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RESEARCH PAPER

An analysis of the synergistic training program utilizing the scientific and technological infrastructure scheme's impact on advancing scientific capacity of India

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Abstract
The Department of Science and Technology (DST), Government of India, supports to strengthen the Science and Technology capacity and capability through its wide range of funding schemes. In 2022, DST launched the guidelines for the two major policies for strengthening and efficient utilization of S&T facilities, Scientific Social Responsibility and Scientific Research Infrastructure Management and Networks. In light of these policies, DST has taken novel initiative to launch the dedicated Training Scheme known as STUTI (Synergistic Training Program Utilizing the Scientific and Technological Infrastructure). This scheme is a distinctive one, which encourages the knowledge capacity building through training and awareness programs on state-of-the-art research facilities across the country. The present article includes the major objectives and methodologies adopted in the STUTI scheme. The article highlights the major objectives, methodologies adopted and distinctiveness of this scheme, along with the detailed analysis and accomplishments achieved from the organized training and awareness.

Keywords R&D infrastructure · Human capacity building · Training programs · Awareness programs · Science and technology

Introduction

The education and research in science, technology, engineering and mathematics (STEM) are essential modes of operation for cultivating a society capable of contributing towards the accumulation of scientific knowledge. This scientific knowledge, in-turn, fuels the generation of innovative ideas (Li et al. 2020). Furthermore, advancement in scientific knowledge expedite the development of new applications, discoveries and investigations. Scientific knowledge, therefore, comprises a collection of reliable new information acquired experimentation and data collection (Bonney et al. 2009). In this regard, R&D facilities and infrastructure play a critical role as integral component of scientific research. From synthesis to characterization, scientists rely on variety of research facilities to synthesize, measure, characterize and analyze various materials relevant to their research topics (Cross et al. 2015). There exists a multitude of research facilities utilized across various fields including chemical sciences, physical sciences, mathematical sciences, engineering and technological sciences, and life sciences etc. (Boyack et al. 2009; Blaiszik et al. 2016; Abolhasani et al., 2023; Gerbaud et al. 2022; Adb El-Haleem et al. 2022).

The advancement in the research facilities has the capacity to dramatically enhance the eminence of R&D. Moreover, the technological revolution, have implemented to achieve life-changing breakthroughs that advances the present and nurture the future. The scientific instruments are at the heart of the developments, allowing researchers to advance innovative intuitions and unlock more secrets of mankind (Alberts 2022). Advanced scientific research facilities have potential for speeding up the processes to achieve faster and more accurate results. For instance, the development and discovery of Covid-19 vaccine is one of the rapidly develop innovative technologies via state-of-the-art research

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facilities (Alshrari et al. 2022). Although, there are variety of schemes and programs available for providing funding for state-of-art scientific instruments and research facilities. Still, there is indispensable requisite for higher education institutions to train the researchers capable for facile operation and analysis of advance scientific research facilities to meet the need of knowledge society. In this prospect, the hands-on training and awareness programs are one of practice to build-up human capacity (Skurkova et al. 2014). The study of scientific instruments offers fundamental insights into the creation and transmission of knowledge. The hands-on training on scientific instruments also enrichen the understanding of scientific method and practice (Ornstein 2006).

Hands-on training programs on scientific research facilities provides learning by simultaneous performing the things. It involves the experience and sensitization which thereby, enhances the ability of critically thinking (Vong and Kaewurai 2017). The commendable hands-on educational practice on research facilities combines effective learning, full sensitization and questionnaire. Also, the training and awareness programs facilitate the active participation of learners and make learning directly via observing and understanding. These activities develop the curiosity, competency and creativity in the young researcher (Ferrari et al. 2009). These programs generate highly-skilled staff for state-of-the-art instruments and thereby reducing the restrictions in research.

The R&D infrastructure division of DST targets to reinforce the S&T research facilities of the country via implementing various schemes like FIST (Fund for Improvement of S&T Infrastructure in Universities and Higher Educational Institutions), PURSE (Promotion of University Research and Scientific Excellence), SAIF (Sophisticated Analytical Instrument Facilities), and SATHI (Sophisticated Analytical & Technical Help Institutes) from many years (R&D Infrastructure, 2023). These schemes targeted to foster the well-equipped and cutting-edge R&D facilities in labs, centers or research institutions ranging from post-graduate colleges to State/Central Universities, Institutes of National Importance (INIs) and Institutes of Eminence (IoEs) etc. across the country.

