# Draft STIP Consultation: Experts' Recommendations - II

The previous issue of the *Science Diplomacy* digest brought out a cover story on the upcoming 5th Science, Technology and Innovation Policy (STIP) of India. It aimed to collate the recommendations put forward by experts during 'Across the Table' consultation process, in a two-part series. The first part included panel discussions on five themes: 1. Research & Development Ecosystem, 2. Equity and Inclusion, 3. STI Policy Governance and Program Linkages, 4. Skilled Human Resources and Capacity Building, and 5. STI Governance and System Interconnectedness. The present issue was to cover the remaining thematic discussions. However, the release of draft STIP intrigued us to compile the experts' comments on the same. Hence, the current issue brings out the views of the esteemed experts involved in the STIP consultation process. We are grateful to our experts for sparing their time and efforts. We hope these suggestions and comments would help finalize the policy document.



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## STIP - A Sustainable Policy for Collaborative and Consolidated S&T in India

(*The author participated in '*Across the Table*' discussion on '*Mega Science and International S&T Engagement*' under track-I of the 5th STIP process)

### An Integration of STIP and Atmanirbhar Bharat

Self-reliant India campaign or Atmanirbhar Bharat Abhiyaan is the vision of a new India envisaged by Prime Minister Narendra Modi outlining five pillars – Economy, Infrastructure, Systems, Vibrant Demography and Demand. While all the pillars of the Atmanirbhar Bharat Abhiyaan are fundamental to the growth of India, I am very exacting about the success of and the mechanism by which the 'Systems' pillar will be achieved. This is because of the need to develop science and technology towards building India.

The 2030 Agenda for Sustainable Development, adopted by all United Nations Member States in 2015, provides a shared blueprint for peace and prosperity for people and the planet, now and into the future. The 17 Sustainable Development Goals (UN-SDGs) are an urgent call for action by all countries in a global partnership. It has become imperative for governments and policymakers around the world to focus on fulfilling these goals by blending them into new policies for national and global development. In alignment with this, the fifth Science Technology and Innovation Policy (STIP) of India is being developed. This policy critically analyses the sub-pillars that the 'Systems' pillar will need to function effectively.

The STIP document is the realization of the emergence of disruptive and impactful technologies, which poses new challenges and simultaneously excellent opportunities. India will catalyze the socio-economic development of the country and also make the Indian STI ecosystem globally competitive. To facilitate the success of this policy document while acknowledging sustainability in India's development, the document outlines certain strategies:

- Ensure systematic governance of the expanded STI financing landscape
- Create a fit for purpose, accountable research ecosystem
- Collaborations between grassroots innovators and scientists
- Impetus to the mainstreaming of equity and inclusion
- Improve science teaching, science communication and science pedagogy
- Engagement with the diaspora
- A robust STI Governance
- Establishing an STI Policy Institute

These strategies being deployed are set to achieve certain goals. Some of them are to:

1. Achieve technological self-reliance and position India among the top three scientific superpowers in the decade to come.
2. Attract, nurture, strengthen, and retain critical human capital through a 'people-centric' science, technology, and innovation (STI) ecosystem.
3. Double the number of Full-Time Equivalents (FTE) researchers, Gross Domestic Expenditure on R&D (GERD) and private sector contribution to the GERD every 5 years.
4. Build individual and institutional excellence in STI with the aspiration to achieve the highest level of global recognition in the coming decade.

While the goals are more elaborate, I found these particular ones interesting because of how tied they are to keep a flow of knowledge; it might be subtle, but the sustainability plan is commendable on how it advances collaboration as an important ingredient in its success. This has been tested in the middle of a global pandemic. An impressive alliance between R&D institutions, academia, and industry has proven to us that we can do so much more as a country if we allow for more fruitful collaborative endeavours.

If this collaborative method, the exact synergy and cross-sectoral partnerships are upheld, it will pilot India on the global front towards harmonizing and leveraging its STIP.

Ideally, one would wonder India's position before the introduction of this new policy. India has maintained a progressive pattern over the years. STIP notes that through previous S&T policies, India has been successful in building a robust STI ecosystem. However, the new challenges today necessitate a different policymaking approach. The current pandemic has catalysed the need for a new policy instrument that amalgamates the profound and incremental approaches. Such a policy must adequately prioritize and strategize across the STI landscape in alignment with UN-SDGs through a balance of short-term mission-mode projects along with long-term ones. There is a need to increase public funding and private investment in R&D, boost existing FTE, build and empower critical infrastructure, improve governance of STI initiatives, intensify global linkages in the STI sector, develop indigenous technologies in key areas such as health and medicine,

agriculture, energy, environment, etc. Additionally, technology capacity also needs to be enhanced to make India scientifically self-reliant and ready for unpredictable exigencies. Thus, this policy instrument, in its design and objective, aims to be evidence-driven, inclusive, and bottom-up for the well-being of the nation and its people with socio-economic and environmental considerations.

**Transformational Ecosystem**

STIP aspires to build an ecosystem where research data, infrastructure, resources, and knowledge are accessible to all. Consequently, a National STI Observatory will be developed as a central repository for all kinds of data related to and generated from the STI ecosystem. The observatory will be centrally coordinated and organized in a distributed, networked, and interoperable manner among the stakeholders. Cross-cutting interoperable digital platforms within the observatory will be organized into verticals, including but not limited to: (i) establishing knowledge and data repositories; (ii) setting up a computational grid; (iii) developing a virtual communication and interaction platform; (iv) enabling virtual access of equipment, laboratories, and other physical resources, talent mapping; (v) conducting analyses on projects, funding, outcomes, technological capabilities, Technology Readiness Levels and Business Readiness Levels (TRLs & BRLs); and (vi) establishing evaluation, accreditation, ranking and rating protocols for benchmarking. Additionally, this will involve a national subscription plan so that everybody can get materials from publishers at no personal cost.

In the area of education and research, STIP directly relates to Goal 4 of the SDGs to promote and facilitate a more thorough teaching model which will involve mixing technology and traditional learning. The introduction of Innovation and Entrepreneurship Centres will help in the success of this part of the policy.

All of these are pointers to responsible leadership and a continued acceptance of scientific collaboration, which India needs in building its desired future. I particularly favour in transforming existing R&D institutions to research universities. This will foster better linkages between research and education, offer incubators and also enable effective utilization of research infrastructure.

