Best Practices Report on STEM Capacity Building

APEC Policy Partnership on Science, Technology and Innovation

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Preface

Prof. KiHo KIM
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It is my great pleasure to present this report on STEM Capacity Building across the APEC region.

In an era defined by rapid technological transformation, climate challenges, and increasing demand for future-ready skills, STEM education has become more than a sectoral priority—it is a foundational pillar for sustainable, inclusive, and innovation-driven growth. Across APEC economies, there is a growing recognition that strengthening STEM capacity is essential not only for economic competitiveness but also for addressing shared regional and global challenges.

This report brings together valuable insights from 14 APEC economies, offering a comprehensive analysis of policies, programs, and practices that shape STEM capacity-building efforts. It highlights both the progress made and the persistent challenges faced, including disparities in access, the need for stronger teacher capacity, and the importance of coherent implementation across systems. By synthesizing these diverse experiences, the report provides practical recommendations to support more effective, equitable, and sustainable STEM development across the region.

As an expert-driven platform dedicated to advancing STEM talent development and collaboration across APEC, the APEC Mentoring Center for the Gifted in Science (AMGS) is committed to fostering a dynamic ecosystem in which knowledge, experience, and opportunities are continuously shared and expanded. We believe that capacity building is not a one-time effort, but a sustained and collaborative process that relies on strong partnerships among governments, academia, industry, and young innovators.

Looking ahead, we hope this report will serve as a meaningful reference for policymakers, educators, and stakeholders across APEC. More importantly, we hope it will inspire continued collaboration and collective action toward building resilient STEM ecosystems that empower the next generation of leaders.

We sincerely appreciate the contributions of all participating economies and experts who made this report possible. We look forward to strengthening our shared efforts in advancing STEM capacity for a more connected and prosperous APEC.

Executive Summary

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1. Purpose and scope

Science, technology, engineering, and mathematics (STEM) education is increasingly recognised as both a foundation for inclusive growth and a strategic capability for economies navigating rapid technological change, climate and sustainability challenges, and shifting labour market demands. This Executive Summary synthesises evidence from the contributions of 14 APEC economies to the APEC Report on STEM Capacity Building: 12 economy reports (Australia; Brunei Darussalam; Canada; Indonesia; Japan; Republic of Korea; Malaysia; The Republic of the Philippines; Singapore; Chinese Taipei; Thailand; United States) and two selected cases (China; Viet Nam). A practical approach for integrating slide-based cases allows readers to quickly grasp the essence of a case while preserving the integrity of the original presentation material.

The report's purpose is to: (i) identify cross-economic patterns in how STEM capacity building is conceptualised and implemented; (ii) highlight the strategies that appear to be effective and explain why; (iii) clarify common constraints that limit impact, sustainability, and equity; and (iv) propose practical recommendations for both economy-level action and APEC-level cooperation. Although policy contexts vary widely, the contributions converge on a shared agenda: building robust, future-ready STEM ecosystems that expand participation, improve learning quality, and strengthen transitions to further study and work.

2. Why STEM capacity building matters

STEM education is increasingly framed not only as preparation for specialist careers but also as a foundation for scientific literacy, critical thinking, and problem-solving competencies essential across many occupations and civic roles. Another key rationale is that 21st-century innovation is becoming increasingly collaborative and interdisciplinary. Breakthroughs often emerge from teams that combine diverse expertise, translating knowledge into scalable applications.

Several economy profiles position STEM education within long-term visions of "future-ready" human capital and digital transformation, including initiatives targeting emerging fields such as AI, data analytics, semiconductors, digital technologies, and advanced manufacturing (notably in Republic of Korea and Chinese Taipei). Many profiles link STEM learning to real-world societal challenges, including sustainability, productivity, and inclusive development. From a talent development perspective, high-level STEM performance depends on both interconnected knowledge structures and the ability and willingness to solve various problems. Therefore, capacity-building should support both broad participation and advanced pathways for highly capable and motivated learners. Several economies have explicitly adopted this dual approach: Japan emphasises targeted support for high-capability learners alongside wider participation in STEM/STEAM; the Philippines combines specialised science high schools with scholarship systems; and Singapore integrates a rigorous curriculum and teacher professionalism with applied learning and industry relevance.

Across economies, STEM capacity building is justified by three mutually reinforcing imperatives:

Societal and sustainability challenges: Climate adaptation, disaster risk reduction, food and water security, public health, and responsible technology governance all require citizens who can interpret evidence, reason for uncertainty, and participate in science-informed decision-making. STEM education thus functions as a form of civic capacity, supporting scientific literacy, ethical judgment, and sustainability-oriented innovation.

Economic transformation: Advanced manufacturing, digital industries, health and bio-innovation, and the energy transition all require workforces with strong quantitative reasoning, problem-solving abilities, and technological fluency. However, STEM capacity is not solely related to the production of specialists. Economies increasingly emphasise that foundational STEM literacy supports adaptability across occupations, enabling workers to learn new tools, engage in continuous upskilling, and contribute to productivity in knowledge-intensive sectors.

Equity and social mobility: Many economies stress that STEM education can widen opportunities when designed inclusively, reducing geographic and socioeconomic disparities, strengthening foundational learning, and creating credible pathways to high-value careers for groups historically underrepresented in STEM, including girls and women, rural learners, and marginalised communities. In this sense, STEM capacity-building is both a competitiveness strategy and an inclusion strategy; the two are inseparable because talent and innovation are broadly distributed, while opportunity and access often are not.

3. Analytic approach and its limitations

This Executive Summary draws on (i) key elements of 12 economic contributions (Australia; Brunei Darussalam; Canada; Indonesia; Japan; Republic of Korea; Malaysia; The Republic of the Philippines; Singapore; Chinese Taipei; Thailand; United States), (ii) key challenges from these 12 economies, and (iii) two selected cases (China; Viet Nam) provided as presentation slides and incorporated as case materials. Evidence was gathered from the 12 economic profiles and the two selected cases provided as presentation slides. To enable comparison across diverse governance structures, the report organises the findings using seven recurring dimensions identified through the economy profiles: (1) domestic strategy and vision, (2) key programmes and pathways, (3) investment and funding mechanisms, (4) institutional and cross-sector partnerships, (5) monitoring and performance indicators, (6) major barriers and implementation gaps, and (7) equity and gender-responsive measures.

The synthesis uses qualitative content analysis to identify shared patterns, distinctive models, and transferable design principles, while remaining attentive to contextual constraints (e.g. centralised versus devolved governance, differences in school system structure, and varying levels of infrastructure and teacher supply). The goal is not to rank economies but to distil practical lessons and priority actions for capacity building across APEC.

4. Cross-economy findings: what is working

The economic profiles indicate strong momentum in STEM capacity building across APEC. While each economy has distinct institutional and cultural contexts, the evidence converges on several design features that consistently appear in initiatives reporting improved engagement, stronger coherence, and better alignment with future skill demands.

4.1. Domestic strategies increasingly align STEM education with development, innovation, and sustainability goals

A shared feature across economic profiles is the explicit alignment between STEM education and broader domestic strategies such as innovation-driven growth, digital transformation, and sustainable development. Australia frames STEM as a lever for economic competitiveness, workforce resilience, and social equity, and articulates a coordinated domestic direction through the National STEM School Education Strategy 2016–2026, while allowing states and territories to tailor implementation. Korea's policy trajectory illustrates sustained domestic commitment: after introducing a domestic STEAM (convergence education) policy in 2011, Korea has continued to strengthen STEM/STEAM through interlinked domestic plans, including the Master Plan for Science, Mathematics, Information, and

Convergence Education (2025–2029), aligned with dedicated master plans for mathematics, science, information, and STEAM education.

Singapore positions STEM education as a cornerstone of domestic competitiveness, emphasising system coherence, rigorous curriculum standards, teacher professionalism, and strong alignment with innovation and industry strategies. Similarly, Chinese Taipei integrates education, innovation, and industry within a unified domestic vision of competitiveness and innovation-driven growth, with particular attention to strategic sectors. Brunei Darussalam and Thailand link STEM development to long-term domestic development agendas and human capital formation, emphasising resilience and workforce readiness. Malaysia's National STEM Movement reflects a strategic commitment to strengthening human capital for digital transformation and sustainable development.

This strategic alignment is a strength, as it increases the likelihood of sustained commitment and links educational reforms to workforce and research ecosystems. However, multiple economies also note that coherence at the strategy level does not automatically translate into coherence in implementation, particularly when responsibilities are distributed across jurisdictions (as in Canada; United States), or when reforms must be delivered across regions with uneven capacity and infrastructure. Capacity building, therefore, requires attention to the implementation structure, including roles and responsibilities, staffing and professional learning, infrastructure baselines, and evidence systems that support course corrections.

4.2. Programme structures blend excellence pathways with broad participation strategies

Most economies adopt a dual strategy: expanding participation in STEM/STEAM, while reinforcing advanced pathways for high-potential learners. Excellence-oriented mechanisms include specialised science high schools and scholarship pipelines (the Philippines), advanced upper-secondary STEM programmes linked to research opportunities and external partnerships (e.g., Japan's Super Science High School), and enrichment pathways such as competitions, camps, research immersion, and innovation festivals (Brunei Darussalam; the Philippines; and Chinese Taipei). Several economies emphasise applied learning that connects STEM to societal and economic contexts. For example, Brunei Darussalam hosts a local centre that organises practical learning initiatives and contests; the Philippines offers research immersion and entrepreneurship training embedded within domestic science events; and Singapore has an applied learning orientation.

At the same time, broad participation strategies include enquiry-based curriculum reforms, interdisciplinary learning, early digital literacy, and expanded informal learning opportunities. Indonesia places emphasis on learner-centred, integrated approaches through ongoing curriculum reforms and school-level innovation initiatives.

A distinctive cross-economic trend is the mainstream use of STEAM and interdisciplinary learning. Canada views STEAM as a legitimate pathway for educational innovation and sustains a large informal STEM sector, including science centres, museums, university outreach hubs, and domestic non-profits, which complement formal schooling at scale. Korea positions convergence education as a sustained domestic priority, shifting from examination-driven instruction towards more authentic, problem-oriented learning. Multiple economies reference education models such as design thinking, entrepreneurship, and project-based learning as practical approaches for developing transferable competencies.

4.3. Teacher capacity is the central constraint and the central lever for quality at scale

Across economies, teacher capacity has emerged as a decisive factor in determining whether STEM reforms can be scaled without sacrificing quality. Common challenges include shortages of qualified STEM teachers, uneven access to professional learning, limited

preparation for integrated STEM/STEAM pedagogy, and difficulties in sustaining enquiry-based teaching under examination pressure. Brunei Darussalam highlighted constraints related to the availability of qualified STEM educators and infrastructure. Thailand has reported teacher shortages, regional inequities, and examination-oriented constraints limiting effective implementation. Chinese Taipei acknowledges the challenge of strengthening training for integrated STEM instruction, whereas Korea identifies the ongoing task of balancing rigorous disciplinary standards with learner-centred innovation in a system shaped by examination traditions.

Economies respond with diverse instruments:

- Systematic professional development, collaborative learning networks, and strengthened pre-service and in-service structures (Republic of Korea; Chinese Taipei).
- Career-linked incentives and recognition structures that reward teaching effectiveness and innovation (Chinese Taipei).
- Digital platforms and AI-enabled tools designed to support teachers and personalise learning (Korea and related digital transformation initiatives).
- Change-agent models in which selected principals and teachers are trained and supported as leaders in school improvement and digitalisation (Indonesia's School Mover Program).
- Partnerships that supplement school-based capacity through expertise and facilities from universities, research institutes, industry, and non-profit organisations (Canada; Japan; Malaysia; Singapore).

One key capacity-building lesson is that teacher development is most effective when it is continuous, practically embedded, and supported by professional communities, mentoring, and stable time and resources.

4.4. Investment is expanding, but infrastructure, sustainability, and scale-up risks remain

Public investment underpins STEM reforms across economies and is often complemented by private sector contributions and partnerships. Economies describe targeted funding for digital infrastructure, STEM facilities, innovation hubs, mobile laboratories, and scholarship systems. The Philippines has highlighted scholarship initiatives to widen access to science and technology education, targeting academically strong and economically disadvantaged learners, along with investments in facilities and innovation hubs that strengthen experiential learning and connect education with research and industry. Chinese Taipei focuses on funding artificial intelligence (AI) education, interdisciplinary learning, digital access to disadvantaged regions, and bilingual instruction to strengthen global engagement. Singapore's sustained investment in teacher training and digital platforms supports quality and equity.

