further about the fluorination mechanism of ferric oxide (Fe_2O_3) and stannic oxide (SnO_2). The speaker has also successfully tested a humidity sensor for breath-rate monitoring and touch sensing during her research. The next talk by Anjan K. Banerjee, IISER, Pune, discussed the induction of aerial and belowground tubers in potato as a classic example of developmental plasticity and modulation of plant architecture. The take home message of the lecture was that in potato, all axillary meristems have the capacity to form tubers and under permissive conditions any shoot meristem can produce aerial tubers. However, this potential is suppressed, except in stolons.

The annual meeting came to a close with a special lecture by Ashok Sahni, Panjab University, Chandigarh, on greenhouse explosion of biodiversity, focusing mainly on Indian Eocene Palaeobiota. He indicated that the global diversity has increased exponentially during the Eocene greenhouse and the Eocene thermal events have triggered biotic radiations and species diversification. He further elaborated the importance of amber, a fossilized tree resin and how its inclusions such as fungi, mosses, bees, wasps, termites help to characterize microenvironments. He also explained as to why the development of mycorrhizal associations is considered a key innovation that has enabled vascular plants to extensively colonize terrestrial habitats.

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COMMENTARY

Innovation barriers and a possibility kaleidoscope: the NEP imperative

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In the context of research and innovation objectives of National Education Policy (NEP), this note elicits five innovation barriers prevailing in the higher education institutions in India and presents an innovation possibility matrix based on two dimensions of resources (lightweight versus resource-intensive) and openness (open versus closed). At the policy level, this approach helps as a lens for informed resource allocation that is balanced across different institutions and kinds of innovations. At the institution level, it helps us understand what kind of innovation direction can institutions take in different projects, the gaps to be filled and capabilities to be built.

One of the core features of the National Education Policy (NEP) is its focus on research and innovation. While autonomy, good governance and new institutional structures are pathways to realize this, how the idea of innovation is conceived and enacted in a densely diverse educational system is a significant implementation challenge.

In the background of research and innovation objectives of NEP, this note elicits five prominent innovation barriers prevailing in the higher education institutions (HEIs) in India and presents an innovation possibility matrix based on resources and openness.

The research, development and innovation plan of NEP is evident in three ways. First is the establishment of new institutional structures. The National Research Foundation (NRF) is one such initiative to build high-quality research institutions with collaboration of Government, universities and industry. The National Education Technology Forum (NETF), another proposed institutional structure, focuses on educational technology across a range of institutions, and aims to improve pedagogy and assessment resulting in innovations in teaching and learning processes.

Second is the thrust of NEP on priority and disruptive research areas such as green technologies, Artificial Intelligence (AI), Virtual Reality (VR), robotics, nanotechnology, block chain and Internet of Things. Third are the pedagogical measures. Modular examinations to test core capacities, degrees by research work, streamlining higher research degrees, more incubation facilities, technology development centres, deeper industry–academic interface and interdisciplinary research are some pedagogical and general educational measures that can support the research ecosystem.

It is expected that as a combined outcome of all these factors, the level of innovation and the number of intellectual property attempts will improve in our institutions. However, this enhancement will be uneven unless we are mindful of two important factors, viz. what prevents institutions from innovating and what possible spectrum of innovations exists and is available for institutions.

Innovation barriers

The successful implementation of innovation initiatives envisaged in NEP needs to recognize the current barriers to innovations in our institutions. Clarifying and plugging these gaps can ease the implementation process. From experience and the literature, we distill five innovation barriers here.

Lack of space for failure and experimentation

By default, education honours achievers and is therefore prone to discard failures. This is also visible in the approach of academia in confronting uncertainty. Resulting from the academic tendency to overrate failures and avoid uncertainty, HEIs provide negligible space for experimentation, which reduces the possibility for innovations.

