Perspectives of STEM Education and Policies for the Development of a Skilled Workforce in Australia and India

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Abstract
In an increasingly competitive world, invention, development, and profusion of new technologies through science and technology are the fundamental source of economic progress. Australia, is one of the world leaders in education and India has the capacity to produce the highest number of young skilled manpower to lead the world. Both countries understand the current situation and have signalled their commitment to restoring a national strategy for STEM education. The study focuses on a comparative understanding of the interplay of inclusive policies, governments' initiatives, knowledge gap and potential future challenges that Australia and India could face in STEM education at the school level. The question we asked is: What are the important inferences and best practices in STEM education that can be mutually beneficial to broaden a Strategic Partnership? The governments of both the countries are determined to utilise the young population for a skilled workforce in order to meet the future demand of industries. Australia's constructivist approach to education and the well-defined system of vocational training outperform India, which is still following the traditional

approach. However, Australia has failed to engage students adequately in STEM and needs to revisit the efficacy of the current education model, while India needs to adopt the well-defined Australian framework, which could help to enhance quality infrastructure, curriculum, constructivist teaching, and transparent policy implementation. In addition, both nations must work hard to attract high performing students in the teaching profession in order to promote a conducive environment for scientific learning.

Key Words: STEM, policy development, , high school, constructivism

Introduction

The term SMET first appeared in 1993 at one of the programmes of the National Science Foundation (NSF) to improve the quality of the USA's science, mathematics, engineering, and technology (SMET) education (Mohr-Schroeder, Cavalcanti, & Blyman, 2015). However, in 2001, Judith Ramaley, the director of NSF at the time, reordered the words to show a more interdisciplinary emphasis:

I did so because science and math support the other two disciplines and because STEM sounds nicer than SMET. The older term subtly implies that science and math came first or were better. The newer term suggests a meaningful connection among them.(Chute, 2009)

Now, the term 'STEM' is being used frequently in the education sector and is gaining increased popularity day by day. STEM integrates all four discrete disciplines to develop the skills required for designing processes through creativity, developing technologies and discovering needs-based practical solutions. In an increasingly competitive world, education has long been a driving tool for economic well-being which directly impacts the economic growth of nations. Earlier research also supports significant positive associations between quantitative measures of schooling and economic growth (Barro, 1991; Lavergne, Doppelhofer, & Miller, 2004; Mankiw, Romer, & Weil, 1992). Three main mechanisms have been emphasised which can have an impact on education (Hanushek, Wößmann, Jamison, & Jamison, 2008). First, education can increase the productivity and outcome by integrating human capital in the labour force (Mankiw, et al., 1992). Second, education contributes to the growth of the economy by introducing new knowledge for new technologies, products, and processes (Aghion, Howitt, Brant-Collett, & García-Peñalosa, 1998; Lucas, 1988). Third, education can facilitate the diffusion and transmission of knowledge to share or understand available technologies (Benhabib and Spiegel, 1994; Nelson and Phelps, 1966). Nevertheless, the impact of education has been effected with many other factors also like differences in cognitive skills, health and cultural believes. (Hanushek, et al., 2008).

Latest reports confirm that innovation, creativity, problem solving attitude, critical thinking and profusion of new technologies have become the key to success for the future economy and jobs (Rothwell, 2013; Scientist, 2014). Rising global problems such as climate change, health, biodiversity, ecological sustainability and economic prosperity followed by declining enrolment trends in STEM education have forced policy makers to take serious steps in creating an interest and to motivate children towards the undertaking of STEM education (Ali and Shubra, 2010; Elías, 2009; Sjøberg and Schreiner, 2005). The Australian and Indian governments are aware of the present situation and have signalled their commitment to redesign and restore the focus on a national strategy for STEM in schools. Both governments are committed to train and inspire the youth of their nations and produce a skilled workforce that would make invaluable contributions to their STEM industries. The vision for Australia and India is to provide an innovative education system that supports students' interests, inherited skills, achievements through well-resourced infrastructure and a trained passionate team of teachers (*National Innovation and Science Agenda Report* 2015; *National Policy on Education* 2016).

This study focuses on a comparative understanding of the interplay of inclusive policies, governmental initiatives to address STEM education, knowledge gap and future challenges faced by Australia and India in STEM education at the school level. Both the countries have strong historical bilateral cooperation in education and research, economic relationships and common priorities for their future development. The question we asked is: what are the important inferences and best practices in 'STEM education' that can be mutually beneficial? The outcome of the study may help to strengthen the ongoing tie-ups as education is acknowledged as a central pillar of strategic partnership between both the countries. Australia has also become one of the preferred destinations for Indian students for higher education.

Methodology

A descriptive case study approach has been adopted to compare the research literature, policy documents and educational philosophies of both the countries. The literature includes published research papers, policies, position and issues papers, and impact of ongoing major science and technology (S&T) programmes in both the countries.

Perspectives

Australian system of Education and Policies

Education Structure

In Australia, school education is compulsory for children between six and sixteen years of age (Year 1 to Years 9 or 10) and is divided into primary (Kindergarten/Preparatory to Years 6 or 7), secondary (Years 7 to 10 or 8 to 10) and senior secondary school (Years 11 & 12). There are a total of 9414 schools (71% government, 18% catholic and 11% independent) with 3,778,656 students (65.3% government, 20.3% catholic and 15.5% independent) and 394,763 teachers, as per the data published by the Australian Curriculum, Assessment and Reporting Authority (ACAR) in 2016 (National Report on Schooling data in Australia, 2015).

