Implementation of National Science Technology and Innovation Policy 2019: Assessment of Challenges in Government Organizations of Nepal

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ABSTRACT

Government of Nepal promulgated the third policy on science and technology including innovation in 2019 (NSTIP-2019). This policy being aligned with the federal and provincial governance system has given stronger emphasis on innovation and entrepreneurship for economic development. Online questionnaire survey was conducted to assess the status and capabilities of governmental research organizations and universities because they are in the forefront in executing action plans formulated in NSTIP-2019. An encouraging response from a total of 36 respondents representing 17 organizations was received. All respondents have reported the poor infrastructure and lack of budget for research activities in their respective organization. Low productivities of research institutes and academia were attributed to erroneous understanding existing in policy makers and underdeveloped research culture prevalent in research and academic institutions including limitations in governments' system of budget allocation, leader/staff recruitment and procurement of necessary research materials. Based on the information and suggestions provided by a wide range of expertise in survey respondents, this paper identifies enablers of positive research and innovation culture in Nepalese perspectives. Key attributes of 'sound research and innovation ecosystem' discussed here are most likely to guide implementation process of NSTIP-2019 with higher levels of confidence and effectiveness.

Keywords: Research and development, Scientific culture, Skilled manpower, Motivation

1. INTRODUCTION

Development in science and technology ensures prosperity and improved socio-economic conditions of citizens and welfare of the nation. Pivotal role of Science, Technology and Innovation (STI) for sustainable development has been globally recognized (UN/ECOSOC 2015; ESCAP 2018). Building national capacity in science and technology eventually helps countries to promote an innovation ecosystem that creates a healthy environment for innovative ideas, novel products and knowledge systems (Granstrand & Holgersson 2020). Progressive policies adopted by governments in education, organizational restructuring, good governance, and research & development establish foundations for increased productivities and economic growth (Karasev *et al.* 2018; Raghupathi & Raghupathi 2019). Several western countries and countries of Asia-Pacific were able to achieve rapid economic transformations within a couple of decades through their improved policy frameworks on STI (EU 2013; ESCAP 2018). Developed countries are leading the global economy through their sustained role in technological innovations along with smart and novel services (Raghupathi & Raghupathi 2019). However, capabilities of developing countries in scientific research and technological innovations are severely hampered by low investment in STI related activities, unskilled labor force and negligible innovation inputs (Cirera & William 2017). Large gaps are evident between developed and developing nations in terms of STI capacities (UNCTAD 2014).

Nepal has a golden history of architecture development and traditional art. Licchavi and Malla periods are regarded as historically prosperous time when magnificent building construction, stone sculptures as well as woodcarving and agriculture were in prominence (Shaha 1992). In these periods ancient water spout system called 'hitis' were also developed (Shaha 1992; Gautam 1994; Joshi 2015). However, we are late starter in modern science and technology (Singh & Bhuju 2001; Bhuju *et al.* 2021a). When the Late King Prithivi Narayan Shah was actively engaged in the unification of Baise Rajya (22 kingdoms) and the Chaubasi Rajya (24 kingdoms) to build unified and united greater Kingdom of modern Nepal, Europe was actively engaged in an industrial revolution and subsequent technological developments in different sectors including agriculture. After Prithivi Narayan Shah, his successors, viz. Bahadur Shah, Rajendra Laxmi and Gribanyuddha Bikram Shah had completed his unification campaign in different phases. After unification, particularly the Rana rulers, had imported technologies and established agriculture based industries such as match factory; rice, oil, jute, sugar and cotten mills; 500kw and 900kw Pharping and Sundarijal hydro-electric power house, ropeway, suspension bridge, railway etc. Unfortunately, due to almost a century long isolation from the outside world, public schooling of our grandparents was severely hampered during this period. Education (both formal and informal) is the most important factor that is related to the poverty in the country (Thapa 2013). Illiterate people can join less technical jobs, get low level of payment, thus remain at low levels of living. The nation with illiterate and unskilled masses are less productive as advanced technology cannot be implemented in the workplace. Our own demographic data have clearly shown that educated families have a high living standard than of less educated families (CBS 2011).

The new constitution of Nepal promulgated in 2015 has opened new avenues in political, social and economic spheres but science, technology and quality education have invariably lagged behind in the priority list of the government. We are consuming technological products of developed countries but could not develop a productive culture of research and innovation inside the country. Although Nepal is a late starter in modern science and technology (Singh & Bhuju, 2001; MoEST 2019), Science and Technology (S&T) policies were formulated in 1989, 2005 and 2019. After each political change in the country, policies in S&T tend to be changed but such phenomena are becoming merely a political-administrative process. If reviewed in details, there are no significant differences between the first and second science and technology policies. Both of the policies

were highly progressive and had the potential to make substantial changes in Nepali societies. Implementation of the both policies were backed by very limited supportive activities, therefore visible change could not be observed in science education, technology and engineering sectors.

