Integrating the function of a university to a work place to promote post-academic research

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Earlier universities had 'teaching' and 'research' as two missions and in recent times 'contributing directly to industry' has been added as the third mission. Considering that work places generate and disseminate knowledge, one can integrate the functions of a university to a work place. The author was involved in the implementation of such an integration and this article is an outcome of that experience. The article presents a summary of the relationship between science and technology, describes policy statements related to science and technology issued by the Government of India, and glimpses into the structure of research establishment in India. The Ministry of Human Resource Development (MHRD) is tasked with setting up Higher Education Institutions (HEIs), and its efforts have been supplemented by many other agencies of the Government. Agencies other than MHRD, including mission-oriented agencies, have oriented the HEIs established by them to cater to the needs of the business allocated to them. The article lists the motivations for setting up an HEI by a mission-oriented agency, where the idea of integrating the university function to a work place has been implemented.

Keywords: HEIs by agencies other than MHRD, methods of knowledge production, relationship between science and technology, S&T policy.

TOOLS and crafts developed by humans based on empirical, but highly systematic and intuitive approach, beginning from hunter–gatherer days have evolved into present-day technologies. This development, for the most part of human history, was independent of the quest for knowledge, pursued for the sake of knowledge by savants and well-endowed individuals. However, Bush[1] proposed a linear model stating that basic science leads to technological development and this became the basis for scientists to seek, and for funding agencies to provide, funding for research and the slogan 'knowledge for the sake of knowledge' became a manifesto of many scientists after the second world war. Surveys of inputs resulting in developments of new products and processes were done and the result was a challenge to the linear model. A reverse linear model emphasizing that new scientific possibilities created by technology was proposed and by 1972, the science historian bid farewell to the linear model[2]. Stokes[3] proposed a two-dimensional model and coined the term 'use-inspired basic research'. Models of the relationship between science and technology (S&T) proposed during recent decades are non-hierarchical, acknowledge full intertwining and mutual dependence of S&T, and semi-autonomous progress forward. Empiricism used to build on existing technology pursued prior to about mid-19th century is now being supplemented, in some instances replaced, by tools based on engineering science and natural sciences.

Grover[4] has summarized the complex relationship between science and technology, evolution of engineering science as a discipline, constantly evolving relationship between research and its application, changes that are taking place in methods of knowledge production, and opined: 'work places such as industry, consultants, non-governmental think tanks, and international agencies are store-houses of knowledge; they use knowledge as well as generate and disseminate knowledge. Knowledge production, therefore, is now distributed across many agencies. It is not a new element. Prior to the advent of research universities and laboratories, work places were generating knowledge and they are doing so again now'.

It is difficult to define knowledge precisely. It is a broad concept and includes phenomenological knowledge, observable facts, knowledge embodied in products, processes and systems, knowledge gained from operation of plants and facilities, and professional practices. The stock of knowledge is increased by research. Research also provides new applications of available knowledge. For an activity to be classified as research or research and experimental development, it has to be novel, creative, systematic, transferable and/or reproducible and its outcome should have uncertainty[5].

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Acknowledging that categorizing research is difficult and using the terminology proposed by Ziman[6], Grover[4] has suggested simple categorization – academic research and post-academic research. 'Both academic and post-academic research can have epistemic and use objectives. Dominant objective in the case of the academic research is epistemic. It can have immediate (as against distant) utilization as its sub-objective and it may or may not be a scheduled activity. On the other hand, post-academic research is pursued with use as the end goal, and it will always have an epistemic sub-objective.' Using these arguments, the author has proposed a representation of the relationship between science and technology (Figure 1) that recognizes their intertwining and acknowledges that the progress in one depends on itself and the other. The boundary between academic and post-academic research is not sharp, rather there is a large overlap between the two, and post-academic research is invariably accompanied by development. In an organization pursuing post-academic research, knowledge is produced at the point of application, while knowledge flows from academic institutions to industry through technology transfer and translational research.