The Australian Science Curriculum, is organised around three interrelated strands: science understanding, science inquiry skills and science as a human endeavour, aligns science with the Australian government's national priorities (Shape of the Australian Curriculum: Science, 2009) and draws significance of two important science research documents. The first one is the Australian School Science Education National Action Plan 2008–2012, which argues that the fundamental purpose of school science education is to promote scientific literacy in each student to understand the basic scientific concepts and their use to address the societal need in their daily lives (Goodrum and Rennie, 2008). The document emphasises ~~on~~ reforming the curriculum, improving the quality of teachers and engaging the community. However, another document (Taylor, Tobin, & Cobern, 1994) significant on 'Redesigning Science Education' to overcome the diminishing proportion of students in the post-compulsory years who are undertaking science-related studies, particularly in the physical sciences. The document also highlights the shortage of professional science teachers in Australian schools and the shift in momentum of science-based development towards developing countries (Tytler, 2007). It is well understood that countries having high quality teachers like Finland concentrate on attracting the brightest students as teachers and nurturing teacher leadership talent through adequate support and professional development programmes ("Finland: Teacher and Principal Quality," 2017; Sahlberg, 2011; Stewart, 2010).

Current situation of STEM education

Although, Australia is producing 2.6 percent of the OECD nations' total number of science and engineering graduates at the doctorate level (Pettygrew, 2012), significant changes have been occurring in Australian school science education in ~~the~~ recent years. The Australian Council for Educational Research (ACER) released a national report on the 'Trends in International Mathematics and Science Study' (TIMSS), and the 'Programme for International Student Assessment' (PISA)' which showed that Australia's performance and ranking in these international programmes has declined in mathematics and science when compared with the top five countries (Thomson, De Bortoli, & Underwood, 2017; Thomson, Wernert, O'Grady, & Rodrigues, 2016). Australian students performed above the Organisation for Economic Co-operation and Development (OECD) averages, but are not comparable to their Asian counterparts, such as Shanghai, Singapore, Japan and South Korea (Scientist, 2014). The results of PISA 2015 showed that Australia slipped to the 10^{th} position (from being the 8^{th} in 2012) in science, 20^{th} in maths (from 17^{th}) and 12^{th} in reading (from 10^{th}) (Thomson, et al., 2017). Apart from these reports, a recent datasheet released by the office of the Chief Scientist also showed that participation in most Year 12 mathematics and science subjects is declining and it was observed to be the lowest for science in 20 years. Datasheets reflect that only 1 in 10 students completed advanced maths in Year 12 ("Science and Maths in Australian Secondary Schools," 2016).

These reports are not encouging for the country when STEM literacy is becoming the core part of every industry or occupation to support innovation and enhance productivity. TheAustralian

Bureau of Statistics predicted the increase in professional, scientific and technical services by 14 percent and almost 20 percent in health care in coming years. A PricewaterhouseCoopers report also estimates that changing 1 percent of Australia's workforce into STEM-related roles would add $57.4 billion to the Gross Domestic Product (GDP) (Australia, 2015; Perspectives on Education and Training: Australians with qualifications in science, technology, engineering and mathematics 2010-11).

National STEM Policies

The trailing average scores in international tests, the large achievement gaps between students with different backgrounds (Thomson, et al., 2017; Thomson, et al., 2016), the decreasing number of science students (Kennedy, Lyons, & Quinn, 2014; "Science and Maths in Australian Secondary Schools," 2016) and increased demand of scientific skills among future generations all constitute a 'national concern' for STEM education.

By keeping the above in mind, the Australian government is proactive in implementing the strategies necessary for maintaining this focus throughout schooling. Planning and initiatives are focussed on promoting the problem solving, critical analysis and creative skills that lift foundational skills in STEM learning areas. Five key areas were identified to make a significant changes at the foundation level of education: increasing student STEM ability, engagement, participation and aspiration; increasing teacher capacity and STEM teaching quality; supporting STEM education opportunities within school systems; facilitating effective partnerships with tertiary education providers, business and industry, and building a strong evidence base (National STEM School Education Strategy 2015).

TheAustralian education ministry identified literacy and numeracy as the foundation pillars of schooling for young Australians and released the National STEM School Education Strategy 2016–2026 with the aim to coordinate current activities, and improve STEM education (Mohr-Schroeder, et al., 2015). The Office of the Chief Scientist of Australia under the Department of Industry, Innovation and Science also understands the need to promote science and provided fresh momentum for national focus on STEM education (Science, Technology, Engineering and Mathematics: Australia's Future 2014). Statement available on the Chief Scientist's website describes their role in the promotion of STEM (National Report on Schooling in Australia 2010):

'Science is infrastructure and it is critical to our future. We must align our scientific effort to the national interest; focus on areas of particular importance or need; and do it on a scale that will make a difference to Australia and a changing world'.

A series of reports, media statements, interviews, public appearances, and policy papers released in the last few years seem to be supportive of STEM education (Carter, 2016). TheNational Innovation and Science Agenda (NISA; also known as the Ideas Boom), a policy centre piece of the Turnbull government announced in December 2015, to 'inspire all Australians – from pre-schoolers to the broader community – to engage with STEM' confirms that science and innovation are key factors for a prosperous Australia with a generous social welfare safety net. Its website describes the agenda thus (*National Innovation and Science Agenda Report* 2015):

‘Innovation and science are critical for Australia to deliver new sources of growth, maintain high wage jobs and seize the next wave of economic prosperity. Innovation is about new and existing businesses creating new products, processes and business models’.

