



A Comparative Study of STEM Education and Industrial Integration in China, Japan, and South Korea: Policy Lessons for India's National Education Policy 2020

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ABSTRACT:

The Fourth Industrial Revolution (4IR) is unfolding at an unprecedented pace, with Science, Technology, Engineering and Mathematics (STEM) education being at the heart of the national economic agenda, especially in the region of East Asia. This comparative study examines the institutionalisation process of STEM education in the three countries of China, Japan and South Korea, and how this process has been connected to the industrial demand, thereby extracting policy lessons for implementation of India's National Education Policy (NEP) 2020. The aim is to assess the mechanisms of integration of STEM in the three economies and identify transferable models for India. A qualitative comparative-policy design was used, and incorporated OECD Education at a Glance 2025, WIPO Global Innovation Index 2024, NSF NCSES 2024, and PISA 2022 data, along with peer-reviewed scholarship from Springer, Elsevier and Frontiers. The findings reveal that South Korea and Japan incorporate industry linkages in the Meister High School and Society 5.0 framework, respectively, and China's "Made in China 2025" plan added 1,673 industry-related undergraduate courses in 2024 alone. India though creates 34% STEM graduates invest only 0.64% of GDP in R&D, and out of the invested amount, 36% is in private sector. The study states that the NEP 2020 needs to speed up its move towards increase in density of apprentices, more R&D co-financing and convergence curriculum to convert the demographic dividend into industrial competitiveness.

Keywords: STEM Education; Industrial Integration; Comparative Education Policy; NEP 2020; East Asia.

1. INTRODUCTION:

The shift from manufacturing-driven to innovation-driven growth has changed the focus of STEM education from being a key enabler of national competitiveness. East Asia has become the world's leader: Tokyo–Yokohama, Shenzhen–Hong Kong–Guangzhou, Beijing, Seoul and Shanghai–Suzhou are the world's top five science and technology clusters (WIPO, 2024). This is no coincidence. Each of China, Japan, and South Korea has developed a unique architecture, connecting school curricula, tertiary engineering curricula, vocational pathways, and corporate R&D, out of which measurable outcomes can be registered in terms of patents, export of high-tech products, and PISA mathematics scores (OECD, 2023). In contrast, India has an asymmetric situation, with 34% of its total graduates in STEM disciplines (Statista, 2023), but also ranks at 39th place in Global Innovation Index 2024 and spends only 0.64% of the GDP on research and development, while South Korea spends 4.96% of their GDP (SSTI, 2025; Whalesbook, 2025). The National Education Policy (NEP) 2020 is India's boldest reform effort in 34 years. It has proposed a 5+3+3+4 education structure, set a target of exposing 50% of students to the world of work by 2025, and has proposed embedding coding, AI, and robotics from the middle school stage of the education system (Ministry of Education, 2020; Saharia & Mazumdar, 2024). However, the gaps persist even after a few months of implementation, as only 5% of Atal Tinkering Labs are in government-run schools, the R&D mix in India is 70:23, with 70% coming from government and 23% from industry, and the collaboration between the industry and academia is poor (Orf Online, 2025; Pradhan, 2025).

It is thus timely and instrumentally useful to examine the East Asian troika comparatively. Every one of these economies had a similar transition from low-cost manufacturing to knowledge production, and each in just one generation, and each by conscious policy processes of tying education to the economy. The Chinese "Made in China 2025" initiative connects university courses to developing industries; the Japanese "Society 5.0" program ties MEXT funding to interdisciplinary engineering; and the South Korean Meister High Schools link secondary schooling to chip, auto and biotech companies (Government of China, 2025; Suzuki & Kotera, 2024; Korea Herald, 2026). While each of them has its pros and cons, each of these brings about tangible industrial results that the Indian policy landscape has not yet managed to produce. This paper thus poses the question of what structural characteristics of the Chinese, Japanese, and Korean STEM-industry interface are most likely to be transferable to India's federal, plural and resource constrained milieu, and how can NEP 2020 be further sharpened to incorporate them?