Following the global trend, the third policy 'National Science, Technology and Innovation Policy' was promulgated in 2019 with greater emphasis on innovation. This policy has devised 11 objectives, 29 strategies and 49 action plans to be implemented in prioritized areas viz. industrial production and productivity; commercialization of agriculture and utilization of land; sustainable infrastructure development (housing, water supply, tourism and green energy); sustainable utilization of biodiversity and mineral resources; climate change and disaster risk reduction, and good governance, delivery of service, cyber and national security. Defined activities in the policies are also aligned with the system of federal and provincial governance. Special features of this policy are: provision of high level National Science and technology Development and Coordination Council for policy guidance and coordination of research and innovation related activities, formation of Science, Technology and Innovation Fund to support STI initiatives and increase investment up to 3% of GDP in research and development.

Formulation of policy and its effective implementation are two different but strongly interrelated actions (UNCTAD 2011a). National STI policy 2019 has been prepared with the participation of a wide range of stakeholders representing varied cross cutting sectors from all seven provinces of Nepal. Extensive discussion and interactions were carried out during its preparation (Sharma *et al.* 2021). Similar efforts, commitment, energy, inclusiveness and increased investment are required to execute this policy. Government research institutions and universities are at the forefront of executing work plans formulated in STI policy 2019 therefore, this study aims to measure and evaluate perceptions of researchers and professionals working in governmental research organizations and universities regarding the implementation status.

2. MATERIALS AND METHODS

2.1 Primary Data Collection

This study is based on primary data collected through questionnaires designed in Google forms and sent to potential scientists/technologists, researchers, and professors working in 25 various government research institutes and academia through email. Government organizations were selected based on their regular activities on research, innovation and teaching. A total of 21 questions related to objectives of organization, research activities, challenges and hurdles in execution of research plans, availability of funding for research, infrastructure and scientific culture, organizational difficulties and obstacles on timely completion of research and its publication, evaluation of research outputs and performance of researcher, career development and promotions of researchers, etc were included. In addition to the questionnaire survey, infrastructure in different research institutions was assessed and evaluation, monitoring, promotions, and recruitment mechanisms were studied.

2.2 Data Analysis and Interpretation

Primary data obtained through internet survey was tabulated and the data matrix was analyzed using descriptive and frequency analysis methods. Cross tabulation analysis was also performed to examine relationships between survey responses (different variables) submitted by scientists working in different institutions.

3. RESULTS

In this survey, a total of 36 respondents currently engaged in various research activities have participated actively, representing 17 government organizations. Most of respondents appreciated the opportunity to take part in the survey and showed their keen interest to follow up to the survey findings. Few respondents have commented on single answer multiple choice questions where they were requested to choose the most relevant one option, but they wanted to select more than one.

3.1 Demography of the Respondents

The respondents embrace from government organizations involved in research, policy formulation and service delivery in the field of education, health, agriculture, forestry, livestock, veterinary, engineering, environment, biotechnology, physical science, mines and geology, infrastructure development, water resources management and hydrology were major components in this survey. Among the respondents a large proportion (78%) of them were male (Fig. 1a). Respondents' service periods in their respective organizations were more than ten years among 36%, followed by more than five years among 28%, more than 15 years among 19%, more than 20 years among 14%, and exactly five years among 3% (Fig. 1b).

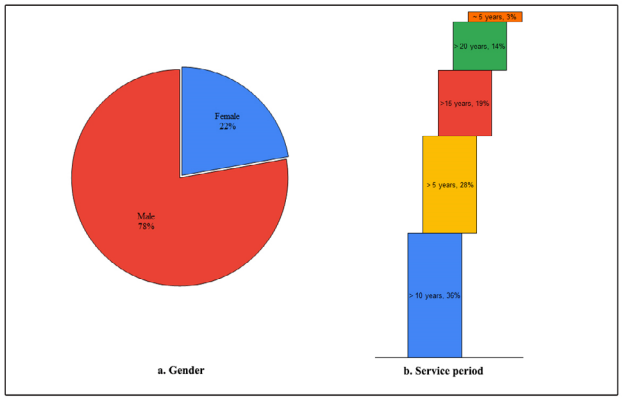

Fig. 1. Demography and service period of the participants in the survey.

According to the respondents, 64% informed that their organizations' annual activities embrace research (>50%) as dominant activities, 21% respondents represent from university, and 15% thought that outreach, awareness and administration related activities are dominant (>50%) in their organization (Fig. 2a).