Earlier universities had two missions that are 'teaching' and 'research' and in recent times 'contributing directly to industry' has been added as the third mission. One may expand the third mission as contribution to industry and society to include fields other than STEM. A university accomplishes its missions by performing functions such as imparting skills and knowledge through course work and training for research based on structured programmes, providing certification, and encouraging socialization[7]. 'Considering that work places generate and disseminate knowledge, one can think of the idea of integrating the functions of a university to a carefully chosen work place.' This is regularly practised in health sciences as every medical school is attached to a hospital. The present author was intimately associated with the process of setting up a university-level institute that is Homi Bhabha National Institute (HBNI), which implements the idea of integrating the function of a university to a cluster of R&D centres – that is a work place[8].

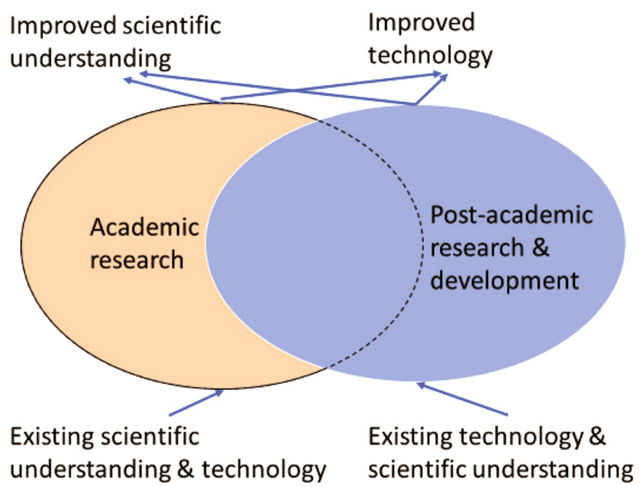

Figure 1. A representation of the relationship between science and technology. Note: The words 'scientific understanding' used in the figure represents understanding in all branches of science including natural sciences, engineering sciences, health (or medical) sciences, agricultural sciences and social sciences.

This article examines the science and technology policy statements issued by the Government of India, the structure of research establishment in India, and setting up HEIs by agencies of the Government of India other than MHRD, specifically HBNI by the Department of Atomic Energy.

Policy statements

University education was given high importance after India achieved independence in 1947 and an early initiative was to constitute a ten-member commission, consisting of educationists from India, the UK and the USA, chaired by S. Radhakrishnan 'to report on Indian University Education and suggest improvements and extensions that may be desirable to suit present and future requirements of the country'. The focus of the report is education, but it does touch upon issues related to research, and the importance of the linkages between universities, and research and development institutions[9]. It acknowledges the overlap between basic and applied research, and describes the interest of the Government of India in scientific research as utilitarian to aid agriculture, industry, medicine, engineering, etc.

Report of the Education Commission set up under the leadership of D. S. Kothari is another comprehensive report and expresses 'deep conviction that the progress, welfare and security of the nation depend critically on a rapid, planned and sustained growth in the quality and extent of education and research in science and technology'[10]. The report cautions that academic research (referred by them as pure research) can drive away post-academic research (referred by them as applied research) unless due emphasis is placed on the latter[10] and calls for prioritizing research geared to meet national needs. The report also calls for inviting selected scientists from national laboratories to participate in teaching and research in universities.

Draft report of the committee chaired by Kasturirangan recommends setting up a National Research Foundation for competitive peer-review funding, establishing research universities, and empowering affiliated colleges to grant degrees[11].

Various laboratories in India have been recognized as centres for conducting doctoral research and scientists working in laboratories have been recognized as research advisors. A programme called 'external registration', launched in 1972 by the Indian Institute of Science and adopted by some other institutes, further strengthened doctoral research in laboratories. This feature is not unique to India and similar programmes, albeit with variations, exist in other countries. For example, CEA laboratories in France have about one thousand students pursuing doctoral research at any given time. DOE, USA facilitates students, pursuing doctoral research in universities, to do a part of their research in DOE laboratories.

The Government of India constituted several other commissions and committees to reform education[12], but the focus in most cases is education. One frequently made comment about higher education is that the faculty lacks experience in industry and therefore, teaching has a strong bias towards theory[13].

In May 1971, the Government of India established the Department of Science and Technology (DST) with the objective of playing the role of a nodal department for organizing, coordinating and promoting S&T activities, and also formulate policies related to S&T. While the first policy statement was issued prior to establishing DST, subsequently three more statements have been issued. The statements are the following: (i) The Science Policy Resolution (SPR), 1958; (ii) The Technology Policy Statement (TPS), 1983; (iii) The Science and Technology Policy (STP), 2003, and (iv) The Science, Technology and Innovation Policy (STI), 2013.