Innovation and Science Australia (ISA) was established to develop a 2030 Strategic plan as an independent statutory body to provide a vision, set goals, outline the actions required and review the performance of innovation, science and research system of the nation (Carter, 2017b). The National Science Statement (NSS) was produced to facilitate ISA and to ‘bring the collective strengths together & guide investment and decision making in the longer term’ to develop an explicit framework and enduring science objectives ("Australia's National Science Statement ", 2017; Carter, 2017a, 2017b).

Teacher’s philosophies

Despite all the proactive initiatives of the Australian government, issues are identified in Australian elementary teachers as lacking sufficient pedagogical content knowledge, confidence in teaching science, use of available resources to teach science and motivation to prepare science lessons. As a result, science is one of the least taught learning areas, with as little as 5 percent of the total teaching time dedicated to it (Appleton, 2003; Chubb, 2012; *Mathematics, Engineering & Science in the National Interest*, 2012). The issues have been the same in science teaching in the last 30 years, where the focus has predominantly been on ‘supply and demand, attracting quality recruits and providing quality outcomes for the nations’ students (Dyson, 2005).

To address the crisis of insufficient skilled science and mathematics teachers, the Australian federal government has introduced various national standards and established various organisations to improve the accountability of school and teacher education. The Australian Institute for Teaching and School Leadership (AITSL) was formed in 2011 to define and maintain the national standards for teachers and the national accreditation procedures for initial teacher education programmes (AITSL, 2013a; "Australian Institute for Teaching and School Leadership," 2018; *Australian Professional Standards for Teachers*, 2011). The Minister of Education also appointed a panel of experts for the Teacher Education Ministerial Advisory Group (TEMAG) to 'provide advice on how teacher education programmes could be improved to better prepare new teachers with the practical skills needed for the classroom' in early 2014 (Teacher Education Ministerial Advisory Group, 2014).

Skill development programmes

Other than formal education, vocational education and training (VET) has been part of the Australian school education system for decades and was supported by a series of goals for national collaboration set out in the Adelaide Declaration on National Goals for Schooling in the Twenty-first Century ("Vocational Education and Training," 2018). The National Goals articulate the need for a paradigm shift in the way schools develop and deliver school education and further strengthen schools as learning communities where teachers, students and their families work in partnership with business, industry and the wider community (Force, 1997a, 1997b; *Gender equity: A framework for Australian Schools*

1997; Taskforce, 1997; Watters and Christensen, 2013). The Australian education system focuses on strong linkages between t~~he~~ schooling, and the vocational and higher education systems to make these sustanaible and credible.

STEM for School Initiatives: Government of Australia

Significant activities are going on all across the country - within schools, school systems, universities, amongst communities and the business world to improve and encourage STEM education. The Australian government funds school-based programmes like ‘Early Learning STEM initiatives’, ‘Let’s Count’, ‘Little Scientists’, ‘Early Learning STEM Research’ and ‘STEM partnerships with schools’ under the ‘inspiring all Australians in digital literacy and STEM’ measures of the NISA ("Support for Science, Technology, Engineering and Mathematics," 2017).

As an attempt to assist the nation’s science agenda and meet the quality standards, various science learning materials have been widely introduced at school level such as ‘Primary Connections’, an innovative initiative of the Australian Academy of Science (AAS), which aims to enhance primary school teachers’ confidence and competence in science teaching. It focuses on developing students’ knowledge, understanding and skills in both science and literacy ("Primary Connections ", 2017). ‘Science by Doing’ is a comprehensive online science programme for Years 7 to 10, available free to all Australian students and teachers and supported by award winning professional learning modules. The Scientists and Mathematicians in Schools (SMiS) programme is a major Australian initiative funded by the Department of Education and Training of the Australian Government in conjunction with the Commonwealth Scientific and Industrial Research Organisation (CSIRO), which delivers the programme through a national SMiS programme team. The programme involves volunteer STEM professionals working in partnership with teachers in primary and secondary schools to engage students in quality learning in the STEM disciplines. Since its inception in 2007, the programme has facilitated almost 6,000 partnerships and on average reaches over 60,000 students per year (Program evaluation, 2007).

The BHP Billiton Science and Engineering Student Awards are Australia's most prestigious school science and engineering awards with partnership between CSIRO, the BHP Billion Foundation and the Australian Science Teachers Association to reward young people who have used technological innovation to design needs-based invention. The programme was given almost $65 million for the professional development of teachers, and to pay for specialised STEM programmes in classrooms ("The BHP Billiton Foundation Science and Engineering Awards," 2017). This programme also provides an opportunity to Australian students to participate at the Intel International Science and Engineering Fair (Intel ISEF), the world's largest international pre-college science competition, held annually in the United States of America, similar to the Initiative for Research and Innovation in Science (IRIS) programme in India ("IRIS National Science Fair," 2017).

Australia's national science channel RiAus also produces thought-provoking and entertaining events, broadcasts and publications as well as education and teacher support programmes, aimed at middle and secondary school teachers (*STEM Programme Index* 2016).