As scientific R&D facilities are the essential part of any scientific research in every field of S&T and there are variety of schemes available to offer funding for the establishment and maintenance of these facilities. However skilled and trained personnel for the facile handling, operation, working and significance of high-end sophisticated research equipment is still a challenge. Therefore, dedicated scheme for improving the performance or skills of researcher which also reduces the managerial obsolescence in society is major requirement (Van et al., 2001). In this perspective, DST in 2021 initiated the STUTI scheme with the main envision to enrichen the human resource and knowledge capacity building via hands-on training/awareness programs. These programs provide open access to S&T research facilities across the country for researcher, school students and industry persons (National Research Council 2010). This scheme in-turn can enhance scientific capabilities, foster collaboration, contribute to the overall development of the country and thereby aligning itself with the national mission of *Self-Reliant* or *Atmanirbhar Bharat Abhiyaan* (Dubey and Dubey 2020). STUTI Program has been evolved by DST to accomplish one of the major objective of the SRIMAN Policy i.e. Capacity Building of Operators/ Technicians for efficient operations to achieve efficient and optimum utilization of R&D facilities. With an unwavering commitment to transparency, the STUTI scheme has artfully paved the way for the effective utilization of awe-inspiring infrastructure, opening doors to innovation, propelling research forward, and nurturing a celestial constellation of skilled minds within the scientific community. Through this present article we describe the major objectives and methodologies adopted in the incredible initiative of DST-STUTI scheme. The article highlights the distinctiveness of this scheme, along with the detailed analysis and accomplishments achieved from the organized training and awareness.

Theoretical background: about the STUTI scheme

The state-of-art research facilities are undoubtedly boosted-up the quality and measure of scientific outcomes. These outcomes have tremendous impact on nations' domestic improvements along with other areas of strategic importance. The STUTI training program has been designed to cater the human resource and its capacity building through open access to S&T Infrastructure across the country by organizing short term courses/workshops on the awareness, use and application of various instruments and analytical techniques. As a complement to the various schemes of DST funding for expansion of R&D Infrastructure at academic institutions, STUTI envisions a hands-on training program and sensitization of the high-end state-of-the-art equipment as well as promoting transparent access and sharing of scientific equipment and infrastructure (STUTI program 2023). During the execution of STUTI, it was ensured to have the availability of state-of-the-art technological infrastructure to support the training program which facilitates hands-on training activities and learning experiences. To promote a holistic learning experience, the collaboration and knowledge exchange among experts from different disciplines has been encouraged. The training program involved faculty/ participants from various domains, including science, technology, engineering, medicine etc. This interdisciplinary approach enriched the program by providing participants with a broader perspective and fostering innovative thinking. To ensure the effectiveness of the training program,

the robust evaluation and feedback mechanism has been implemented. Regular assessments, quizzes, and discussion together with evaluations were conducted to gauge the participants' learning. The detailed feedback has been taken from the participants, enabling them to identify their strengths and areas that require further improvement in their research. This iterative process encouraged continuous learning and development.

Alignment of DST-STUTI with National policies

In 2022, DST launched the guidelines for the two major policies for strengthening and efficient utilization of S&T facilities, Scientific Social Responsibility (SSR) and Scientific Research Infrastructure Management and Networks (SRIMAN) (SSR and SRIMAN guidelines 2023). The SSR policy focuses on the delivering the benefits of science to society via providing better access and sharing of scientific research facility to scientists, researchers and industry professionals (SRIMAN guidelines 2022). Whereas the SRIMAN policy promotes the indigenization, efficient utilization & maintenance and simplified accessibility of the S&T research facilities (SSR guidelines 2022). The objectives of both of these policies are allied in the origination of STUTI scheme. The SRIMAN policy is the genesis of STUTI scheme with the advancement on envision of hands-on training and awareness program for human capacity building on state-of-the-art S&T research facilities.

The National Education Policy (NEP) 2020 emphasize on fostering the scientific temperament, quality education, scientific encouragement and holistic development of school education as well as high education institutions (National Education Policy 2020). The STUTI scheme augments the scientific temperament and intellectual curiosity in young generation via organizing hands-on training and awareness programs. Thereby STUTI scheme also line up with the recommendation of NEP 2020 for achieving the goal of sustainability with high quality education and research in frontier areas of S&T.