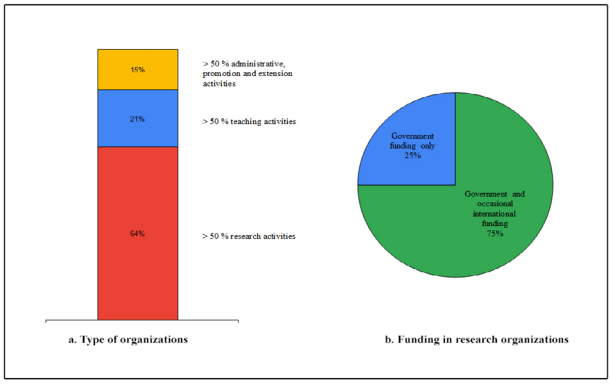

Fig. 2. Nature of organizations to which the respondents belong and their sources of annual budget for regular activities.

3.2 Funding Research Activities

All participating organizations receive funding for annual activities from the government, however 25% receive a budget solely from the government and the rest (75%) have provision of obtaining international funding for their research activities (Fig. 2b). Few scientists/ technologists working in the organizations where their organization can receive additional funding for research from national and international sources has also expressed their reluctances to apply for funding because of the

bureaucratic hurdles they have to face mainly on mobilizing fund by the principal investigator to execute stipulated research activities.

3.3 Execution of Research Independently

When asked whether they can submit a proposal to get funding for their research in the organization; 47% gave positive answers and 17% gave negative answers but 36% were reluctant to apply because of the official hurdles they have to face from their office during proposal submission and project execution (Fig. 3a). Hesitation of respondents to apply for international funding is also attributed to organizations' internal mechanisms that do not allow respondents (80%) to lead funded project independently as 'Principal Investigator (PI)' (Fig. 3b).

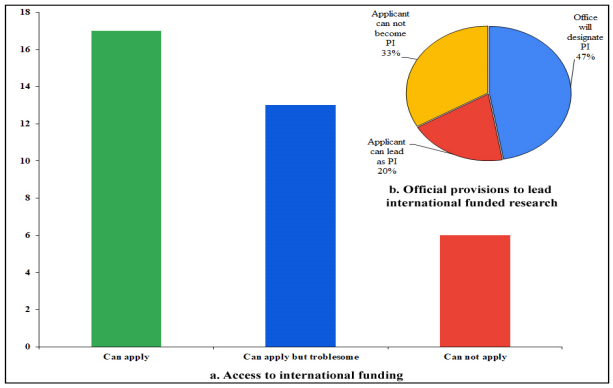

Fig. 3. a. Access to international funding to the respondents of the survey and b. organizational provision to allow researcher lead project as 'Principal Investigator'.

3.4 Research Allocation

Organization allocates tasks to scientists and researchers. Job descriptions of scientists tend to change when they are transferred to different offices or different departments/units internally. Questions on organizational design, and changes in job description reveal that 37% respondents were given different job descriptions other than their areas of expertise from two to several times during their service periods. About 15% respondents informed that they are working in a field different from the subject in which they have expertise or had formal education/training.

3.5 Research Publications

Publications of literature like research articles, popular articles, proceedings, books, training manuals, etc have been emphasized in all participating organizations with 92% positive responses. However, respondents who are asked for regular publications by their organization accounted only the 69% and the rest of other do not have mandatory provisions of regular publications of their research activities.

3.6 Capacity Building/Empowerment and Motivation

Regular support to build capacity and empower scientists and researchers always acts as force to motivate them for higher performances in research activities. Existence of programs like exposure visits, trainings, further education, recognition and award / publications/innovation/novel ideas or knowledge system in the organization was inquired. A total of 67% respondents informed that such mechanisms lack in their organization while 78% of respondents have not realized that such type of encouragement they ever got from their organization.

3.7 Field Based Researches and Laboratory with Sophisticated Equipment

Responding to the question asking whether organizations have necessary equipment for research, 53% respondents showed hurdles/ problems they have to face during procurement and 75% of the respondents informed that they usually end up with low quality equipment/

chemicals procured. In the case of field research, respondents were asked whether the present field allowance and stipulated days are enough, 71% were not happy with the allocated days and even the higher respondents, 91% strongly suggested to increasing the present field allowance.

3.8 Evaluation of Scientists and Their Products

Respondents were asked about the system of scientists' assessment during decisions of hiring, promotion, and tenure. The vast majority of respondents (91%) strongly signaled that higher education (PhD, Mphil), specialization on the subject matter, high number and quality publication records, obtained research grants, dedication on the activities of organization's research objectives, etc. are not considered and necessarily applied consistently during hiring and promotion of scientists/technologist. Same principles are being adopted and in practice while hiring and promoting scientific and technical staff for research and innovation and other administrative/managerial staff for civil services.