While all of these are promising endeavours, one needs to examine how strong or weak this will be against the backdrop of an existing situation.

The STIP notes that mission mode programmes with deliverables for technology and innovation will be established in the priority sectors (e.g., Agriculture, Water & Health). In the healthcare sector, an international example is Hadron therapy for effective cancer treatment. What this project has proven over the last two decades is that effective collaborations can empower S&T innovations, and academia & industry intersect towards building sustainable solutions with a massive impact on society, economy, and environment. This is also reminiscent of the essential need to embrace science diplomacy and international collaboration compelling us to acknowledge the need to create globally competitive innovative enterprises by stimulating investment towards building indigenous technological capabilities across a diverse range of S&T-based entrepreneurial activities with a global impact.

The STIP equally yokes technology development, innovation and indigenisation. This is to embrace the development of local technological efforts while working for global objectives. I will once again refer to the Hadron therapy project for certain reasons. India is largely dependent on the import of technologies in the priority sectors. The TRLs in the country is low as compared to its global counterparts due to lack of interface systems, inadequate technology capacity, poor quality of research outcomes, weak linkages and procurement policy clauses. There are additional challenges in leveraging India's participation in mega-science projects in terms of building technological core competence domestically and translating those know-hows to benefit other sectors. Major hurdles for India in achieving technology indigenisation are:

unbalanced allocation of resources between academic and Post-academic Research (PAR), unavailability of trained human resources, weak interconnect between stakeholders, lack of effective strategy for development, deployment and commercialisation.

But as a country that is constantly working towards getting better, we must remember how much have we achieved, and what needs to be done, in terms of international mega-science projects that demand us to become exceptional as a nation in S&T.

The STIP equally acknowledges Technology Indigenisation for Atmanirbhar Bharat. Aligned to national priorities along with the aim of achieving a self-reliant economy, a two-way approach to technology development will be adopted:

a) developing indigenous technologies, and

b) adapting imported technologies.

There will be increased focus towards promoting efforts in the development and demonstration of indigenous technologies, development of capital goods, and absorption of imported technologies. This dual focus of utilising local and international collaboration will not only work but will be highly effective in the success of STIP.

Another aspect of the STIP, which addresses the UN-SDGs heads-on is equity and inclusion (E&I). The STIP ensures that there is equitable participation in STEM concerning gender, social, regional, and economic diversity in India. This will address a lack of an inclusive culture in the practice of science, besides inadequate incentives and institutional arrangements. A lacuna of E&I related assessment indicators, frameworks and instruments also exist.

While E&I has factored in, it is of great importance to highlight the attempt at science communication and public engagement. The STIP once again notes that there exists a disconnect between science and society at large with limited scope for citizen engagement in the STI ecosystem. To bridge this gap, the STIP will, as it is largely intending to do, address this through multilayered collaborations. This will involve private organizations, academics, regional supports, communities, and international partnerships. It mentions further that in line with the national policy on *Scientific Social Responsibility* (SSR 2020), scientists and researchers will be motivated and incentivised to engage in Science Communication and Public Engagement activities. Institutes and organizations will be encouraged to earmark a percentage of allocated budget (SSR fund) for science communication and public engagement activities. This is not only promising, but encouraging for the scientists and other stakeholders who will make it happen.

Taking it a step further, the STIP addresses scientific collaboration with international partners. To be fervent in international STI engagement, the STIP aims to accelerate India to a position where we will have:

- Participation in Global STI Agenda Setting and Governance
- International Bilateral, Multilateral and Regional Engagements
- Participation in Large S&T Initiatives
- Engagement with Indian Diaspora
- Proactive STI Diplomacy Strategy

If India can successfully penetrate these global scientific frontiers, it will create an avenue for us to become a top competitor not just in Asia but across the world. As it is often said nowadays, collaboration is the new competition. And the more collaboration India can build under the STIP, the more the chances of executing both the STIP and the Atmanirbhar Bharat Abhiyaan policies.

**Accountability for Meaningful Impact**

An important question is who governs the governor? Who is in-charge of the administrator? How do we ensure that governments focus on policies rather than on personal victories? The STIP makes a clear provision for that.

In the draft policy, reference is made to how dynamic monitoring, evaluation, and incentivization framework need to be strengthened. Besides, it is imperative to address issues related to rationalising data and regulatory frameworks. There is also a challenge of weak interconnectedness across the ecosystem. A robust Research and Innovation (R&I) governance framework will be set up and adequately linked with the proposed '*National Research Foundation' (NRF)* to facilitate, stimulate, and coordinate R&D activities across the sectors. This will be guided by the overall STI governance mechanism set up at the highest level. A suitable metric will be developed to evaluate and recognize the outcome and impact of research activities with respect to its direct relevance to Indian needs while continuing to maintain international comparability. This metric must reflect the meaningful impact of science on society, solving local problems and resource optimization, among others. To ensure transparency, accessibility and accountability within the STI ecosystem, a comprehensive administrative and financial management will be put in place within the broader R&I governance framework.

Additionally, STIP emphasis on monitoring, evaluation and feedback framework. Digital platforms will be created for monitoring, impact assessment, accounting and other analyses of STI initiatives. A feedback mechanism will be established between policymakers and relevant stakeholders after the implementation process begins. Baseline and mid-term reviews will be conducted and a transparent reporting mechanism for implementing agencies will be created to ensure regular updating of the policy progress. Methods such as social assessments through household surveys, focused group discussions, process tracing, participatory mapping of STI planning and implementation can be used to monitor and evaluate the policy implementation. Quantitative measurements/indicators - specific to the policy and/or programme - will be used alongside qualitative measurements to assess policy impact. Metrics will be created or a Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis will be conducted to map policy implementation programs, aligned with bench-marked aspirational outcomes.

**Atmanirbhar Bharat Needs to Work**

Notably, while making plans and policies at the national level, we are no longer just doing it for national development, but for regional, continental and global development. A good allusion is made to SDG 17, which promotes collaboration. India and other countries looking to exact crucial projects must look inwards to develop the local intellectual economy, but must also look outwards to collaborate and foster incisive action. Aatmanirbhar Bharat Abhiyaan will be successful, but must leverage on scientific collaborations, the mega-science projects, local talent development, and a sustainability plan that ensures continuity for posterity.



