
Maps of science as interdisciplinary discourse: co-citing contexts and the role of analogy

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Assumptions about interdisciplinarity:

- Interdisciplinarity can be manifest in many forms: through collaboration or communication between scientists in different fields, or through the work of individuals who employ concepts in different fields, or span fields.
- We will address the latter form, and try to understand how ideas in different fields can come together using the techniques of science mapping and co-citation context analysis.
- We use maps of science to suggest potential interdisciplinary links and then confirm these with co-citation contexts.

Assumptions about maps of science:

- Maps of science summarize or capsulize relationships between large aggregations of scientific literature.
- In our methodology, the larger aggregates are formed by an iterative co-citation clustering procedure producing macro-clusters linked by residual co-citations.
- By analogy to biological evolution, a map of science is like an adaptive landscape and a macro-cluster on the map is a fitness peak within which scientific concepts are highly evolved and adapted to their local environment.
- Interdisciplinary co-citation is analogous to valley crossing - moving from one fitness peak to another through regions of low fitness or adaptation, and high uncertainty.

Assumptions about citations & co-citations:

- Citations are a form of discourse because when we cite prior work, we are saying something about it, whether trivial or profound. Trivial: “X is about Y.” Profound: “X is wrong about Y.”
- Co-citations potentially provide commentary on the relation of two prior works, e.g., “X is similar to/different from Y.”
- Cue words are words found in the citation contexts or co-citation contexts that characterize cited works or describe their relationship, such as “important”, “different”, etc.

Reference:

Mercer, Frequency of hedging cues in citation contexts in scientific writing, 2004.

Inter-disciplinarity as a function of clustering level

Level of Aggregation	% of interdisciplinary links
Level 2	4.7%
Level 3	27.0%
Level 4 (global map)	53.4%

Links between clusters with differing journal category assignments increase with increasing aggregation (higher levels).

Attributes of linked clusters

Level3 front	Core papers	Mean year	Mean cites	Top Journal categories	Top 2 Journals
27	37	2005.3	47.4	Microbiology	Science, Journal of Natural Products
263	88	2004.7	69.3	Chemistry	J Am Chem. Soc, Chem. Reviews

A total of 29 co-citing papers connect the level 3 clusters #27 and #263. These are analyzed to uncover the nature of this presumed interdisciplinary link.

Sample co-citing passage:

“Extending the *analogy* between biological hydroxylation and halogenation . . . when nature carries out hydroxylation at unactivated carbon sites . . . it turns to iron enzymes and generates high-valent oxoiron species as powerful oxidants.” [italics added]
(Vaillancourt, 2006)

Frequently occurring cue words in co-citing passages

Cue word grouping	frequency
discovery, novel, elucidated, remarkable	10
analogy, similar, parallel, others like, complementary	9
speculate, unsolved, questions, unclear, postulate	5
recent, infancy	4
promise, utility, extend	3

Mapping an analogy*:

Chemical reaction in lab
involves a halogenation step.

The process is happening
Intra-molecularly (cryptically).

Bacterial process involve
halogenations.

Not all of these appear to be
due to known enzymes and
are not seen in genes.

Therefore bacteria also
undergo cryptic halogenations

Chemical
System (source)

Bacterial
System (target)

A : B
⋮ ⋮
C : D

= inference by analogy

*Source: Holyoak & Thagard, *Mental leaps: analogy in creative thought*, 1995.

Sample co-citing passages:

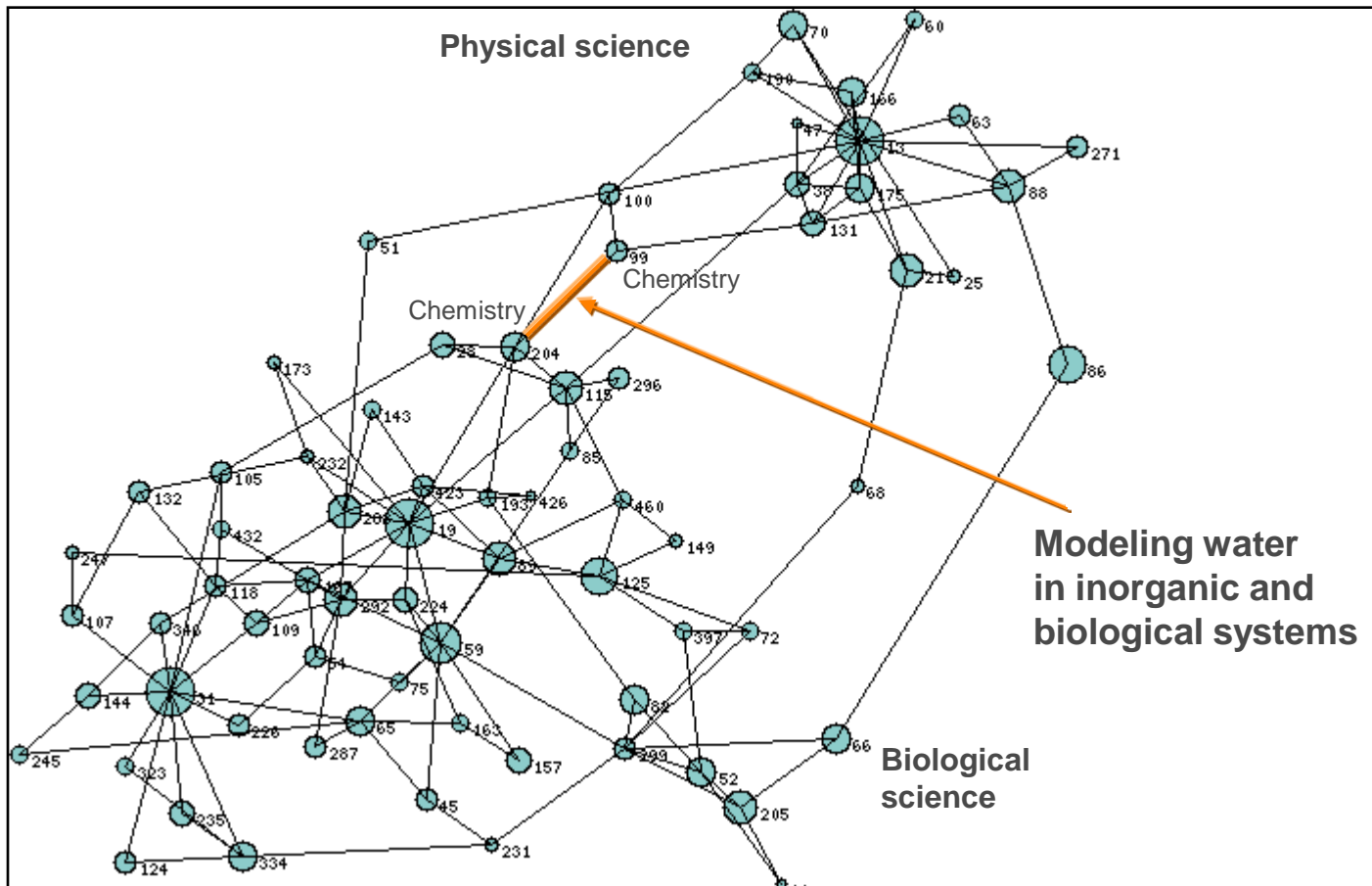
“Photosynthetic ring structures have been mimicked in various clever ways by synthetic chemists . . .” (Hobben, 2005)

“As in nature, porphyrins are among the pigments most frequently employed as light harvesting antenna.” (Roy, 2008)

Frequently occurring cue words in co-citing passages

Cue word grouping	frequency
novel, important, advance, breakthrough, excellent, improvement, successful, noteworthy, significant	14
mimic, as in, symbiosis	4
efficient, useful	4

Case #3: An intra-disciplinary link



Sample co-citing passages:

“Such disagreement between implicit and explicit solvent models may suggest that the dielectric surface requires modification or that a pure implicit model is simply insufficient.” (Feig, 2006)

“A key point is that it does not seem sufficient to incorporate water into protein structure prediction merely via some heuristic potential that acknowledges the existence of hydrophobic interactions” (Ball, 2008)

Frequently occurring cue words in co-citing passages

Cue word grouping	frequency
disagreement, insufficient, expensive, inadequate, challenge, discord, demanding, drawbacks, underestimate, unfortunate, time-consuming, inferior, prohibitive, counter-intuitive, debate	19
exciting, successful, indispensable, accurate, novel, significant, new, careful, suitable, consistent, insightful, popular	12

The link represents a scientific controversy.

Are intra-disciplinary links more likely to represent controversy?