3.9 Factor that Motivates Nepali Researchers and Faculties in Science and Engineering

Questions asked in this section were about the motivation of Nepali scientists, technologists, research scholars and university faculties, that kept them working in the research. Irrespective of different factors associated in research and academic organizations, 47% of respondents have strong desire to share/implement what they have learnt, 39% want them to be engaged in research activities, 6 % of each respondents do research to support own organization's objectives and to progress in the field of expertise respectively. 3% of the respondents have given negative answer and did not show his/her interest to involve in the research. As for the question of achievements of organizations on research activities, 54% of them accepted that their organization could not get productive outputs as expected while 40% of respondents gave negative answers with strong dissatisfaction on lower performance of their organization in research and 6% were satisfied in their research. Question related to effectiveness and productivity of researches in government organizations was answered positively by only 9% of the respondents while rest of (91%) the respondents strongly believed that all government research organizations are facing similar problems and going through almost identical challenges. We have checked the relationship between the service period of our respondents and their interest in research and innovation activities which revealed the rejection of null hypothesis ($X2$ (16, 36) = 9.682, p =0.972). However, relation between low performance of research institutes and academia is positively correlated to scientific culture present in the organization ($X2$ (3, 36) = 11.897, p = 0.01607). Both of the above statements clearly indicate that better research culture and integrity in both the person and organization involved depend on collective support among team members and research conduction and support mechanism exist in each institution irrespective of individual attitude and effort for whatever time period.

3.10 Major Barriers for Scientific Research

Barriers to conduct scientific research considered by respondents were: dominance of administrative system over academic activities (33%), lack of trained manpower in the organization (3%), less priority given to research and scientific activities (7%), and finally the large portion of respondents (57%) strongly agreed upon the mentioned former factors and number of additional barriers such as lack of research culture in the organization and inadequate budget for research (Fig. 4).

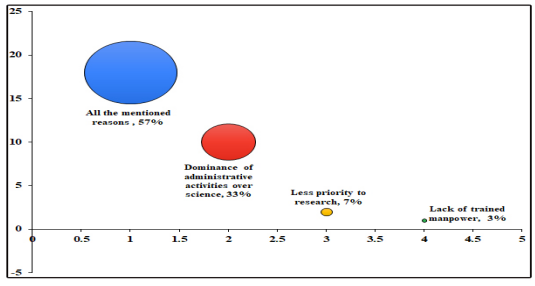

Fig. 4. Barriers for productive research culture in research institutes and academies in Nepal.

Moreover, respondents were requested to choose possible reasons for their outstanding performance during their further education/ training in developed countries but comparatively poor performance back to their homeland. A large number of respondents (36%) considered lack of an appropriate operational framework for research and innovation related activities in their organizations, followed by lack of motivations (25%), and limited budget and poor environment for research (19%). Respondents have also signaled toward less support obtained from the office to conduct research (7%) and irrational spending of available research budget by authorities (6%) (Fig. 5).

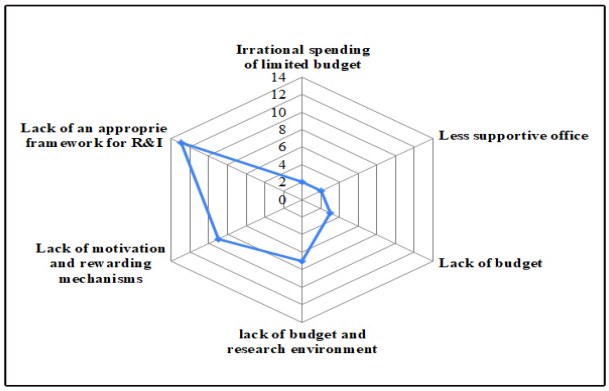

Fig. 5. Respondents' opinion about their poor performance in the organization they are currently affiliated with.

3.11 Access to Infrastructure and Review of Staff Recruitments and Promotions System

All research organizations including academia were found to have lack of equipment necessary to conduct dedicated research as specified in the objectives of each organization. Some equipment even if present was of low quality and others were left idle for longer period due to lack of regular operation and maintenance mechanism. Situation of campuses other than central departments were found even worse where basic equipment, consumables and reagents that help to train students in fundamental researches are lacking.

Hiring scientists and technicians in research institutes follow Civil Service Act 1992 (amendment 2014) and Civil Service Rules and Regulations 1993, formulated by the Government of Nepal. Public Service Commission (PSC) has devised mechanisms to hire fresh candidates and promote the existing staff. Hiring mechanisms are entirely based on written examinations followed by interviews for the candidates who pass the written examination. These examinations are mainly targeted to the fresh graduates who are eligible for civil service. Hiring of skilled and experienced candidates necessary for sophisticated research programs does not seem to be possible through the conventional recruitment mechanisms adopted by PSC. Universities have their own Service Commission. In recent years, Tribhuvan University has started to recruit highly trained and experienced scientists through specialized mechanisms of evaluation, which is based on research performance (scientific papers, research grants and research experience) of the candidate. This modified recruitment mechanism adopted by Tribhuvan University is likely to absorb trained and experienced Nepali researchers working in the developed countries.