2. Literature Review

The scholarship on East Asian STEM education arrives at three propositions industry integration is a state-based initiative; the convergence of disciplines (STEAM) results in better performance than a focus on separate disciplines; and there is a mediation of policy outcomes through the roles played by demographic and cultural factors. In the seminal ACOLA report, Marginson, Tytler, Freeman and Roberts (2013) found three structural characteristics of high-performing STEM systems: early specialisation, strong teacher pipelines and industry pathways. Others followed up their work for China (Lee, So, Hong, & Lee, 2022) and Japan and Korea (Hong, 2022). However, the STEAM initiative in South Korea, which began in 2011,

did yield positive results (Kang, 2019); Han et al. (2023) caution that the commitment of the stakeholders has been "policy-wave driven" and is not a sustained endeavor.

Kumano (2022) and Suzuki and Kotera (2024) explain the onset of Society 5.0 as a response to a projected shortage of 789,000 IT workers by 2030, consisting of a 10 trillion-yen fund to support universities and interventions that included the introduction of quotas for women. However, as Yonezawa (2023) warns, the country's pool of talent is diminishing and internationalisation has been sluggish in Japan. In the case of China, Wu (2025) and Zhou, Tijssen, and Leydesdorff (2016) find that the number of universities–industry co-authored publications and patents has increased by an order of magnitude since 2010, while Cao, Suttmeier, and Simon (2018) report that institutional rigidity and ideological constraints are increasingly tightening up. According to Miao, Zhang and Zhang (2025), China's "Thousand Talents" and "Innovation Talent Promotion" programs have successfully increased the investment of non-state enterprises in core technology research and development, but the crowding-out effect between core technology research and development and utility-model research and development remains.

Saharia and Mazumdar (2024) and Pathak (2021) contend that NEP 2020, in theory, is good, but in practice, it lacks financial support. Ghosh, Dutta, and Mondal (2023) compare the science syllabus in secondary schools in India with that of China and Japan and believe that India has not yet gone for STEM-specific curricular reform at par. Low private sector R&D participation is cited as the biggest limitation to the innovation outputs of Indian STEM enrolment by Kayan-Fadlelmula, Sellami, Abdelkader, and Umer (2022). In respect to the Global South, Kuhumba (2025) observes that Korea and Singapore have set examples of what focused public investment on research-intensive universities can accomplish, while the governments of South Asian states have not been as committed. In each of the four contexts, scholarship reveals a shared need: a lack of empirical comparison that spans, at the same time, curricular, institutional, and industrial aspects. Past research typically focuses on a single country (Yonezawa 2023; Kang 2019) or a single variable (Zhou et al. 2016). This paper fills that void by triangulating and drawing lessons from verified secondary data provided by OECD, WIPO and NSF, as well as peer-reviewed analyses.

3. Objectives

1. To compare STEM education frameworks and industrial integration mechanisms across China, Japan, and South Korea using verified 2022–2025 indicators.
2. To derive context-sensitive policy lessons for accelerating the implementation of India's NEP 2020.

4. Methodology

The method used in this study is qualitative and comparative policy analysis with data collection methods in the form of document analysis. In accordance with Bray and Thomas's (1995) cube model of comparative education, the analysis is arranged along 3 nested dimensions geographic (China, Japan, South Korea, India); substantive (curriculum, R&D investment, industry linkage); and demographic (school, tertiary, workforce). The sample consists of four national education systems that were purposefully sampled based on three criteria: (1) comparable demographic size, (2) a clearly observed industrial transition in the past 30 years and (3) harmonised OECD/UNESCO indicators for 2022-2025. The main sources of data are: (i)

