Research Trends

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Mapping unknown regions

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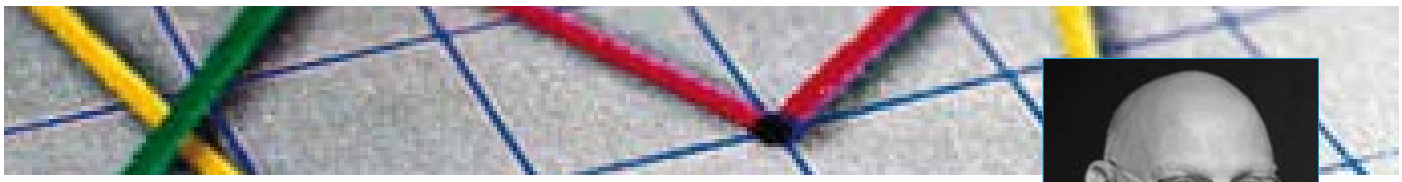

Mapping unknown regions

Richard Klavans (pictured) and Kevin W. Boyack

A map of science is a diagram showing how different areas of science are related. The earliest maps tended to be hierarchical, starting with mathematics, then physics, chemistry and biology. Applied sciences would be like branches off this tree – electrical engineering branching off physics, chemical engineering branching off chemistry, and medicine and agricultural science branching off biology (with some chemistry).

But our analysis does not support the hypothesis that science is actually structured this way. We analyzed 20 maps of science. Two of these maps were made by experts, 17 were drawn through analysis of the citation patterns of millions of articles in thousands of peer-reviewed journals and one was based on course requirements at a university.

We found that science looks more like a circle than a hierarchy. Starting (arbitrarily) at mathematics, one can proceed through the areas mentioned above (physics, chemistry, engineering, earth sciences, biology, biotechnology, infectious diseases, medicine) and continue around the circle through health services, brain research, humanities, social sciences, computer science and back to mathematics (see figures 1 and 2) There isn't agreement about the order suggested here (some might put computer science next to biotechnology, others might put chemistry closer to medicine), but there is consensus that these are the most common connections for all of the maps we examined.

Why use a circle?

Mapping science as a (non-hierarchical) circle is a useful aid for career counseling. A hierarchical map of science implies that one's path should always be aimed towards "central" areas (and correspondingly avoiding "peripheral" areas). A circle has the unique characteristic that there is no "center" (or, to say it more accurately, each point is the center). A circle illustrates what we need to communicate to a student – that many paths are equally valid.

Mapping science as a circle is also useful for understanding science policy. Governments support investments in science, just like one places weights on the edge of a wheel. Balancing the wheel of science reflects fundamental tradeoffs between supporting the arts, providing an understanding about how people behave, providing health and well-being to society, pursuing techno-economic goals, and supporting basic research which may have no immediate economic or social impact. Maps, presented as weights on a wheel of science, can play an important role in communicating the national orientation towards these different objectives.

What is a map of science?

A map of science consists of a set of elements and the relationships between the elements. These elements can be any unit that represents a partition of science. Maps must have partitions, where science is separated into different parts, and these partitions must be linked, either explicitly (such as a line drawn between two partitions), or through proximate location (or physical adjacency) that explicitly denotes linkage.

Here there be dragons

In the 13th and 14th centuries, maps of the world showed the known world floating on a sea of uncertainty with unexplored regions marked "here there be dragons". This metaphor is still important today. Science education should be about communicating that there are many more areas yet to be discovered, students can take part in this process, and society, as a whole, can benefit from this discovery process.

One can communicate this same sense of excitement by placing what we "know" on the edge of a circle and what is "unknown" as the white space inside the circle. We should communicate, to both students and the public at large, that there still need to be explorations into the heart of the unknown. More and more of this exploration is interdisciplinary, which means it's further from the known edges of the circle of science. Deep inside the circle are the dragons that the next generation must face and conquer.