As explained in the above answers provided from survey respondents, promotion of scientists/technologist in research organizations follows a very crude system of evaluation by PSC where annual activities of the scientists and his/her colleague working at an administrative division are evaluated in the same type of form

'Annual performance evaluation form' (Barsik Karya Sampadan Mulyangkan). Scientists' publications, research outputs and academic qualification are hardly evaluated as merit for promotion.

4. DISCUSSION

4.1 Policy Formulation and Its Implementation

Progress in scientific research and innovation depends on the evolution of national science policy of the country (Attri 2016). Policy framework of one country may not be equally applicable to another country because of differences in economy, social and cultural patterns and availability of natural resources. In addition to the national development goals, targets of national STI policies should aspire to meet national needs taking consideration of the comparative advantages of the country. Two neighbors of Nepal, China and India and other countries in and around Acia-Pacific viz. China-Taiwan, South Korea and Singapore have timely realized the importance of S&T and prioritized national needs wisely thus are able to leapfrog in technological and economic progress (Qureshi *et al.* 2021).

We are at an initial phase of executing NSTIP-2019. Implementation strategy adopted by concerned authorities will guide the process to translate policy into actions. Implementation of any policies will depend on determinants like policy design, stakeholders and their involvement, institution and context and the execution strategies (Tezera 2019). Therefore, policy execution is considered core of the policy process (Hill & Hupe 2015) and success or failure of NSTIP-2019 will also not depend on its own merits, rather in its process of implementation (Artuc *et al.* 2020). The Ministry of Education, Science and Technology has to strengthen and support this implementation phase to ensure intentions are turned into results.

There are, of course, several challenges to implement NSTI-2019. Major challenges as informed by survey respondents range from limited financial resources, poor physical and communication infrastructure, and lack of innovation ecosystem in the country. In most of the low income countries like Nepal, research is seen as luxury (Harris 2004). Politicians, administration heads and policy makers have a very crude perception that scientists know everything and they can produce results at any time (within the time frame of their tenure). Moreover, politicians think that their role has been completed when they include S&T in their electoral calendars and party's manifesto (Bhuju *et al.* 2021a) and if elected their focus will be on making legislation through policies. Such understanding is equally prevalent in administration heads of research institutes and academia as well. Politicians and administrators/ policy makers should work with scientists, technologists and innovators and prepare a roadmap with clearly defined outcomes (Acharya *et al.* 2021).

Science itself is unprecedented (Lisk 2020), therefore a wisely designed roadmap only can gradually nourish the 'innovation ecosystem' in the country. During Covid-19 pandemics several established laboratories worked together to find the causes and prevention of infection (OECD 2021). In Nepal too, our university graduates who were not accustomed to highly infectious diseases like Covid-19, have successfully operated more than 83 PCR testing laboratories established across the country (MoHP 2021). The first report of Covid-19 in Nepal was not possible to whole genome sequencing inside the country (Sah *et al.* 2020) however, laboratories having dedicated research and diagnosis culture viz. National Health Public Laboratory (NPHL); Tribhuvan University, Central Department of Biotechnolgy; Dhulikhel Hospital, Epidemiology and Disease Control Division (EDCD) and Center for Molecular Dynamics – Nepal (CMDN) were able to carry out whole genome sequencing of Covid-19 within very short time of pandemics. Such an ecosystem might have limited outcomes (disease diagnosis in case of PCR laboratories) during the period of five to ten years however, in the long run research and innovation capabilities of the country will be enhanced substantially (Kreiman & Maunsell 2011; Canti *et al.* 2021). Oslo manual defines innovation as the

introduction of new products or services, use of new process and implementation of novel practices in new organizational settings (OECD/ Eurostat 2018). Innovation does not necessarily mean 'sophisticated products' developed in well-equipped laboratories or in big industries. It could just be a process of 'turning opportunity into new ideas and of putting these into widely used practice" (Tidd *et al.* 2001).Building innovation ecosystem requires an involvement of numerous elements like Actors (all types of social & economic) playing various roles; Capital (financial assets with actors); Infrastructure (physical or technical conditions that support innovation process); Regulations (appropriate laws); Knowledge (formal, informal, specialized or technical knowledge that are available to learn), Ideas (actions or thoughts that activate innovations) and Interface where innovation may get tested and provide positive or negative results depending on the culture, behavior or mindsets of people (Rabelo & Bernus 2015; Granstrand & Holgersson 2020). In this regard 'innovation ecosystem' is a holistic approach of collaboration among several dependent and independent actors inside a network like structure. There is no universal model to build a successful innovation ecosystem because local culture and environment and so do types of expected impacts from heterogeneous actors differ subsequently (Rabelo & Bernus 2015).

