Convergence Innovation: Nanotechnology Development at the Intersection of Disciplines, Organizations and Products

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A Primer on Convergent Innovation in Nanotechnology

Convergence Innovation is the paradigm where discovery and technology creation occur at the intersection of multiple disciplines and organizations. In nanotechnology, convergence between the chemical, biological, cognitive, physical and information sciences is evident. Firms and researchers will cross the boundaries between these disciplines to create technological value--finding solutions to address health, environmental and energy challenges. In parallel will be emergence of new models of collaboration to enable knowledge creation and knowledge dissemination. Central to Convergence Innovation will be a determination of the common value of knowledge versus the private value of knowledge across the associated disciplines—with the goal of advancing and commercializing technology.

Levels of Convergence in Nanotechnology

Convergence in nanotechnology can be considered at three levels—namely, convergence in the sources of knowledge for research, convergence in organizational forms to enable technology development, and convergence at the product level with the embodiment of knowledge in complementary products. While nanotechnology research has been shown to have a dominant focus on material sciences, additional analysis has demonstrated that nano-based research increasingly draws its knowledge from other areas (Porter and Youtie, 2009). Specifically, Porter and Youtie (2009) reveal that while nano-based publications center on materials science (including chemistry and physics) nano-based research also significantly involves many other fields, including biomedical sciences, computer sciences and mathematical sciences, environmental sciences, and engineering. Citation patterns further show extensive referencing across macro-disciplines—with a preponderance of references in nano-related articles to research outside the macro-discipline in which the article is published (Porter and Youtie, 2009). Consequently, at this level of convergence, the sharing and absorption of research across the involved disciplines will be necessary for downstream value creation. (Figure 1)

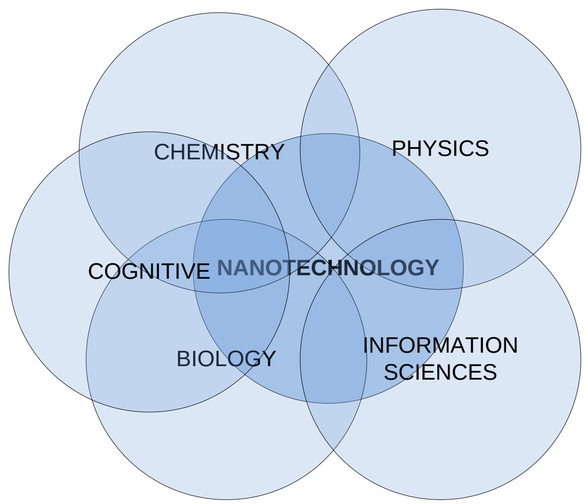

Figure 1: Convergence at the Disciplinary (Knowledge Sources) Level

At the next level of convergence—the organizational level—the interaction between technological convergence and models of open innovation is becoming apparent. Licensing, mergers, acquisitions, and strategic alliances such as joint ventures, as well as new structures such as innovation networks and open innovation communities represent alternative strategies that may be used to acquire or access the necessary knowledge or assets for nano-based discovery and development. From a convergence perspective, the opportunity exists for a (public or private) stakeholder to not only interact with other (public and/or private sector) stakeholders through simple one-to-one traditional collaborations, but with many stakeholders through more complex mechanisms such as consortia, crowdsourcing, and other such open innovation communities. For example, the need for shared scientific expertise and large scale infrastructure in both nanotechnology and biotechnology is thought to be responsible for the development of networks spanning both fields. (Figure 2) The pervasiveness of enabling technologies such as information and communications technology (ICT) have encouraged innovation networks to increase in dominance and have lead to the blurring of organizational boundaries among research organizations (Powell, Koput and Smith-Doerr, 1996; Roijakkers and Hagedoorn 2006). In such collaborations, the opportunity to assume multiple roles exists to enable nanotechnology R&D including: the collaborator who shares knowledge with one or many partners for the purposes of discovery or development; the incubator who provides funding or expertise to other stakeholders to support venture development; the enabler who provides access to tools, equipment, large scale infrastructure or other services to support product development; and the orchestrator who manages the network of partners with either the objective of knowledge creation or knowledge application (Melese, Lin, Chang and Cohen, 2009). At this level of convergence, there is the critical need to closely examine the management processes associated with collaboration, as the collaborative strategies have not only grown in relevance, but also in terms of impact and the number of participants involved.