Linkages with tertiary institiutions

The Australian government has taken initiatives to create innovative partnerships between schools and universities, and other relevant organisations which provide hands on experience to school students in world class universities. The 'Australian Mathematics and Science Partnership Programme', the University of Adelaide's 'Digital Technologies MOOC', supported by Google, 'STEM for Schools' of Queensland University of Technology, 'Cracking the Code', which offer fun and engaging coding activities and challenges for Years 4 to 12 students developed by the University of Sydney, CSIRO's 'STEM partnership with schools' ~~the~~ 'CREativity in Science and Technology' (CREST) awards, and the Young ICT Explorers competition are few initiatives of Australian research and higher education institutions to improve the quality of pedagogical experts at the school level. There are many subject-based programmes like 'The Professor Harry Messel International Science School', 'LabRats', 'The Learn Experience Access Professions (LEAP) Programme', 'Science Outreach and Science in the City', developed and offered by different world leading Australian universities to make networking among tertiary institutions, STEM professionals and school students. Apart from the above programmes, 'Curious Minds' and 'Coding Across the Curriculum' have been funded by the Industry, Innovation and Competitiveness Agenda. All these programmes aim to encourage talented young people to pursue further studies and careers in science ("Support for Science, Technology, Engineering and Mathematics," 2017).

Teacher's professional development

Many reports analysed the commonalities of best-performing school systems in the world and identified teachers as the single most important factor in improving students' performance within schools (Barber and Mourshed, 2007; Hattie, 2008). Barber and Mourshed (2007) highlighted their key arguments by stating that ‘the quality of an education system cannot exceed the quality of its teachers’ and that ‘the only way to improve outcomes is to improve instruction’ (Hattie, 2008). The Australian government acknowledges this fact and has formulated many needs-based programmes to support Australian school science educators and technicians. The National Science Teachers Summer School (NSTSS), a five-day professional development programme is an Australian government initiative for experienced and new secondary science teachers from across Australia, which has been offered for more than fifteen years ("National Science Teachers Summer School," 2018). ‘ReSolve: Mathematics by Inquiry’ is a new bold national programme, managed by the AAS in collaboration with the Australian Association of Mathematics Teachers to promote innovative approaches to mathematics teaching in Australian schools ("ReSolve," 2018). ‘Enhancing the Training of Mathematics and Science Teachers’ programme, involving 25 universities funded by the Australian government, provides innovative approaches and supplies the evidence base which is needed for action ("Enhancing the Training of Mathematics and Science Teachers Program," 2018).

Indian system of Education and Policies

Education System

‘Swadeshe pujyate raja, vidwan sarvatra pujyate’ meaning ‘a king is honoured only in his own country, but one who is learned is honoured throughout the world’ was written during the Vedic period. This strongly exemplifies the importance of education in ancient India. The Indian Education system is among the largest and most complex in the world, with about 26 crore children enrolled in classes 1 to 12, located in 36 states and union territories, 683 districts, about 7300 blocks and more than 82,000 clusters, covering more than 15.1 lakh schools; the total number of teachers functioning in the system (both in public and private schools) is of the order of 80 lakhs. This elaborated system is shared by nearly one fifth of the population and provides a platform to interact directly through the teaching and learning process (National Policy on Education 2016; School Education in India, 2014-15).

The National Council of Educational Research and Training (NCERT) is an apex resource organisation set up by the government of India with the objective of assisting and advising the central and state governments on policies and programmes for qualitative improvement in school education ("National Council of Educational Research and Training," 2018). The Central Board of Secondary Education (CBSE), Council of Indian School Certificate Examinations (CISCE), state government boards and National Institute of Open Schooling (NIOS) are the biggest national boards of education for public and private schools, following the uniform '10+2' pattern of education (Indian School Education System: An Overview, 2014). This system follows the recommendation of the Kothari Education Commission of 1964 – 66: elementary education consists of primary (for 6-10 year olds) and upper primary levels (for 11-14 year olds) while secondary education consists of secondary (for 14-16 year olds) and higher/senior secondary levels (for 16-18 year olds) (Commission and Kothari, 1966). The 2009 Right to Education (RTE) Act, provides schooling for free and it is compulsory for all children from 6 to 14 years old.

Current situation of STEM education

In spite of the commendable work of ancient Indian scholars like Charaka, Susruta, Aryabhata, Bhaskaracharya, Chanakya, Patanjali and Vatsayayna and numerous others in diverse fields of science and technology, the scenario has changed in the present world. It is pertinent to point out that whilst the school education system in India is increasing its emphasis on the two endsubjects of the philosophy acronym STEM, neither engineering nor technology are part of the regular curriculum of pedagogy (*National Policy on Education* 2016). Science education is facing three practical challenges in India: availability and access of basic infrastructure and scientific equipment ~~to be~~ used while teaching science, shortage of quality teachers who are equipped with ~~in~~ the latest knowhow in their respective fields and the nation's science curriculum, which needs immediate attention (Malti, 2017; Sarangapani, 2017). Lacking critical thinking, inquiry-based learning and hands-on learning are the major reasons for the large number of dropouts from science education at the high school level. Apart from good infrastructure and quality teachers, a remarkable gap in administration, in addition to the academic and casual attitude of regulators have all contributed to the diminished quality of the Indian education system. The parallel business of paid academic coaching is a clear indicator of the lack of credibility of the Indian school system (*National Policy on Education* 2016).

National STEM Policies

India has made remarkable progress since independence and established the department of education and literacy under the ministry of human resource development on August 29, 1947 with the objective of expanding educational facilities. The National Policy on Education, as formulated in 1968 and 1986 and then modified in 1992, recognises education as a precondition for development and sets out three critical issues - equity, accessibility and quality. Despite the robustness in conception and orientation, earlier education policies failed to change the state of education in last several years. However, the 'National Policy on Education 2016' during 12 Five Year Plans (recent policy planning) recognised education as the most important tool for social, economic and cultural transformation and emphasised on innovation, critical thinking and skills development. This identified four essential components: building values, awareness, knowledge and skills to enable citizens accomplish~~ed~~ and be competent for contribution in the nation's well-being, strengthens democracy, and fosters social cohesion (*National Policy on Education* 2016).