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# New National STI Policy - Effective Implementation through the Involvement of States

(*The author participated in '*Across the Table*' discussion on '*STI Policy Governance and Program Linkages*' under track-I of the 5th STIP process)

The new National Science Technology & Innovation Policy aims to nurture evidence and stakeholder-driven growth of STI in the country. The draft policy evolved through extensive consultation process covers wide-ranging steps envisioned to be taken for the same. The on-ground implementation of policy across the country can only be ensured through effective participation of the States. The succeeding paras cover some pointers for the same which, if included in the final policy, could be the true game-changer.

The policy proposes to set up a National STI Observatory. It is of paramount importance that the States be also supported in building uniform data architecture on key STI indicators in the form of State STI Observatories to ensure the information flow from actual stakeholders to the state nodal point and subsequently to the National Observatory. This will also help the states in assessing and augmenting their strengths which will go a long way in building the cumulative strength of the country.

Further, the draft policy acknowledges the presently existing disconnect between teaching & research in India and proposes to transform existing R&D institutions to research universities. However, it is equally important that adequate funds be channelized towards the existing universities to leverage their huge manpower strength to increase the research competence of the country.

Furthermore, the draft brings forth a very novel idea of developing a cadre of practising scientists and technologists in the form of prestigious Science Policy Fellowships at the mid-career senior level for curating and updating knowledge & its application in emerging sectors. Along with this, the final version of the policy could also define a specific mechanism to encourage setting up of Researchers' Networks in the key knowledge sectors at the state level and developing dedicated platforms for providing national & international connect to these networks. This will help immensely in developing a strong community of researchers within the country.

The draft policy commits towards creation of facilitating channels for the diaspora to contribute to national development. The mechanism also needs to be institutionalized to galvanize diaspora for strengthening STI ecosystem in their native states in the country.

The huge gap in the domain of tech-commercialization has also been acknowledged. In this context, it would be ideal if the existing network of Patent Information Centres set up by DST-GoI across the country be strengthened to also serve as Tech Transfer Facilitation Offices.

The draft emphasises on aligning research with the grand challenges and technology gaps of industry and starting Mission Mode Programs to address the same. The State of Punjab is taking focused steps in this direction. One such program aimed at addressing unmet needs of industry for cleaner technologies has brought 1300 MSMEs on board in the past three years leading to private sector investment of Rs. 300 crore and greenhouse gas reduction of 5.88 lakh ton $CO_2$/annum thereby providing a cleaner work zone environment to more than 25,000 industrial workers. The State will also be institutionalizing such initiatives through State STI Policy being developed in line with the new National Policy.



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# A Pragmatic Science, Technology and Innovation Policy

(*The author participated in '*Across the Table*' discussion on '*Skilled Human Resources and Capacity Building*' under track-I of the 5th STIP process)

*"If you look at history, innovation doesn't come just from giving people incentives; it comes from creating environments where their ideas can connect."* -- Steven Johnson

The purpose of Science, Technology and Innovation Policy (STIP) has been to promote a science and technology-led innovation ecosystem in the country, and link STI to socio-economic priorities of the country. It has to follow a sustainable development pathway. The draft STIP, the 5th one nationally, has been formulated through a carefully crafted participatory process. Released on 31 December 2020, it identifies relevant issues on the ground and contains several progressive proposals that could potentially be a big booster for the Indian scientific research community, in an inclusive way.

A strong scientific research setting is essential for economic progress and long-term sustainable development of a nation. Today in the higher education space, while it is fashionable to talk about Liberal Arts on one hand, and disruptive technologies of artificial intelligence (AI), machine learning (ML), virtual reality (VR) on the other, we must remember that Liberal Arts is incomplete without physical sciences, and the disruptive technologies alone will not be able to solve all societal problems. Science has shaped our world, and today the global pandemic has reinstated the importance of basic and applied scientific research, and also of stable research infrastructure and funding, for survival and sustenance. Scientific discoveries, new technologies and innovative applications of cutting-edge knowledge have become increasingly essential to address the challenges in diverse areas of health, environment and national security. As we navigate towards a Knowledge Economy, it is important to address the issues to strengthen the science research ecosystem in India.

As I have been arguing for some time now [e.g., in FICCI *Eduwrap*, November 2020], research in Basic Science has been the foundation for transformational technology. In the history of science, all technological innovation - from life-saving vaccines to space satellites - can be traced back to the work of scientists motivated purely by a desire to understand the world. Basic Science sits at the foundation of the national progress pyramid - it leads to technological innovation, followed by wealth creation and an increase in GDP. Countries which have a strong base in Research and Science have developed faster. A careful study of the trends on the research and development landscape of our country brings forth the point that though there have been select remarkable successes, the entire research ecosystem - for basic and applied research - has not progressed uniformly.

Education should accelerate invention (while innovation will continue to show up from unexpected quarters as well), and to emerge as a Knowledge Economy, deep education and research must remain India's top priority while AI will be a multiplier. In India, publicly-funded research is concentrated in specialized research institutes under different government departments. Universities must play a critical role in creating a talent pool for research and generating high-quality research. Our universities must continuously engage in carrying out high-quality research and become 'Centres of Excellence' to attract the best minds not only from India, but from across the world.

India could indeed capture a higher share of global knowledge-based work, by leveraging its demographic dividend if there is adequate focus on higher education and its research quality is globally benchmarked. This highlights the need for universities to expose undergraduate students to research, providing them with training in research-oriented scientific thought to address societal and industrial needs.

The country needs robust industry-academia partnerships to translate the generated knowledge into applications, while at the same time, continue to generate new knowledge through basic/fundamental research. There should be concerted efforts from the government, academia, and industry to address the issues of IPR, funding and systemic technological translation.

A policy is needed for intervention in our collective wisdom where organic, natural growth is not enough. The draft STIP indeed proposes quite a few such interventions.

