Indian Knowledge Systems: Perspectives and Practices
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AN INDIAN PERSPECTIVE ON STEM EDUCATION AND RELATED EFFORTS

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Abstract: STEM is the acronym for Science, Technology, Engineering, and Mathematics. STEM education, as it is perceived now, seeks to teach these science subjects not in an isolated manner but in an integral way to foster creativity and develop real-life problem solving skills in students. This approach encourages the students to think critically while solving a real-life problem and to understand how these subjects work together to produce a worthwhile practical outcome. To make education more comprehensive and holistic STEM is now replaced by STEAM with the inclusion of Arts in STEM. Apart from modern technical skills, STEAM education aims at imparting critical thinking, innovative skills, research aptitude, and ethics in the students, which would enable them to face the challenges in the future job market as well as in society. The importance of STEM education cannot be over emphasised for the continuation of India's economic growth in the coming decades. India produces around 30 lakhs graduates annually in STEM subjects and equipping them for the future job market and social challenges is of paramount importance for our country. This article would attempt to discuss the details of STEM/STEAM education, how it aligns with NEP 2020, the efforts that have been made by the Indian Government and various private organisations in implementing STEAM based education, and the challenges that are to be overcome for implementation of STEAM education throughout the entire country.

Introduction: the urgent need to change our approach to education

It is universally agreed that Education plays the most crucial role in empowering people to become economically independent, to achieve full potential as a human being, contribute to the society meaningfully, and in ensuring our future growth which is aptly reflected in the statement of Catherine Russell, Executive Director of UNICEF: "The trajectory of our education systems is the trajectory of our future. Low levels of learning today mean less opportunity tomorrow." It is also clear that globally we are surely heading towards a future where economics is going to be more and more dependent on technology. So, good quality education with an emphasis on technical education is of primary importance for any country especially for highly populous developing countries like India.

However, technology has advanced in an unprecedented rate in the last few decades and before we could fully realise the digital technology has become an integral part of our everyday lives. Advances in technology has impacted everything, especially the world of work. The job sectors are emerging and then disappearing, making often today's desired and hard-earned skills of no or little value tomorrow. Employment is becoming fluid and people are moving from one profession to several others in their working life. The future global market would demand innovation skill rather than the service skill since technology and automation would slowly make service sector redundant and the economy would make a transition from service-based economy to innovation based economy.

These rapid changes in the world of work has left a gap between the knowledge generated by the conventional education system and the skills demanded by the employers and the job market and this gap is widening each day. This has put a huge demand on our education system to change and become flexible in a way that matches the requirements of tomorrow.

STEM/STEAM Education, what it is: STEM is the acronym for Science, Technology, Engineering, and Mathematics. Transforming our education system to meet the requirements of the emerging new global world where economics is dominated by technology that is itself fast evolving, would certainly require, among other things, a

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priority focus on STEM subjects: Science, Technology, Engineering, and Mathematics (STEM). The education system of most countries including India have long since prioritized learning of STEM subjects. However, in many countries including India the education has put too much emphasis on theory and rote learning. Also, the STEM subjects are taught mostly separately which fails to equip students in handling real-life issues where success often depend upon application of knowledge from multiple STEM subjects. The conventional education have thus resulted in producing a workforce that is skilled more for the service sector than for sectors needing innovation and critical thinking skills. So, it has become urgent to change this approach to a new one that fosters innovation and critical thinking skills. The modern STEM education approach is about teaching these science subjects not in an isolated manner but in an integral way through solving real-life problems that require knowledge of multiple STEM subjects. This is a project mode hands-on learning which involves working in small groups. This would foster creativity, real-life problem solving, and collaborative skills in students. The approach is student-centric, encourages the students to think critically while solving a real-life problem and helps them to understand how these subjects work together to produce a worthwhile practical outcome.

However, the narrow focus of STEM on the future job market's possible requirements makes it a less comprehensive model for education. Education must lead to holistic development of a person and an entirely STEM-centric educational system would ignore a good number of critical components of human development. All future developments should have an ethical basis and ethical decisions need to be guided by empathy, understanding of literature, history and philosophy. The global issues such as global warming, AI ethics, etc. need a humanistic understanding of the society that requires a thorough knowledge of Arts subject. Also, Arts subjects kindle imagination, abstract reasoning, and emotional intelligence apart from helping develop complex communication skills. Also, true innovations often require the ability to connect apparently unrelated ideas across different domains. Thus the inclusion/integration of Arts (that includes visual arts, music and drama) is equally necessary since future careers will rely heavily upon the so called 21st century skills- critical thinking, problem solving using mathematics and offering technological solutions, collaboration, creativity, cultural awareness and power of expression; Arts would help to foster creativity and power of expression. Inclusion of Arts transforms STEM education into STEAM education that aspires to arm today's learners with the necessary skills of tomorrow in this fast technology-induced rapidly changing world. A good number of pioneering research and scholarly review articles have been published which help provide the foundation of STEAM education and how it is implemented in practice. Some of these are listed in references 1 to 5.