Despite progress, persistent gaps remain:

- Regional disparities in infrastructure and access, especially for rural or isolated schools (Brunei Darussalam; Thailand, an issue echoed in the profiles).
- Risks to sustainability during scale-up include staffing constraints and the maintenance of program quality over time.
- The limited longitudinal tracking of outcomes constrains the ability to judge cost-effectiveness and adjust investments based on evidence.

4.5. Cross-sector partnerships are a hallmark of high-functioning STEM ecosystems

Multi-stakeholder collaboration is a defining characteristic of effective STEM capacity-building. Economies describe partnerships among government agencies, schools, universities, research institutions, industries, and community organisations. These partnerships support the

following outcomes:

- Authentic learning experiences and work-based pathways (industry-linked learning, internships, and applied projects).
- Access to expertise, equipment, and real-world problems that enrich classroom learning.
- Scaling of informal and community STEM opportunities (Canada's informal STEM sector; Brunei Darussalam's domestic centre and outreach programs).
- Diffusion of effective practices through platforms, networks, and recognition mechanisms (Japan highlights an industry–academia–government–education platform that accelerates innovation diffusion and recognises exemplary STEAM and enquiry practices).

Partnerships also create demand for governance. Without safeguards, they risk concentrating opportunities in already advantaged schools or urban areas. Therefore, effective capacity building requires the following partnership design principles: clarity of roles, shared accountability for learning outcomes, transparent resource flows, and inclusion strategies that target underserved communities. Effective partnership models clarify partner roles in learning design and ensure that teachers and students use external resources as part of sustained pathways.

4.6. Monitoring and evidence use are widely recognised, but maturity varies across economies

All economies recognise the importance of evidence-based policies, yet monitoring systems differ in sophistication and scope. Some profiles emphasise international assessment performance, enrolment patterns, and contest achievements as indicators (Chinese Taipei), whereas others focus on teacher credentialing, digital skill indicators, employer feedback, and system-level monitoring of programme participation (Brunei Darussalam). Devolved systems such as those in Canada and the United States face particular challenges in building coherent data systems across jurisdictions, despite benefiting from innovation and diversity at the local level.

A recurring need is to shift from activity monitoring to outcome- and equity-oriented evaluations, including:

- Persistence and transition along STEM pathways (retention across schooling stages and entry into further study or work).
- Equity outcomes, including who benefits, which regions, and under what conditions.
- Skill development aligned with emerging fields, such as AI, data analytics, and advanced manufacturing, as well as broader societal competencies.
- Long-term outcomes for programme alumni and the contribution of programmes to innovation ecosystems.

The pre-survey synthesis highlighted integrated data dashboards for decision making and longitudinal tracking as priorities. Such systems enable economies to detect implementation gaps early, provide target support, and justify sustained investments.

4.7. Equity and gender-responsive design are increasingly mainstream

Equity and inclusion are explicit in many economic strategies and are often linked to digital inclusion and regional access. Brunei Darussalam identified gender equity as a significant asset, with strong female participation across educational levels, and equity integrated into policy oversight. Chinese Taipei recognises persistent gender disparities in higher STEM domains and addresses them through legal frameworks and targeted initiatives.

Japan highlights persistently low STEM enrolment and emphasises earlier gender-sensitive interventions and broader outreach to expand pathways into STEM. The United States and Canada highlight the long-standing equity challenges linked to decentralisation and uneven resources, emphasising the importance of targeted funding and evidence frameworks that can guide local implementation.

Across economies, equity requires both access to and experience with policies. Access policies included infrastructure, scholarships, outreach, and digital connectivity. Experience policies include pedagogy that supports belonging, mentoring, and representation, especially for girls; culturally relevant learning contexts; and safe and supportive learning environments.

5. Key challenges across economies

These sections show that, alongside clear progress and innovation, economies face a recurring set of constraints that limit impact, sustainability, and equity. These challenges do not signify a lack of effort; rather, they reflect the complexity of system changes and the time lag between educational investments and observable workforce outcomes.

The value of consolidating challenges at the Executive Summary level is two-fold. First, it highlights where shared solutions and cross-economy learning are most likely to yield returns (e.g. teacher capacity, evaluation methods, and pathway participation). Second, it establishes clear logic for recommendations: what to preserve and scale from successful approaches, what constraints need to be addressed, and what enabling infrastructure APEC can use to accelerate progress.

5.1. Participation and pipeline fragility in advanced STEM

Several economies have reported declining or insufficient participation in advanced secondary STEM subjects and "pipeline leakage" at the transition points into the upper secondary and tertiary pathways. In some contexts, participation is strong in the early stages but decreases in the upper secondary and beyond stages, weakening the long-term talent pipeline. Gender disparities are particularly salient; even when overall participation is improving, advanced STEM pathways and engineering/technology fields often remain male-dominated. Some submissions also highlighted achievement gaps between high- and low-performing students, suggesting that both excellence and equity challenges coexist within the same system.

A key implication is that capacity-building must address both interest formation and sustained progression. Early engagement must be paired with credible pathways (specialised tracks, mentoring, and career visibility) and support that reduces attrition (academic support, scholarships, flexible entry points, and guidance at key transitions).

5.2. Teacher shortages, uneven preparation, and workload constraints

Teacher capacity is simultaneously the most emphasised lever and the most persistent constraint. Multiple economies have reported shortages of qualified STEM teachers, especially in lower secondary schools and rural or remote areas. Others emphasised that while teachers possess strong discipline knowledge, they often lack preparation for interdisciplinary STEM integration, engineering design processes, or technology-rich pedagogy. Teacher confidence has been reported as lower in areas such as engineering and technology, which can narrow the range of classroom experiences available to learners.

Workload is a cross-cutting constraint. Effective STEM/STEAM implementation requires additional time for instructional design, collaboration, and reflection. Where teachers are burdened with heavy administrative duties, or where adequate time is not allocated for collaboration, implementation tends to be superficial or confined to a small number of motivated individuals. This creates sustainability risks, uneven quality, and inequitable access

across schools.

5.3. Curriculum coherence and the 'implementation gap'

Many economies describe a persistent gap between policy ambition (enquiry-based, applied, interdisciplinary STEM) and classroom reality (content-heavy, examination-oriented instruction). In several contexts, STEM is not fully embedded in curriculum standards and assessment systems; consequently, its implementation shifts to extracurricular activities, enrichment programmes, or competitions. While these can be powerful, they may not reach all learners equally and may fail to change mainstream instructional practices, especially when teacher time is limited.

Economies also highlight the ambiguity in how STEM and STEM/STEAM are operationally defined across schools and regions. Without shared definitions and high-quality instructional materials, implementation becomes fragmented, STEM remains siloed by subject, interdisciplinary integration is limited, and continuity across grades is weak.

5.4. Infrastructure, resources, and geography-driven inequities

Infrastructure and resource constraints remain decisive factors for hands-on STEM learning. Some economies report limited access to laboratories, shared facilities in rural areas, and an uneven availability of digital tools and connectivity. Geographic disparities compound these constraints by limiting access to specialist teachers, sustaining professional learning opportunities, and providing partnership opportunities.

Even when systems are relatively well-resourced, unequal access to enrichment and advanced opportunities can reinforce socioeconomic stratification. While private tutoring plays a significant role in advanced mathematics and science, public systems may struggle to provide equitable, high-level learning experiences. Capacity building, therefore, requires not only programme design but also targeted resourcing strategies that close access gaps and ensure that rural and underserved schools can implement enquiry-rich learning rather than symbolic STEM activities.

5.5. Governance fragmentation and coordination challenges

Decentralised governance can enable adaptation to local contexts, but it also creates structural challenges, such as limited cross-jurisdictional comparability, fragmented data systems, and difficulties in coordinating pathways across agencies responsible for schooling, higher education, and workforce development. Even in more centralised systems, overlapping mandates across ministries can weaken coherence unless joint planning, shared metrics, and stable implementation structures are in place.

A recurring issue is the alignment across transition points, secondary to tertiary education, and education to work. Where agencies operate in silos, curricula and pathway support can become misaligned, reducing continuity in STEM learning and increasing attrition. Strong coordination mechanisms are essential to maintain a coherent pipeline from early learning to workforce participation.

5.6. Evidence, evaluation, and attribution of long-term outcomes

Across economies, there is strong recognition that STEM initiatives should be evidence-informed, yet many report difficulties linking interventions to long-term outcomes such as tertiary STEM completion and workforce entry. The methodological challenges include time lags, multiple interacting reforms, and limited longitudinal tracking. Consequently, systems may over-rely on short-term proxies (participation and satisfaction) or, conversely, hesitate to scale promising models because of insufficient causal evidence.

A balanced approach is required: evaluation designs that are rigorous but feasible,

respect system complexity, and combine quantitative indicators with qualitative evidence on implementation quality and context. Improving data integration and longitudinal tracking is a priority; however, economies also emphasise that action cannot wait for perfect evidence, and evaluation must provide timely learning and adaptation.

5.7. Skills mismatch, rapid technological change, and the need for agile curriculum governance

Rapid advances in AI, automation, robotics, and data analytics have outpaced curriculum renewal cycles in multiple economies. Employers may report skill mismatches when graduates' competencies do not align with emerging industry requirements. This challenge is not limited to the addition of new content. This requires agile curriculum governance, teacher upskilling, and partnerships to keep learning tasks connected to evolving real-world practices.

Several submissions have also stressed that technical competence must be complemented by ethical, societal, and sustainability dimensions. As socio-technical systems become more complex, capacity-building includes responsible innovation, data ethics, and sustainability-oriented engineering as integral elements of STEM education.

5.8. Talent retention and pathway credibility in small or rapidly changing labour markets

Some economies highlight the difficulty of rapidly scaling up the STEM workforce and retaining highly trained talent. When high-performing learners pursue tertiary study or research opportunities abroad, economies may face shortages if graduates do not return or if domestic labour markets cannot offer attractive technical pathways. Even in larger economies, students may struggle to envision STEM careers when pathways are opaque, role models are scarce, or social environments discourage certain groups from pursuing STEM.

This challenge highlights the importance of a full-pathway ecosystem: career guidance, industry-linked experiences, mentoring, and visible trajectories that make STEM futures credible and desirable, particularly for girls and other underrepresented groups.

5.9. Learner engagement, well-being, and the risk of 'high performance–low interest'

Some high-achieving systems report a tension between strong assessment performance and lower student interest or well-being in science. High-stakes examination cultures can discourage enquiry, creativity, and pedagogical risk-taking, while also increasing stress. In these contexts, capacity building increasingly includes attention to motivation, relevance, and well-being so that STEM competence is paired with curiosity, agency, and responsible judgment.

This is an issue of equity. When learning becomes narrowly performance-driven, students without access to external support may disengage earlier, widening the disparities in who can sustain advanced STEM participation.

6. Recommendations for APEC STEM capacity building

Building on shared strengths and recurring challenges across the 14 economies, this report proposes six priority directions for APEC-level capacity building. These priorities are designed to be actionable across governance contexts and strengthen both quality and equity.

1) Strengthen early STEM exposure and sustained engagement

- Introduce enquiry-based and interdisciplinary learning from primary education, integrating age-appropriate problem solving, design activities, and scientific practices.
- Invest in early gender-sensitive interventions (mentoring, representation, and classroom practices that foster belonging) to widen participation in STEM pathways.

- Embed societal challenges (sustainability, health, digital citizenship, and disaster resilience) as authentic contexts that increase relevance and motivation.

2) Bridge the equity divide through targeted access and localised delivery
- Expanding digital access (connectivity, devices, and learning platforms) and localised maker education in rural and underserved communities.
- Develop mobile outreach and blended learning hubs (mobile labs, regional STEM centres, and community partnerships) that reduce geographic barriers.
- Use targeted equity funding and minimum service standards to prevent opportunity concentration in already advantaged schools and regions.

3) Ensure systemic capacity building for teachers and leaders
- Provide continuous professional learning that is practice-embedded, collaborative, and aligned with curriculum and assessment reforms.
- Use digital and AI-enabled tools to support planning, formative assessment, and personalisation, while preserving teacher agency and professional judgement.
- Institutionalise expert–teacher collaboration (universities, research institutes, museums, and industry) and develop specialist certification or career pathways for STEM/STEAM leadership.