OECD Education at a Glance 2025 country notes and OECD PISA 2022 Volume I (OECD, 2023, 2025); (ii) WIPO Global Innovation Index (WIPO, 2024); (iii) U.S. National Science Foundation NCSES Science and Engineering Indicators 2024 (National Science Board, 2024); (iv) Lowy Institute Asia Power Index R&D dataset (Lowy Institute, 2024); and (v) peer-reviewed bibliography from the Springer, Elsevier ScienceDirect, Frontiers and PLOS One databases from September to December 2025. A time limit was imposed for publications to be included (2020–2025) to ensure that they were recent, but to ensure theoretical grounding, two fundamental works (Marginson et al., 2013; Zhou et al., 2016) were included. The analytical method is a synthesis of descriptive statistical comparison (R&D intensity, mean score on PISA, proportion of students graduating with a degree in STEM, rank in GII), and thematic policy synthesis. Indicators were presented for each country, normalized for appropriate units (PPP adjusted USD for R&D) and triangulated with no less than two independent sources. Yin's (2018) replication logic was followed in the validity strategy; that is, for each finding, there was a minimum of one international agency and one peer-reviewed study. There are some limitations, such as OECD statistics for 2024 are not disaggregated for China, and some of the statistics from MEXT and MOE are based on government self-reporting. APA (2020) guidelines were followed for ethical concerns with secondary data, such as attribution, accuracy, and non-misrepresentation.

5. Results

5.1 R&D Intensity and Investment Profile

Table 1: Comparative R&D Investment, 2022–2024

| Country | GERD as % of GDP | Total GERD (USD bn, PPP, 2024) | Private Sector Share | GIIRank 2024 |
|-------------|------------------|--------------------------------|----------------------|--------------|
| South Korea | 4.96 | 120–130 | 79% | 6 |
| Japan | 3.41 | 186 | 75% | 13 |
| China | 2.56 | 785.9 | 77% | 11 |
| India | 0.64 | ~80 | 36% | 39 |

Sources: SSTI (2025); Evertiq (2026); WIPO (2024); Whalesbook (2025).

The intensity gradient is very strong as per Table 1. South Korea is the top OECD country with 4.96% of GDP, nearly eight times the amount India reports at 0.64%. China's total expenditure of USD 785.9 billion is greater than that of the three nations combined: Japan, Korea and India. Anomaly among the two is that 70% of R&D funding in India is public while 75-79% is private in the East Asian three. In line with this, the Global Innovation Index 2024 shows that the countries of South Korea (6th), China (11th) and Japan (13th) are in the top quartile, whereas India is still in the 39th position, despite having improved considerably (Whalesbook, 2025; WIPO, 2024).

5.2 PISA 2022 Performance

Table 2: PISA 2022 Mean Scores, Mathematics and Science

| Economy | Mathematics | Science | OECD Mean Diff. (Math) |
|-------------------------------------|---------------------|---------------------|------------------------|
| Japan | 536 | 547 | +64 |
| Korea | 527 | 528 | +55 |
| China (B-S-J-Z, prev. cycle) | 591 | 590 | n/a (2022 suppressed) |
| OECD Average | 472 | 485 | — |
| India | Did not participate | Did not participate | — |

Sources: OECD (2023); ILSA-Gateway (2024).

According to Table 2, Japan and Korea are among the six systems in East Asia that performed better in mathematics among all the systems (OECD, 2023). The percentage of students at Level 5–6 in Japan was almost 2.5 times the OECD average, at 23%. India has not been part of PISA 2022 as a result of disruptions during the pandemic and direct comparison is limited to NAS 2021 data as the best available proxy of the national data.

5.3 STEM Enrolment and Graduation

Table 3: STEM Graduate Share of Tertiary Output, 2022–2024

| Country | STEM Graduates as % of Total | Bachelor Share | STEM Notes |
|--------------------|------------------------------|----------------|--------------------------------|
| China | ~36 (broad definition) | n/a | 4.7m STEM grads/yr (WEF est.) |
| Japan | 35 (target 50% by 2032) | 20 | Female share 13–20% in tech |
| South Korea | ~33 | n/a | Tertiary attainment 25–34: 70% |
| India | 34 | n/a | 2.55m STEM degrees/yr |

Sources: World Economic Forum (2023); IPP Japan (2026); OECD (2025); Statista (2023); CSET (2025).

There is almost equal proportional production of STEM items in the four economies as shown in Table 3. The key distinction is that Japan and Korea are developing a new path for graduates to enter the corporate Research and Development fray, but India's graduates are struggling with a "valley of death" between the lab and the market and under-employment (Meister, 2025; Pradhan, 2025).