In conjunction with its education policy, India's Scientific Policy Resolution (SPR) of 1958 also resolved to 'foster, promote and sustain' the 'cultivation of science and scientific research in all aspects'. Science, technology and innovation have been identified as the drivers that have the potential to accelerate India's sustainable and inclusive growth (*Science, Technology and Innovation Policy* 2013).

Teachers' philosophies

India is known to put *Gurus* (teachers) on a high pedestal, yet, it is in need of a trained army of teachers to lead the next generation of students. There are disproportionate numbers of young people from the arts and social science backgrounds rather than mathematics and science offering to be trained as teachers. Most of the primary school teachers are not confident about their own knowledge of mathematics and science. Inappropriate education of teachers is also one of the reason for poor quality teachers. The initial one-year bachelor of education (B. Ed.) with the option to pursue through distance education does not equip the future teacher with the required subject knowledge or teaching skills. The quality and infrastructure of most of the educational institutions who provide these degrees are still far from satisfactory. This has resulted in the employment of teachers with low academic knowledge and inadequate pre-service training in government schools, in the last 3-4 decades. Recently, the RTEact and the National Council for Teacher Education (NCTE) have laid down undergraduate degree as an entry level qualification for teachers of upper primary sections with a compulsory two-year B. Ed. course which might result in better quality teachers in the future. However, till then the system will have to depend on existing teachers who are not so proficientto improve learning standards in government schools (*National Policy on Education* 2016).

Skills development programmes

Another reason to leave the science field by students is that there is no rigorous attempt to make formal linkages of vocational fields with academic accomplishments and provide avenues for horizontal and vertical mobility in India. However, the formulation of a new comprehensive national policy for skills development and entrepreneurship in 2015 to envision the integration of 25 percent of the schools with the skill development programmes by 2022 showed the vision of the Indian government in making 'Skill India' (*National Policy on Skill Development and Entrepreneurship* 2015).

The government's efforts can also be seen through Rashtriya Madhyamik Shiksha Abhiyan (RMSA) which has been revisited, revamped and redesigned as 'Vocationalisation of Higher Secondary Education' during the 12th Plan to impart skills to the students from Years 11 onwards. Under this scheme, more than 0.15 million students have been trained in 3,000 schools across 16 states to date ("Rashtriya Madhyamik Shiksha Abhiyan ", 2017). This scheme is in parallel to the ongoing vocational education training (VET), which has been running in Australian schools to train high school students since decades in different vocational skills. The VET curriculum is relevant and provides diverse opportunities, in addition to post school pathways including entry into university, Further, VET apprenticeships and traineeships, and employment, VET in schools improves student retention and trains them to join the skilled workforce as compared to other school leavers (Tom, 2007).

‘STEM for School’ Initiatives: Government of India

By taking advantage of the demographic dividend, the Indian government is working hard to foster scientific temperament among school students through various interesting programmes and providing them research training opportunities to build a skilled workforce. The major science and technology programmes of the Indian government for school students are as follows:

National Children's Science Congress (NCSC)

NCSC is a nationwide flagship programme of the Department of Science and Technology (DST), government of India, initiated in 1993. NCSC invites open-ended scientific projects from an individual or team of young innovators, based on different themes since its inception and provides a platform to approximately 1 million children aged between 10 and 17 years every year, to exhibit their creativity and innovation to address societal problems through the intervention of Science and Technology (S&T).

The increase in the number of NCSC projects from 304 in 1993 to 11,739 in 2016 with approximately 2,357,600 of indirect beneficiaries in one of the largest states of India (Uttar Pradesh) demonstrates its popularity among young children and their huge participation (Table 1, data was not available for entire country). Annually, about 650 projects from across the country participate in NCSC ("National Children Science Congress," 2017a; "National Children Science Congress," 2017b).

Innovation in Science Pursuit for Inspired Research (INSPIRE) Programme

INSPIRE is an innovative programme developed by the DST in 2008 during the 11th Plan with long term foresight for attracting young talent to the excitements of a creative quest for science as a career option and building the required critical human resource pool for strengthening and expanding the research and development base in the country. The INSPIRE scheme includes three components to facilitate all categories from school students to young researchers to do research (see Figure 1). Recently the INSPIRE Award - MANAK (Million Minds Augmenting National Aspiration and Knowledge) has been revamped to align with the action plan for the 'Start-up India' initiative launched by the Honorable Prime Minister of India ("Innovation in Science Pursuit for Inspired Research ", 2017; "INSPIRE Awards - MANAK," 2017).

INSPIRE Awards target approximately 0.2 million of school children every year within the age group of 10 to 15 years; that is Year 6 to 10 and provide an opportunity to showcase his/her imagination, innovation and creativity through science and technology. About 1,408,551 INSPIRE Awards, 28,000 scholarships for students in the age group of 17 to 22 years, 2,900 INSPIRE Fellows in the age group of 22 to 27 years and 378 individuals under the Faculty Award for Assured Career have been awarded to encourage individuals to undertake a STEM career and participate in research work during its inception. Currently, under the INSPIRE Internship, about 800 Science Camps have been held covering about 0.2 million students between 16 to 17 years and the participation of 40 Nobel Laureates, alongside 8,000 resource persons ("E Management of INSPIRE Award Scheme," 2017; "Innovation in Science Pursuit for Inspired Research ", 2017).