At one level, innovation is viewed as the number of attempts irrespective of the results. Larger quantity of ideas is not sufficient for innovation. Yet, every great idea

was rejected at least once before its execution and acceptance; a fact later ignored because of the widespread diffusion of the idea or innovation. According to Paul C. Lauterbur, Nobel Prize laureate: 'you can write the entire history of science in the last 50 years in terms of papers rejected by *Science* or *Nature*'[1]. Not providing enough space for rejection, experimentation and failure will block many potential innovations. What makes this barrier severe is that as institutions and individuals we are unprepared to face refutations, even if we claim that innovation is a priority. Reorienting institutional structures to accommodate innovation failures gracefully and honestly is a cultural challenge that cannot be addressed by policy enactments. Academic freedom, autonomy, internal democracy and research integrity as an integral part of the institutional DNA will naturally pave the way for freedom to experiment.

Silos effect and compliance focus

One of the major barriers at the last-mile policy implementation is pigeonholing the initiatives of different bodies at the institution level. Though capability building for research, innovation and incubation is a felt requirement of all institutions; unifying the initiatives at the institutional level is a leadership challenge. Robust innovation ambience in a university or college is a function of shared mindset around innovation, which can seldom be solved by regulations. As regulations are primarily seeking compliance, innovation becomes a distant possibility as long as compliance remains the target.

Lack of innovation strategy

If innovation is a priority for the institution, it needs a strategy that works on how to collect, prioritize and allocate resources to different and competing requirements of departments and research teams[2]. Through innovation strategy, the institutional governance supports sprouting of innovation possibility. In the absence of an innovation strategy, the much touted need for innovation culture remains as an aspiration value devoid of any practical implications.

Entry barriers and collaboration blockers

The interaction of an average Indian faculty member is mostly within the academia and much limited to the end-users of the research. Many innovations outside the mainstream academia go unacknowledged as most institutions keep high barriers of entry for grassroots innovators. The entry barriers appear in varied forms, such as disciplinary silos, recruitment compliance, regionalism and loyalty frameworks. They prohibit entry of experimenters and innovators to the system. Innovative universities worldwide explicitly recognize that the proximity of the researcher with the end-user will trigger more concrete ideas to innovate.

Funding

In most colleges and universities, low level of funding is one reason that makes the research more individualistic and centring it on career progression. NEP mentions that the research and innovation investment of India has only been 0.69% of the GDP, which is far less compared to many other countries such as the United States (2.8%), Israel (4.3%) and South Korea (4.2%)[3]. Lack of familiarity with exploring parallel funding sources from private foundations, corporate bodies, organizations abroad, crowd-sourcing and new financing models adds to the problem.

Specific barriers of each institution are the variations, combinations and resultants of the above obstacles. A few national institutions may be outside of these barriers. However, in most of the universities and colleges where 80% of the students are enrolled, the barriers remain to be broken. Expanding the innovation space is one way to make inclusive participation of a variety of institutions.

An innovation kaleidoscope

A closer look at the innovation space in the Indian higher education system reveals two levels of educational innovations and research attempts. First is research and innovation as documented by international organizations and world-wide rankings of educational institutions based on patents, citation counts, R&D funding and research commercialization matrices. Second is the frugal innovation using bootstrapping and cost-efficient methods, most of which are unscaled and less technology-intensive. The current system of measurement of innovation tends to underrate frugal innovations. Researchers from established institutions will be at an advantage in the current system of measurement. Being a zero-sum game, dislodging or displacing top-ranked institutions becomes the priority in the ranking race. Attracting R&D funding is subject to the institutional ranking, competence of researchers and credibility of the institution, all of which together create an entry barrier for the institutions which are already at the bottom of the innovation pyramid.

While we emphasize on international R&D-based innovations for all kinds of institutions in India, we are systematically overlooking the advantage of well-placed researchers in top institutions. Clearly, we miss the possible innovations in pedagogy, educational administration and many other areas which may not be directly linked with enormous resources. To view the innovation space more holistically, we present two dimensions – resources and openness.