Evolution in the title of the documents is revealing. First only science, then only technology, then both together and finally innovation added to science and technology.

An imprint of the linear model can be seen in the SPR-1958 when it says, ‘technology can only grow out of the study of science and its applications’. The linear model is also present in the TPS-1983. It says, ‘Given clear-cut objectives and the necessary support, our science has shown its capacity to solve problems’. It also says, ‘consolidation of the existing scientific base and selective strengthening of thrust areas in it are essential. Special attention will be given to the promotion and strengthening of the technology base in newly emerging and frontier areas such as information and materials sciences, electronics and bio-technology’. This quote begins with the consolidation of scientific base and then moves to technology without bringing linkage between the two. The statement goes on to say, ‘The time cycle from scientific research to utilization is a long one’. This again is a reference to the linear model, though the policy statement does not include examples to explain the thinking.

Change is visible in STP-2003, when the title of the document then issued changes to Science and Technology Policy. The document says, ‘Science and technology have become so closely intertwined, and so reinforce each other that, to be effective, any policy needs to view them together’. The policy also talks about ‘basic research in science, medical and engineering institutions’ and acknowledges that ‘a strong base of science and engineering research provides a crucial foundation for a vibrant programme of technology development’. This policy statement places science and engineering on equal footing and acknowledges their interdependence.

However, STI-2013 presents a mixed picture. It acknowledges that the ‘Science and Technology Policy of 2003 brought science and technology together’, but maintains that ‘scientific research utilizes money to generate knowledge and by providing solutions converts knowledge into wealth and/or value’. In the subsequent part of the statement, science and technology appear together. The above quote seems to disown knowledge generated during the process of technology development. The statement also brings in ‘innovation’ in the debate. Innovation is larger than technology, which in turn is larger than science and all three are interdependent and distinct[14]. Innovation consists of several activities and R&D may or may not be a part of the activity of innovation. Innovation includes some or all of the following: R&D that is generating new knowledge or a new application of available knowledge, acquisition of existing knowledge, machinery, equipment and other capital goods, training, marketing, design and software development[5].

The statements have tried to steer clear of the debate regarding categorization of research or the perceived divide between science and technology, but it is clear that the linear model was woven into the thinking of the experts who drafted the statements SPR-1958, TPS-1983 and STI-2013. Utilitarian aspect of research is underscored by all the four statements.

Structure of the research establishment

Government of India has set up several establishments for pursuing research. To understand their structure and spread, one can categorize them, with categories not representing any hierarchy, as follows. The first category consists of mission-oriented departments that are characterized by the fact that they pursue research in the laboratories administered and funded by them, and also utilize the research output. They are thus their own clients and this is a recipe for success. These include the Department of Atomic Energy (DAE), Department of Space (DOS), and Defence Research and Development Organisation (DRDO). Research and development units, industrial units and funding agencies dedicated to fund research related to their mission are part of the mission-oriented departments; their internal structure is an acknowledgement of the intertwining of science and technology. Support to industrial laboratories provides right climate for creation of technologies and novel discoveries[15].

In the second category are Councils like the Indian Council of Medical Research (ICMR), the Indian Council of Agricultural Research (ICAR), the Council of Scientific and Industrial Research (CSIR), and the Indian Council of Forestry Research and Education (ICFRE). They have their own institutes or laboratories and are, thus, hands-on agencies. They are also engaged in human resource development and fund extra-mural research. The ICAR has played a pioneering role in increasing the production of food grains, eggs, fish, milk and horticultural products in India through research and technology development.

In the third category are departments like the Department of Science and Technology, and the Department of Bio-Technology, which fund research in Higher Education Institutes (HEIs), though they do have some institutions that are directly administered by them.

In the fourth category are Universities (Central, State, Deemed and Private), HEIs like Indian Institutes of Technology (IITs), Indian Institute of Science (IISc) and Indian Institutes of Science Education and Research (IISER). Institutions for scientific and technical education financed by the Government of India have been declared by the Parliament to be institutions of national importance that is INIs such as IITs and IISERs. IISc, IITs, IISERs and Central Universities are funded by MHRD.