The Initiative for Research and Innovation in Science

The Initiative for Research and Innovation in Science (IRIS) is a research-based programme introduced in 2006 to infuse the spirit of discovery, increase interest in STEM and build a robust scientific attitude among the young innovators of the country. IRIS is an outstanding example of public–private partnership initiated by the Intel Technology India Private Ltd (Intel) with the DST, and the Indo-US Science and Technology Forum (IUSSTF). The fair promotes and nurtures science and scientific research among young Indian innovators and provides a platform for winning students to represent India at the Intel ISEF, similar to The BHP Billiton Science and Engineering Student Awards of Australia. To date, 113 awards have been won at ISEF by Team India with 127 winners ("The BHP Billiton Foundation Science and Engineering Awards," 2017; "IRIS National Science Fair," 2017).

Science Express

Science Express, a mobile science exhibition is an innovative mega outreach programme of the DST, with the partnership of the Ministry of Environment, Forest and Climate Change, Indian Railways, Department of Biotechnology, Wildlife Institute and Vikram A. Sarabhai Community Science Centre (VASCSC) mounted on a 16-coach air conditioned train. Science Express was launched at the Delhi Safdarjung Railway station on October 30, 2007 with the objective of arousing the interest of young people in the field of science and technology. To date, this unique mobile exhibition has completed nine phases, which includes four phases of ‘Science Express’~~, three~~ phases of ‘Biodiversity Special’ (SEBS) and two phases of ‘Climate Action Special’ (SECAS). So far, it has travelled 141,800 km, has had 455 halts, and has been visited by more than 18 million people in 1602 exhibition days, primarily composed of students and teachers (approximately 45,000 schools, 4.067 million students and 0.22 million teachers) (see Table 2). It has thus become the largest, the longest running and the most visited mobile science exhibition having twelve entries in the Limca Book of Records with extensive media coverage ("Science Express," 2017).

Atal Tinkering Laboratories

With a vision to cultivate one million children in India as neoteric innovators, Atal Innovation Mission is in the process of establishing Atal Tinkering Laboratories (ATLs) in schools of minimum Years 6 to 10 to foster curiosity, creativity and imagination in young minds; and inculcate skills such as design mindset, computational thinking, adaptive learning, and physical computing. ATL, designed to provide a work space with equipment and tools where young minds can give shape to their innovative ideas through hands on do-it-yourself mode to understand the concepts of STEM. Nine hundred and forty-one ATLs have been granted to date under this mission in different public and private schools ("ATAL Tinkering Laboratories - Innovation Challenge ", 2017).

Science Exhibition

Since 1971, NCERT has been organising an annual national level Jawaharlal Nehru National Science, Mathematics and Environment exhibition with a view to encourage, popularise and inculcate scientific attitude among children at the state and national levels.. The exhibition provides an opportunity to students and teachers to showcase their talents, network and listen to eminent scientists and scholars ("Science Exhibition," 2017).

Apart from the programmes as listed above, there are many other non-governmental, non-profit organisations like the Science Society of India (INSEF) ("Indian Science & Engineering Fair," 2017), the International Movement for Leisure Activities in Science and Technology (MILSET) ("MILSET - Mouvement International pour le Loisir Scientifique et Technique," 2017), Amity’s Children Science Foundation ("Amity's Children Science Foundation ", 2017), which organise many regional, state and national science fairs to promote science activities and provide opportunities to students to participate at ~~the~~ national and international science competitions.

Linkages with tertiary institutions

In spite of having the world's largest higher education system, which includes technical education with 799 universities, 39,071 colleges (*Annual Report* 2014-15) and 11,923 stand-alone institutions in India (*All India Survey on Higher Education*, 2015-16), it is becoming difficult to link school education with tertiary institutions to motivate school students, make use of infrastructure and knowledge base, and spread awareness about available future STEM career options. Not a single ongoing programme of the government of India is implementing through linkages of schools and tertiary institutions.

Teacher's professional development

The DST provides a platform to the teachers of the country through the National Teachers Science Congress (NTSC) to develop and share an innovative teaching-learning methodology in the fields of science and mathematics education. To date, seven NTSCs have been organised as a biannual activity with the participation of thousands of teachers ("National Teachers' Science Congress," 2017). The Department of Education in collaboration with NCERT also provides pre-service and in-service training of teachers in the fields of science and mathematics ("National Council of Educational Research and Training," 2018).

Discussion

Science and technology in Australia and India have significant scope for bilateral cooperation as several Australian and Indian universities have already established joint research facilities (Science Technology Innovation: Australia and India, 2013). Collaboration within both the countries can be seen as an investment in innovation of capital and skills development with collaborative research and development projects. The governments of both the countries are working passionately to achieve the desired goals, but Australia outperforms India on most international comparisons with regards to students' performance and net spending on education. The PISA study of 74 countries has ranked India virtually at the bottom in performance in mathematical literacy and scientific literacy (Thomas and Watters, 2015).

Expenditure on Education

The Indian National Education Policies have endorsed a norm of 6 percent of GDP as the minimum expenditure on education (*National Policy on Education* 2016) and 0.88percent of its GDP towards research and development (*Research and Development Statistics* 2011-12) as compared to 3.2 percent on education and more than 2 percent of GDP on research and development in Australia. Yet, the expenditure by the Education Departments of the Centre and States has never risen above 4.3 percent of the GDP, and is currently around 3.5 percent in India (*National Policy on Education* 2016). The limited contribution of the private sector in research and development drag behind the desire of the government of India to invest 2 percent of GDP on research and development ("GDP in Science Research," 2014).