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As such all the subjects in STEAM are also taught in the conventional education. But unlike in the conventional education which is predominantly theory based with a focus on remembering facts, formulas, definitions, etc. (the rote learning), STEAM would focus on problem solving and collaboration using interdisciplinary approach that help developing critical thinking, innovation, and the ability to work in a group. STEAM is a project based interdisciplinary approach integrating Arts to STEM to solve real-world problems. The curriculum of STEAM education would combine Science, Technology, Engineering, Mathematics, Languages, Visual Arts and Music with optimum weightages and the teachers would act as facilitators guiding students who work collaboratively on projects. Creativity, problem solving using multidisciplinary approach, collaboration and empathy would be skills emphasised and the evaluation would be based primarily on that. STEAM would not eliminate exams completely but these will have much lesser weightage as compared to that in the conventional education system.

The integration of STEAM subjects in the classroom makes learning much more enjoyable, challenging, and effective. This approach encourages the students to think critically while solving a real-life problem and to understand how these subjects work together to produce a worthwhile practical outcome. The integration of Arts that include visual arts, music and drama with STEM, helps to develop a skill set that is more innovative. The STEAM education prepares the students to respond smartly to today's rapidly changing world where technology would sooner than later replace repetitive tasks. It prepares them for life in the 21st Century irrespective of the career they choose.

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There are many already a number of sites (a few are listed in References 6 to 9) available in the internet that contain typical examples of well thought STEM based projects for the elementary, middle, and high school. For example one of STEAM projects at the elementary level could be to design and construct a water filtration system consisting of plastic bottles, sand, gravel and filters. Through this project the students learn earth sciences, a bit of chemistry, and how to experimentally measure the flow rate. Another example could be a geometric origami project that needs the students to fold paper into intricate 3D shapes, blending there by art and mathematics. Once students are trained in this manner they will develop a love for learning and interest will grow in them to think of innovative projects that has some applications in real-life. This makes the study an interesting and absorbing challenge rather than a punishment requiring to memorise a never-ending set of different types of information.

In the subsequent sections we would discuss the Indian perspective (how important is it for us to implement STEAM education), the efforts that have been made by the Indian Government as well as private organisations towards implementing STEAM education, and the challenges that are need to be overcome for implementing STEAM education country-wide.

STEAM Education and the Indian Perspective: As it is mentioned already India produces about 30 lakhs graduates in science and engineering subjects. India's STEM workforce constitute at present about 30% of the global talent pool but only a small percentage of these students about join research in core research areas like physics, material science, and biotechnology. This is because these graduates come out of an education system that primarily anchors on rote learning. Presently, a major fraction of students goes to the IT service sector and software engineering. But competitiveness in the future global market would require innovation skill rather than the service skill since technology and automation would slowly make service sector by and large redundant.

Research is also the key and perhaps the only way to achieving the Strategic Autonomy, which aims at reducing import dependence of semiconductors and other critical materials, strategic arms including missiles, and energy production. Emerging technologies like AI, Quantum Computing, and Green Hydrogen also requires a large number of motivated and capable researchers. Also, India is a very young country. Thus a failure to impart the skills necessary for the future world would lead to huge unemployment in the country in the coming decades. This would obviously create multiple social problems and disturb our social fabric in a major way. So, from Indian viewpoint major changes in the educational policy shifting the focus from theory based rote learning to innovation based learning and from teacher-centric to student-centric learning needs the most urgent attention.

STEM Education and the Indian efforts: Reacting to these demands, India has formulated the National Educational Policy 2020 ((NEP2020) (Ref. 10) with the aim to transform teaching of subjects from the rote learning mode to a dynamic problem solving mode requiring critical thinking skills. The emphasis is on practical project-based learning that is interdisciplinary in nature (as opposed to mostly theoretical learning of each individual subject separately in the existing education system) to develop innovation and critical thinking skills in the learners. The projects at various levels in schools are to be chosen so that the execution of those involves application of knowledge of multiple STEM subjects and often an Art subject. STEAM has five key objectives as envisaged in NEP2020: to develop critical thinking, creativity, communication, collaboration and character. Robotics, AI and Coding are to be introduced as early as in Grade 6. The foundational mathematical concepts are to be taught as early as early as at the age of 6 years using games and puzzles. By the 8^{th} standard students are to be exposed to vocational crafts to build real-world capabilities. In Indian context, a major issue is the "Leaky Pipeline": Women although constitute 43% of STEM graduates only about $1/3^{rd}$ of them join the workforce. This is a huge loss to our investment in education of STEM subjects. NEP 2020 has a special emphasis to promote STEM for girls to remove the gender disparities in the field of science and technology.

For higher education, NEP 2020 seeks to promote interdisciplinary education allowing science and engineering students to choose humanities courses (say, for example allowing a student to choose Physics and Music). NEP 2020 puts special emphasis on research by the way of equipping the institutes of higher learning with technology

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development centres and research facilities in frontier areas like biotechnology, AI, material science, renewable energy production etc.