In the fifth category are establishments and HEIs set-up or administered by other departments and ministries such as the Department of Pharmaceuticals, the Ministry of Petroleum and Natural Gas, and the Ministry of Statistics and Programme Implementation.

In the sixth category are surveys like Geological Survey, Archaeological Survey and Zoological Survey. They are engaged in specific functions.

Research establishment in India, thus, has a distributed structure. The intertwining of science and technology has been acknowledged in setting up institutions, but a disconnect is seen between policy statements and setting up of institutions. SPR-1958 gives primacy to science, but the first institutes set up by the Government of India were IITs. TPS-1983 is oriented towards technology and was issued when five IITs had already been set-up. Setting up of IISERs was taken up during the middle of the first decade of this century – when STP-2003 placed science and technology on equal footing.

Setting up of universities by the central agencies other than MHRD

Ministries and Departments of the Government of India perform functions assigned to them through ‘Allocation of Business Rules’, which can be seen on the website of the Cabinet Secretariat. They have set up research centres and have also HEIs accredited to perform university functions tailored to their needs in the area of education and training, as well as research and development. While a beginning regarding setting up HEIs was made in 1950s, this trend has accelerated in recent decades (see Table 1 for details). Some of the HEIs listed in the table were set up as a research centre or a learned society, but became deemed universities or INIs subsequently; for example, the Tata Institute of Fundamental Research, and the Indian Statistical Institute.

To understand the motivation of agencies other than MHRD in setting up accredited HEIs, one has to recall the relationship between science and technology, how knowledge is produced, and utilization aspect of knowledge. Motivations listed later in this section are based on the experience of the author in setting up HBNI[8] and issues related to human resource development for nuclear energy programme in India[16]. Some of the motivations are applicable in similar other cases. Demands of interdisciplinarity of real-life situations, and the knowledge base and skill-set requirements are unique to a business. Agencies other than MHRD have oriented their HEIs to cater to their needs. In some cases, a desire to run academic programme efficiently has also been a motive.

DAE has set up research and development centres and also provides full funding for running grant-in-aid institutions. HBNI was set-up as a deemed university to integrate human resource development programmes ongoing in 10 institutions of DAE under a single academic framework and expand the programmes. National Institute for Science Education and Research was set up subsequently and is an off-campus centre of HBNI. Annexure 1 lists all the institutions of HBNI. While NISER, SINP, IoP, IMSc, HRI are akin to conventional university institutions, research and development centres are work places engaged in: (i) post-academic research; (ii) design, development, construction and operation of mega research and first-of-a-kind (FOAK) fuel cycle facilities, and (iii) design and development of FOAK nuclear power plants. IPR has a hybrid character and mandate of TMC includes treatment, research and education focused on post-graduate (MD) and super-specialty programmes (DM and M Ch) in oncology.

HBNI has a distributed structure and pursues research in areas related to missions assigned to DAE. Doctoral programmes, post-graduate and super-specialty medical programmes have seen significant expansion (see Figures 2 and 3) since setting up HBNI. About 40% of doctorates have been completed by employees of DAE. *Nature*, in its issue dated 20 September 2018, has included HBNI in the category of ‘Rising Stars’. The approved annual intake for the post-graduate and the super-specialty medical programme for the academic session starting in mid-2018 was 129. Completing one-year of course work is compulsory for scientists and engineers joining DAE establishments through BARC Training School, and doing one-year of project to complete an M Tech is an option available to engineering graduates. Since inception, 1236 students have completed M Tech. Number of students who have completed a Ph D in engineering science is 194 out of a total of 1363 (Figure 4). HBNI also offers several programmes that aim at development of skills. These include Diploma in Radiation Protection (for