In this context successful implementation of NSTI policy 2019 also depends on existing infrastructure and research environment and policy's new intervention that will foster an excellent culture of research and innovation in the country. Studies have shown that even developed countries' immense effort and investment to foster an 'innovation ecosystem' in different sectors were futile and in many cases became less productive (Durst & Poutanen 2013; Olsen & Dahlberg 2013) when relevant enablers were not identified and mobilized effectively.

This is a right time for us to critically review national scientific and technological capacities along with careful evaluations of the hurdles on research and innovations as reported by the respondents. NSTI-2019 policy execution bodies should identify key actors and enablers and their typical inter-relations and outcomes. Such enablers are governmental and increasingly its private sector institutions, those in collaboration can effectively create a rich environment where people can get together to innovate. Given the competitive nature of the global market our competitiveness and ability to innovate will depend on development goals we set to achieve in coming decades. We should be clear on whether we want to become basically a modernization-industrialization oriented country or a country that adopts its own development model conducive to resilience and sustainability through promoting cultural and natural tourism, natural resources management through micro-macro scale enterprises and nature-friendly organic farming taking care of regional as well as globalized challenges such as climate change, biodiversity loss, degradation of arable land and desertification.

4.2 National Perspective on Research and Innovation

Survey conducted to assess the status of research and development in Nepal has helped us to understand relative positions of Nepal and other countries in this sector. Male dominant respondents in S&T sector of Nepal (Singh 2013) has also been reflected in this survey with only 23% participation were females. This proportion of respondents aligns with the regional average (23.9%) of female researchers in Asia and the Pacific region (UIS 2019). Nevertheless, we have to encourage more women to pursue careers in science, technology, engineering and mathematics (STEM) and reduce the gender gap to achieve a better and more sustainable national R&D sector. Promoting gender equality into national STI framework and action plans only can contribute our development concerns adequately (UNCTAD 2011b). Nepal has established a good number of public research institutions working in diverse fields (Bhuju *et al.* 2021a). These institutions can engage a large number of nationally and internationally trained manpower in scientific, technological and innovative activities.

Investment in science and technology plays a key role to progress on economic transformation

and development. Investment on research and development promotes knowledge and innovation which in turn support national development through generating knowledge-capital, trained manpower, establishing new start-up businesses etc (Acharya & Pathak 2019). Currently research oriented governmental organizations in Nepal are solely funded by government budget. In Nepal about 0.35% of governments' annual budget is invested in S&T (UNESCO-Nepal 2011; UIS 2019; Bhuju *et al.* 2021b). Global spending on science and technological research and development of 2019, worth $1.7 trillion dollars and top ten countries from North America, Western Europe and East Asia and Pacific are investing more than 85% of this amount (UIS 2019). Wide gap exists in amounts of investment on R&D between developed and lower income countries including Nepal. GDPs and per capita income of lower countries is very low (<$1500) (The World Bank 2020) and are seriously affected by political instability, poverty, lack of infrastructure and unemployment (Acharya & Pathak 2019). Therefore, every new government's primary agenda would be to fulfill her people's basic need of food, shelter, clothes, education and health. In addition to such challenges, political leaders, policy makers and bureaucrats of developing countries have retrogressive perceptions on scientific researches. They generally consider research as an investment and resource demanding activity (Vose & Cervellini 1981).

Since developing countries' governments in general are unstable, politicians are less willing to fund research activities that do not guarantee visible outputs within a short period. Instead they are interested in funding social issues and physical infrastructures like roads, building, bridges, irrigation canals, etc which can secure their political career (Acharya *et al.* 2021). Despite poverty and lack of modern facilities in rural villages, locals are rich in traditional knowledge on herbal based treatments, wild and local landraces of plants, indigenous breed of livestock, terrace and organic farming and many other aspects of livelihood. A large population of rural people may not have formal education but their level of knowledge on varied subject matter related to their livelihood is very high (Manandhar 2002). Therefore, research and innovation are an integral part of human civilization including ours. Existing traditional knowledge preserved by multi ethnic communities inhabiting different parts of Nepal is attributed to decades-long research effort of that community's ancestors. In this regard erroneous understanding of research and innovation prevailing among our political leaders, bureaucrats and sometimes even with academicians need to be changed (Jayaratna & Wood 2008).

Irrespective of limited financial resources and lack of hi-tech facilities, our initial focus should be on creating a conducive environment and culture of research in our research organizations including in universities. Researchers working in different academic/research organizations but engaged in similar research areas should work together to solve common problems and cross-cutting issues (Shrestha 2006). The first and foremost impediment of the R&D sector in Nepal is investment. The current budg *et al.* location for R&D is not adequate however a good number of respondents also have the opinion that even this limited budget can have a greater impact on productivity growth if invested wisely (Sharma *et al.* 2021).