It has proposed an Open Science Framework, with free access for all Indians to findings from publicly-funded research. It will foster more equitable participation in science through increased access to research output, better resource utilization, greater transparency and accountability in research, and will make an exchange of knowledge between the producers and users of knowledge possible. The output from research that is not funded by the government will be outside the purview of this framework, but they will be encouraged to participate in this framework. The STIP envisions free access to all journals, Indian and foreign, for every Indian against a centrally-negotiated bulk payment mechanism. This is a dream proposal! R&D institutions in India currently spend huge amount of money subscribing to journals, but still, only a handful of the (potential) researchers get access. Researchers in remote areas, poor students who can not pay for such articles, or those who are not part of government institutions, do not have access to this essential resource. This is a serious impediment. Not just accessing expensive scientific journals, more serious is the issue of article processing charge or publication fee, charged to authors to make their work open access in many journals by the publishers. This is curious commercialization, given the fact the authors or the reviewers do not get paid for their contribution to the journal. Our researchers need support for an integrated system of "read and publish".

One key issue in India's R&D ecosystem has been the low investment. The need of the hour is to understand that there has always been a translational coherence between basic and applied research. It is now the opportune time to increase the funding for basic research.

India clearly needs to redouble its efforts to improve the status of the science and research ecosystem in the country by increasing the national expenditure on basic research and development. Needless to say, there should be accountability, in some measurable form. Funding must be increasingly directed towards building a strong foundation that may create new knowledge. Our researchers and students, in turn, be also creators of wealth from this knowledge for our economic growth that impact the well-being of our people and the planet. India can emerge as a scientific power, establishing itself as a leader in industrialisation and technological development, if the right investments, incentives, and institutional environments are put in place for a robust and deep research ecosystem.

The draft STIP just mentions "*Implementation Framework*" – the roadmap is yet to be developed. It sets a target for doubling the number of Full-Time Equivalents (FTE) researchers, Gross Domestic Expenditure on R&D (GERD) and private sector contribution to the GERD every five years. We need to build a robust ecosystem, and hence numbers do matter. But the big question remains: How does one support and assess excellence in science, technology and innovation output? How will one thus measure the success of the policy? The document does not give any details, but simply mentions: "*Quantitative measurements/ indicators - specific to the policy and/or programme- will be used alongside qualitative measurements to assess policy impact. Metrics will be created…*". It is time to roll out the actionable parts while these necessary details get figured out.



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# 5th Science, Technology and Innovation Policy (STIP): Building Capacity, Unleashing Potential

(*The author was Co-Chair of the thematic group 'Education' under track-II and also participated in '*Across the Table*' discussion on '*Skilled Human Resources and Capacity Building*' under track-I of the 5th STIP process)

Indian science is ascendant. The Covid-19 pandemic brought to the fore the immense scientific potential of the nation. The launch of the world's largest vaccination drive with two locally produced vaccines will be a pinnacle moment in the nation's history. It was preceded by almost a year-long arduous churning on every front. Perforce, from education to research to enterprise, all augmented capacity to stay afloat in a hybrid world. Moving beyond statis of decades-long rhetoric, accelerated adoption of digital technologies and innovative solutions fortified each sector. This entailed agile synergy between public and private entities in addition to communities at large. Above all, it necessitated strong leadership, nimble decision making and facilitation by the government and the funding agencies.

The 5th STIP, albeit in its draft form yet, could not have come at a more opportune time. New formats for education and work have nudged communities towards being a technically savvy society ready to embrace change. The importance of effective assimilation of science and innovation in daily lives is palpable. More than ever before, there is a felt need to ensure that the benefits of science and technology reach the remotest areas and the most marginalized communities. It is now imperative to scale-up participatory and collaborative efforts to solve the grand challenges humanity is facing and stay prepared to deal with future disruptions. The task is mammoth. Then building capacity for scientifically trained human resources, and also the pervasive public understanding of evidence-based science, is of foremost importance.

India aspires to be a world leader in the coming decades. It augurs well that the upcoming STIP dovetails the New Education Policy (NEP) that has been promulgated. In conjunction, these policies envision catapulting India on the 21st-century global stage as a strong, progressive and developed nation on the strength of its scientific prowess. The policies mirror the spirit of new India that champions self-respect and being self-reliant, being self-confident while being self-reflective. This is the spirit that the country wants to inculcate at all levels, especially in the young students who constitute the demographic advantage.

Both policies seek fundamental and substantive changes in the landscape of education, research and innovation ecosystem at all levels. The aim is to restore excellence on the continuum of heritage and legacy. On one hand, this requires preserving the traditional knowledge systems. It entails recognizing the inherent creativity of the ubiquitous frugal innovations that emerge from the grassroots. On the other hand, it entails deepening scientific literacy and scientific temper. The quality of institutions needs to be strengthened to make them competitive at par with the global best. This requires advancing research on the frontiers and digital technologies that are transforming every sector of the economy. Overarching this is the national mandate to expand access to quality education – addressing issues of diversity, gender, equity, inclusion and equal opportunity for all. The rapid pace of changes in the work environment makes imperative skilling, upskilling, reskilling and lifelong learning on a massive scale. The canvas is indeed big and strokes bold as the nation sets out to reimagine an entire system, its ethos and most importantly, the quality and outcomes.

The proposed agenda for capacity-building rests on radical educational reforms that span the life-cycle from early education to a productive career in science. The predominant aim is to enhance the creative

research and innovation quotient across the spectrum. The way is shown by the successful existing programmes such as the Atal Tinkering Labs, MANAK (Million Minds Augmenting National Aspirations and Knowledge) for schools; the growing culture of project-based learning and Innovation and Entrepreneurship Cells established in undergraduate colleges. Furthering the agenda of 21st-century skills, NEP introduces design thinking, programming and coding in early grades. Then colleges and universities have to prepare themselves as a new generation progresses to higher education.

Mainstreaming scattered exemplary practices and institutionalizing global best praxis necessitates rooting: (i) *Interdisciplinary curriculum* that breaks the silos and has a strong emphasis on liberal arts, humanities and social sciences along with STEMM disciplines, with special focus on languages, art, culture, values, citizenship, and societal engagement. Art of evidence-based argumentation and communication skills are increasingly critical for scientists. (ii) *Student-centric pedagogies* with emphasis on active learning, problem-solving, design thinking and higher-order analytical skills with early participation in research on the frontiers and innovation. Self-driven lifelong learning in hybrid modes will now prevail. (iii) *Faculty enrichment programmes* that help faculty remain on the leading edge of technology, pedagogic and content knowledge will be critical. Learning-design and learning-analytics will be crucial in an engaged classroom. (iv) *Technology enriched active learning environments* with national repositories of high-quality resource material for immersive experiential and AI-based personalized learning, virtual and remote labs for STEMM disciplines. Consortiums for collaborative development of virtual resources on open source development platforms must include academia. (v) *Teaching-Learning Centres (TLC)* mandated to research on science education to better understand the teaching-learning processes, effective pedagogies, create resource materials, innovative curricula, and innovative faculty development programmes to improve the overall quality of education.