STUTI scheme facilitate the support for mainstreaming in the direction of achieving Sustainable Development Goals (SDG) monitored by NITI (National Institution for Transforming India) Aayog in India. SDGs targets to meet the urgent environment, social and economic changes facing world. NITI Aayog is the nodal government body for SDGs in India, with spirit of cooperation and competitive federalism. Through capacity building and open access to S&T state-of-the-art facilities along with the encouragement for the women participant in training and awareness programs DST-STUTI scheme is promoting SDG-5 (for providing equal access to education for women and girls) and SDG 9 (building resilient and sustainable infrastructure to promote sustainable development) (An overview of SDGs 2024).

Methodology implemented for the execution of STUTI scheme

DST envisages the organization of training as well awareness programs under STUTI scheme. In the *Awareness Program*, school students (Science Stream) were made aware of the R&D equipment by means of quizzes, short trainings and other popular science events; whereas in the *Training Program*, Scientists/Researchers actively involved in research were given hands-on training on the state-of-the-art R&D equipment for a minimum duration of 7 days. The organization of these activities shall take place at institutes all over the country by the Project Management Units (PMUs) identified by the DST under the STUTI program. The training or awareness programs have been organized on a *Hub-and-Spoke* model approach in this scheme (An et al. 2015). The *Hub-and-Spoke* model provides a means of distribution that relies on a central location (the hub) and a number of spokes leading out from that hub. The main hub is where the goods are stocked, and the spokes represent the various distribution centers that deliver the goods to consumers. The participation of nearly 7500 students from different schools and 7500 researchers from various institutes were targeted in the Awareness Programs and Training Programs respectively for the commemoration of 75th year of Indian Independence.

In the *Hub-and-Spoke model*, DST works as an apex body and identify institutes that act as Project Management Units (PMUs). These PMUs were selected on the basis of their performance on the availed projects under DST schemes like FIST/ PURSE/ CURIE/ SAIF/ SATHI along with criteria of having h-index greater than 10 and i10-index greater than 500. It would be desirable that the PMU has prior experience in organizing training programs and at least 5-year experience of running a state-of-the-art R&D facility. The PMUs were selected under Pan India basis from different geographical spread and from different academic (like Autonomous Institute/ University/Deemed University) and funding (like Central Govt./ State Govt./ Aided/ Private) status. In the year 2022–2023 the 13 PMUs were selected from 10 different states and one Union Territory of India. The selected PMU work as a hub and recognize the host institutes/departments in the specific areas for initiating and organizing the training/awareness program in a smooth and effective manner. The host institutes act as spokes and will organize various training and awareness program for researchers and school students respectively. Figure 1 shows the *hub-and-spoke* model for STUTI scheme. Under the STUTI scheme, DST will provide the grant and expenses to PMUs/institutes for organizing the training/awareness programs. DST act as an apex body and identify institutes that act as Hubs or PMUs which further recognizes the host institutes or departments for initiating and organizing the training and awareness programs.