4) Institutionalise monitoring frameworks that track long-term outcomes
- Develop integrated data dashboards for decision-making across agencies and levels, with indicators for participation, quality, and equity.
- Track long-term outcomes for programme alumni, including transitions to further education and employment in emerging fields.
- Build evaluation capacity so that programme scaling is accompanied by quality assurance and improvement cycles.

5) Promote public–private synergy with governance and equity safeguards
- Scale effective industry-linked models through shared standards, co-designed curricula, and authentic problem-based learning.
- Use incentives (grants, matching funds, and other mechanisms appropriate to domestic contexts) to encourage corporate and philanthropic support, especially in underserved regions.
- Establish governance arrangements that ensure partnerships advance public educational goals and are access-inclusive.

6) Foster regional collaboration and shared tools through APEC platforms
- Leverag APEC and related regional networks to share toolkits, curriculum resources, professional learning modules, and evaluation instruments.
- Co-create scalable digital STEM curricula and micro-credential pathways for teachers that can be adapted locally.
- Develop peer-learning mechanisms (policy dialogues, joint pilots, and case-based workshops) to accelerate the diffusion of proven practices.

7. Concluding remarks

Taken together, the 14 economic contributions show that STEM capacity building in the APEC region is advancing beyond isolated initiatives towards more coherent ecosystems that connect policy, pedagogy, partnerships, and pathways. While economic contexts vary, the synthesis suggests a set of transferable design principles for capacity building.

- Combining system-level direction with local adaptation. Australia illustrates how a coordinated domestic vision can coexist with decentralised delivery, enabling coherence while allowing for regional tailoring.
- Building STEM learning ecosystems rather than isolated programmes. Canada and United States have demonstrated that partnership-driven ecosystems and strong informal sectors can complement formal schooling. However, intentional coordination is required to protect equity and coherence across pathways.
- Treat digital transformation as a pedagogical and capacity-building strategy, not only as infrastructure. Korea's integration of AI and digital tools within a master plan and Chinese Taipei's investment in digital access, alongside enquiry-based reform, exemplify this approach.
- Institutional excellence pathways alongside broad participation. Japan's dual strategy and the Philippines' science high school and scholarship systems show that advanced pathways can align with equity goals when access support is provided.
- Aligned curricula, assessments, and professional learning. Economies report that enquiry-based and integrated STEM cannot be scaled if assessment systems remain narrowly examination-focused or if teachers lack sustained support and professional time.

APEC can accelerate progress through regional collaboration, which shares practical tools, supports peer learning, and strengthens a common language for quality and equity. The next phase depends on translating ambitions into actionable and sustainable implementation conditions: capable teachers supported by time and materials, coherent curricula aligned with authentic STEM practices, equitable access to infrastructure and enrichment, and evidence systems that guide learning and improvement over realistic time horizons. APEC can add unique value by enabling economies to share what works, develop interoperable tools and indicators, and accelerate capacity building through sustained communities of practice. With careful attention to equity, teacher capacity, and evidence-informed implementation, STEM education can become a powerful tool for inclusive innovation and sustainable development across regions.

1. Australia

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Summary: Australia's approach to STEM education is characterized by a domestically coordinated vision combined with decentralized implementation, positioning STEM as a central lever for economic competitiveness, workforce resilience, and social equity. Unlike Canada's fully devolved education model, Australia has articulated a shared direction through the National STEM School Education Strategy 2016–2026, endorsed by all education ministers. This strategy provides a unifying framework while allowing states and territories to tailor delivery according to local contexts. A defining feature of Australia's policy orientation is its emphasis on participation, aspiration, and capability building, rather than short-term academic performance alone. STEM education is framed not merely as preparation for specialist careers, but as a foundation for scientific literacy, critical thinking, and problem-solving skills required across a wide range of future occupations.

1-1. Domestic Strategy and Vision

Australia's domestic STEM vision is anchored in two overarching goals: ensuring that all students acquire strong foundational STEM skills, and increasing participation in advanced STEM learning pathways, particularly among students from underrepresented groups, during secondary education and beyond. To advance these goals, the domestic strategy identifies five priority areas: student engagement and aspiration, teacher capability, school-level opportunities, partnerships with industry and higher education, and the development of a strong evidence base for continuous improvement.

Australia's approach to STEM education is characterized by the coordination with state and territory–level implementation, enabling policy coherence while allowing for local flexibility. The cornerstone policy framework is the National STEM School Education Strategy 2016–2026, endorsed by all Australian education ministers. This strategy frames STEM education as essential not only for specialist careers, but also for fostering scientific literacy, problem-solving capability, and critical thinking across the broader student population.

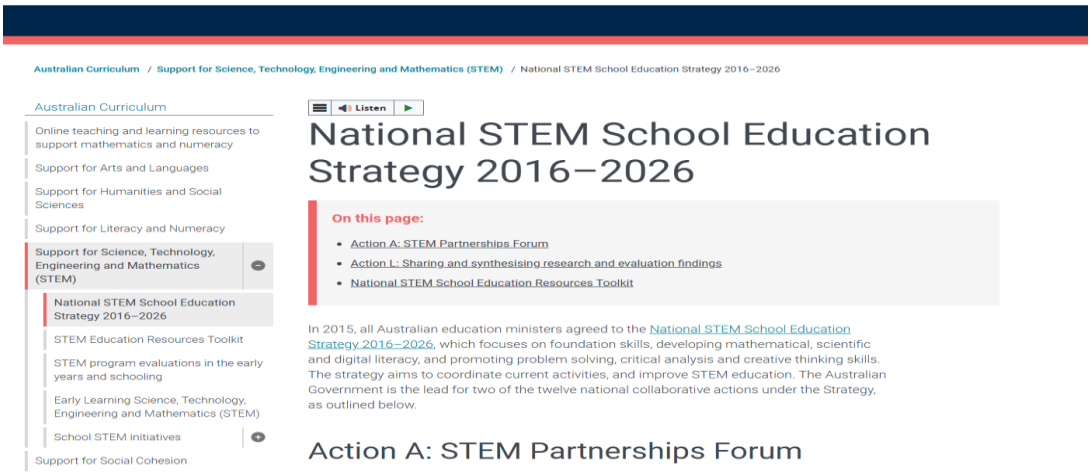


Figure 1. Official Website of Australia's STEM School Education Strategy (2016–2026). https://www.education.gov.au/australian-curriculum/support-science-technology-engineering-and-mathematics-stem/national-stem-school-education-strategy-2016-2026

Within this framework, STEAM is not formally defined as a separate policy category. Nevertheless, interdisciplinary learning, creativity, and real-world problem solving are increasingly promoted through curriculum design and pedagogical guidance. In practice, many state-level initiatives and school-based programs integrate elements of arts, design, and creativity into STEM learning, even when not explicitly labelled as STEAM.

Rather than prioritizing short-term test score gains, Australia's vision places emphasis on student participation, aspiration, and capability development, alongside workforce relevance and equity. This reflects a broader understanding of STEM education as a long-term investment in human capability, where interdisciplinary and creative approaches are progressively embedded within STEM initiatives across policy, program, and school levels.

1-2. Key STEM Education Programs

a. STEM Education Programs and Initiatives

Australia operationalizes its STEM vision through a portfolio of domestically funded and strategically coordinated programs delivered by scientific academies, research organizations, universities, and non-profit partners. Rather than relying on curriculum reform alone, this approach reflects a policy belief that sustained improvement in STEM outcomes depends on teacher capability, authentic student engagement, and real-world relevance across the youth STEM pipeline.

A flagship initiative is STEM Professionals in Schools, delivered domestically by Commonwealth Scientific and Industrial Research Organization (CSIRO). This program partners classroom teachers with STEM professionals from industry and research sectors to co-design and implement authentic STEM learning experiences. Longitudinal evaluations consistently report positive impacts on teacher confidence, pedagogical practice, and student engagement. Participating teachers indicate an increased ability to contextualize curriculum content through real-world applications, while students demonstrate greater awareness of STEM careers and pathways.

Teacher capacity building is further supported through a recognized suite of inquiry-based professional learning programs developed by the Australian Academy of Science. Key programs include *Primary Connections, Science by Doing, and reSolve*, all of which focus on strengthening teachers' pedagogical content knowledge and inquiry-oriented instructional practices. These initiatives have been sustained through targeted federal funding over multiple policy cycles, underscoring their role as system-level capacity-building mechanisms rather than short-term interventions.

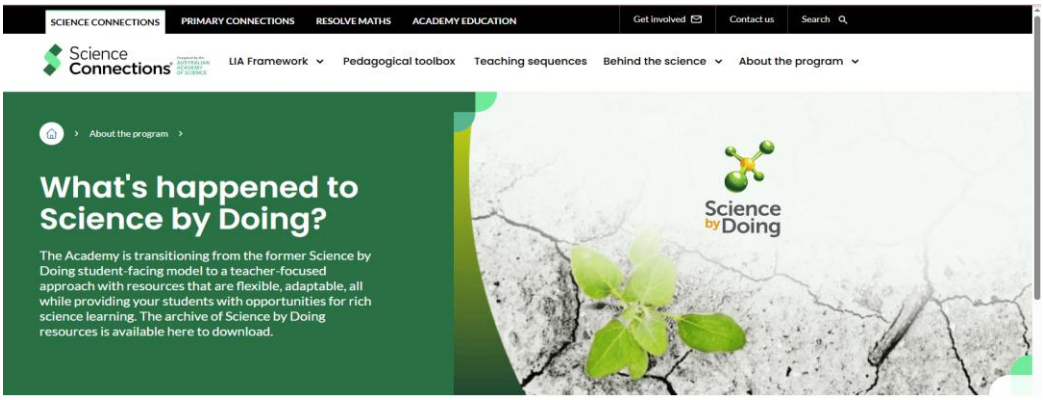


Figure 2. Official Website of the "Science by Doing" Program (Australian Academy of Science) https://scienceconnections.edu.au/

Australia also places strong emphasis on early STEM capability development, recognizing that participation gaps often emerge well before secondary subject specialization. Programs such as *Let's Count and Little Scientists* promote numeracy, scientific inquiry, and problem-solving in early childhood and primary education. These initiatives aim to build foundational dispositions toward STEM learning, particularly among children from disadvantaged backgrounds.



Figure 3. Official Webpage of Little Scientists Australia Highlighting Early STEM Education Recognition and Engagement Initiatives. https://littlescientists.org.au/stem-awards-info/

To address geographic and socio-economic inequities, Australia operates a National Lending Library that enables schools—especially those in rural and remote areas—to borrow digital technologies and STEM equipment at no cost. This shared-access model reduces infrastructure barriers and supports more equitable participation in hands-on STEM learning, without requiring each school to independently invest in high-cost resources.

Gender-responsive initiatives further complement Australia's STEM program portfolio. Programs such as Curious Minds provide STEM camps, mentoring, and enrichment opportunities for girls, particularly during the middle years when interest in STEM subjects often declines. These initiatives focus on building self-efficacy, identity, and aspiration, rather than short-term achievement gains, reflecting a pipeline-oriented approach to gender equity.

Taken together, Australia's STEM education initiatives illustrate a distributed yet coherent implementation model, in which domestic priorities are realized through partnerships with expert organizations and targeted programs that address teacher capacity, student engagement, early intervention, and equity.

b. Talent Development and Scholarship Programs

In addition to broad-based STEM education initiatives, Australia supports targeted talent development and scholarship programs designed to nurture advanced STEM capability and sustain progression into tertiary education and the workforce.

Selective enrichment programs, Olympiad pathways, and university-linked extension initiatives provide high-achieving students with opportunities for advanced learning, research exposure, and academic acceleration, particularly in mathematics, science, and engineering-related fields. These programs often operate through collaborations between universities, professional societies, and state education authorities.

At the post-secondary transition level, scholarship schemes and industry-linked fellowships play an important role in supporting students pursuing STEM degrees, particularly those from underrepresented or regional backgrounds. While administered across multiple agencies and jurisdictions, these mechanisms collectively reinforce Australia's commitment to maintaining a strong and diverse STEM talent pipeline aligned with domestic workforce needs.

c. Teachers' Capacity Building

Teacher capability is treated in Australia as a primary driver of STEM education quality. Domestic survey data indicate that teacher confidence remains uneven across STEM domains; for example, only around 32% of primary teachers report confidence in teaching engineering-related content, highlighting a significant system-level capacity gap. However, evidence also suggests that targeted professional development can substantially narrow this gap. Among teachers who have participated in STEM-specific training, reported confidence levels rise to approximately 48%, underscoring the effectiveness of focused capacity-building interventions.