STIP takes forward the idea of creating *School Clusters, Innovation Hubs & Entrepreneurship Centres.* These would enable sharing of resources, capacities and talent pools. They would link synergistically schools, higher education institutes, corporate entities and local communities for augmenting curriculum relevance and mentoring opportunities. The facilities would promote early research and innovation, nudging students to engage with real-world problems at both the school and undergraduate level.

Educational institutions will also have a critical role to play in establishing innovative programmes for skill-building and technical training in multimodal formats. Vocational training with sector-specific skills following National Skills Qualification Framework (NSQF) has to meet the rapidly changing needs of the industry. However, it is best to mainstream vocational education, weaving in both generic and specific skill components across the spectrum of education. Promoting collaboration between industry and academia will strengthen future skills in new areas to enhance innovation and develop entrepreneurial skills.

On the other end of the spectrum, NEP has mooted the idea of Research Universities as part of the plan to completely restructure the educational system. Existing R&D institutions could well be thus transformed to foster better linkage between education and research. STIP focuses on improving the quality of research with a coordinated approach to building and enhancing infrastructure. Important suggestions include establishing: (i) *Research Excellence Framework for HEIs (REFI)* for creating a holistic, dynamic and responsive research ecosystem across the full academic spectrum. It would assess the overall research contribution of HEIs every few years, based on parameters of importance for India, including measures like citation, translational value, impact on industry, economy and society. Block research grant value would be calibrated accordingly to incentivize performance and global standing. (ii) *Collaborative Research Centres (CRCs)* that will bring together corporate entities, industries, medium and small scale entrepreneurs, start-ups, R&D institutions, HEIs and the government to promote collaboration, improve industrial research and innovation; and enhance global competitiveness. (iii) *Higher Education Research Centres (HERCs)* in reputed research-focussed universities and institutes to study higher education system per se, in order to provide research-based inputs to policymakers and higher education leaders.

The success of the policy initiatives rests critically on all government entities, at the central and state level, working in unison to usher change on a massive scale. The idea of each ministry and each state earmarking funds for S&T will not only increase layout but also bring the stakeholders together in ownership of the programmes. The real challenge is in laying a clear roadmap for transformative reforms, and rolling out prioritized plans for implementation in a time-bound manner without losing the sheen or the impetus generated.



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## Time to Earn Our Return on Investment (ROI) through Science Entrepreneurship

(*The author participated in '*Across the Table*' discussion on '*Innovation & Entrepreneurship*' under track-I of the 5th STIP process)

Integrating scientific innovation with our lives creates both impact and profit. Over the last several decades, independent thinkers have been hypothesizing different theories for India's lag in science-driven innovation. Some notable shortcomings included lack of deep interactions between different agencies, poor incentives for institutions to translate science into innovation, missing project management skill amongst scientists and lack of transparency and accountability within the system. However, COVID-19 pandemic is transforming this and bringing science closer to public service delivery. Our scientific enterprise has adopted new behaviors, by converging individual brilliance into collective excellence. Still, we need concerted efforts towards reformatting our scientific enterprise and transforming perception towards scientific research, as a profitable career option for the youth of India. We need to appreciate science management as a skill independent of scientific research and enable the creation of an army of science managers instead of expecting high-quality scientists to themselves turn into science managers.

I propose here a series of recommendations encompassing both policy reforms and an action plan, to fundamentally transform the way scientists conduct business, and raise, spend and also earn money, thereby providing ways to cutting edge science-based entrepreneurship.

India needs bold structural reforms to empower public R&D labs to solve problems of industry in India and globally, and thereby encourage the participation of the private sector and philanthropic organizations in S&T driven R&D. Our scientific enterprise needs an independent S&T management agency, to enable and empower public-funded R&D labs to promote and manage their R&D. Such an independent agency will act as an aggregator of user requirements (industry/ local govt) for (a) social and economic needs (b) national strategic S&T needs and obtain commitments from public-funded R&D labs to deliver desired R&D outcomes to the users. This may be facilitated through existing or new independent entities (private or Government), or existing programs/missions of the GoI, that can be empowered to conduct such aggregation activities. The agency may encompass three broad functions:

a. Raising non-Govt funding for public-funded R&D labs
b. Enabling transparency and accountability in S&T program management
    i. Lay down SOPs for business processes in scientific institutions
    ii. Peer to peer review of outcomes across science, technology and business functions

iii. Enable incentive-driven technology commercialization

c. Human Resource (HR) development: creating programs by industries for developing capability in Indian scientists, through the world's best quality trainers

While the existing autonomous bodies/ institutes under different government departments and ministries may continue ownership of funding and managing researcher-initiated programs, all other areas which are of interest to industry, State governments, and philanthropic organizations may be managed through an independent structure.

Secondly, Indian science enterprise needs enabling umbrella structures such as S&T Clusters, to reformat public-funded R&D labs to enable seamless collaboration under one shared ecosystem and solve problems of industry in India and globally. Establishing clusters is a globally accepted phenomenon, first recognized by Prof. Alfred Marshall in his book Principles of Economics, published in 1890, and later promoted by Prof. Michael Porter from Harvard University, who defines clusters as geographical concentrations of interconnected companies and institutions in a particular field. It derives its essence from Aristotle's famous philosophy; *the whole is greater than the sum of its parts*. Clustering should not be an exception, instead become an institutional practice. Such a cluster-driven framework is being supported by the Office of the Principal Scientific Adviser to the GoI, for integrating top-down policy actions and bottom-up organic activities, towards creating enabling structures, incentives, flexible processes and culture to improve the overall return on investment in S&T. It is worth mentioning here that such sharing of publicly funded research facilities has also been introduced into the new draft STI policy.