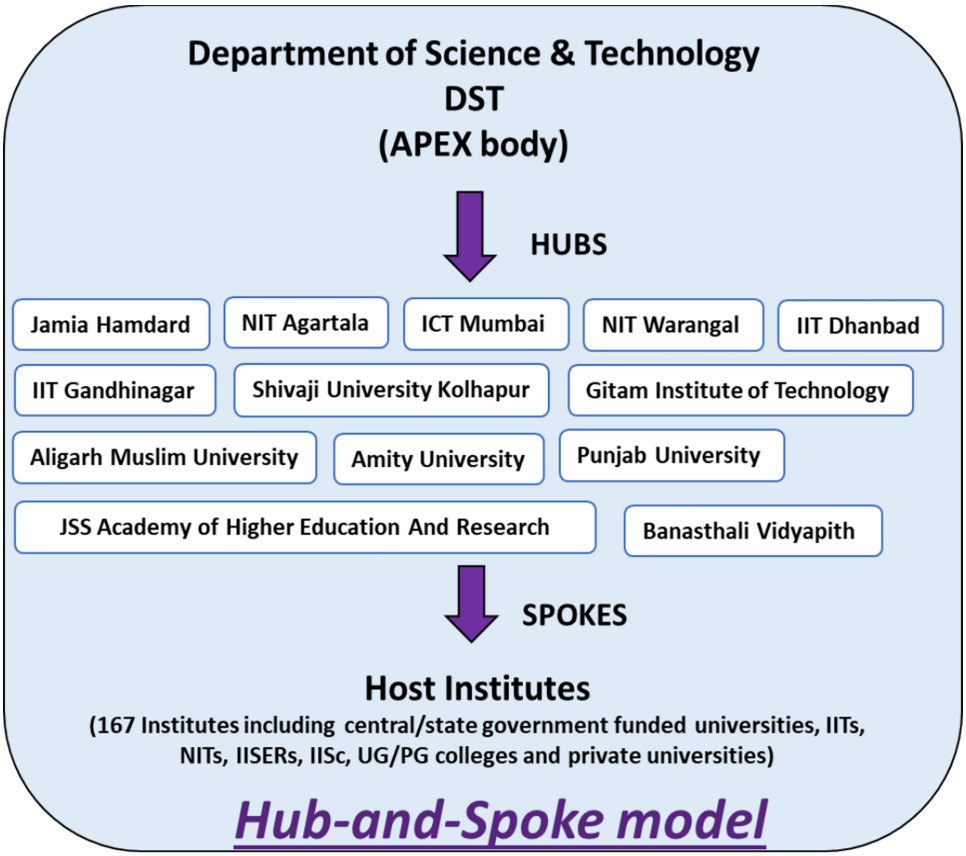

Fig. 1 Hub-and-Spoke model for STUTI scheme

Objectives of the STUTI scheme

During the execution of STUTI program, it was ensured to have the availability of state-of-the-art technological infrastructure to support the training program which facilitated hands-on training activities and learning experiences. Herein, to promote a holistic learning experience, collaboration and knowledge exchange among experts from different disciplines has been encouraged to participate. In the training programs faculty/participants from various domains, including science, technology, engineering, medicine etc. were participated. This interdisciplinary approach enriched the program by providing participants with a broader perspective and fostering innovative thinking. The assurance of the effectiveness of the training and awareness programs has been done by robust evaluation and feedback mechanism.

The major objective of this scheme is to create human capacity building and inspiring young minds to inculcate career in S&T through hands-on training/awareness programs for the open access and sensitization of state-of-the-art research instruments. These programs were based on the awareness, use and application of state-of-the-art research facilities. These courses/workshops were not only targeted to Scientists/ Professors/ PhDs/ Post-docs/ industry persons actively engaged in R&D from institutions across the country but also to organize awareness program for school students (science stream). The programs aimed to raise science and technology inquisitiveness and inspire students to pursue careers in the scientific fields.

Distinctiveness of the STUTI scheme

Although there are various hand-on training programs organized by various Institutes for the expansion and advancement of research temperament, among them, STUTI scheme is distinct one, as it not only provides hands-on training but also offers the open access with complete sensitization of the state-of-the-art research facilities. The major points which makes this scheme unique from the others hands-on training programs are as follow: -

- Open access to state-of-the-art R&D instruments/facilities.
- Theoretical along with experimental sensitization on various state-of-the-art research facilities supported by DST.
- More than half duration of each program is dedicated for practical training.
- Demonstration and hands-on use of equipment by each participant.

- Active participation of Scheduled Caste -Scheduled Tribe and women candidates in the training programs.
- Minimum of 25% women candidates must be trained in each session.
- Awareness sessions on research instruments and facilities for school students.
- Participation of personnel with different backgrounds including faculty, Ph.Ds, post-docs, researchers, scientist, industry persons etc.
- The PMUs were selected from variety of geographic spread.

Through this scheme highly skilled resource persons will be created and trained for the effective utilization of available state-of-the-art S&T facilities. In this direction the scheme aligned itself to the national cause of research community in creating skillful research personnel for operating state-of-the-art R&D facilities available in the country. Also, through this scheme the available R&D facilities in the country will be utilized by wider societies as the STUTI scheme, facilitates the pathway towards the collaborative research activities. Therefore, this scheme is designed for the optimal utilization of available high-end R&D facilities created by DST in nation via involving persons from various background and numerous geographic spreads.