Against this backdrop, programs such as STEM Professionals in Schools and inquiry-focused professional learning initiatives are positioned as leading indicators of system improvement. Rather than relying solely on curriculum reform, Australia has invested in strengthening teachers' instructional confidence, pedagogical repertoire, and professional networks, recognizing that these factors have a decisive influence on classroom practice and student engagement.

A central role in this effort is played by the Australian Academy of Science, which delivers domestically recognized inquiry-based programs including *Primary Connections, Science by Doing, and reSolve*. These initiatives focus on deepening teachers' pedagogical content knowledge and inquiry-oriented instructional practices in science and mathematics. Federal budget documentation indicates that these programs continue to receive targeted and sustained funding, reflecting their function as system-level capacity-building mechanisms rather than short-term professional development offerings.

Additional evidence of impact is provided by the STEM X Academy, a domestically recognized immersive professional learning initiative. Evaluation data show that 95% of participating teachers reported significant improvements in their classroom practice, while 87% indicated enhanced capacity to engage students in STEM learning, particularly through project-based and applied approaches.

Another flagship initiative, STEM Professionals in Schools, delivered by the Commonwealth Scientific and Industrial Research Organization (CSIRO), pairs teachers with STEM professionals from industry and research sectors. Independent evaluations consistently report gains in teacher confidence, instructional relevance, and real-world contextualization of curriculum content, alongside increased student awareness of STEM careers through sustained exposure to authentic professional practice.

Taken together, Australia's approach to teachers' capacity building illustrates a coherent, evidence-informed strategy that prioritizes professional learning as a lever for systemic improvement. By investing in sustained, practice-oriented development rather than episodic training, Australia seeks to strengthen the foundations of high-quality STEM instruction across diverse school contexts.

d. STEM Facilities and Learning Environments

Student STEM learning in Australia is supported through a combination of school-based instruction, domestic programs, and extracurricular opportunities. However, participation data reveal persistent challenges at key transition points in the STEM pipeline. In particular, enrollment in advanced secondary mathematics subjects—such as Specialist Mathematics—remains low. Recent estimates indicate that only around 8–8.4% of Year 12 students enroll in advanced mathematics, highlighting a significant bottleneck between broad STEM participation and advanced specialization.

In response, Australia has adopted a pragmatic and equity-oriented approach to STEM infrastructure. Rather than emphasizing uniform provision of permanent facilities, domestic policy prioritizes shared resources, mobile equipment, and partnerships with external experts. This model aims to expand access to contemporary STEM learning while mitigating geographic and socio-economic disparities, especially in an economy characterized by wide geographic dispersion and remote communities.

Australia's STEM learning environments therefore extend beyond traditional classrooms to include flexible learning spaces, shared equipment pools, and outreach partnerships with research organizations and industry. Domestic initiatives such as shared lending schemes for digital technologies and STEM equipment enable schools with limited resources to participate in hands-on and technology-rich STEM learning without incurring prohibitive costs. This portfolio-based approach reflects a long-term policy orientation toward system resilience, scalability, and equitable access, rather than infrastructure-intensive reform.

e. Student STEM Participation and Pipeline Development

Australia's STEM participation profile reveals strong engagement at early and middle schooling stages, coupled with attrition at advanced secondary levels. While many students participate in general STEM subjects, progression into advanced mathematics and science pathways remains limited. Data from the Australian Mathematical Sciences Institute indicate that in 2023 only 8.4% of Year 12 students enrolled in advanced mathematics, a key gateway to tertiary STEM study. Among these students, 36.5% were female, pointing to continued gender imbalance at the highest levels of school mathematics.

These participation patterns underscore a central challenge in Australia's STEM pipeline: maintaining student engagement and aspiration beyond foundational STEM exposure, particularly during the senior secondary years when subject choices become more consequential for postsecondary pathways.

1-3. Education Effects and Measured Outcomes

Evidence on the effects of STEM education in Australia indicates that the most consistent and robust impacts are observed in student engagement, confidence, participation pathways, and longer-term workforce outcomes, rather than in immediate improvements in standardized academic test scores. Domestic and program-level evaluations consistently show that STEM initiatives have contributed to increased student interest in STEM subjects and careers, improved teacher confidence and instructional quality, and enhanced participation among underrepresented groups, including girls, Indigenous students, and students in regional and remote areas.

International assessment results confirm that Australia maintains solid foundational performance in STEM subjects, though it does not rank among the highest-performing systems globally. In PISA 2022, Australian 15-year-old students achieved average scores of 487 in mathematics and 507 in science, both above the OECD averages of 472 and 485, respectively. At the same time, domestic analyses highlight persistent variation in achievement, including substantial gaps between high- and low-performing students and uneven attainment of proficiency benchmarks across jurisdictions. These patterns reinforce the need for targeted academic support alongside broad participation strategies.

Participation data further reveal structural challenges in the STEM pipeline, particularly at the senior secondary level. Enrollment in advanced mathematics subjects, such as Specialist Mathematics, remains limited, with only around 8–8.4% of Year 12 students participating in recent years. Gender imbalance persists at this stage, with female students comprising approximately 36.5% of advanced mathematics enrollments. These figures point to a critical bottleneck between general STEM exposure and progression into tertiary STEM study and related career pathways.

Longer-term indicators provide important insight into system-level effects. Data from the STEM Equity Monitor 2025 show notable progress in diversifying Australia's STEM workforce. The number of First Nations people employed in STEM-qualified occupations increased by approximately 36% between 2012–13 and 2021–22. Over a similar period, the proportion of women in STEM occupations in remote and very remote areas increased from around 8% to 11%, and the gender pay gap in STEM industries narrowed modestly from approximately 18% in 2021 to 16% in 2024. In addition, the proportion of students with disability enrolled in university STEM fields roughly doubled, from about 6% to 12%, indicating improved access and inclusion.

Despite these positive trends, women remain underrepresented in university STEM enrolments, particularly in fields such as engineering and information technology. The analyses emphasize the importance of early and sustained interventions to support girls' and women's STEM aspirations and to strengthen transitions from school to higher education and employment.

Taken together, these findings underscore a defining feature of Australia's STEM policy framework: education effects are cumulative and time-lagged, becoming most visible in participation patterns, equity indicators, and workforce outcomes rather than short-term academic metrics alone. While achievement levels remain above international averages, persistent gaps at key transition points—especially in senior secondary subject selection—require continued policy attention. This pattern aligns with Australia's emphasis on broad participation, equity, and workforce relevance, and highlights the importance of continuous monitoring, targeted supports, and cross-sector partnerships in advancing domestic STEM and STEAM goals.

1-4. Investment and Budgetary Patterns

Australia's STEM education investment model is characterized by an emphasis on sustained, moderate funding rather than large-scale, one-off reform packages. Federal budget documents for 2025–26 indicate that approximately AUD 7.0 million has been allocated to ongoing domestic STEM initiatives. These investments support a balanced portfolio of activities, including teacher professional learning, student engagement programs, early STEM interventions, and infrastructure access schemes designed to broaden participation.

This funding approach reflects a deliberate policy choice to prioritize continuity, scalability, and partnership leverage. By channelling investment through established research organizations, scientific academies, universities, and non-profit partners, Australia seeks to extend the reach and impact of public funding while maintaining fiscal sustainability. Rather than pursuing rapid or disruptive system transformation, the investment model supports incremental improvement and long-term capacity building across the STEM education ecosystem, aligning financial commitments with Australia's broader emphasis on participation, equity, and workforce relevance.

1-5. Partnerships

Partnerships are embedded as a structural element of Australia's STEM ecosystem. Schools commonly collaborate with universities, scientific academies, research agencies, industry partners, and community organizations to enhance curriculum relevance and provide students with exposure to authentic STEM practices. These partnerships support not only student learning, but also teacher professional growth, curriculum innovation, and alignment with emerging scientific and technological fields.

Domestic strategy documents explicitly identify partnerships as a core policy mechanism for connecting education with future workforce needs while maintaining educational integrity. Collaboration with research agencies such as CSIRO and with industry partners enables access to real-world problem contexts, contemporary expertise, and mentoring opportunities, while partnerships with universities and academies strengthen pathways between school, higher education, and employment.

Taken together, Australia's partnership-based approach reflects a recognition that effective STEM education requires coordination across sectors. By embedding partnerships within the strategy, Australia reinforces the relevance, authenticity, and sustainability of STEM learning, while supporting scalable implementation across diverse school contexts.

1-6. Performance Indicators and Monitoring

Australia's approach to monitoring STEM and STEAM performance is grounded in the use of multi-dimensional indicators that capture both short-term educational processes and longer-term system outcomes. Rather than relying on a single high-stakes metric, policymakers emphasize trend analysis, longitudinal evidence, and triangulation across multiple data sources to inform continuous improvement.

Performance monitoring typically encompasses five interrelated domains. First, student achievement indicators, including international assessment results such as PISA mathematics and science scores, provide a benchmark for foundational learning outcomes. Second, participation indicators, particularly enrollment in advanced secondary STEM subjects, are

used to assess progression and retention within the STEM pipeline. Third, teacher capability measures, derived from professional learning evaluations and program-level assessments, track changes in instructional confidence and pedagogical practice.

Fourth, Australia places strong emphasis on equity and inclusion metrics, monitoring participation and outcomes by gender, Indigenous status, disability, and geographic location. These indicators reflect domestic priorities related to access, fairness, and workforce diversification. Finally, longer-term transition indicators, including postsecondary enrolment, workforce participation, and wage data in STEM-related fields, are used to assess the downstream effects of education policy.

Together, this monitoring framework reflects a shared policy understanding that STEM system performance cannot be captured by any single measure. Instead, Australia prioritizes the analysis of patterns and trends over time, recognizing that the effects of STEM and STEAM education investments are often cumulative and time-lagged. This evidence-informed approach supports adaptive policy design and aligns performance monitoring with Australia's broader goals of participation, equity, and workforce relevance.

1-7. Gender Inclusivity and Equity

Gender inclusivity and broader equity considerations are treated in Australia as core dimensions of STEM system performance, rather than as supplementary policy objectives. STEM policy frameworks embed targeted support for girls, Indigenous students, students with disability, and learners in regional and remote communities, while outcome monitoring increasingly relies on disaggregated participation and workforce data to track progress toward inclusion.

At the program level, equity goals are addressed through targeted and developmentally sequenced initiatives. For example, Curious Minds (STEM Summer Schools for Girls) focuses on sustaining girls' interest and confidence in STEM during the middle years, a critical period when participation often declines. Complementary early-intervention programs such as Little Scientists and Let's Count strengthen foundational STEM dispositions in early childhood and primary education, reflecting recognition that equity gaps often emerge well before secondary subject selection.

Access to learning resources is further supported through the National Lending Library, which enables schools—particularly those in rural and remote areas—to borrow STEM equipment and digital technologies at no cost. This shared-access model prioritizes equitable provision over uniform infrastructure, helping to reduce geographic and socio-economic barriers to participation in hands-on STEM learning.

- Longer-term indicators suggest gradual but measurable progress in equity and participation. According to the STEM Equity Monitor (2025):
- the number of First Nations Australians in STEM-qualified occupations increased by approximately 36% between 2012–13 and 2021–22;
- in remote and very remote areas, the share of women in STEM-qualified occupations rose from around 8% to 11%;
- the proportion of students with disability enrolled in tertiary STEM programs doubled, from approximately 6% to 12% between 2015 and 2023; and
- the gender pay gap in STEM industries narrowed modestly, from about 18% in 2021 to 16% in 2024.

Taken together, these trends indicate that Australia's STEM and STEAM initiatives generate their most pronounced effects in participation, inclusion, and workforce diversity, rather than in immediate academic score gains. Importantly, equity is increasingly framed not as an add-on to STEM policy, but as a central indicator of system effectiveness, supported by sustained programs, domestic monitoring mechanisms, and evidence-informed policy adjustment.

1-8. Key Challenges and Distinctive Features

Despite notable progress, Australia continues to face a set of persistent structural challenges in advancing STEM education. A central concern is the low participation in advanced secondary STEM subjects, particularly advanced mathematics, which constrains progression into tertiary STEM pathways and narrows the future talent pipeline. This challenge is compounded by gender imbalance at advanced levels and persistent achievement gaps between high- and low-performing students.