Table 1. HEIs administered by Departments and Ministries other than MHRD

Ministry/department	HEI (year of establishment as an HEI)
Ministry of Railways	The National Rail and Transport Institute*, Vadodara (2018)
Ministry of Petroleum and Natural Gas (MOP&NG)	Indian Institute of Petroleum and Energy*, Visakhapatnam (2018)
Department of Science and Technology (DST)	Indian Association for the Cultivation of Science** (2018)
Ministry of Food Processing Industries	National Institute of Food Technology Entrepreneurship and Management**, Sonipat (2012)
Ministry of Health & Family Welfare (MH&FW)	National Institute of Mental Health and Neurosciences*, Bengaluru (2012)
Department of Industrial & Scientific Research	Academy of Scientific and Industrial Research* (2011)
Ministry of Defence (MOD)	Indian National Defence University*, approved in 2010 and now coming up in Gurugram
MOP&NG	Rajiv Gandhi Institute of Petroleum Technology*,Rae Bareli (2008)
MH&FW	Post-Graduate Institute of Medical Education and Research*, Chandigarh (2008)
Department of Space	Indian Institute of Space Science and Technology**, Thiruvananthapuram (2007)
Department of Atomic Energy (DAE)	Homi Bhabha National Institute**, Mumbai (2005)
DAE	Tata Institute of Fundamental Research**, Mumbai (2002)
Ministry of Commerce & Industry	Indian Institute of Foreign Trade** (2002)
MOD	Defence Institute of Advanced Technology**, Pune (2000)
Dept of Pharmaceuticals	National Institute for Pharmaceutical Research*, Mohali (1998); and now at six more places
Ministry of Environment, Forests & Climate Change	Forest Research Institute**, Dehradun (1991)
Ministry of Agriculture & Farmer's Welfare: Indian Council of Agriculture Research (MA&FW-ICAR)	ICAR-National Dairy Research Institute**, Karnal (1989); ICAR-Central Institute of Fisheries Education**, Mumbai (1989) ICAR-Indian Veterinary Research Institute**, Izatnagar (1983)
DST	Sree Chitra Tirunal Institute for Medical Sciences and Technology*, Thiruvananthapuram (1980)
MH&FW	Jawaharlal Institute of Postgraduate Medical Education and Research*, Puducherry (1966)
Ministry of Statistics & Programme Implementation	Indian Statistical Institute*, Kolkata (1959)
MA&FW-ICAR	ICAR-Indian Agricultural Research Institute**, New Delhi (1958)
MH&FW	All India Institute of Medical Sciences*, New Delhi (1956) and now at six more places

*An institute of national importance; **A deemed to be University.
Notes: (a) HEIs are listed in reverse chronological order. (b) In case of multi-campus institutes, the city where the headquarter is located is indicated in the table. (c) The table does not list HEIs engaged in vocational education, or research in fields other than STEM. These include the following: (1) Ministry of Textiles established National Institute of Fashion Technology having 15 campuses in 1986 and it became an INI in 2006; (2) Ministry of Shipping has set up Indian Maritime University under an Act passed in 2008; (3) Ministry of Civil Aviation established Rajiv Gandhi National Aviation University in 2013, and all flying schools are expected to get affiliated to it. At present it offers only short-term diploma programmes; (4) Ministry of Commerce and Industry established Footwear Design and Development Institute having 12 campuses in 2006. It became an INI in 2017; (5) Ministry of Commerce & Industry has set up Indian Institute of Packaging as a non-formal institute; (6) Department of Corporate Affairs has set up Indian Institute of Corporate Affairs (non-formal); (7) Ministry of Culture has three HEIs dealing with Buddhist Studies.

training students to work as Radiation Safety Officers), Diploma in Medical Radio-Isotope Technology, Diploma in Fusion Imaging Technology and M Sc in clinical research.

Motivations for setting up HBNI from the perspective of the author are as follows.

(i) The field of nuclear science and engineering is the result of splicing of several fields of science and engineering and therefore, running academic programmes in this area requires setting up facilities necessary to provide training and conduct experimental research, and recruit faculty belonging to several disciplines. It does not lend itself to a silo-based approach. This is applicable to some other fields as well such as Biomedical Engineering[13]. The issue of faculty resources becomes acute as many of the specializations needed by DAE to cover missions assigned to it are unique. Examples include accelerator science and technology, high-frequency engineering, nuclear chemistry, reactor physics, plasma physics, nuclear fuels, nuclear chemical engineering, molten salts chemistry, liquid metal heat transfer, radiation damage resistant materials and so on. In units of DAE, all such resources already exist and HEIs in India do not have large faculty resources[17].