Discussion

Response of the training/awareness programs organized so far under the STUTI scheme

This scheme has adopted a participant-centric approach, aiming to create an inclusive and interactive learning environment. Till May 2023, (from January 2022) 248 training programs and 132 awareness programs were successfully organized via active involvement of 13 PMUs from different region and 167 institutes (including central/state government universities, IITs, NITs, IISERs, IISc, Under graduate/Post graduate colleges and private universities) with diverse geographical spread. The training programs includes the demonstration of various high-end research facilities in the field of STEM subjects. The program focuses on creating an understanding on the importance of science, technology, and innovation in addressing societal challenges and fostering sustainable development. The programs emphasize the importance of industry-academia collaboration, innovation, and technology transfer for socio-economic development. Among these training programs 8573 researchers have been trained from different educational backgrounds and different subject areas. There are about 4589 male and 3984 female candidates have participated from different institutes including state government funded institutes (209 participants) and post graduate colleges (432 participants). Also, 1154 candidates are from North-East (NE) and Jammu & Kashmir region have participated in the training programs and more than 600 participants are from underrepresented regions including Bihar, Odisha and Chhattisgarh.

There are nearly 11,441 school students who attended the 132 awareness programs related to many state-of-the-art instruments and technologies. Figure 2 shows the number of participants from different subject areas and their percentage. The maximum participants are from life sciences (~36.4%) followed by chemical sciences (21.6%), physical sciences (19.6%) and engineering sciences (14.7%). In earth sciences (4.2%) and mathematical sciences (3.5%) very less candidates participated. Active participation of the researchers and industry persons from different subject areas can be seen from the figure. Many of the participants are from

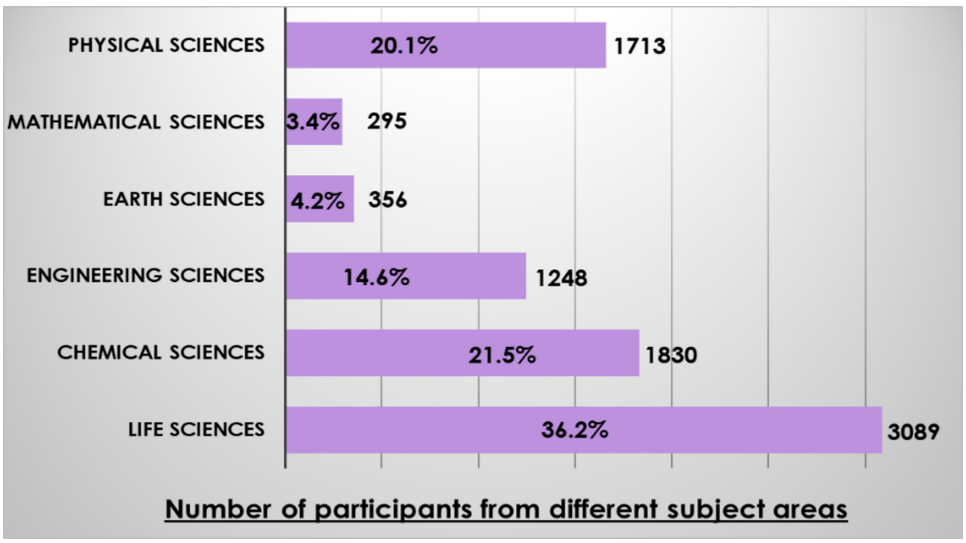

Fig. 2 Subject wise number and percentage of participants in training programs

the Life sciences, Chemical sciences, Physical sciences and engineering sciences areas.

Figure 3 shows the number of participants from various backgrounds with the respective proportion of male–female. More than 50% participants (~4366) are from research scholars with post-doc and Ph.D fellows. Nearly 29% are Postgraduate or B.Tech students and ~20% are Professor/ Scientist or Industry person. The male–female ratio is maintained from the participants from different backgrounds. Figure 4 shows all the 13 PMUs along with their geographic spread on the political map of India (MapChart 2023). Here the number of training and awareness program conducted by each PMU has been shown. The PMUs were selected from different regions of India including states from north to south and east to west along with North-East region under the Pan-India strategy.

Details of the training and awareness programs conducted under STUTI scheme

During the execution of STUTI program, it was ensured to have the availability of state-of-the-art technological infrastructure to support the training program which facilitated hands-on training activities and learning experiences. Herein, to promote a holistic learning experience, collaboration and knowledge exchange among experts from different disciplines has been encouraged to participate. The training program involved faculty/participants from various domains, including science, technology, engineering, medicine etc. This interdisciplinary approach enriched the program by providing participants with a broader perspective and fostering innovative thinking. The assurance of the effectiveness of the training and awareness programs has been done by robust evaluation and feedback mechanism. A dedicated website has been available for the details of the training and awareness programs organized by the different PMUs (DST STUTI 2022).

