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Title

The emergence of interdisciplinary communities at the science-technology overlap in the life sciences: evidence from particle therapy of cancer

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This study focuses on the emergence of a new interdisciplinary scientific community at the intersection of "big science", life sciences, and technology. How does this emergence relate to the dynamics of inter-organizational and inter-disciplinary networks? How do different organizations tie different disciplines together to make new knowledge emerge?

The empirical study focuses on the emergence of "particle therapy", a cutting-edge therapy of cancer that originated from the application of particle accelerator technologies and the respective "big science". It combines qualitative analysis of 22 semi-structured interviews and specific key documents, with quantitative bibliometric and network analyses of more than 2,800 scientific publications over the past four decades. Access to data and experts was facilitated by scientists at CERN (European Organization for Nuclear Research) and GSI (German Heavy Ion Research Lab) that are two key organizations contributing to particle therapy developments.

The qualitative study focuses on the history and emergence of particle therapy through an open-ended inquiry. Particle therapy of cancer had its origins more than 60 years ago. Two scientists, who were previously involved in the Manhattan project that produced the atomic bomb, started this research in the aftermath of World War II. Particle therapy gradually emerged as particle acceleration improvements coupled with computer processing improvements empowered cancer research. Different disciplinary boundaries have been crossed for a new community to shaped, involving mainly physics, bio-medical and clinical sciences, chemistry and engineering.

These developments resulted from the collaboration among many universities, hospitals, companies, and government laboratories mainly in the US (e.g. Harvard, LBL Berkeley, Stanford, Varian), Europe (e.g. CERN, Heidelberg University, Siemens), and Japan (e.g. NIRS, Hitachi, Chiba University). They received important funding at the supranational (e.g. EU Framework Programmes), national (e.g. US National Science Foundation), and local levels (e.g. Hesse, Germany).

Particle therapy offers one key strength vis-à-vis conventional radiation therapy of cancer (i.e. based on beams of X-rays). In particle as well as in conventional radiation therapy, beams are delivered to the patient to destroy tumor cells. As inevitable, the surrounding healthy tissues also receive some radiation doses. The damage is lower with particle therapy than with X-rays in terms of higher precision and energy deposition when irradiating the target region.

The quantitative network analyses focused first on the analysis of the disciplines network. A descriptive analysis with a main focus on records count (scientific outcome) and Freeman betweenness centrality as indicator of inter-disciplinarity (Leydesdorff 2009) has been carried out.

Secondly, the 2-mode network of organizations and disciplines within the community is analysed first statically and cumulatively (covering 40 years) and then slice by slice (10-year slice) through Principal Component Analysis as a scaling technique. This type of analysis allows studying the interdependencies across different levels (e.g. organization, and disciplinary space). The interpretation of the scaling results is problematic, and interviews are very helpful to overcome this issue by informing the interpretation of

results. I am now seeking patterns through which different organizations tie different disciplines together.

So far the Principal Component Analysis of the cumulative network has identified core, relevant and peripheral (but complementary) disciplines within an interdisciplinary spectrum (proceeding from physics to the medical side). The organizations that tie different disciplines together have been placed visually in the interdisciplinary space and scored quantitatively. Three factors explain more than 50 % of the joint variance in the interdisciplinary space. These factors have different disciplinary composition. The organizations that load to each factor reveal a different composition of organization types. I am currently carrying out the Principal Component Analysis slice-by-slice (10-year slice).

So far three key sides have been identified in the interdisciplinary spectrum of the community. The beginning of the spectrum featured by physics, nuclear science and other satellite disciplines; the middle of the spectrum, where radiology emerges as key discipline; the end of the spectrum, including a vast array of medical disciplines where oncology emerged as key.

The most interesting aspect is the role of specific disciplines that are not that relevant in terms of publications count but do play an important complementary role by integrating a wide array of different disciplines. The role of university hospitals and clinics is key in the community. They do move community forward and give legitimacy and wider scientific evidence to the particle therapy paradigm. This turns out into better improvements of accelerators and other technologies used in the therapy process. The role of universities is key in terms of integration of different disciplines through complementary ones. The qualitative study points to potential hybrid organizations playing an important role: the standardization of clinical trials'data collection.

The pattern followed by disciplines and organizations reveals how the community emerges as inter-disciplinary. This emergence in terms of scientific evidence is driven by the disciplines at the end of the spectrum revolving around oncology. Hospitals, clinics and universities linked to them do lead this emergence together with few government laboratories that bring together medical and other disciplines such as radiology. Yet, the integration of the community is driven by a few disciplines revolving around physics at the beginning of the spectrum. Government laboratories do play a key role in this regard.

Disciplines such as physics and spectroscopy do open up new research avenues for other disciplines. They therefore also bind together different disciplines. New technological developments are produced, empowering the scientific developments of the community itself. As evidence increases in support of the paradigm, the market opportunities become more interdependent with the scientific and technical developments. The new community emerges out of this process at the intersection of science and technology.