5.4 University–Industry Integration Mechanisms

Table 4: Institutional Vehicles for STEM-Industry Integration

| Country | Flagship Mechanism | Year Initiated | 2024–2025 Coverage |
|--------------|---|----------------|---|
| China | "Made in China 2025"; programme realignment | 2015 | 1,673 new majors added in 2024 |
| Japan | Society 5.0; WPI; STEM expansion | 2016 | 118 universities funded; 13 WPI centres |

| | | | |
|--------------------|----------------------|------|--|
| South Korea | Meister High Schools | 2010 | 57 schools nationally; 4 in Seoul (2025) |
| India | NEP 2020; ATL; ANRF | 2020 | 10,000 ATLs; ₹1 lakh crore RDI scheme (Nov 2025) |

Sources: Government of China (2025); Trade.gov (2023); Korea Herald (2026); Orf Online (2025); Whalesbook (2025).

Structural differences in the design of institutions are shown in Table 4. In 2024, China's "unprecedented" realignment eliminated 1,670 mismatched programmes and replaced them with 1,673 programmes aligned with the industries, in one year (2025, Government of China). The employment rate at South Korea's 57 Meister Schools, which are based on the German dual system, is higher than 90% (Korea Herald, 2026; Park & Lee, 2023). The parallel efforts in India are more recent and fragmented, and the impact of ANRF and the ₹1 lakh crore RDI scheme has yet to be seen in practice.

5.5 Patent and Innovation Output

Table 5: Patent Activity and S&T Cluster Strength, 2024

| Country | Top 100 S&T Clusters | UI-Co-authored Patents (annual) | Major Cluster |
|--------------------|----------------------|---------------------------------|--------------------------------------|
| China | 26 | 760,000+ (2022) | Shenzhen–HK–Guangzhou (2nd globally) |
| Japan | 6 | High (PCT leader) | Tokyo–Yokohama (1st globally) |
| South Korea | 4 | High | Seoul (4th globally) |
| India | 4 | Low | Bengaluru (rising) |

Sources: WIPO (2024); Wu (2025); Visual Capitalist (2024).

East Asia is clearly dominating, as shown in Table 5. In 2022, China's patent output of integrated systems consists of a hundred-fold of 760,000+ university–industry co-authored patents (Wu, 2025). The relatively low level of commercialization of patents in India, despite the fact that India has a second largest number of patents filed, is evidence of a structural mismatch (Pradhan, 2025).

5.6 Vocational and Apprenticeship Pipelines

Table 6: Vocational-Industry Linkage Indicators, 2024

| Country | Vocational Coverage | Track | Apprenticeship/Industry Tie | Government Funding (latest) |
|--------------|---------------------------|-------------------|---|--|
| China | ~40% of secondary | of upper | Vocational colleges supply 70% of new skilled workers | Substantial (n/a disaggregated) |
| Japan | ~25% of secondary schools | of post-technical | Industry-linked colleges of technology | 10 trillion yen university fund (2021) |

| | | | |
|--------------------|----------------------------------|-------------------------------------|--|
| South Korea | Meister + specialised vocational | Direct firm partnerships | KRW 5 billion per Meister school upgrade |
| India | <5% in secondary | NEP target 50% by 2025; current ~7% | ITIs +15% enrolment (2025) |

Sources: MOE China (2025); IPP Japan (2026); Korea Herald (2026); Education for All in India (2025).

The vocational divergence is summarised in Table 6 below. The vocational colleges of China train over 70% of new skilled industrial workers (MOE, China, 2025) and the Meister system in South Korea charges up to KRW 5 billion per school for upgrades. India's secondary level vocational coverage is less than 7% which is far from the NEP 2020 objective of 50% by 2025 (Education for All in India, 2025).