The training programs employed in the STUTI scheme has adopted collaborative methodologies, industry expertise, and hands-on experiments to enhance learning outcomes, offering comprehensive understanding and analysis of advanced instruments like NMR, HRMS, XRD, SEM, Raman, and AFM, helping researchers to explain structure-property correlations and material characteristics. The science awareness week and training programs were organized, featuring lectures and demonstrations on topics like astrophysics, condensed matter physics, nuclear physics, materials analysis, nanoscale research, genomics, proteomics, bioinformatics, molecular biology research, drug delivery systems, pharmacokinetics, pharmaceutical research, renewable energy research, energy efficiency, semiconductor fabrication, plant biology, water resource management and sustainable development etc. Some of the PMUs organized special programs and sessions for women for empowering female researchers, and participants. The training and awareness program promotes scientific literacy and emphasizes industry-academia collaboration, focusing on innovation and technology transfer for socio-economic development across diverse fields. Also, the awareness programs have been conducted during science week for motivating school students about higher education prospects, applications in the real world, enhancing skill performance of concerned subject, cognitive development, quick response preparation through different scientific lecture, and vising different laboratories containing sophisticated instruments.

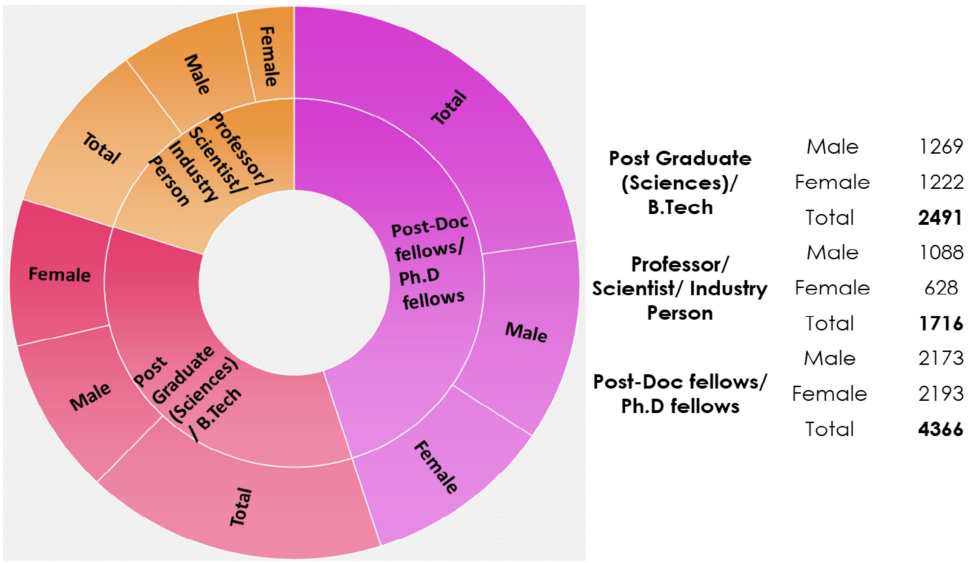

Fig. 3 Participants from different backgrounds with the male–female proportion

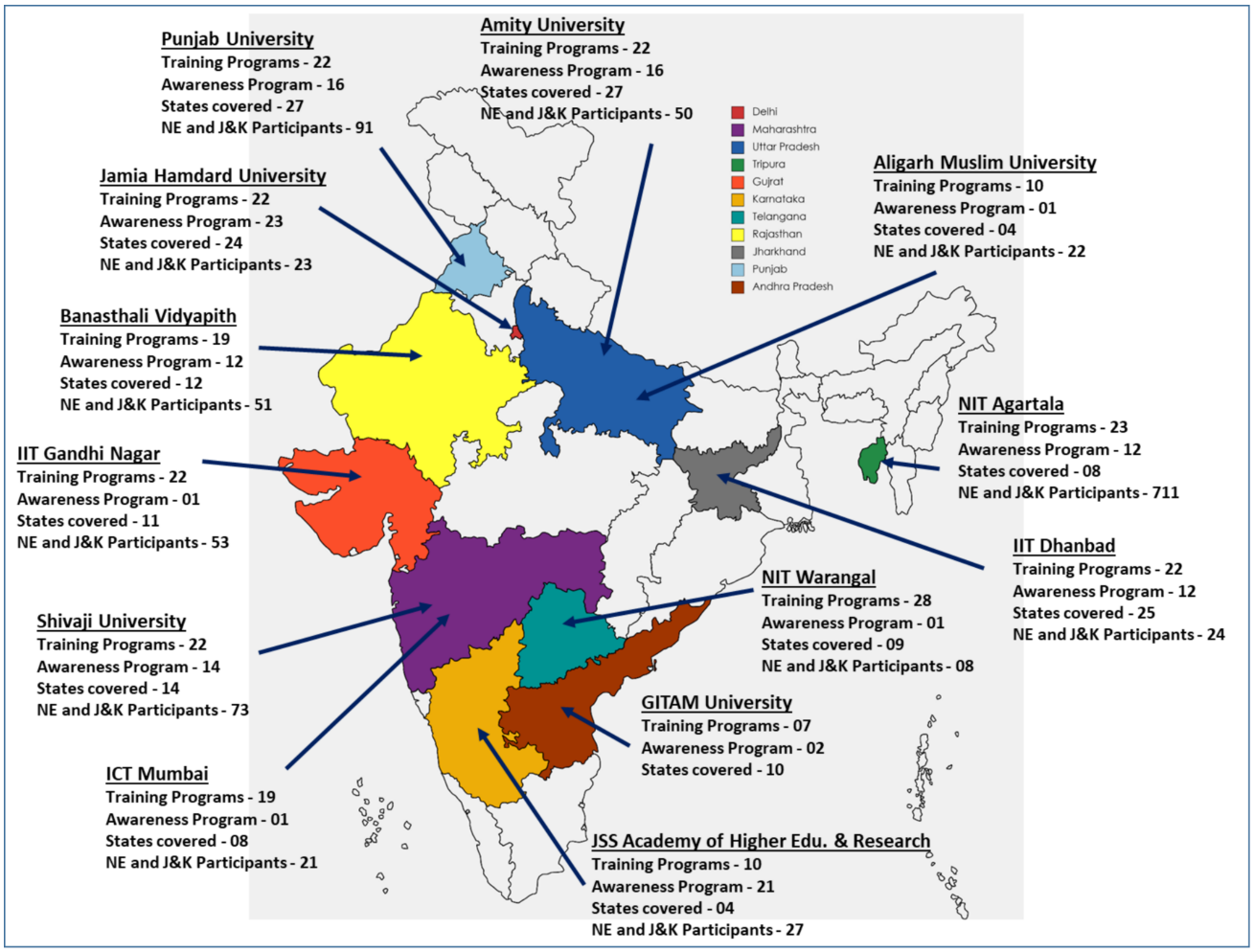

Fig. 4 Geographical spread of the 13 PMUs and their respective numbers of training and awareness programs

Conclusion and future perspective of the STUTI scheme