Geographic disparities further complicate implementation. Ensuring consistent quality of STEM delivery across diverse regions and school contexts—including rural and remote areas—remains an ongoing challenge, particularly where access to specialist teachers, resources, and sustained professional learning is uneven. In addition, teacher confidence varies across STEM disciplines, with lower confidence in areas such as engineering and technology continuing to affect classroom practice.

Another structural limitation lies in evaluation and attribution. While many school-based STEM initiatives demonstrate positive effects on engagement and participation, directly linking these interventions to long-term educational and workforce outcomes remains methodologically complex. This complicates impact assessment and policy prioritization.

At the same time, Australia's STEM education model exhibits several distinctive strengths. It is characterized by a teacher-first reform logic, which prioritizes professional capacity and instructional confidence as primary levers for system improvement. The strong involvement of domestic scientific institutions in program delivery enhances credibility, real-world relevance, and coherence across initiatives. Equity considerations—spanning gender, Indigenous participation, disability, and geography—are explicitly embedded within core policy design, rather than treated as peripheral objectives. Finally, Australia adopts a realistic, evidence-informed approach to evaluation, acknowledging system complexity and the time-lagged nature of educational effects.

Together, these features position Australia's STEM strategy as incremental, adaptive, and equity-oriented, while underscoring the need for continued attention to advanced pathway participation, regional consistency, and long-term outcome alignment.

2. Brunei Darussalam

Orteza RONNALEE, Executive Director, DOST-Philippines Science High School System, the Philippines

Summary: Brunei Darussalam is a small, high-income Southeast Asian economy whose long-term development goals place strong emphasis on human capital formation as a foundation for economic resilience and sustainability. It has embraced a unified and forward-looking strategy for science, technology, engineering, and mathematics education as a key factor in developing human capital, with STEM skills regarded as vital for enhancing productivity, fostering innovation, and engaging in a digital and knowledge-driven economy. This vision is implemented through a contemporary educational framework that encourages comprehensive learner growth, inquiry-focused and experiential learning, early digital proficiency, and specific science and technical tracks in secondary education. Domestic reforms are progressively incorporating emerging technologies like artificial intelligence, data analytics, and immersive digital tools to equip learners for changing workforce needs. A key component of Brunei Darussalam's STEM ecosystem is a domestic center that organizes practical learning initiatives, enhances curriculum, strengthens teacher and institutional capabilities, and fosters collaboration with industry, universities, and global partners. Student contests, innovation contests, projects centered on sustainability, camps, and festivals significantly contribute to bridging classroom education with real-world experiences, nurturing creativity, problem-solving abilities, environmental consciousness, and entrepreneurship skills, while outreach programs enhance accessibility for rural and isolated schools. These initiatives are backed by ongoing public funding, with education consistently obtaining a significant portion of the domestic budget, which includes specific financial support for STEM facilities, digital infrastructure, and programs relevant to the workforce. Collaborations with key industries, financial organizations, and educational institutions enhance practical learning and career transition routes. The evaluation of system performance involves monitoring student achievement, teacher credentials, enrolment patterns, digital skills, and feedback from employers. Even with robust policy alignment and funding, there remain obstacles such as a lack of qualified STEM educators, infrastructure deficiencies, a limited talent pool, brain drain, and skill misalignments caused by swift technological advancements. Gender equity stands out as a significant asset, characterized by strong female involvement at all educational levels and equity integrated into policy oversight. Brunei Darussalam's holistic strategy showcases a robust dedication to developing an inclusive, resilient, and future-ready STEM workforce that aligns with domestic development objectives.

2-1. Strategy and Vision

Brunei Darussalam's long-term development agenda is anchored on Wawasan Brunei 2035, which envisions the economy as one that is recognized for the accomplishments of its well-educated and highly skilled people, enjoys a high quality of life, and sustains a dynamic and diversified economy (Government of Brunei Darussalam, 2014). Integral to this vision is the development of strong human capital, with education identified as a strategic driver of economic transformation, social cohesion, and domestic resilience.

STEM education occupies a critical position within this vision, as it underpins Brunei Darussalam's aspirations to move toward a knowledge-based and innovation-driven economy. The government recognizes that competencies in science, technology, and engineering are essential for strengthening productivity, supporting emerging industries, and enhancing domestic competitiveness in a rapidly evolving global economy. Consequently, domestic

education policies emphasize not only academic achievement but also the development of critical thinking, problem-solving, creativity, and digital literacy.

The strategic direction of Wawasan Brunei 2035 is operationalized through the System Pendidikan Negara Abad ke-21 (SPN21), otherwise known as the National Education System for the 21st century, which has been implemented since 2011. SPN21 promotes holistic learner development by integrating eight learning domains, strengthening early digital literacy, and offering elective science and technical streams at the secondary level to nurture students' interests and aptitudes in STEM-related fields (Ministry of Education Brunei Darussalam, 2022). The framework emphasizes inquiry-based learning, experiential approaches, and applied knowledge, aligning classroom instruction with the competencies required in modern STEM professions.

To further align education with future workforce demands, the Ministry of Education has aligned its Education Cluster Master Plan with emerging and frontier technologies. Recent reforms prioritize the integration of artificial intelligence (AI), blockchain, mixed and extended reality, and data analytics into teaching, learning, and assessment processes. These initiatives aim to support personalized and adaptive learning environments, strengthen pedagogical innovation, and better prepare learners for Industry 4.0 and digital economy careers (Ministry of Education Brunei Darussalam, 2022). Taken together, these strategies demonstrate Brunei Darussalam's coherent and forward-looking domestic approach to STEM talent development in support of its long-term socioeconomic objectives.

2-2. Overview of Key STEM Education Programs

a. Educational Programs and Initiatives

Brunei Darussalam advances STEM talent development through a range of structured educational programs and domestic initiatives designed to align learning outcomes with workforce and economic priorities. A central institutional mechanism is the Science, Technology, and Environment Partnership (STEP) Centre under the Ministry of Education, which serves as the domestic hub for promoting STEAM (Science, Technology, Engineering, Arts, and Mathematics) education in schools. The STEP Centre delivers hands-on, inquiry-based programs that aim to stimulate students' interest in science and technology while strengthening creativity, innovation, and problem-solving skills (Ministry of Education Brunei Darussalam, 2022).

In addition to direct program implementation, the STEP Centre functions as a collaborative platform that enables external strategic partners—including industry players, higher education institutions, and international organizations—to conduct STEAM-related activities for students. Its four core services—STEAM programs, awareness and roadshow visits, consultancy, and training and coaching—support both learners and educators by enhancing instructional quality, promoting curriculum enrichment, and building institutional capacity for effective STEAM integration. These initiatives are explicitly aligned with SPN21 and the domestic Industry Competency Framework, ensuring coherence between education provision and labour market requirements (Ministry of Education Brunei Darussalam, 2022).

Complementing education sector reforms, Brunei Darussalam has adopted a broader digital transformation agenda through the Digital Economy Masterplan 2025, a whole-of-

government framework that emphasizes digital identity systems, cloud adoption, Industry 4.0 readiness, digital infrastructure, and AI governance. A central pillar of this masterplan is digital manpower and talent development, which focuses on equipping youth with future-ready competencies through ICT proficiency programs, coding initiatives, computational thinking, and inclusive "digital-for-all" strategies that broaden access to digital skills across society (Authority for Info-communications Technology Industry of Brunei Darussalam [AITI], 2020). Together, these education and digital initiatives reflect an integrated domestic approach to strengthening STEM and digital talent pipelines.

b. Student Competitions and Events

Student competitions and experiential learning events play a critical role in Brunei Darussalam's STEM talent development strategy by translating classroom learning into authentic, real-world applications. The STEP Centre serves as the principal coordinator of youth STEM activities, offering a suite of highly recognized "iconic" programs that provide progressive opportunities for skills development, innovation, and collaboration (Ministry of Education Brunei Darussalam, 2022).

Flagship initiatives such as F1 in Schools expose students to international engineering standards through the design, simulation, and racing of miniature Formula 1 cars, strengthening competencies in physics, aerodynamics, computer-aided design (CAD), and project management. The National STEM & Innovative Design Challenge (NSIDC) promotes interdisciplinary STEAM learning by challenging students to develop engineering solutions to contextual problems through prototyping and systems thinking. Programs such as Students in STEAM and R.E.A.L. (Relevant, Experiential, Applied Learning) further support inquiry-based learning by encouraging students to communicate scientific ideas through creative and applied outputs (STEP Centre, 2023).

Sustainability-oriented initiatives—including Green School Gardening and Green Initiatives—integrate STEM learning with environmental stewardship, introducing students to hydroponics, smart agriculture, and sustainable resource management. These programs align STEM education with Brunei Darussalam's commitments to sustainable development and environmental resilience. Meanwhile, STEP Awareness and Roadshow Visits extend hands-on STEAM experiences to rural and remote schools, addressing equity concerns and broadening access to STEM opportunities economy-wide (Ministry of Education Brunei Darussalam, 2022).

Beyond school-based programs, innovation-focused camps and festivals—such as the STEAM Festival at Universiti Brunei Darussalam and the STEM Exploration Camp—provide immersive learning environments that integrate emerging technologies, entrepreneurship, and industry engagement (Universiti Brunei Darussalam, 2025). Project-based activities and hackathons, including Teens in AI Brunei and Shell NXplorers, further empower students to address real-world challenges using coding, data analysis, and design thinking, reinforcing digital transformation objectives (AITI, 2020).

2-3. Investment and Budget

Education remains a core priority in Brunei Darussalam's development agenda. Public spending on education consistently accounts for approximately 12–13% of the domestic budget,

or about 4.4% of GDP, placing Brunei Darussalam among the highest education spenders in ASEAN relative to population size (UNESCO Institute for Statistics, 2023). This sustained investment reflects the government's recognition of education—particularly STEM education—as a strategic enabler of economic diversification under Wawasan Brunei 2035 (Government of Brunei Darussalam, 2014).

For the 2024/2025 fiscal year, the Ministry of Education was allocated BND 810.4 million, supporting curriculum reform, infrastructure development, teacher capacity-building, and system-wide digital integration (Ministry of Finance and Economy Brunei Darussalam, 2024). A significant share of this allocation supports STEM priorities, including laboratory expansion, digital learning infrastructure, and programs coordinated by the STEP Centre (Ministry of Education Brunei Darussalam, 2022). These investments are increasingly aligned with the Digital Economy Masterplan 2025 to ensure coherence between education, technology, and workforce development (AITI, 2020).

2-4. Partnerships

Partnerships with industry and private-sector organizations play a significant role in strengthening Brunei Darussalam's STEM talent development ecosystem by complementing public education initiatives with real-world exposure, resources, and expertise. The Government of Brunei Darussalam actively collaborates with multi economies corporations, local enterprises, financial institutions, and higher education institutions to enhance youth capacity-building in science, technology, engineering, and mathematics. These partnerships help bridge the gap between formal education and workforce requirements while supporting goals under Wawasan Brunei 2035 and the Digital Economy Masterplan 2025 (Government of Brunei Darussalam, 2014; AITI, 2020).

A notable example is Shell Brunei, which sponsors programs such as NXplorers and supports initiatives at the Seria Energy Lab, providing students with inquiry-based learning experiences focused on energy, sustainability, and problem-solving. Through these programs, students engage in design thinking, data analysis, and innovation challenges that mirror real-world engineering and environmental issues, thereby strengthening STEM competencies and career awareness (Shell Brunei, 2023). Similarly, Hengyi Industries collaborates with government agencies and educational institutions to provide scholarships, vocational training, and technical skills development, particularly in petrochemicals and industrial operations, supporting workforce readiness in key economic sectors (Hengyi Industries, 2022).

Financial institutions and consumer brands also contribute to STEM outreach and innovation. Bank Islam Brunei Darussalam (BIBD) has supported the Universiti Brunei Darussalam (UBD) STEAM Festival, promoting youth engagement in science, technology, and entrepreneurship through exhibitions, competitions, and innovation showcases (Universiti Brunei Darussalam, 2025). Meanwhile, companies such as Cuckoo Brunei and Aewon Brunei have provided sponsorships and logistical support for domestic STEM festivals and student innovation events, helping expand participation and public awareness of STEM learning opportunities (Ministry of Education Brunei Darussalam, 2022).