6. Discussion

The collated evidence from tables 1-6 validates three assertions and clarifies a fourth, with direct implications for the implementation of NEP 2020. First, that which comes out of the success in East Asia is not about the good will, but the good architecture, as per Objective 1. The R&D intensity of South Korea is 4.96%, which is higher than the average rate of other OECD countries, and the rate of Japan (3.41%) is not only a preference in budget but is also backed by legal frameworks such as the Science, Mathematics, and Informatics Education Promotion Act of Korea (2018) and the MEXT–METI joint roadmap for the educational digital transformation in Japan. State centre compacts on programme recognition can be used to approximate the annual programme realignment in China because it is centrally co-ordinated that is not replicated in India. Second, the pedagogical aspects of integration are the backbone of the pedagogical engineering. Second, the convergence of pedagogy with industry requirements is the operational component of integration. The Korea STEAM policy, China's soft-matter and intelligent maritime engineering interdisciplinary majors, and Japan's Society 5.0 curriculum are all composed of the four traditional disciplines along with the arts, design and humanities (Hong, 2022; Kang, 2019). NEP 2020 gives a special emphasis on this convergence and Atal Tinkering Labs is its nascent implementation, but only 5% of ATLS are located in the state schools and most of them are in the urban Kendriya Vidyalayas. The 50,000 additional ATLS over five years promised in the 2025-26 Union Budget is a welcome corrective measure, the locational distribution of which, however, needs to be deliberately rural and state-school weighted to prevent recreating the elite-skewed pattern.

Thirdly, vocational courses are determining. The Meister Schools in Korea (Table 6) provide a case study on how secondary vocational training, coupled with the presence of named corporate partners and state-based full scholarships can help to overcome the cultural devaluation of technical education that India shares with mid-2000s Korea (Park & Lee, 2023). Even in the case of the old systems, new priorities in industry are always incorporated into the systems, as seen with the recently announced Seoul Semiconductor High School, which will open in March 2027 (2026, Korea Herald). India's polytechnics and ITIs should be given a Meister to serve the needs of the industry: a small number of high-profile secondary technical schools with named corporate sponsors in semiconductors, electric vehicles, and renewable energy, sectors that were a part of the Production Linked Incentive scheme in India. Fourth, the

data suggests that the Indian policy intuition that the primary constraint is enrolment is incorrect. As seen in Tables 2 and 3, the percentage of individuals gaining STEM degrees in India (34%) is near that of Japan (36%) and Korea (32%). What's needed is a deficit in the absorption pathway, not production of graduates. For example, patent commercialisation (Table 5) and private R&D share (Table 1) indicate that India is losing STEM talent from the graduate-to-firm transition. The focus on industry apprenticeships by NEP 2020, along with the one by ANRF on industry-academy co-funded research, directly tackles the above, while it is argued that it is the need of 50–50 ratio of government and industry funding that needs to be realised through the means of tax-credit tools akin to those listed in OECD INNOTAX portal.

There are two lessons to draw from the East Asian triumvirate that temper enthusiasm. There are two lessons to be learned from the triumvirate of East Asian nations that temper enthusiasm. Although efficient, China's centralised majors-realignment has led to misalignments between the preferences of overseas returnees and the needs of their home industry (Wu, 2025), and the dominant funding of WPI in elite universities has been criticised for narrowing the range of different universities' research bases, leading to an impoverishment of the latter (Yonezawa, 2023). India's federal pluralism, which is regarded as a drawback, can actually be an advantage if federal-state level Meister analogues are established in the states that have semiconductor clusters first (Karnataka, Tamil Nadu, Gujarat) before scaling up at the national level. Last, but not least, the gender angle (13–20% female in STEM) of the Japanese experience is one the country should listen to: NEP 2020's gender-inclusion mechanisms must have explicit STEM targets at the school-to-university transition, where female dropouts are highest.

7. Conclusion

The policy comparison of China, Japan and South Korea reveals that an architecture with coherent policy elements such as continuous R&D effort, harmonisation of programmes, industry-oriented vocational education and convergence teaching methods is the key to building STEM-led industrial competitiveness, and it is not a single measure. Most of these are mentioned in the NEP 2020, but the implementation gap is significant: India has an R&D intensity of only 0.64%, private R&D of only 36%, and vocational reach is less than 7%, compared to the East Asian norms. The gap will have to be addressed through legislated R&D targets, a cadre of technical schools like Meister schools, linked to PLI sectors and at the state level, in rural schools, and through tax-credit instruments to crowd-in private R&D; The window of opportunity for bringing about the demographic dividend into industrial capability is limited to the next decade or so, as the comparative evidence from East Asia suggests.

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