The program has already organized many innovative activities aimed for creating human capacity building via providing open access and full sensitization on cutting edge research facilities to researchers/school students/industry persons etc. Indeed, these activities have served as a bridge to narrow the gap between resource-endowed and resource-limited institutions, also promoted collaboration and fostered a sense of responsibility within the scientific community. By organizing training programs across the entire country and providing access to sophisticated research instruments through STUTI support, the training initiatives successfully have empowered participants from different regions of the country. This approach has nurtured a more inclusive and equitable learning environment, allowing trainees to enhance their skills and knowledge regardless of their geographical constraint. To date, nearly 8573 researchers from various educational backgrounds and subject areas have been trained, which is ~14% more than the targeted value of 7500 researchers. Additionally, 11,441 school students (representing a ~52% increase from target) have attended the awareness programs on various cutting-edge R&D facilities/technologies.

While many researchers from various subject area have participated in the training programs, it's noted that Mathematical and Earth sciences have been least involved subjects. In the future, PMUs can plan to organize more workshops or training programs for these grey areas. DST can also propose for organizing the further advance level training programs for more sophisticated R&D facilities. The training programs in future can include more advance characterization techniques applicable in applications like fuel cells, batteries, solar cells, thermoelectric materials, superconducting materials, water purification techniques, etc. Based on the outcomes from the previous year, DST is planning for the advancement of the program for the upcoming years.

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Data availability All data supporting this work had been provided within the manuscript.

Declarations

Competing interests Authors report no competing of financial interest related to the manuscript.

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