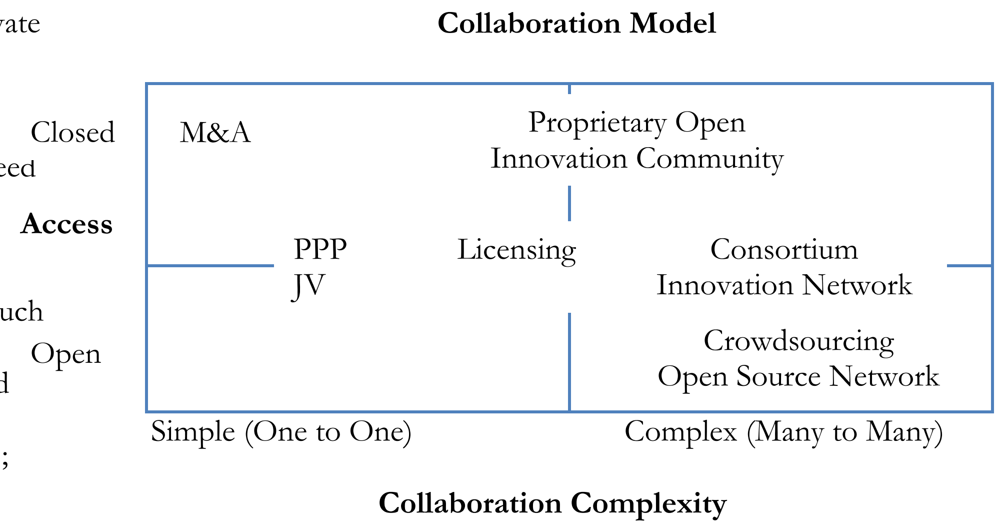

Figure 2: Convergence at the Organizational Level
Open Access=Participation Open; Closed Access=Exclusive Partnership; Simple=One to One Link between Partners; Complex=Many Links between Several Partners; PPP=Public Private Partnership; JV=Joint Venture
The location in the above grid determines the extent to which the collaboration is open or closed and between one, few or many partners.

Finally, the outcomes from any collaborative interaction will increasingly lead to convergence at the product level. In this case, multiple components or products will be packaged together to enhance the value over individual product offerings. (Figure 3) Such bundled products will have the goal of simultaneously meeting several technological needs be it for biomedical treatment as seen in the use of nano-based diagnostics paired with therapeutics; in agriculture or environmental applications as seen in the use of nano-sensors to measure pathogens in food and the environment or the use of nanospheres to selectively detect harmful materials in water and then used for detoxification; and in the creation of novel energy technologies as seen in the use of catalysts in nanoparticles for biodiesel synthesis to name a few (Schmidt, 2007). At the product level, effective intellectual property management strategies and coordination between regulatory agencies will be paramount.

