54	14.24	12.77	12.26
R3	10.00	11.26	10.76	10.30
Y2	5.21	4.92	5.39	6.31
Z4	8.68	8.66	8.11	8.11

Field	Class1	Class2	Class3	Class4
A1	9.56	9.27	6.25	4.97
C3	10.53	13.98	15.89	15.05
E3	16.31	10.37	7.98	5.68
G5	8.05	7.50	6.42	6.84
H2	4.85	2.78	2.62	1.76
I2	11.04	10.20	8.88	9.24
M2	6.21	5.15	5.30	5.84
P2	13.14	11.51	9.30	5.94
R3	11.00	8.96	7.83	6.93
Y2	5.52	5.32	5.62	6.12
Z4	8.34	8.89	7.81	6.77

Table 4. Mean variety (left) and disparity scores (right) over citing documents by variety (left) and disparity (right) classes

Field	Class1	Class2	Class3	Class4
A1	4.43	5.40	6.11	7.27
C3	2.29	5.18	6.45	7.63
E3	3.98	4.67	5.19	5.75
G5	2.99	4.67	5.36	6.06
H2	1.81	2.64	3.27	4.28
I2	4.24	5.77	6.58	7.21
M2	2.51	4.61	5.65	6.67
P2	3.45	4.65	5.36	6.29
R3	5.03	6.16	7.12	7.82
Y2	3.28	4.36	5.16	5.95
Z4	3.75	4.67	5.85	7.32

Field	Class1	Class2	Class3	Class4
A1	10.39	12.54	16.27	18.58
C3	11.27	26.21	36.05	41.51
E3	7.60	13.26	19.37	35.99
G5	11.09	13.43	18.04	20.02
H2	12.93	21.02	34.09	85.98
I2	9.30	11.73	15.85	19.87
M2	21.42	44.15	95.87	118.91
P2	6.79	12.68	22.54	25.04
R3	8.47	11.15	16.60	30.01
Y2	11.52	18.51	25.23	27.19
Z4	8.63	10.80	15.05	18.76

Conclusions and future research

First results of the present research-in-progress have already yielded interesting finding on how interdisciplinarity is associated with impact and contributing further interdisciplinary research. Further and detailed results are available at STI2022_ECOOM. In further stages of the projects, these random-sample based results will be deepened and further elaborated to reliable statements and robust conclusion of more generality.

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