(ii) The increasing complexity of technological systems is driving the development of analytical, computational and simulation tools. This requires design tools and analytical methods grounded in phenomenological understanding. This is particularly important for anticipating failure modes under extreme but conceivable conditions

Annexure 1. Constituent institutions and the off-campus centre of HBNI

Constituent institutions

(i) Research and development centres of the Department of Atomic Energy:
- (a) Bhabha Atomic Research Centre (BARC), Mumbai
- (b) Indira Gandhi Centre for Atomic Research (IGCAR), Kalpakkam
- (c) Raja Ramanna Centre for Advanced Technology (RRCAT), Indore
- (d) Variable Energy Cyclotron Centre (VECC), Kolkata

(ii) Grant-in Aid Institutions under the administrative control of the Department of Atomic Energy:
- (a) Saha Institute of Nuclear Physics (SINP), Kolkata
- (b) Institute for Plasma Research (IPR), Gandhinagar
- (c) Institute of Physics (IoP), Bhubaneswar
- (d) Harish-Chandra Research Institute (HRI), Allahabad
- (e) Tata Memorial Centre (TMC), Mumbai
- (f) The Institute of Mathematical Sciences (IMSc), Chennai

Off-campus centre

National Institute for Science Education and Research (NISER), Bhubaneswar

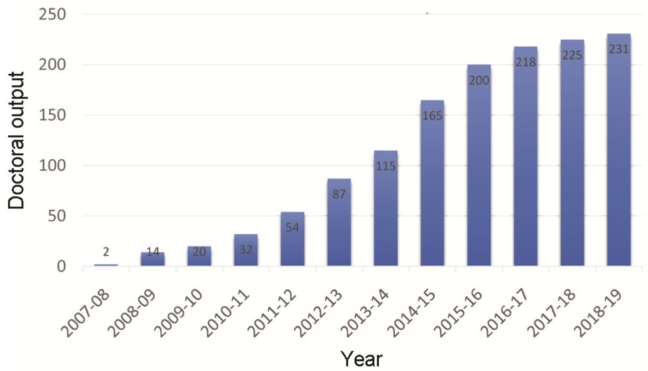

Figure 2. Year-wise doctoral output from Homi Bhabha National Institute.

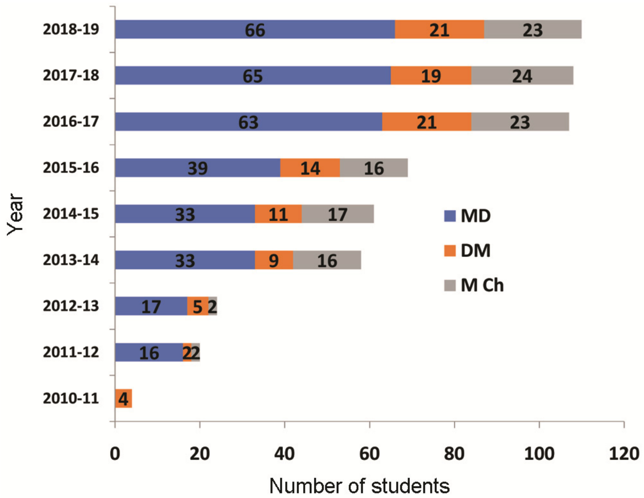

Figure 3. Year-wise output of MD/DM/M Ch from Homi Bhabha National Institute.

of service of complex technological systems. In fact, this is the major activity that comprises engineering research. In this kind of research, the element of practice is as important as the element of theory, is contextual and lies at the intersection of academic and post-academic research (Figure 1). As DAE establishments had been pursuing contextual research, adding the mission of human resource development to its existing missions was a natural next step.

(iii) Developing new technology, or improving or finding a new application of an existing technology can throw unforeseen challenges and could require inputs based on research. Even when DAE lays emphasis on post-academic research, pursuit of academic research (note the large intersection of academic and post-academic research in Figure 1) is necessary to have in-house experts in relevant areas, who can help in addressing unusually difficult challenges requiring new knowledge. Selection of subject areas for academic research has to be skillfully managed for their relevance to the mission of the DAE. Many such areas, as already explained, may not be of general interest, and so are not pursued by HEIs. The result is that mission-oriented agencies, in general, find it difficult to get support from HEIs in the country in all areas of interest to them. In all such cases, mission-oriented agencies have to pursue academic research in their own research centres and when possible, supplement their own efforts by funding such research in HEIs.