As a part of NEP 2020 mandate, the Indian Government has taken a lot of measures to promote STEM education by way of creating various facilities. These initiatives include:

a) Atal Tinkering Labs (ATLs), pushed aggressively by NITI Aayog's Atal Innovation Mission. Under this mission thousands of schools are to be equipped with laboratories having robotics, AI, 3D printing, Internet of Things (IoT). ATLs makes these topics an integral part of the curriculum and ensure students get hands-on experiences so that critical thinking and innovative skills develop in them.
b) Skill India & CBSE Skill Modules: CBSE has included and embedded in their curriculum AI, coding and computational thinking.
c) Digital Learning Platforms: This is another initiative by the Government by way of launching SWAYAM and I-STEM portal. These offer open access modules, skill-building, and R&D support for students and teachers.
d) Digital STEM Rollout: Government has launched the Samagra Shiksha Scheme aiming to convert classrooms at the secondary level into digital STEM labs which will make high quality science and mathematics resources available to students.
e) Rashtriya Avishkar Abhiyan (RAA): RAA focuses on promoting hands on STEM activities at rural and backward India.

Private Sector involvement in STEM education: The involvement of Indian Private Sector in STEM education is significant and many companies and NGOs are working together to set up labs to close the skill gap. Their involvement is primarily driven by corporate social responsibility and public-private partnership. The major organisations are:

a) India Stem Foundation (Ref. 11): The main objective of this organisation is to make STEM education accessible to all. The programs they follow are CSIR powered and they focus on providing STEM facilities to underserved schools and students across India. They provide schools with practical learning tools, help in setting up infrastructure/hands-on STEM labs, teacher training, and a platform for global robotics competitions (World Robot Olympiad, WRO) and the First LEGO League (FLL). They also provide Certified Teacher Training Programs and Structured Educational Programs to close the gap between the theoretical and practical knowledge of engineering.
b) CRY (Child Rights and You) STEM Foundation (Ref. 12): CRY India also focusses on providing STEM education to underprivileged and rural sectors. It sets up Mini Science Centres/labs in schools to facilitate hands-on learning and to impart practical knowledge to students. They also run dedicated community programs to encourage girls to pursue STEM carriers.
c) Companies like Google, Infosys, WIPRO, IBM, and TCS contribute in specific areas (code to learn, science labs, providing scholarships, data science, high quality STEM materials, etc.)

Challenges to overcome for STEAM Education: It is obvious that STEM / STEAM approach to education doesn't constitute a mere shift or improvement over the present educational system that anchors predominantly on rote learning but requires an almost revolutionary change in our education system. The implementation of STEM/STEAM based education constitute huge challenges and requires working of a solid roadmap that includes: new curriculum, new evaluation methods, well trained teachers, and huge investments from the government as well as from the private organisations; keeping in mind simultaneously that education shouldn't be entirely for the future job market and should also boost fundamental research that will in turn shape our future as well as the job market. It should also prepare us to solve the future social issues and global problems with empathy that would ensure the survival and progress of human race.

There a number of major barriers to be crossed for implementing STEAM Education throughout the country. These include:

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a) Infrastructure and digital divide between the major cities and the rural areas. Schools in rural areas often lack basic infrastructure that include high speed internet connection, enough computers, uninterrupted power, and lack of hardware and software support.
b) Outdated Curricula and Pedagogy: Traditional Institutions still want to rely upon rote learning and many teachers are reluctant to embrace the new student-centric and problem solving mode pedagogy. It is also a tremendous task to draw curricula based on modern STEM education needs and implement it throughout the country. That education is both a Centre as well as State subject as per our constitution, one definitely apprehends problem in implementation of a uniform strategy and curriculum for STEAM education throughout the country.
c) Gender Disparities: Female students even after completing science education often don't join the workforce in engineering, technology and scientific research. This is referred to as the "leaky pipe line".
d) Severe shortage of trained educators: STEM teachers need to be highly proficient in computer use and digital pedagogy, innovative to help students in executing the STEM projects and appreciate the need for multidisciplinary learning. Presently, there is a huge dearth of such teachers in India.
e) Huge investment: Implementing STEM Education throughout India requires huge investment on the part of Government and from the Private Sector.

Conclusions

India produces a huge number of STEM graduates each year and enabling them suitably through STEAM based education represents a huge prospect for our economy and the country. A failure to implement STEAM education successfully and quickly enough would affect adversely our country's future growth and sovereignty. However, successful and effective implementation of STEAM based education needs almost a revolutionary change in our existing education system and in our age-old perception of what education is. The Indian government has already made considerable efforts in terms of formulating NEP 2020 and initiating projects to build STEAM-friendly labs and facilities in schools. The corporate sector and also NGOs are also responding enthusiastically to this need and started contributing significantly to STEM/STEAM education. The successful implementation of STEAM Education throughout our vast and highly populated country is truly an extremely challenging task but for our country's future we need to plan meticulously and work hard hand in hand to make it a reality within a decade or so.

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