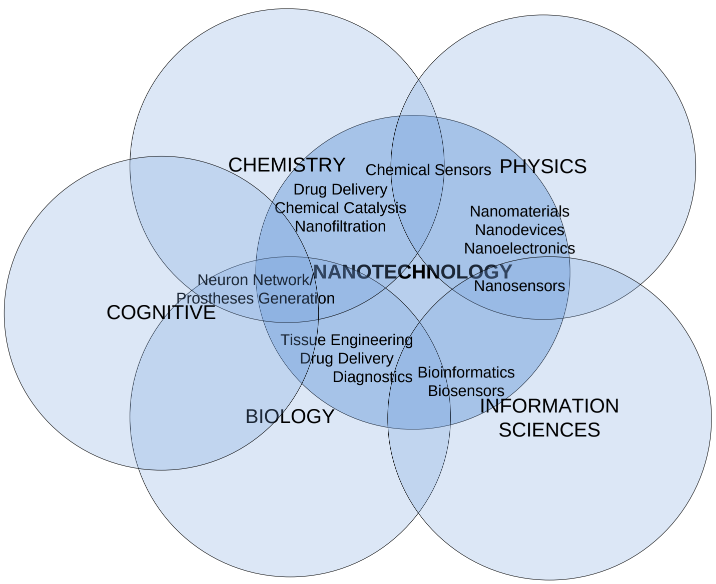

Figure 3: Convergence at the Product Level

The Impact of Convergence

At each level of convergence, there are several complexities that either impact the management of stakeholder interaction or the management of the knowledge based assets generated through such interactions. For example, given the expected intersection between disciplines, knowledge complexities including varied types (such as biological information and biological structures, chemical knowledge and structures, physical knowledge and structures) and forms of knowledge (disembodied and embodied) will drive the need for a common platform for knowledge integration, validation, and standardization. Beyond integration of knowledge, it is expected that teams of biological, chemical, and physical scientists, will increasingly form to develop and bridge together the necessary tools and equipment for R&D activities (Ideker, Galitski and Hood, 2001; Kitano, 2001; Kautt, Walsh and Bittner, 2007; Boardman, 2008; Boardman and Ponomarioy, 2009). We must also consider the impact of convergence on the downstream rights to develop products. Lemley (2005) discusses that unlike other industries in which patentees are actual or potential participants in the downstream market, a significant number of corporate nanotechnology patentees will own rights not just in the industry in which they participate, but other industries as well. Analysts fear that over-patenting alongside the large shadow of such patents, could not only fragment nanotechnology, but could discourage stakeholders in a number of industries from attempting to develop products incorporating infringing technologies (Lemley, 2005). It is important to consider that as multiple disciplines increasingly working together, each discipline will have its own priorities and conventions regarding knowledge dissemination and knowledge appropriation (Hilgartner, 1996). One discipline may signal its success during knowledge generation through the enclosure and the sale of disembodied knowledge. Another discipline may measure its success exclusively by the embodiment of knowledge in medical products (Hilgartner, 1996). While patent pools are a suggested solution to the possible patent holdups (D'Silva, 2009), it has been proposed that as has occurred in the genomics arena, innovation-based networks with rules regulating the development and appropriation of critical nanotechnology building blocks, could not only circumvent the product development and legal problems of the past, but will also bring together the requisite intellectual and physical capital (D'Silva, 2009; Allarakhia and Walsh, 2010).

A Template for Managing Nanotechnology-Based Interactions and Knowledge-Based Assets
Governance strategies must seek to align the incentives for participation in collaborative activities for multiple stakeholders. The use of rules to define actions, communication mechanisms used to enable and monitor actions, and to share the outcomes are all critical to ensure that goals are achieved.

Structure and Roles: It is expected that the chosen collaboration mode—one to one, one to many or many to many collaboration and objectives set for the collaboration—pooling of assets, generation of new assets, and/or policy creation will impact the type of participants that will join. The organizational structure chosen will be determined in part by the attributes of the resources to be contributed or developed—information, supporting tools, technology as well as the location of participants—with linkages established through physical clustering or virtual networking. Thereafter, the organization of participants may be a function of technological expertise, geographic location, or project-based management expertise.

Resource Types and Outcomes:
Participants will contribute several inputs including funding, equipment, and human capital. The resulting outcomes include data, materials, tools, and technology. Facilities store artifacts in order to make them accessible. Traditional facilities have been libraries and archives containing books, journals, and papers. New technologies have made electronic, distributed information possible. Artifacts are discreet, observable, nameable representations of ideas, such as articles, research notes, books, databases, maps, computer files, and web pages (Foray, 2004; Hess and Ostrom 2006). In the context of nanotechnology, databases, material and model repositories, accessible laboratories that aggregate equipment and tools for nanotechnology development are varied options to manage the outputs. Hence, any outcomes analysis should seek to determine the success of collaboration including the amount of data produced and accessed, the material generated, housed and accessed, the tools created and used, and the technology produced by participants.

Governance: Internal rules or mechanisms used to promote cooperative behaviour can include: formalizing the requirements to join the initiative; ensuring frequent interactions; encouraging communication between participants; monitoring and punishing defection; and setting the boundary for access to resources. An authority that regulates access to resources can ensure that a fair and efficient governance strategy is used (Ostrom, Gardner and Walker, 1994). While access generally refers to disembodied assets such as data, extraction can involve the removal and/or use of physical materials, models, and tools. Knowledge use and access can be governed by the following rules: sharing with partners only (closed access); sharing with partners and the public at large (open access); and intellectual property assignment potentially on information, materials, tools, and technology with the specification of rights to use based on licensee type, geography, or target market for product launch.

Creating Value: The Path Forward in Nanotechnology

The path forward will require the creation of supporting policies encouraging multi-disciplinary collaboration. At a national level, several governments have recognized the importance of innovation networks to develop capacity and compete on an international level. Consequently, policies are now providing more R&D funding and incentives encouraging the formation of multi-sectoral networks (Corley, Boardman and Bozeman, 2006). New products of convergent technologies will necessitate cooperation among regulatory bodies with the coordination of information flow, coordination of duties, and increased harmonization between international regulatory bodies (Castle et al., 2006; Drezek and Tour, 2010). To avoid the mistakes of the past, policies outlining guidelines for the management of intellectual property rights can ensure that stakeholders will correctly assess the common value of knowledge versus the private value of knowledge—resulting in the transition from open knowledge to appropriated knowledge with the objective of pursuing (unilateral or collaborative) downstream product development.

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