Thirdly, enabling 'Open Science' in India, for allowing shared access to data, research publications and technological innovations, is imperative to boost the science and technological entrepreneurship opportunities. Complex problems such as climate change and biodiversity loss, often require metadata analysis and series of solutions. It will take interdisciplinary collaboration among the experts in public health, biological sciences, microbiologists, ecologists, and veterinarians to unravel the effects of climate change and loss of biodiversity. Therefore, to promote complementary R&D and avoid duplicity, the knowledge created by research, must be accessible to the scientific community.

The ongoing pandemic demonstrated the positive outcomes of science openness, where the viral genome first sequenced by China was placed in an open-access data repository gene bank, which in-turn was leveraged by researchers around the world to immediately develop diagnostic technologies. India has been devising a national framework on the paradigm of 'one nation one subscription' for enabling open access publications and is vouching for a single national institutional repository system for S&T research publications. Though consultations have been conducted with several stakeholders, the national plan is still in the draft stage. It derives inspiration from the Plan S, a European consortium initiative and Latin America's open access publishing practice. The good news is that the draft STIP further elaborates on the need of promoting an open science framework in India.

Finally, experimenting with innovative models of public financing and public procurement for deep technologies is imperative for commercialization and scale-up of deep-technology and science entrepreneurship. In addition to the existing public funding models, leading science institutions/universities in India should create institutional mechanisms through deep technology endowment funds, by tapping into their global alumni network, to back deep-science ventures coming from Indian research labs. Recently, IIT-Delhi and IIM-Ahmedabad have launched endowment funds, but we need more such examples.

Similarly, several favorable policy shifts have been introduced in the last five years, to enable indigenously manufactured technologies to participate in public procurement, however, their uptake remains a challenge. It requires moving away from 'price' only based procurement to a more holistic 'value' based approach.

Value-based procurement follows a 'systems' approach and takes into account the following parameters 1. life-cycle cost economics, 2. overall product outcome, efficacy, and efficiency, 3. environmental impact and sustainability instead of the conventional price-based procurement. What this also requires is an institutional mechanism to help deep technologies transition into safe, effective and manufacturable products, that are validated for performance measurement. This derives essence from several global best practices including the United Nations, where 'best value for money', is a key guiding principle for bulk procurement, instead of a price only model. Similarly, the European Union recently launched its new directive on medical device procurement, that involves smart procurement process, Most Economically Advantageous Tender (MEAT), involving procurement based on quality, product life-cycle cost, best price-quality ratio and broader socioeconomic considerations.

It is worth mentioning that the new STI policy draft that has been recently published for seeking public opinion, includes most of these and plenty more recommendations. The draft policy has been designed taking into consideration the principles of behavioural science, in order to drive a paradigm shift in the way science R&D in conducted in India. What will be interesting to observe is that how we focus, consolidate and implement the policy at the last mile, to build towers of excellence in India.

In summary, it is imperative that increasing funds in R&D alone will not lead to better technology outcomes, as anticipated in a linear approach to STI, instead, India needs a 'systems' approach, focused on enabling structures, incentives, processes and a culture that allows measurement and management of science, to improve outcome efficiency and the overall return on investment in science. It is time, we look at science not just as a public good, but also as a profitable business opportunity for scientists.



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## Open Science and the Draft Science, Technology and Innovation Policy

(*The author participated in '*Across the Table*' discussion on '*Access to Knowledge and Resources*' under track-I of the 5th STIP process)

The draft version of the 5th Science, Technology and Innovation Policy (STIP) is released for public comments on 31 December 2020. As a vision document that would guide institutions and researchers in India on diverse aspects of production and dissemination of science, it has, and it should receive considerable attention among all stakeholders. For the open science advocates, there are at least two noteworthy aspects of the policy: first, the bottom-up and inclusive approach taken in the policy drafting process; and second, the high emphasis on open science practices.

### Prioritising Open Science

The unique aspect of the draft policy is its strong emphasis on open science. While the term 'open science' has not been defined anywhere in the document#, one can see its vast implications getting reflected in different segments of the policy document.

#There are no universally accepted definitions for 'open science'. As part of the open science project at the Centre for Innovation, IP and Competition, we had tried to evolve a comprehensive definition for open science, based on an extensive review of diverse definitions of open science. It reads as follows: "scientific inquiries wherein the characteristics of accessibility, transparency, usability, and non- or minimal existence of IP restrictions, are evident and exist throughout all stages of research. It is also characterised by openness to inclusiveness, collaboration, constant and continuous transfer of knowledge between producers and users of knowledge, and prioritisation of research and innovation based on social needs."

The notable contributions in this regard are strong mandates on open access and open data. As per the open access mandate, the full-text of the final accepted author-versions of manuscripts (often referred to as "post-prints"), along with supplementary materials, which are arising from publicly-funded resources will have to be deposited in an institutional repository or central repository, immediately upon journal's acceptance[1]. While the mandate is specific to post-prints, the alternative to share pre-print versions of those manuscripts is also available. Though the DBT-DST open access policy has been in existence for a long time, it has been facing numerous challenges, including the lack of an effective monitoring and enforcement mechanism[2]. A broader and enforceable mandate on open access to scholarly publications will facilitate efficient sharing of knowledge generated using public funds.

Moreover, the draft policy directs the sharing of all data used in and generated from public-funded research under FAIR (findable, accessible, interoperable and reusable) terms[3]. The only exceptions provided are situations wherein open sharing might negatively impact privacy rights, national security, and intellectual property rights. In such cases, the policy has mandated release of suitably anonymised and/or redacted data. It also recommends evolving suitable mechanisms to share the data with bonafide/ authorised researchers. It is particularly noteworthy that no embargo periods are mentioned in the case of both open access and open data mandates.

The open sharing of data is further strengthened by setting up a dedicated portal titled Indian Science and Technology Archive of Research (INDSTA)[4]. This portal is envisaged as a gateway to all publicly-funded research outputs that encompasses manuscripts, research data, supplementary information, research protocols, conference proceedings, monographs, and book chapters[5]. The current list, which might see additions as per the requirements of the research community, also reflects the diverse forms of communication adopted in different disciplines. For example, in a few areas, journal articles are the primary form of scientific communication, while in some others, books or conference proceedings might be the primary mode of dissemination. INDSTA will be interoperable with other repositories and is envisioned not as a static but a dynamic repository that would encourage interactions among the various stakeholders. Taking into consideration the current needs of the scientific research community, the draft policy also focuses on facilitating TDM (text and data mining), querying and visualisation. INDSTA is also ideated as an integral part of a broader national Science, Technology and Innovation Observatory, which will promote sharing of all kinds of data on the STI ecosystem, including those that can facilitate access of equipment, laboratories, and other physical resources[6].