Light weight versus resource-intensive innovations

Innovations that are less capital-intensive or lightweight innovations, themselves are a disruptive way of thinking about idea generation and execution[4]. They seek to bypass organizational silos and the fortified nature of academic infrastructure prevailing today. Light-weight innovations are not expected to replace or reduce the existing resource-intensive research, but to affect each other to be more inclusive and be available for more number of institutions in India. Being frugal, organic and regionally relevant, innovation is an immediate possibility to accommodate the large number of students and institutional clusters in rural areas, small towns and non-metros.

Open versus closed innovation

Open innovation strategies that eliminate the entry barriers to innovation and seek to broaden the pool of ideas from external sources have produced considerable success in many countries[4]. Specific innovation goals supported by civil society will be a useful perspective[5]. Unlike the IP based attempts limited to few institutions, open innovation can build capacity for high-velocity, high-volume parallel innovation over long periods of time in more number of institutions.

While open innovation seeks to expand the sources of new ideas, lightweight innovation attempts to disaggregate and speed up innovation, and invent and reinvent

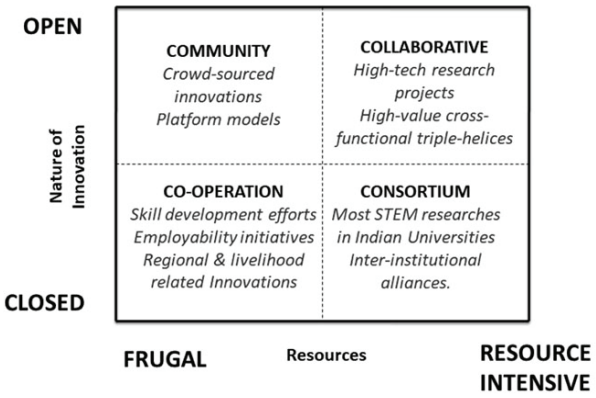

Figure 1. A kaleidoscope of innovation space.

new platforms. Over the next decade the lightweight model of innovation will force large organizations in all sectors to develop open innovation models that are more agile, lean and user-driven. Thus, combining the dimensions of resource intensity and openness we get a template for thinking – a kaleidoscope of innovation possibilities (Figure 1).

Community-driven initiatives include crowd-sourced innovations, open ideations, open prototyping and open standards. Collaborative initiatives are top–down, big-budget project innovations. Consortiums are inter-institutional alliances with high-volume resource-sharing. Innovation in cooperative structures can facilitate rapid prototyping and can have new ideas such as pop-up laboratories. Essentially they are scalable to community or collaborative or consortium-based innovations, on the basis of infusing the required openness and resources required.

At the policy level, this approach helps as a lens for informed resource allocation that is balanced across different institutions and kinds of innovations. At the institution level, it helps us understand what kind of innovation direction can the institutions take, locate gaps where the capability can be built, and what sort of IP structures and protections are aimed at. The idea is not to claim that one kind of innovation is superior to another, but to get clarity on the possibility of innovations available.

Towards high density of innovations

The literature in the last decade suggests that the innovation process can be ignited and managed in educational settings. Innovation is about 30% nature and 70% nurture[6]. Still, research and innovation are sometimes seen as a random process in many institutions. Mindful of this fact, we need to be considerate on the possible types of innovations as mentioned in the kaleidoscope to increase the density of innovations.

India's ability to innovate is much higher than in the past because of the technological facility to share information and insights. To advance it by NEP implementation, the kaleidoscope of innovation forces us to consider innovation capabilities that go beyond traditional R&D. It will augment the shift from a centralized, standardized, monoculture understanding of innovation to a flexible, holistic and diverse innovation domain. When we debate on the volume and value of scientific production, it is useful to include varying innovation possibilities that can be realized in different institutional contexts of higher education[7].

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