(iv) Nuclear technology is subject to technology controls and many artefacts must be reinvented as they cannot be imported. Value system for recognition and promotion followed by HEIs in India makes faculty generally reluctant to pursue research in such areas.

The students are viewed sometimes as low cost, but valuable man power, and sometimes as distraction. This divide was evident within DAE during the debate for setting up HBNI. While some in the top decision-making bodies viewed students as 'distraction' and the university function 'a strain', majority favoured it. Research and development centres, and industrial laboratories tend to have static work forces, which is necessary to provide continuity of skills. In such work-places students are not a distraction, but a source of innovation, which is a necessary element for the development of technologies by mission-oriented agencies. According to Etzkowitz and Leidesdorff[18], students 'represent a dynamic flow-through of 'human capital' in academic research groups'. The permanent scientific staff consisting of scientific officers and technical support personnel provides continuity of skills, and students provide dynamism. The resulting atmosphere can provide ideas for future technologies and scientific discoveries. Considering importance of the contribution of scientific officers, HBNI has been set up in a manner that the reward-system existing in the R&D centres has not been disturbed. Promotions in R&D centres are decided by contribution of an individual to the mission of the Department and not solely on the basis of publications and citations thereof. Globally, academia has a tendency to aim at peer recognition, which comes from publications. However, one has to strike a balance between international recognition and national needs[13].

R&D centres of DAE, which are also Constituent Institutions of HBNI, are engaged in the design and development of a FOAK high-tech projects requiring scholarly inputs from multi-disciplinary teams and calling for combining theory and practice with greater intensity. This involves a large number of experts belonging to different disciplines working together in a team over a long-time frame. System engineering, interface management and configuration control become dominant challenges during the implementation of such projects. Doctoral students interact with faculty who also double as scientific officers and grapple with complex problems while implementing FOAK projects. This inculcates in the students an appreciation and respect for post-academic research, design and development including development of experimental methods and devices, and industrial work. Such developments are important and have led to Nobel prizes[19].

Every institution has certain norms, values and beliefs. Educationists refer to it as 'hidden curriculum' as it is conveyed to students not through explicit means, but by shaping their behaviour based on socializing mechanisms on the campus. Respect for industrial work, design and development, and post-academic research is the hidden curriculum of the doctoral programme (particularly at some of the institutions viz. BARC, IGCAR, RRCAT, VECC and IPR) of HBNI.

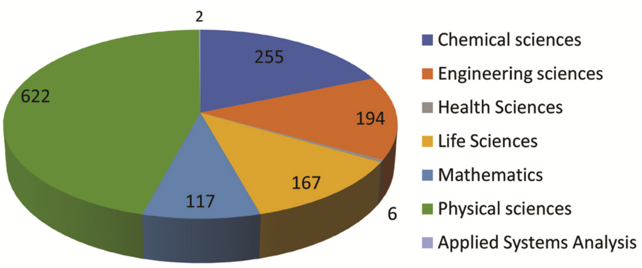

Figure 4. Discipline-wise doctoral output from Homi Bhabha National Institute.

DAE has several institutions and working under a single academic umbrella has been helpful in bringing these institutions together and benefit from the expertise of each other. The number of engineering graduates pursuing Ph D has significantly increased and the number of students making use of mega facilities for doctoral research at R&D centres has also increased.

Every institute provides an environment to researchers and that includes elements like its mission, its culture (meritocracy, transparency and entrepreneurship), leadership that defines the balance between the focus and the freedom[15]. In an institute like HBNI, the balance has a tilt towards focus on research related to the mission of the DAE, while in a conventional HEI, the tilt is towards freedom to select topics for research including freedom to keep switching the topics.

HEIs, set up by agencies other than MHRD, are supplementing the existing HEIs and research by them has a focus on the business allocated to them. However, HBNI is unique because of its distributed structure, recognition of researchers in R&D centres as faculty following stringent criteria, and use of existing research infrastructure for doctoral research. It also endorses utilitarian aspect of research emphasized by all policy statements. HBNI is, thus a new idea of a university and is an addition to the several ideas of a university that are co-existing[20].