The draft STIP also moots the idea of 'one nation, one subscription' policy[7]. Currently, different institutions are subscribing to journals individually, or as part of small consortiums. Though no official figures are available, a few rough estimates indicate that Indian institutions are collectively spending around INR 1500 crore annually to get access to different journals. While institutions with good funding support get relatively good access, the majority of them face an access-crisis. The current situation is also undesirable from a broader equity and inclusion perspective. The policy thus, recommends the government to negotiate with publishers for a single subscription, enabling access of all publications to everyone in India[8]. Though many publishers are unlikely to agree to such a proposal, the idea can radically change how the public access scientific literature, if it ever gets implemented. The minimum the GoI could achieve from this move is to use the results of the negotiations with publishers as a piece of evidence if the government eventually decides to use compulsory licensing under copyright law as a tool for enabling access of scientific literature to the general public in India.

Another promising aspect of the policy is the opening up of research facilities and libraries[9]. Many of the public-funded institutions in India impose restrictions on access to physical resources like laboratories and libraries. The policy envisages the optimal sharing of such resources through better use of technology and minimal restrictions on access. The policy also advocates for the strengthening of the public library system in all districts in India[10].

For Open Educational Resources (OER), the policy has taken note of the fact that currently most of those resources are shared with numerous restrictions on usage. The policy suggests sharing of public-funded OER with minimal restrictions and mentions specifically that translations of such works should be permitted[11]. It further endorses that learning spaces should be universally accessible, particularly for people with special needs and more support shall be given to community-driven learning spaces[12].

The significance of open science reflects in the whole draft policy. For example, in Chapter 2, the policy advocates the use of special measures like scholarships and orientation programmes to ensure inclusion of various groups based on gender, geography, language, disability, and social order[13]. Chapter 4 talks about incentivising collaborations at institutional and individual levels for addressing national problems[14]. Chapter 5 identifies due recognition to the potential role of grassroots innovations and traditional knowledge systems in the broader education, research and innovation ecosystem[15]. Chapter 7 acknowledges the absence of an inclusive culture in the practice of science in India and proposes the creation of an Equity & Inclusion Charter for addressing discriminations based on gender, caste, religion, etc[16]. Chapter 8 pushes for the need of making science communication accessible to the broader public and endorses the use of popular modes such as folk arts, theatre, dance, poetry, community radio, and interactive digital platforms for democratising access to scientific knowledge[17]. In recognition of the importance of science communication and broader engagement with the public, the draft policy strongly recommends establishing a dedicated team for science communication and public engagement in STI-related activities in each public-funded institution[18].

**Some Missing Elements**

While most of the steps taken in the realm of open science are laudable, the draft policy misses out on some opportunities for making substantial changes. One of them is the issue of addressing the crisis in research evaluation. While the policy document states that "research culture will be reoriented wherein the quality of research will be assessed, recognized and rewarded based on both academic achievement as well as social impact", an explicit rejection of impact factor of a journal as a criterion in quality assessment could have gone a long way in overhauling the research assessment mechanisms in India and preventing the undue influence of major publishers in the research assessment system. The policy could also have made propositions for revamping the current Academic Performance Index system used by institutions because it focuses on the quantity rather than the quality of publications.[20] It has led to the proliferation of predatory journals and publishers, which publish manuscripts without any peer-review, in return for a fee. An explicit rejection of payment of Article Processing Charges (APC) from public funds could have also helped in addressing the increasing challenge of predatory open access journals. Some of these limitations could be addressed during the implementation phases of 5th STIP. The policy altogether has provided the mandate and strength for turning the focus from where a work is published, or the number of publications, to what is being published.

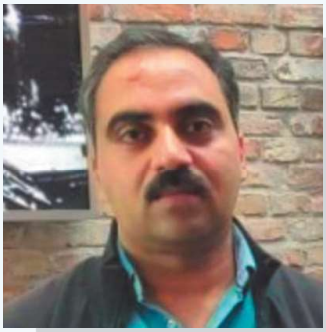
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# Science Technology and Innovation Policy Draft: Where do we stand?



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(#The author participated in '*Across the Table*' discussion on '*STI Policy Governance and Program Linkages*' under track-I of the 5th STIP process)

The draft of new Science, Technology and Innovation Policy (STIP) has recently been released for public consultation. The draft policy is in a sense an emphatic articulation of the Indian Government's desire to create a strong enabling ecosystem of STI for the country. The draft policy is not only ambitious but is also bold enough to highlight the gaps between aspirations and the realities. It is expansive in scope and forward-looking as it proposes the creation of many new and important structures relevant to the Indian STI ecosystem. Some of these include 'National STI Observatory' for open science, 'STI Financing Authority' and 'STI Development Bank' for financing STI, 'Digital Platforms and E-governance' for ease of doing science, and an 'STI Policy Institute' for STIP governance.

The policy should also be seen within the larger context in terms of the salutary paradigm shift we observe in government to bring innovation and entrepreneurship as key enablers for economic development and inclusive growth. The 'Startup India', 'Atal Innovation Mission', the 'National IPR Policy 2016' among others are key policies in this direction. The 'Make in India' call is now further underscored with 'Atmanirbhar Bharat', which aims to make India as a self-reliant country in technologies and across the whole process-product value chain. The draft STIP 'includes as well as adds to the initiatives' of the National Education Policy 2020 (NEP2020). The NEP2020 envisions an education system that can contribute directly to 'transforming India' into an 'equitable and vibrant knowledge society', which synergistically complement the new STIP vision and initiatives. The STIP draft not only calls for 'individual and institutional excellence in STI' but also aspires to 'position India among the top three scientific superpowers'. While the upcoming national policy ambitiously envisions to achieve 'technological self-reliance' and a 'people-centric STI ecosystem'; there exist multiple challenges in achieving the objectives. This article draws attention to some selected sections of the policy document, namely Open Science, Research and STI Policy Governance, and looks closely at the status-quo, the relevant policy articulations, and the challenges that lie ahead.