Limited national budget in the research and development can be supplemented by several international grants available for the research organizations of developing countries (Acharya *et al.* 2021). Such funding will help toward increased research collaboration and internationalization. International research funding results in an enhanced capabilities of scientists in developing countries to tackle local and global challenges (UNCTAD 2007). National STI policy should encourage researchers and academicians for international collaborations. Bilateral or multilateral engagement in research and innovation activities strengthen and upscale our scientific and research ecosystem.

Almost three quarters of respondents participated in the survey informed that their organization has a provision to apply for international funding however all of them did not show their interest to apply because of hurdles they have to face from their own office and uncertainties in leading the project as 'Principal Investigator' by the applicant

himself/herself. Research collaborations with scientists and researchers of developed countries is very important to foster broader scientific progress. International and public funding are essentially supportive in R&D but few respondents complain about cases of bribery/biases prevalent both in government and nongovernmental organization. Biases in funding diverts limited national and international public funding to private pockets and discourage innovative activities (Merkle 2017; Acharya *et al.* 2021).

Developing countries should build capacity to make the best use of an existing human resources and funding (Vose & Cervellini 1981). Although our investment on R&D is very low in comparison with the developed countries, budg*et al.*.location to build necessary infrastructure and procure equipment is improving (Bhuju *et al.* 2021b; Acharya *et al.* 2021). However, corruption in the construction of laboratories, procurement of equipment and reagents drives up costs and leads to substandard infrastructure/chemicals and services (ADB 2020). Procurement of low quality equipment and disproportionate spending of budget allocated for reagents and chemicals was revealed by 78% respondents. Usually procurement of highly sophisticated equipment involves very few bidders or so called an authorized supplier that leads to selection of incrementally higher bidder (Merkle 2017). Due to unfair pricing and unfair profit taking, government research institutions pay up to several times higher prices for research equipment, reagents and consumables than in the developed countries (van Helden 2012). Survey participants were worried about laboratories operation and maintenance costs that usually surge up because of several low quality fabricated/assembled equipment with almost similar technical specification/functions to highly tested/cited equipment. Many research institutions are burdened with a large number of low quality and inefficient equipment. Procurement of low quality equipment in higher prices, expectation of financial benefits by procurement officials and lack of budget required for the operation and maintenance of sophisticated equipment's were identified as key problems to run laboratories dedicatedly in government funded organizations.

4.3 Research and Innovation Culture

Fostering research and innovation culture in a nation as a whole is a long term process. Highly improved and established research culture in developed countries is an effort of many years (Casci & Adams 2020). They are upgrading and improving their research culture with regularity over time (HR 2014). Learnings from developed countries have clearly revealed that we have to work seriously towards building and reinforcing a 'positive research culture'. Survey results have also shown strong correlation between research and innovation culture and performance/productivities of research institutes ($X2 = 11.897$, $p = 0.01607$). In our context of lacking a strong research tradition (Acharya *et al.* 2021), successful practices for initiating and maintaining an excellent culture of research requires effective leaderships having both research and management skills. Lower performance in research institutes and academies in Nepal are also attributed to poorly defined objectives and goals of respective organizations. Clearly defined goals of organizations ensure high research productivity and optimizes use of limited investment. Almost 95% of the respondents have shown dissatisfaction over their organization's achievements. Such a high percentage of dissatisfaction is mostly related to the poor research culture, wrong leadership and lack of comprehensive activities framework prevalent in institutions (Acharya *et al.* 2021). Several research organizations/departments and new universities are mushrooming in the country however their productivity as revealed by our respondents from varied backgrounds is very low. Moreover, poor performances of our research institutes/academia is also ascribed to imitating organizational practices from the western countries without sufficient understanding of the social, cultural and economic factors influencing organizational behavior and its productivity in our context (Chowdhry 1969). Rather to open new universities and research centers, restructuring and up scaling existing institutions should get high priority.

Furthermore, all respondents pointed to the lack of basic research characteristics in Nepali research institutions. Majority of our respondents

themselves have experienced high quality research environments during their higher education/training in developed countries (HR 2014). Studies have listed important features of productive research institutions as recruitment of competent leader and staff in the institution, effective coordinating mechanism among members, emphasis to research and innovation activities, culture of sharing and testing research related values and practices, spirit of research and innovation among scientific and technical members, national and international communication and sharing, access to funding, facilities and research mentorship, sufficient (24/7) work time for team members, recognition of research/innovation and rewards as well as timely promotions, professional development opportunities for researchers/innovators, etc. (HR 2014; Heng *et al.* 2020).