Collectively, these public–private partnerships enhance the reach, relevance, and sustainability of Brunei Darussalam's STEM talent development initiatives. By leveraging industry expertise, funding, and real-world contexts, these collaborations reinforce applied

learning, strengthen education-to-employment pathways, and contribute to the cultivation of a future-ready STEM workforce aligned with domestic development priorities (Ministry of Education Brunei Darussalam, 2022).

2-5 Performance Indicators

Brunei Darussalam adopts a multi-dimensional set of key performance indicators (KPIs) to assess the effectiveness of its STEM talent development initiatives, ensuring alignment with domestic priorities under Wawasan Brunei 2035, the SPN21 education framework, and the Digital Economy Masterplan 2025. These indicators capture learner outcomes, teacher capacity, system performance, and labor-market relevance, providing a comprehensive view of progress in building future-ready STEM human capital (Government of Brunei Darussalam, 2014; Ministry of Education Brunei Darussalam, 2022).

One core KPI is student performance in international and domestic assessments, particularly participation in global benchmarking tools such as the Programme for International Student Assessment (PISA). Although Brunei Darussalam's participation in PISA is selective, the results provide valuable insights into students' competencies in mathematics, science, and problem-solving, which are essential foundations for STEM careers. Complementing international assessments are academic outcomes in STEM subjects measured through domestic examinations, school-based assessments, and performance tasks aligned with inquiry-based and applied learning under SPN21 (Ministry of Education Brunei Darussalam, 2022).

Teacher quality and qualification levels serve as another critical performance indicator. Brunei Darussalam tracks the proportion of STEM teachers with specialized subject training, professional certifications, and continuous professional development in digital pedagogy and emerging technologies. Investments in teacher training—particularly in ICT integration, inquiry-based instruction, and applied STEM methodologies—are directly linked to improvements in instructional quality and student learning outcomes (Ministry of Education Brunei Darussalam, 2022).

System-level indicators also include enrolment and progression rates in technical, vocational, and higher education, particularly in STEM-related fields. Increasing transition rates from secondary science streams to technical institutes, polytechnics, and universities signal the strength of the STEM pipeline and the alignment of education pathways with workforce needs. These indicators are reinforced through scholarships, industry partnerships, and work-based learning programs that support STEM continuity beyond basic education (Ministry of Finance and Economy Brunei Darussalam, 2024).

In response to digital transformation priorities, student digital literacy and STEM participation rates have become increasingly important KPIs. These indicators track learners' competencies in coding, computational thinking, data literacy, and ICT applications, as well as participation in STEM competitions, innovation challenges, and STEAM programs coordinated by the STEP Centre. Such metrics align closely with objectives under the Digital Economy Masterplan 2025, which emphasizes Industry 4.0 readiness and inclusive digital skills development (AITI, 2020).

Finally, Brunei Darussalam incorporates public and employer satisfaction with

graduate skills as an outcome-based performance indicator. Feedback from industry partners, employers, and public stakeholders provides qualitative evidence on graduates' technical competencies, problem-solving abilities, adaptability, and workplace readiness. This feedback loop helps inform curriculum refinement, teacher training priorities, and industry-education collaboration, ensuring that STEM talent development remains responsive to labor-market demands and domestic economic objectives (Hengyi Industries, 2022; Shell Brunei, 2023).

Taken together, these KPIs reflect Brunei Darussalam's balanced approach to performance monitoring—linking student achievement, teacher capacity, system efficiency, and employment relevance—while reinforcing its long-term commitment to developing a resilient, inclusive, and future-ready STEM workforce.

2-6. Key Challenges

Despite sustained investments in education and strong policy alignment with Wawasan Brunei 2035, Brunei Darussalam continues to face several structural and systemic challenges in the implementation of its STEM talent development programs. These challenges affect the depth, equity, and long-term sustainability of the economy's STEM pipeline and its readiness to support innovation-driven economic diversification.

One major challenge is the shortage of qualified STEM teachers, particularly at the lower-secondary level. Current data indicate that only around 55% of lower-secondary science teachers hold formal STEM degrees, which constrains deep content mastery and limits the effective delivery of inquiry-based and advanced STEM instruction (Ministry of Education Brunei Darussalam, 2022). This gap places additional pressure on teacher professional development systems and affects students' early exposure to rigorous scientific thinking, which is an essential foundation for later specialization in STEM fields.

Infrastructure disparities between urban and rural schools also pose a significant challenge. Nearly 40% of rural schools share laboratory facilities, which restricts regular access to hands-on experiments, practical investigations, and technology-enabled learning experiences (Ministry of Education Brunei Darussalam, 2022). Such limitations affect equity in STEM learning opportunities and may discourage sustained student interest in science and engineering disciplines, particularly in geographically remote areas.

Another constraint is the economy's small STEM talent base. With fewer than 3,000 STEM graduates annually, Brunei Darussalam's human capital pool remains limited relative to the demands of emerging innovation clusters in areas such as digital technologies, advanced manufacturing, and sustainable energy (UNESCO Institute for Statistics, 2023). This demographic reality makes it difficult to scale research and development (R&D) initiatives and to rapidly localize specialized technical expertise.

Closely related is the issue of brain drain as many high-performing STEM students pursue tertiary education and research opportunities abroad. While overseas education enhances individual competencies, a significant proportion of graduates do not return immediately—or at all—resulting in workforce shortages in key technical and scientific sectors (Pareek, 2022). This challenge underscores the need for stronger talent retention mechanisms, return incentives, and industry-linked career pathways within Brunei Darussalam.

Finally, Brunei Darussalam faces a growing skills mismatch driven by rapid technological change. Advances in artificial intelligence, robotics, automation, and data analytics are evolving faster than curriculum revision cycles, creating gaps between graduate competencies and industry expectations. As a result, employers report challenges in recruiting locally trained graduates who are fully prepared for Industry 4.0 environments (Yoon & Bergman, 2024). Addressing this mismatch requires more agile curriculum governance, deeper industry engagement, and continuous upskilling frameworks for both teachers and learners.

Taken together, these challenges highlight the need for Brunei Darussalam to strengthen teacher capacity, expand equitable infrastructure access, enhance talent retention strategies, and accelerate curriculum responsiveness. Addressing these constraints will be critical to ensuring that STEM talent development programs can effectively support domestic innovation goals and long-term economic sustainability.

2-7. Gender Inclusivity and Equity Measures

Gender inclusivity and equity are integral components of Brunei Darussalam's talent development strategy and broader human capital agenda under Wawasan Brunei 2035. The economy has made significant progress in ensuring equal access to education, resulting in near-universal participation of girls across all levels of schooling. Notably, women have consistently outnumbered men at the tertiary level, with female graduates comprising as much as 64% of total enrollees as early as 2006, reflecting long-standing gains in gender parity in higher education (UNESCO GEM, 2022; Brunei National Report, 2024). These outcomes demonstrate the effectiveness of inclusive education policies and sustained public investments in human capital development.

Brunei Darussalam's education and training systems are underpinned by policies that promote equal opportunity regardless of gender, particularly in access to scholarships, technical and vocational education, and higher education programs. Gender equity considerations are embedded within education planning frameworks and are reinforced through financial support mechanisms that enable both male and female learners to pursue advanced studies, including in science, technology, engineering, and mathematics (STEM) fields (Brunei Report, 2024). As a result, women's strong participation in tertiary education has contributed to a growing pool of skilled female professionals across multiple sectors.

Beyond access and participation, Brunei Darussalam explicitly incorporates equity indicators into its key performance indicators (KPIs) and training frameworks, ensuring that gender-disaggregated data inform policy evaluation and program design. These KPIs monitor enrolment, completion, and progression rates across education and training pathways, enabling policymakers to assess whether talent development initiatives benefit men and women equitably. Integrating equity into performance monitoring helps ensure that domestic talent pipelines remain inclusive and responsive to demographic trends and workforce needs (UNESCO GEM, 2022).

Collectively, these measures highlight Brunei Darussalam's strong foundation in gender-inclusive talent development. While continued efforts are needed to encourage balanced participation across all fields—particularly in highly specialized and emerging STEM disciplines—the economy's emphasis on universal access, equity-based monitoring, and sustained investment positions it well to harness the full potential of its human capital for long-

term development.

3. Canada

Hyun-Ju PARK, Professor, Chosun University, Republic of Korea

Summary: Canada's STEM education landscape is shaped by a federal–provincial governance model in which provinces and territories hold primary responsibility for K–12 curriculum and delivery, while the federal government advances priorities through funding for innovation, digital skills, equity, and youth outreach. As a result, Canada does not operate a single STEM school strategy. Instead, it sustains a multi-actor STEM ecosystem that combines provincial curriculum innovation with large-scale, federally supported programs and strong participation from non-profit, research, and community partners. A defining feature of Canada's approach is the treatment of STEAM as a legitimate pathway for educational innovation, rather than as a peripheral enrichment activity. Across jurisdictions, STEM learning is increasingly connected to design thinking, creativity, and real-world problem solving. This orientation is reinforced by Canada's strong informal STEM sector, including science centres, museums, university outreach hubs, and domestic non-profit organizations that complement formal schooling and operate at scale.

3-1. Strategy and Vision

Canada's STEM education is characterized by a decentralized yet convergent policy vision. While provinces and territories retain authority over K–12 education, a broadly shared domestic understanding has emerged: STEM education should cultivate scientifically literate, creative, and adaptable citizens capable of participating in a knowledge-based and innovation-driven economy.

Within this vision, STEM education is framed not only as preparation for specialized careers, but also as a foundation for critical thinking, problem solving, and civic participation. Many provinces explicitly embrace STEAM, recognizing arts, design, and creativity as integral to innovation rather than supplementary elements. This reflects a broader Canadian emphasis on interdisciplinary learning and human-centered problem solving.

Importantly, Canada's STEM vision is closely linked to social and equity-oriented goals. Policy discourse frequently connects STEM education to inclusion, regional development, reconciliation with Indigenous peoples, and broad participation in digital and scientific competencies. Through this lens, STEM education is positioned as both an economic strategy and a social project, aligned with domestic commitments to diversity, equity, and inclusive innovation.

3-2. Key STEM Education Programs

a. STEM Education Programs and Initiatives

Canada's STEM priorities are articulated less through a single strategy and more through coherent, cross-system investments aimed at expanding digital competence, strengthening STEM identity, and improving equity in access and participation. Federal programs and pan-Canadian partnerships play a central role in reducing barriers for underrepresented learners, while operating alongside and complementing provincially governed curricula.

A defining feature of Canada's approach is its reliance on federally funded delivery organizations—including non-profit organizations, science centres, and university-based outreach networks—to scale access to STEM learning economy-wide. Rather than imposing a centralized domestic curriculum, the federal government invests in programmatic infrastructure that enables flexible, locally responsive implementation across diverse regions and communities.

CanCode Communities represents the most prominent domestic investment in this model. Since its launch in 2017, CanCode has invested over CAD 229 million to support digital skills learning opportunities for more than 9 million students and professional learning for over 450,000 teachers across Canada. An additional CAD 39.2 million investment announced in 2024 targets further expansion. CanCode exemplifies a distinctly Canadian policy logic: achieving domestic scale through funding, coordination, and partnerships, rather than through centralized curriculum control.

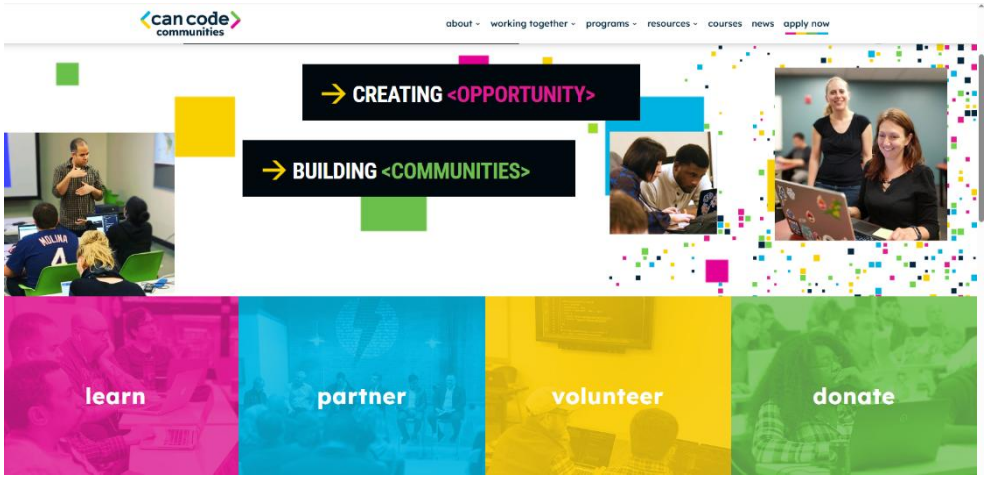


Figure 4. Official Webpage of CanCode Communities: Canada's National Digital Skills and Coding Program. https://cancode.org/

Another cornerstone of Canada's STEM ecosystem is NSERC PromoScience, which funds STEM outreach delivered by universities, museums, science centres, and non-profit organizations. PromoScience treats informal and outreach-based STEM learning as a system-level lever for engagement and equity, particularly for underrepresented populations. In 2018, the program supported 163 organizations with approximately CAD 11.9 million over three years, reaching an estimated one million youth annually.