Useful links:
Places & Spaces
All the original maps and their codings

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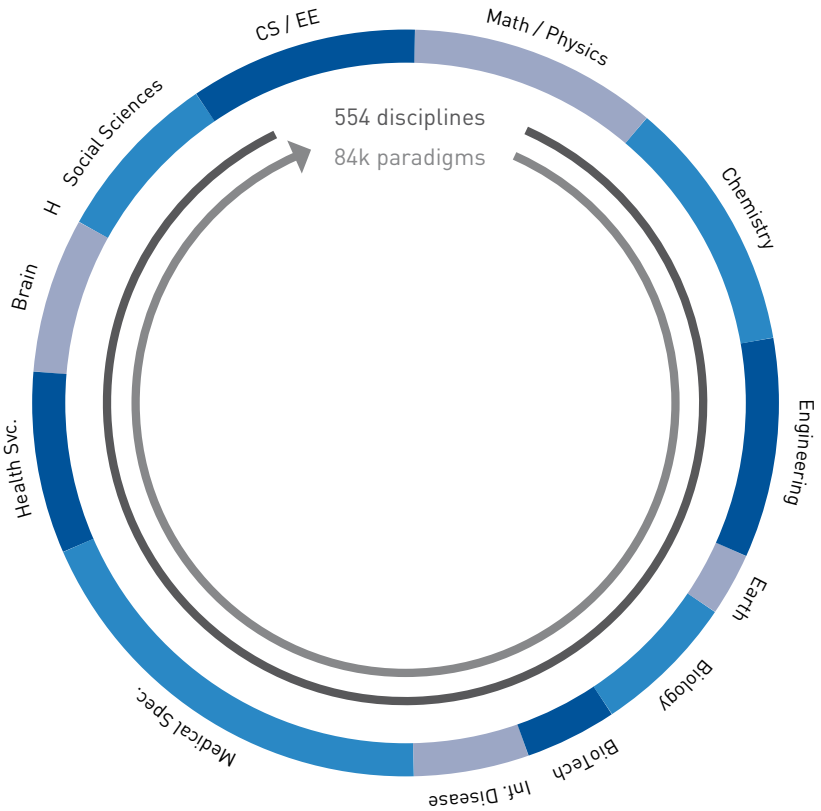
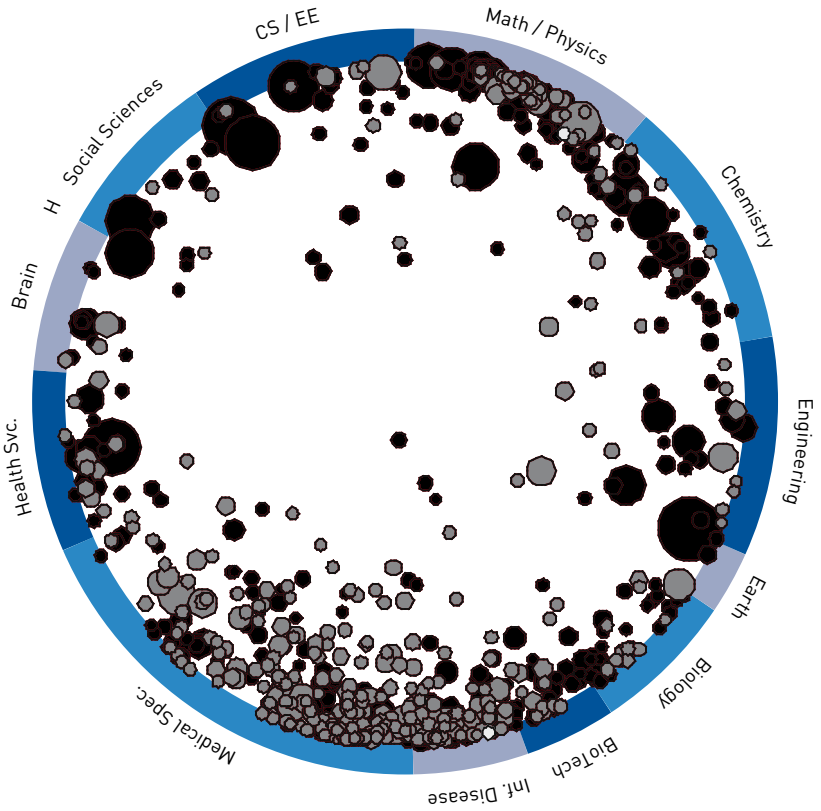


Figure 1- In this map, fields are arranged around a circle based on the meta-analysis of 20 maps of science. The order of the 554 disciplines (journal categories) is based on multiple factor analyses and the 84,000 paradigms (co-citation clusters) are ordered around the circle by discipline.



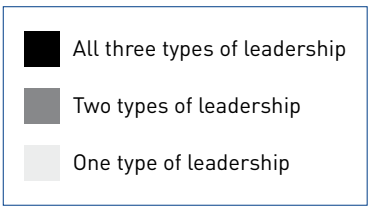


Figure 2 - A country's strengths are located in the paradigm clusters, which are idiosyncratically linked by the country and in which the country has at least one form of leadership – in this case, the USA.

The three types of leadership are:
1) publication leaders: the largest number of current papers (2003–2007);
2) reference leadership: the largest number of cited papers forming the co-citation clusters;
3) thought leadership: referencing more recent papers than the #1 competitor AND publication share →0.8.