In the institutions with such features the leaders recruited from internal mechanisms or through political appointment are expected to be educated, trained, committed and socialized that match the institutions' goal and objectives. Along with leadership, other scientific, technical and managerial staff must be characterized by high morale, dedicated to work and having a spirit of innovation and receptivity to new ideas (HR 2014; Acharya & Pathak 2019; Heng *et al.* 2020). Unfortunately, all our respondents firmly believe that such characteristics of leadership including scientific and technical staff are not possible from the current systems of recruitment adopted by public service commission of Nepal and political appointments. They emphasized the need for the revision of recruitment and promotion strategies where, dedicated, motivated, innovative, skilled and qualified manpower of all age group (both national and highly trained and experienced manpower from Nepali diaspora from abroad) involved in the scholarly activities can get recruitment/promotion as a leader/staff of the organization. Clear mechanisms for evaluating research productivity of research institutions including members involved in the organization needs to be in place following international practices. Research productivity is measured by counting publication, patent, research awards and research grants. Another evaluation approach considers the quality aspects of scholarly activities through bibliometrics such as H-index, citation counts and citation rates (Agarwal *et al.* 2016). Moher *et al.* 2018 has suggested an improved system of assessing scientists primarily based on impacts of research on society, sharing results of research, reproducible research reporting and research on newer fields of investigation (creative research) etc. Moreover, regular support and motivation to the researchers helps to build robust research culture (Sherab & Schuelka 2019), which need to be improved in Nepali research institutes as highlighted by majority of the respondents. Research institutions including researchers and innovators within the institutions should get autonomy to conduct their research without any hurdles. Following lengthy and cumbersome administrative/bureaucratic procedures to get approval for collecting samples, receiving research funds, conducting collaborative research with national and international partners, and implementing innovative ideas causes difficulties to maintain integrity of the research process. Such practice may look simple to follow however if not managed properly that could cause substantial negative impact in fostering a climate of academic freedom and autonomy inside the nation.

4.4 Role of Scholars and Innovators

Researchers and innovators of developing countries should conduct economically, culturally and socially relevant research activities in the context of priority and the need of the country (Rochmyaningsih 2016; Acharya & Pathak 2019). We have enormous research and innovation opportunities in different sectors viz. agriculture and industry, infrastructure building, communication, health and education service, tourism, environment, biodiversity etc. (Acharya & Pathak 2019; Acharya *et al.* 2021). In many sectors, operational and implementation researches are needed to guide effective implementation of program and facilitate interventions. Outcomes of such research are of use for policy makers in decision making. NSTIP-2019 should focus on building capacity to generate knowledge and evidence that are necessary to implement programs effectively and bring sustainable changes in every development sector.

Scientific publications are instrumental to generate, present and document facts, knowledge and evidence. Despite low priorities and recognition (as informed by 69% respondents), of publication by academia and scientific institutions, researchers should continue publishing standard research articles. Scientific publications including popular articles/books/booklets can inform communities, bureaucrats, politicians and an international community about the actual status of our development sectors, necessary interventions for improvement and finally demonstrate our research capabilities. No matter how hard scientists/innovators work and produce results, all our outputs go in vain if we limit our findings among academic circles and do not communicate with decision makers who only have power to implement our findings through policies (Safford & Brown 2019). We must effectively collaborate with local, state or central government authorities and policy makers who make laws and regulations. Scientists should be humble and open and try to establish relationships with elected political leaders and government authorities to translate scientific evidence into policy. Collaborating with private and public research institutes, journalists, government officials, lawmakers and professors working in common issues improve effectiveness of policy dialogue from local to central governments and guide them in political decisions using scientific knowledge to address social issues (Rosen 2018). Unfortunately, many societal issues related regulations and plans of actions prepared and ready to be implemented are not normally solicited for rigorous public feedback before its execution. In other hand scientists should not be attached with a single solution, being an 'honest broker' he/she should have a capacity to convince policy makers about other policy options and their consequences as well (Pielke 2007). Globally scientists are always blamed for working in a small team and isolated both within a lab and between labs (Schrum & Campion 2000). We should understand science as a social activity because research and innovations are mostly to support our livelihood and those require inputs from the people who will be the end user in the future (Wiley 2020).

5. CONCLUSION

Implementation of action plans formulated in NSTIP-2019 helps to translate policy into actions. Multiple factors act independently or in interactions to enrich national capabilities on science, technology and innovation. Identification of these enablers and finding their typical inter-relations determines the NSTIP-2019 successes and failures. Survey respondents working in governmental research organizations and universities has strongly highlighted limitations present in the broader mechanism of STI activities implementation framework. Lack of research and innovation ecosystem in the country has been identified as a major challenge to achieve growth in the national economy through STI undertakings. These challenges are rooted in the level of planning and visions of politicians, bureaucrats and even with academicians. In addition to existing limitations, general agreements among respondents on key enablers for improvements analyzed and discussed in greater depth are: increase budgetary allocations and role of industries and private sectors in STI activities; encourage national and international collaborations; establish dedicated infrastructure; revive and restructure existing organizations; reform recruitment, promotions and motivation mechanisms; promote quality publications; maintaining morale and research integrity in the work place etc.

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