Canada's outreach capacity is further strengthened by Actua, the economy's largest STEM outreach network. Actua engages approximately 500,000 youth each year across more than 600 communities through a network of over 40 university and college partners. From a policy perspective, Actua functions as a domestic delivery infrastructure that connects federal priorities with local implementation, particularly in communities with limited access to specialized STEM resources.



Figure 5. Official Webpage of Actua: Canada's STEM and AI Outreach Network for Youth. https://actua.ca/

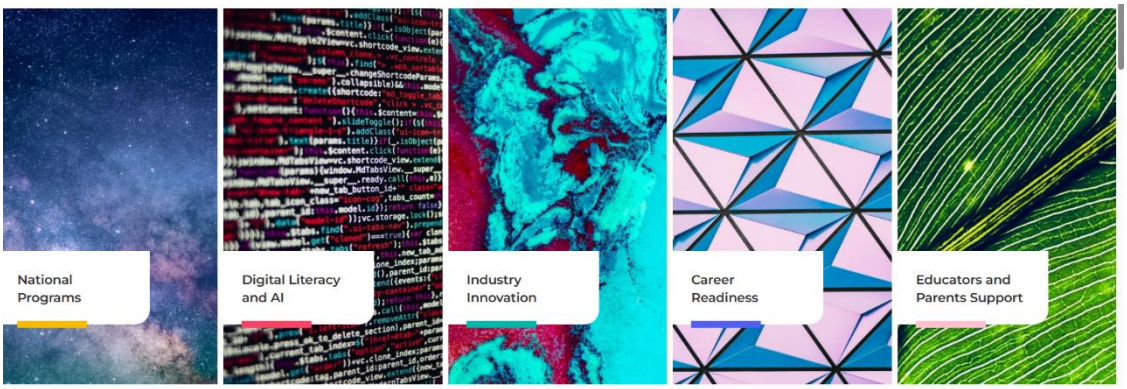


Figure 6. Key Programmatic Focus Areas of Actua's STEM and AI Outreach Framework

At the community level, organizations such as the STEAM Education Centre illustrate how Canada's funding and partnership frameworks are translated into concrete STEAM learning experiences. Based in Ontario, the STEAM Education Centre is a non-profit organization that delivers hands-on, community-connected STEAM programs through schools, workshops, camps, and local partnerships. Its programming integrates science, technology, engineering, arts, and mathematics through design thinking and maker-based learning, emphasizing creativity, critical thinking, and real-world problem solving. By prioritizing inclusion, local relevance, and learning-by-doing, the Centre exemplifies a community-driven implementation model that complements provincial curricula while advancing engagement, equity, and workforce-relevant skills. As such, it represents a localized execution case within Canada's broader STEM and STEAM outreach ecosystem, operating in alignment with federal frameworks such as Actua and PromoScience.

Outcome-oriented reporting within this ecosystem is illustrated by Canada Learning Code (CLC), which tracks learner confidence and interest as key indicators of impact. CLC reports that 72% of participants experienced increased confidence and 74% reported increased interest in technology and coding, with outcomes disaggregated by equity group. This provides a concrete example of how large-scale programming can be paired with measurable short-term outcomes and equity-focused monitoring.

At the provincial level, STEM and STEAM priorities are embedded within curriculum reforms and pedagogical frameworks. Ontario explicitly promotes STEAM and inquiry-based

learning in science and technology education, while British Columbia integrates STEM through its Applied Design, Skills, and Technologies curriculum, emphasizing design thinking and real-world problem solving. These provincial initiatives align with, rather than duplicate, federal investments, reinforcing Canada's multi-level and complementary approach to STEM and STEAM education.

b. Talent Development and Scholarship Programs

Talent development in Canada is supported through a combination of postsecondary scholarships, research funding, and outreach-to-transition pathways, rather than a single talent pipeline. Federal agencies such as NSERC provide scholarships and fellowships that support progression into advanced STEM study, while outreach programs contribute to early aspiration building, particularly for underrepresented groups.

c. Teachers' Capacity Building

Teacher capacity building is decentralized but strongly supported through provincial ministries, school boards, universities, and domestic non-profit organizations. Professional learning emphasizes inquiry-based instruction, project-based learning, interdisciplinary integration, and culturally responsive pedagogy.

Evaluations indicate that teachers participating in STEM-oriented professional learning report increased confidence and improved student engagement. Teachers are positioned not merely as curriculum implementers, but as designers of interdisciplinary learning experiences responsive to local contexts.

d. STEM Facilities and Learning Environments

Canada's STEM ecosystem relies heavily on informal and community-based learning environments, including science centres, museums, maker spaces, and mobile laboratories. These environments complement school-based instruction and are particularly important for rural, remote, and underserved communities.

Rather than prioritizing uniform investment in permanent infrastructure, Canada emphasizes access through networks and partnerships, supporting scalability and equity in a geographically large and diverse economy.

e. Student STEM Participation and Pipeline Development

Canada demonstrates relatively strong participation in upper-secondary science and mathematics compared to OECD averages. However, participation in advanced mathematics and physics declines in later secondary years, particularly among female students, indicating persistent bottlenecks between general participation and advanced specialization. These trends reinforce policy emphasis on early engagement and sustained confidence-building.

3-3. Education Effects and Measured Outcomes

Canada's most consistent STEM education impacts are observed in student engagement, confidence, inclusion, and pathway intention, rather than uniform gains in standardized achievement. Evaluations of PromoScience report strong positive effects on student interest, particularly through hands-on and inquiry-based learning, with notable benefits for underrepresented groups.

In digital skills education, programs such as CanCode demonstrate impact primarily

through scale and diffusion, supporting widespread exposure across the system. Canada Learning Code provides additional evidence of confidence and interest gains, with outcomes disaggregated by equity group.

In academic achievement, Canada continues to demonstrate strong foundational performance. PISA 2022 results show Canadian students performing above OECD averages in mathematics and science, with over 80% reaching baseline proficiency, though outcomes vary by province and socio-economic context.

Canada's STEM outcomes reflect a system where engagement and inclusion are the most visible effects, while academic achievement remains strong but heterogeneous.

3-4. Investment and Budgetary Patterns

Canada's STEM investment follows a distributed, multi-level funding model. Provinces fund curriculum, teacher professional learning, and facilities, while federal investment focuses on domestic-scale priorities such as digital skills, outreach, and equity.

Federal funding through CanCode and PromoScience illustrates a pragmatic policy logic: rather than expanding school systems alone, Canada invests in delivery capacity through networks, enabling rapid scaling of access. This flexibility supports local adaptation but complicates aggregation of domestic investment totals—an inherent trade-off in a decentralized system.

3-5. Partnerships

Partnerships are the core operating model of Canada's STEM ecosystem. University-based networks, non-profits, research institutions, and community organizations enable large-scale delivery, particularly in rural and underserved regions.

In Indigenous contexts, partnerships with local communities and Elders support culturally responsive and land-based STEM learning. Rather than policy standardization, coherence is achieved through shared priorities and trusted networks.

3-6. Performance Indicators and Monitoring

Canada monitors STEM performance through a portfolio of indicators, including international assessments (PISA), participation rates, program reach, self-reported confidence and interest, and equity-disaggregated outcomes. This multi-dimensional approach reflects recognition that STEM performance cannot be captured by a single metric. Short-term learning outcomes are commonly assessed through self-reported measures of confidence and interest. Canada Learning Code reports that approximately 72% of participants experienced increased confidence and 74% reported increased interest in technology and coding following program participation. While these measures do not substitute for standardized achievement data, they offer timely indicators of engagement and learner disposition.

3-7. Gender Inclusivity and Equity

Equity is embedded as a core design principle. Programs such as Canada Learning Code,

Actua, and PromoScience demonstrate measurable gains in confidence and engagement among girls, Indigenous learners, newcomers, and other underrepresented groups. PISA data indicate a relatively small socio-economic achievement gap and a high proportion of academically resilient students, though girls remain underrepresented in advanced STEM pathways.

3-8. Key Challenges

Canada's decentralized governance and ecosystem diversity also generate challenges, including limited cross-provincial comparability, difficulty linking K–12 STEM education to long-term workforce outcomes, declining participation in advanced secondary STEM subjects (especially among girls), and persistent regional disparities.

Addressing these challenges will require sustained investment in data integration, longitudinal tracking, and cross-sector coordination, alongside continued support for inclusive, high-quality STEM delivery.

4. Indonesia

Finarya LEGOH, Professor, University of Indonesia/Head of IR, Indonesian Academy of Science, Indonesia
Dyah Ratna Permatasari, CEO, DoctoRabbit Science Inc., Indonesia

Summary: Law Number 20 of 2003 about the National Education, includes: students with above average intelligence (gifted) need special education to support their superior talents or potentials; schools should develop programs to provide special education for gifted students, which curriculum/ school learning for the gifted should be provided different/ higher from their peers to construct students' own knowledge, learning experiences, including social and competence learning. 2013 Domestic Curriculum: the concept and approach are integrated, covering themes, concepts, and topics; involved multi-disciplines form to provide meaningful and broad experiences to students; 3 competencies needed: knowledge, skills, attitude, with critical thinking & individual ability mindset development; learning approach: curiosity, various resources, scientific approach, motivation and creativity, using development of technology & information, ethics & exemplary. During COVID-19 Pandemic, School Mover Program was introduced as an effort to realize competence education towards SDGs and Industry 4.0, using mainly on-line approaches but it can be offline if no internet access available; the program provides training and assistance to school principals and selected teachers as change agents, to develop programs and human resources for school competency and digitalization. In 2022, the Ministry of Education, Culture, Research & Technology launched "the Merdeka Curriculum" (Freedom to Learn) as an Independent Learning program to improve the quality of learning. The curriculum gives teachers and students freedom to determine focusing on essential materials relevant to local and global needs. In 2024, the Ministry released a Regulation No. 12/2024 about Merdeka Curriculum, shifted from 2013 Curriculum. In February 2025 the Ministry of Primary and Secondary Education released a concept of deep learning, which is an enriching approach that emphasizes creation of a conscious, meaningful, and joyful learning atmosphere, which is processed through holistic and integrated thought, heart, feeling, and action. The learning framework components consist of pedagogical practices, learning environments, learning partnerships, and the use of digital technology. The learning framework components consist of pedagogical practices, learning environments, learning partnerships, and the use of digital technology.

4-1. Global Platform of Education

APEC Education Strategy (2016-2030)

Vision

By 2030, APEC will have a strong and cohesive education community characterized by inclusive and quality education that supports sustainable economic growth, social wellbeing and employability of men and women in APEC economies (competencies; innovation; employability).

Objectives

- Enhancing and Aligning competencies to the needs of individuals, societies and industries: enhance quality assurance systems, qualification frameworks and skills recognition; promote cross-border education, academic mobility and individual pathways within and across education levels; advance modernization of education systems.
- Achieving Accelerate Innovation: improve the use of educational and technological capabilities in teaching and learning processes; promote Science, Technology and

Innovation in education and pedagogical practices; promote government – industry – academia collaboration for R&D and innovation.

- Increasing Employability: promote collaboration between government, higher education and TVET (technical and vocational education and training) institutions, business and education and training stakeholders; develop 21st century competencies for work and entrepreneurship; smooth the transition from education to work.

4-2. STEM Education Policy and Overview in Indonesia

STEM (Science, Technology, Engineering, and Mathematics) was initiated in the 1990s by the National Science Foundation in the United States, as a learning alternative to build 21st century abilities, skills and face the challenges of industry 4.0. STEM education goal is to integrate multidisciplinary science as the key to deep understanding and meaningful learning of Science, Technology, Engineering and Mathematics.