## Open Science

One of the most visible and discussed components of the policy draft is 'open science'. The policy draft calls for 'public access' to 'publicly-funded research output'. This, however, is not an entirely new proposition. The

DBT-DST Open Access Policy released in 2014 has already mandated that public-funded research outcome should be openly accessible. Similar open access mandates have also been issued about the same time by CSIR and ICAR. Some central repositories (such as sciencecentral.in, csircentral.net and krishikosh) have also been created as linking institutional repositories. However, the open-access availability of research from India remains very poor[1]. The deposits of Indian research output to central institutional repositories as well as to disciplinary repositories also remain quite poor[2,3]. Given the poor situation of deposits to these repositories, even when such deposits of public-funded research outputs are mandatory, it remains to be seen whether the new STIP can bring a change.

There are excellent ideas of the establishment of a 'National STI Observatory', a dedicated 'Indian Science and Technology Archive (INDSTA)' portal, and 'One Nation, One Subscription', etc. The establishment of a 'National STI Observatory' is indeed an interesting and important recommendation. This type of institution is a part of the STI ecosystem of different OECD countries. The renewed emphasis, detailed articulation and creation of a national institutional mechanism for open access can be the game-changer. It would, however, be necessary to ensure that platforms so created are discoverable, and backed by some incentives for deposits.

The lack of access to research also comes from non-availability of access to journals and databases, which is highly skewed with only a few reputed organisations having the resources to subscribe to such journals and databases. The 'One Nation, One Subscription' policy can be a major step in this regard, though these negotiations are unlikely to be easy. Surprisingly, one missing aspect regarding open access is the issue of 'Article Processing Charge (APC)'. The new normal in publishing is shifting from a subscription-based model to Open Access Journals. Majority of the journals in different disciplines have publishers from NORTH countries with exorbitant APCs in Euro or US dollar. This is creating a new barrier for researchers in the country to publish their research work. It thus becomes an urgent requirement to provide support to the research community, creating an institutional mechanism that allows a separate component for paying APCs in research grants, projects, etc. Similar to the negotiation that is underscored with publishers for creating 'one nation one subscription' policy, the negotiation needs to be done with them on making the APCs more rational and not as such framed within the NORTH economy context.

**Research**

The STIP draft boldly states "to double the number of Full-Time Equivalent (FTE) researchers, Gross Domestic Expenditure on R&D (GERD) and private sector contribution to the GERD every 5 years". Given that India has one of the lowest numbers of FTE per million among the top research producing countries, this is an important step in expanding the Indian S&T ecosystem. This will allow making the required resources available beyond the elite institutions. The policy, however, appears to assume that Higher Education Institutions (HEIs) will play the major role in S&T expansion, with lack of clarity on the role of organizations like CSIR, DRDO, etc. The India HEIs, including centrally funded ones, are already resource-starved and at present are not able to produce research performance comparable to the top institutions in the world[4–7].

Moreover, the policy draft proposes increased connections and collaborations across different sectors of the S&T ecosystem. Given the current status of University-Industry-Government collaboration[8], provisions for an institutional mechanism to promote and incentivise such collaborations are needed, which at present is not very clearly illustrated in the draft. At present, most of the research in Universities is literature-based, wherein researchers select a research problem by studying and analysing published literature. The University-Industry-Government collaboration can significantly change this by creating an environment that enables Universities to pick up research problems from the Industry, Government or Society.

The policy draft further emphasizes on ease of doing research by creating digital platforms and e-governance structures and reducing the burden of administrative activities associated with the research projects. Though this is a welcome initiative, however, what is desired is a step beyond this, where science funding is based on a premise of 'trust' and 'freedom' rather than excessive controls. The funding should naturally be based on principles of 'accountability', but this accountability should be seen more in the 'research outcomes' than the 'fund utilization processes'.

Another important aspect of research is the dissemination of the research findings. Unfortunately, there are not enough good Indian journals which can publish domestic-oriented research. Most of the international journals avoid publishing research outcomes which are of relevance to a national audience only. This creates problems for researchers in several disciplines, which focus more on locally relevant issues, in finding avenues for publishing their research outcomes. Though some of the Indian journals have a long history of coming from professional bodies, non-profit institutions, and home-grown publishers; the high rising cost of publishing journals (that includes strengthening capacity so that the journal meets global standards) has made many of the journals difficult to survive. The lack of resources has influenced the quality of the journal which has subsequently led to researchers, in-general, ignoring publishing in Indian journals. All this combined sparked off to the emergence of predatory journals. This aspect, therefore, needs to be carefully deliberated upon so that an enabling ecosystem is created for the development of Indian journals to reach global standards.

**STI Policy Governance**

The policy draft proposes to establish an "STI Policy Institute" with a mandate to serve all aspects of STI Policy Governance. This institution is expected to provide an institutional mechanism for "implementation strategy and roadmap, monitoring and evaluation of the policy and programs". Though the structural details of the proposed institute are not yet fully stated, it can best be positioned as an institution responsible for STI data monitoring and research. Establishment of such an institution may not only suitably address the issues of inconsistency between different S&T reports[9,10] but can also allow creating evidence for implementation of newer initiatives in research funding, such as Performance-based research funding in specific thematic areas[11]. The call for 'ease of doing research' would also require better monitoring and evaluation of research outcomes. The proposed STI Policy Institute can meet this objective, and at the same time make the evaluations more evidence-based instead of the currently prevailing practice of solely using a peer review-based system.




Figure 1. Cognitive map of most frequent 'noun phrases' in the 5th STIP draft text

## Concluding Remarks

In discussing a roadmap for creating an enabling STI ecosystem, the draft STIP attempts to delineate the ecosystem based on key dimensions: Open science, capacity development, financing, research, innovation and entrepreneurship, equity and inclusion, science communication and public engagement, international STI engagement, STI governance, and STI policy governance. This provides clarity as well as underscores the need to address each of the key dimensions properly for meeting the vision and aspirations. The mechanism on strengthening each of the dimension is based on creating new institutions or enlarging the role of present institutions. This article has briefly focussed on three key dimensions covered in this policy document namely Open Science, Research and STI Policy Governance. It has drawn attention to this aspect while highlighting the opportunities and challenges for implementation and some of the silences. The cognitive map (**Fig 1**) of the most frequent noun phrases appearing in the draft text shows to some extent the scope and breadth of this policy document. The expansive scope of this document calls for further discussion on each of the dimensions.

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