Shortcomings

India's education system has evolved through ancient culture, moral practice and Vedic literature, followed by many shifts as per the rulers' religion, in sharp contrast to the Australian system, which has directly inherited a modern European system and has evolved through a far more focussed and competency-centred approach of education (Singh, 2014). Despite the Right to Free and Compulsory Education (RTE) act introduced in 2009, the Indian education system is facing more challenges in comparison to other nations, due to its cultural diversity and population size. Nonetheless,, Indian parents are very aspirant and desire 'higher' education specially in science and mathematics for their children. Australia's long experience in the successful implementation of a similar model of free education can be shared as best practice for effective implementation of this act. Science curriculum reforms, poor infrastructure, poor quality teachers and the lack of specialised education to identify early talents are key requirements to improve STEM education in India. However, it has become clear that the implemented specific curricula and pedagogy in Australia have failed to engage students adequately in STEM. Recognition of self-efficacy followed by encouragement to enhance the problem-solving capabilities in mathematics and engagement in investigative processes in science are significant innovations that are capable of engaging students, with appropriate pedagogical support in Australia. The Report of the Australian Education Department also suggests that the key to engaging students lies not so much in the nature of subject content, but rather in pedagogy (Tytler, Osborne, Williams, Tytler, & Cripps Clark, 2008).

Not only is quality an issue but the number of STEM teachers is also inadequate in both the nations. In India, it is estimated that there is a shortage of more than 0.5 teachers in elementary schools; nearly 14 percent of the government secondary s,chools do not have the prescribed minimum of six teachers (National Policy on Education 2016). Most of the vacancies are unfilled as teachers are reluctant to work in rural areas due to inadequate facilities in these areas. Sometimes, the government administration is also unable to address the challenges of the teaching profession as it is politically influenced.

Despite having well-established school teachers' courses of world class Australian universities, Australia is facing the same issue due to the limiting number of eligible applicants for teacher education programmes, which results in the lack of STEM-qualified teachers in Australian schools. Science is being taught by teachers who are not qualified to teach science in most of the schools located in remote areas. The education sector comprises of the largest proportion of low achievers (< 50 percentiles) compared with science and engineering majors, where~~in~~ more than 41 percent of students have achieved 90 percentiles or over (Ferrari and Rushton, 2014). However, the suitability of preservice teachers cannot be determined through high school academic performance according to some teacher educators (Ferrari and Rushton, 2014). A 2011 study states that only 62 percent of teachers possess two or more years of tertiary mathematics (the minimum requirement), more than a third were teaching out of the field and 23 percent had no tertiary mathematics at all for Years 7 to 10 mathematics teaching (Marginson, Tytler, Freeman, & Roberts, 2013).

Apart from the poor quality of teachers in India, large scale corruption in appointments, transfers, approval to affiliated schools and grant recognition of institutions, commercialisation of education and political interference deteriorate the quality of education and influence the functioning of education regulators (*National Policy on Education* 2016). Rigid and lesser options for numeracy are added reasons for the increased failure and dropout rates in early high schools, which can be attributed with poor performance in mathematics and science subjects in the Indian education system. The Indian education system does not permit students to choose the level (higher to lower level) at which they wish to write Year 10 Board

Examinations. However, the Australian system understands the value of numeracy and offers different levels of mathematics education as per the choice and calibre of the student.

The Committee of National Education Policy 2016 in India also recommends two levels: Part A at higher level and Part B at a lower level for the Year 10 Board Examination in Mathematics and Science to provide the freedom to exercise student's choice. (*National Policy on Education* 2016). The Australian education system is strong in terms of offering the necessary support system and providing pathways to enter the STEM field through various choices. The number of students undertaking intermediate and advanced mathematics in secondary school fell by 34 percent over the past 18 years. Students may have a belief that opting for the easier option of general mathematics helps in getting a higher ATAR (percentage) score which is necessary for university entrance (Progressing STEM Skills in Australia, 2015).

Vocational Education and Training

The Australian VET system has been well-recognised internationally. The United Nations' Human Development Index, lists Australia at the 0.927 Education Index, while India stands at 0.473 ("Human Development Reports - Education Index," 2013). However, a report on a project titled "Strengthening School - Industry STEM Skills Partnerships" exposes the gaps in the available resources and provides evidence that teachers require a range of support and professional development to implement successful STEM VET programmes (*Strengthening School Industry STEM Skills Partnerships* 2017). Recent data shows that participation is low in the VET sector in all STEM areas except engineering (Progressing STEM Skills in Australia, 2015). Successful case studies from Australian schools reveal that industry school partnerships in which curricula are co-developed, provide opportunities for contemporary knowledge transfer with focus on applied learning (Watters and Christensen, 2013).

The Indian government also acknowledges the consequences of the lack of vocational courses and pathways to enter in highly competitive STEM streams and it is keen to implement such programmes to fulfil the dream of the ‘Skill India’ programme. Earlier, there were no structured vocational training programmes in Indian schools except for some diploma or certificate level trade trainings after Year 10 or 12 through public examination. Now, around 21 ministries of the central government are working at the ground level to implement the skill development schemes for their respective target groups with the objective to train 400 million people. The National Skill Development Corporation (NSDC), which is an exclusive Ministry for Skill Development and Entrepreneurship (MSDE) is responsible for the coordination and the creating or augmenting of the training delivery capacity. The first milestone was attempted by these ministries and the NSDC through the training of 8.6 million youth during the financial year of 2014-15 (*National Policy on Education* 2016). However, deficient collaborative network of the school system, industry and tertiary education have become obstacles to fostering dignity and social acceptability to high quality vocational trainings. This needs immediate attention to achieve the set targets.