Concluding remarks

The structure of institutions in India, particularly mission-oriented agencies, acknowledges intertwining of science and technology.

To continue to generate new knowledge and to utilize all available knowledge, HEIs that combine theory and practice with much greater intensity are needed, and most of the HEIs nurtured by agencies other than MHRD are eminently suited to do so. Research nurtured in a majority of the institutions of HBNI is a mix of academic and post-academic with a tilt toward the latter, and focus on the missions assigned to DAE.

HBNI has been established in a manner that the reward system prevalent in the research centres including that for scientific officers has not been disturbed. Research centres continue to give equal status to faculty and scientific officers.

For higher education, India has adopted a hybrid model, where unitary universities, affiliating universities, and single (or limited) discipline(s) institutions co-exist. HBNI with its distributed structure and focus on its mission is a new idea of a university and represents the continuing evolution of the idea of a university.

1. Bush, V., *Science – The Endless Frontier*, A Report to the President by Vannevar Bush, Director of the Office of Scientific Research and Development, July 1945, United States Government Printing Office, Washington, 1945.

2. Wise, G., Science and Technology. *OSIRIS*, 1985, **1**, 229–246.
3. Stokes, D. E., *Pasteur's Quadrant: Basic Science and Technological Innovation*, Brookings, 1997.
4. Grover, R. B., The relationship between science and technology and evolution in methods of knowledge production. *Indian J. Hist. Sci.*, 2019, **54**(1), 50–68.
5. OECD, *Frascati Manual 2015: Guidelines for Collecting and Reporting Data on Research and Development*, OECD Publishing, Paris, 2015.
6. Ziman, J., Post-academic science: constructing knowledge with networks and norms. *Sci. Stud.*, 1996, **9**(1), 67–80.
7. Serageldin, I., Tomorrow's universities and the seven pillars of knowledge revolution. *CADMUS*, 2013, **2**(1), 8–25.
8. Grover, R. B., Setting up of Homi Bhabha National Institute, 2017; retrieved at https://www.dropbox.com/sh/3uwqetea7-xuwzd0/AABTh7ZN9zfyhglr68SGNhMXa?preview=Nov+2017+Setting+up+of+Homi+Bhabha+National+Institute+by+Dr+RB+grover.pdf (accessed on 12 June 2019).
9. Radhakrishnan, S., The Report of the University Education Commission', Publication No 606, Ministry of Human Resource Development, 1950.
10. Kothari, D. S., Report of the Education Commission 1964–66, Ministry of Education, Government of India, 1966.
11. MHRD, Draft National Education Policy, 2019.
12. Saha, S. K. and Ghosh, S., Commissions and committees on technical education in independent India: an appraisal. *Indian J. Hist. Sci.*, 2012, **47**(1), 109–138.
13. Ramaswamy, V., *Innovation by India for India: The Need and The Challenge*, SikshA Publications, LLC, USA, 2016.
14. Brookes, H., The relationship between science and technology. *Res. Policy*, 1994, **23**, 477–486.
15. Narayanamurti, V. and Odumosu, T., *Cycles of Invention and Discovery: Rethinking the Endless Frontier*, Harvard University Press, 2016.
16. Grover, R. B. and Puri, R. R., Development of human resources for Indian nuclear power programme. *Sadhana*, 2013, **38**(5), 1051–1064.
17. Jalote, P., India's quest for world-ranked universities. *Curr. Sci.*, 2019, **116**(9), 1479–1482.
18. Etzkowitz, H. and Leidesdorff, L., The dynamics of innovation: from national systems and 'Mode 2' to a Triple Helix of university–industry–government relations. *Res. Policy*, 2000, **29**, 109–123.
19. Dasannacharya, B. A., On the way to innovation. *Curr. Sci.*, 2015, **108**(9), 1586–1587.
20. Kaoru, N., The co-existence of several ideas of a university. In *The Idea of a University in Historical Perspective: Germany, Britain and Japan* (eds Sneba, K. *et al.*), Reviews in Higher Education 84, Research Institute for Higher Education, Hiroshima University, 2005, pp. 79–84.

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