The Silverline

Indian universities are placed lower in world ranking compared to Australian universities. Necessary steps are needed to push Indian universities into gaining a higher position in the global ranking, through the strengthening of approval and evaluation criteria of new institutions. The recent announcement of the Indian Prime Minister allocating a rupees 100 billion package to transform 20 Indian universities into world-class institutions gives a ray of hope to the future generation. ("PM Modi announces Rs 10,000-crore package to transform 20

Indian varsities into world class institutions," 2017). The Prime Minister of India asserted that science, technology and innovation are the key to progress and prosperity of India. He has asked officials to draw up clear goals to identify the brightest and best science talents among school students and effective mechanisms to reduce the drudgery through the intervention of science and technology by 2022, the 75th year of Indian independence. ("Science, technology, innovation keys to India's progress: Modi," 2017). The government of India is trying to introduce the constructivist teaching model by spending a major part of its research budget on STEM programmes for school students. There is no doubt that many programmes are being implemented at mass scale like NCSC, science express and INSPIRE which are helping to enhance awareness about science and its prospective career options. However, there are few shortcomings in the ongoing STEM programmes for school. The selection of just the top 1 percent of students from the INSPIRE programme who score high in the Year 10 board examination leave behind those who may have an aptitude for science but do not score high on the national or state level examinations. There seems to be a continuous repetive participation of many students/schools in science programmes at school level like NCSC and IRIS due to favouritism which discourages the participation of those who are inclined towards innovation and science. There are no direct linkages of such programmes with tertiary institutions in India. However, most of such programmes run with the collaboration of tertiary institutions and recognise the participation of school students during their higher education in Australia.

Despite having a world-class research workforce, Australia's innovation system lags behind due to the mismatch in skills taught in VET programmes during school, universities and those demanded by industries; cultural barriers to encourage the participation in the STEM field and the lack of learning from failure. Australian students' attraction towards oriented courses required for small jobs shows an interest for quick earning and the lack of orientation. However, the government is working to inculcate interdisciplinary skills, which are required to accomplish need based solutions (*National Innovation and Science Agenda Report* 2015). Several initiatives of the Australian government followed by the National Science Statement depict the long-term plan to produce a productive workforce with innovative and creative skills. (*National Innovation and Science Agenda Report* 2015).

Conclusion

Australia and India have strong opportunities for linkages and the sharing of best practices in STEM programmes for school students, teacher training and exchange as well as vocational education. Australia represents a framework of quality vocational education and India represents the world's largest market for such education. The Australian government is facing the problem of insufficient student participation in STEM subjects while the Indian government is trying to raise the standard of the education quality. Australia's performance at the school level, scientific literacy and mathematics at the international level are reported to have declined not only relative to other participating countries but also in absolute terms (*National Innovation and Science Agenda Report* 2015; Sue Thomson, 2015) while India is far behind in this race. This situation may hinder the vision of Australia and India to become world leaders due to the lack of required skilled workforce.

Indian students are more inclined towards science and mathematics but struggle with poor infrastructure, tough competition due to the population size, lack trained teachers, limited resources and language diversity. Australia's high ranking on the education quality parameters may become an area of interest for India. A concentrated effort towards enriching teacher training is an important input for the universities in India, particularly for their Bachelor's and

Master's programs. That being said, there is a need to revamp, redesign and remodel the teacher education system by making the process of selection, promotion, renumeration and transfer of teachers more stringent and transparent. The exchange of teaching tools, methodology, sharing of teacher training resources including trainers would be valuable ways of improving the overall quality of the Indian education system. It would also be significant to understand the Australian pattern of subject-specific teachers at the early levels and assess their replicability in the Indian scenario.

The lack of industry-academia collaboration, non-alignment of syllabi with the current industry trends, untrained trainers, poor infrastructure, non-professional management and lack of opportunities, such as credit sharing, across higher education and vocational education need immediate attention in India. The equivalent system of vocational education in Australia is organised along the same three dimensions. It is however more widely integrated with higher education and hence highly favoured amongst students. The Australian system has been good at integrating vocational education into its secondary education program, an opportunity which India is exploring. The VET model of Australia offers an opportunity for India to learn about how a separate organisational body such as Technical and Further Education (TAFE)that manages vocational education, can be adopted in India.

The Australian school system possesses a benchmarked compared to other OECD countries and has positive learning environment. A pathway forward for Australia is to attaract bright students as science and mathematics teachers, and provide them with continued support for professional development. In addition, Australia has to strengthen incentives for attaining skills as per future market demands and increase the access and performance of students from disadvantaged backgrounds. Indeed the role of family and community in valuing scientific and technological knowledge as well as the importance of acquiring this knowledge are critical attributes of Indian culture (Thomas and Watters, 2015) .

The education system of a nation builds on innovation and has the potential to become a strong competitor to other emerging knowledge economies. Sharing of best practices between two emerging economies may help to fullfill the vision of both the nations. Considering the discussed issues and continuing the collaborative programmes like the Australia-India BRIDGE project, Australia-India Bureau for Vocational Education and Training Collaboration (BVETC) and other bilateral research projects, there is a further need to work in a more mutual relationship in order to look for the common interestby education authorities, industries, universities and others for the effective implementation of their competing programmes and resources for STEM education.

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