STEM education in Indonesia began in 2014, developing teaching materials (worksheets) based on STEM in chemistry subjects. Over time, STEM then became the focus of educational research and its implementation in class learning (media and materials). The dominant themes related to STEM or STEAM education: critical thinking skills, scientific literacy, and learning outcomes.

Government develops traction as a crucial initiative to advance skilled workforce and drive economic growth by actively promoting STEM education through various programs and partnerships. STEM is a means to enhance students' future-demand skills and prepare them for the demands of the modern workforce. It is being integrated into the curriculum, with a focus on practical, real-world problem-solving and critical thinking.

Policies: aiming to improve students' skills in STEM, involving the integration of STEM concepts into curriculum with a focus on students' future knowledge and skills for real-world problems, enhancing teacher training with essential skills, fostering community awareness to campaign to wider community for receptiveness, enhancing international collaboration with organizations and institutions to boost its STEM education capabilities.

Three approaches implemented: Silos, embedded, integrated approach.

(1) Silos approach: the learning taught in each STEM discipline is separated from each other to allow students to gain a deeper understanding of one subject topic.
(2) Embedded approach: is emphasized content and techniques as in the silos approach, but the approach to learning implementation is more emphasized in reviewing S&T several contexts, which is implanted through STEM learning. So it raises competencies in various subjects (often integrated with the Project-Based Learning model).
(3) Integrated approach: fuses its learning components to allow students to gain the competencies mastery needed to solve problems in everyday life by integrating all components in STEM education (often integrated with problem-based learning and Inquiry learning models).

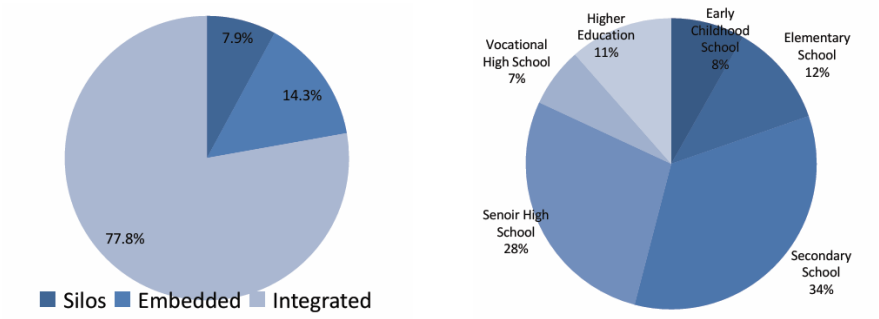


Figure 7. Distribution of STEM/STEAM Approaches and Integration by Education Level in Indonesia
Sources: Adapted from Ilma et al. (2023).

Challenges and opportunities: relatively limited research; effort in training and support to ensure teachers' competency and capacity to have adequate knowledge and skills in STEM subjects and pedagogical approaches; infrastructure development to improve access to quality STEM education - requires investment in infrastructure like internet access, laboratories, technology, and learning resources for today's STEM development.

Examples of STEM initiatives:

- Smart Indonesia STEM: this program aims to improve AI and STEM skills for millions of Indonesian students, including those in Islamic schools.
- Newton Fund Indonesia: collaboration between Newton Fund and government R&D to support youth scientific research and to provide opportunities for international exposure.
- STEM Indonesia: this organization focuses on promoting STEM education through various activities, including advocacy, training, and resource development; and collaboration with international organizations to increase teacher and student capacity in preparing technological advances in the digital age.
- STEMCON: partnership between USAID & Ministry of Higher Education, Research & Technology of Indonesia for higher education (HEPI) – to foster ecosystem that nurtures collaboration between industry and universities which helps learners with experiential learning in STEM.

4-3. Investment, Funding Mechanisms and Cross-sector Partnership

- SMART Indonesia STEM movement:
  - It is a program among Ministries and private sector collaboration, an initiative to enhance literacy and skills of Indonesian youth in STEM.
  - With a funding commitment of approximately USD 30.6 million, the initiative aims to improve AI and STEM skills for 10 million Indonesian students, including those in madrasahs (Islamic schools) and pesantren (Islamic boarding schools). It is an inclusive and collaborative approach, to provide learning modules and teacher training, also develop open digital platform, data-based monitoring system, and modular curriculum adaptable to various educational institutions.

- Private entities have obligation in CSR (Corporate Social Responsibility), a responsibility from the company profits to pay social attention to society and environment. In the partnership between government and companies, CSR programs are expected to help solve social issues, which many of them focus on the education sector.
  - PT Timah Tbk (in the Bangka Belitung Province) in 2018 allocated CSR funds of 24.89 million to 269 education partner institutions, among others and yearly after.

- PT Djarum collaborates with the SMK NU Banat Kudus for fashion design creating skill, proficient, and professional female human resources ready to work in various companies in the fashion industry or even create their own job opportunities; provides scholarships to students and teachers to improve qualified education.
- PT Internusa Jaya Sejahtera provides education funds, which include providing materials for school construction and educational scholarships.
- Samsung Indonesia has established the Samsung Learning House, which programs aimed at helping teenagers aged 17-24 who have difficulties in education costs. The House has educated more than 2000 children and graduated more than 500 children through cooperation with various parties.

4-4. Major Barriers and Implementation Gaps

- There are local variations of STEM implementation through project-based learning, so a specific strategy from school principal is the most influential in STEM implementation.
- STEM education is not embedded in the curriculum reform, teachers are encouraged to integrate STEM into the curriculum, which uses varied ways to implement STEM in their classes.
- The integration of STEM education is predominantly associated with extracurricular activities, with its implementation is being reinforced by external factors such as universities and organizations. This usually involves participation in student competitions, which aligns with the approach adopted in the economy.
- Insufficient knowledge of content integration and methodologies has led to challenges in implementing STEM education among Indonesian teachers, resulting in the continued dealing in STEM as individual subjects.
- Challenges in implementing STEM education: limited resources, inadequate government support, cultural attitudes toward STEM education, and a shortage of qualified teachers. Further training in STEM content and its applications is still needed as implementation continues.
- STEM education still needs the help of enablers, such as the government, education system, culture and family, which will contribute to their capacities and authority to successfully implement STEM learning.

4-5. Gender Inclusivity

- In Indonesia, girls tend to outperform boys in both literacy and numeracy subjects. The research data show that female students in the early grades outperformed male students on basic and comprehensive literacy and numeracy tests. This contradicts the stereotype that girls have lower numerical abilities.
- On the contrary, female students face more challenging situations in secondary schools, as evidence shows that child marriage will reduce female students' access to education in later years. Only about 10 per cent of female students are still able to attend school after marriage.
- Males’ presence in leadership roles is dominant, while females are under-represented or confined to passive and domestic settings. Female achievements are often minimized across cultures and regions.
- Females were portrayed in limited roles, often as observers or assistants rather than as active participants in scientific endeavours. This reinforces traditional gender roles and perpetuates the stereotype that females are less capable in science, which can negatively impact girls' interest and performance in these subjects.

- Adequate education is essential in increasing female's access to quality jobs and the digital sector, help strengthen women's skills, and reducing the gender gap in digital skills. It is necessary to make joint efforts from government, community, and private sector to strengthen women's access to education and opportunities in order to create quality and inclusive employment opportunities for female in the digital economy era.

4-6. Trends and Keywords of Nowadays/ Future Global Education

Trends:
- Global mindset is part of the school environment: which is more reflective of global challenges and perspectives;
- Focused on problem-based learning approach: life-long learning is the key to a successful career, knowledge and skills developed to deal with real-world challenges;
- Technology is the driver: learning is available anytime, anywhere, regardless of physical presence in the world, it will be a reality in all classrooms;
- Education systems is more flexible and adaptable to the economy, environment and the needs of students.

Keywords:
- Common global challenges & SDG goals: Climate change – sustainable, think green; Health – resilient health system, one health; Energy resources – transition to clean & sustainable energy resources;
- Enabler for the drivers: Interlinked with the concept of Industry 4.0 and 5.0; World digitalization – our world in data; S&TI concept of stronger, bolder, better and open.
- Aims: Complexity - connecting the dots, collaboration; global market – cutting edge, better living in “only one world”.

4-7. Take Home Messages

- The domestic education curriculum system is continually updated to adapt the system to provide gifted students within curriculum – motivates them to take on challenges in development of S&T, in line with SDGs, global problems and to cater to Industry 4.0.
- Preparing students to open their mind with real and global problem-solving, out-of-the-box ideas to enrich them with novel creativity, and to prepare themselves to become proficient scientists or professionals in their future career pathways.
- Preparing teachers to be trained by professionals or self-training, to recognize, develop and create appropriate learning programs, to challenge the students to be linked to real-life problems and creativity to solve them.
- Domestic and international partnership and collaboration is a must to enhance STEM learning experience and career pathways, to challenge and solve global problem-solving – so no one is left behind.
- Ideas of partnership and collaboration:
  - Create a project that everybody can contribute and participate in kind or whatever appropriate – can be available / no crossing border budgetary, so each one can participate.
  - Promote and insert the program with various activities, such as: online / off-line workshop or seminar, invite the APEC/PPSTI members / stakeholders to share the ideas about particular themes.
  - Encourage the members write the specific ideas / system / baseline / activities that strengthened and hastened the STEM education system – can be made as an e-reference book / data-base.

5. Japan

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Summary: This report outlines Japan's renewed strategy to strengthen science and technology human resources from primary through upper-secondary education by combining (1) targeted support for highly capable and highly motivated learners and (2) broader participation in STEM/STEAM. A flagship school-based pillar is the Super Science High School (SSH) initiative, which designates upper-secondary schools to deliver advanced STEM programmes and links students to high-level opportunities beyond school. Alongside SSH, the report highlights the Next Generation Science and Technology Challenge Programme, administered by the Japan Science and Technology Agency. It funds talent-development programmes led by universities, research institutions, and other organisations, with an emphasis on inquiry-based learning, STEAM education, entrepreneurship, and learning connected to real societal issues. Another distinctive feature is cross-sector collaboration to embed authentic STEAM and inquiry learning in schools and communities. The Platform for Learning Innovation Japan is presented as an industry–academia–government–education platform that accelerates innovation and diffusion in primary and secondary education, including recognition of exemplary STEAM and inquiry practices. The report also stresses system-wide challenges, including limited opportunities, regional and access disparities, and the limits of relying only on school teachers. Within SSH, challenges include possible drift from the original aims as the programme expands, resource constraints, the vulnerability of "certified" schools that receive no direct funding, and the need to strengthen long-term evaluation.

5-1. Trends in Human Resource Development for Science and Technology in Japan

In discussing the basic direction of future policies on science, technology, and human resources, the Ministry of Education, Culture, Sports, Science, and Technology (MEXT) has organised its priorities into three key areas: (1) strategic promotion of science, technology, and innovation; (2) enhancement and strengthening of the foundations of science and technology, including human resources and the research environment; and (3) advancement and expansion of initiatives for co-creation with society.

The second area, namely enhancement of science and technology foundations, includes the following three components: (1) development and securing of a diverse range of human resources in science and technology; (2) education and human resource development at the school education level; and (3) reform of systems and frameworks related to human resources.

In April 2025, the MEXT established the Working Group on Next-Generation Human Resource Development within the Science and Technology Council's Committee on Human Resources. The purpose of this initiative is based on the recognition that human resources in science and technology form the core foundation of Japan's broad efforts in science, technology, and innovation policy, and that a fundamental expansion of investment in these human resources is essential. In line with this policy, the working group is tasked with examining future directions and initiatives for the development of science and technology personnel across a wide spectrum—from primary and secondary education, to higher education, and including the perspective of social education for the general public—with the aim of fostering talent capable of contributing across academia, industry, and government.

The working group's areas of focus are threefold: promotion of human resource development at the higher education level; promotion of human resource development at the primary and secondary education levels; and promotion of initiatives related to co-creation with society (social education). This report focuses, in particular, on the second of the above-mentioned focus areas.

5-2. Current Status, Challenges, and Future Directions for Developing Human Resources in Science and Technology at the Primary and Secondary Education Levels

5-2-1. Rationale for Prioritising Human Resource Development in Science and Technology

For Japan—an economy with limited natural resources—the promotion of science, technology, and innovation is essential in achieving sustainable economic growth. At the heart of such an effort lies the development and retention of a diverse pool of next-generation human resources. To this end, it is imperative to implement continuous, systematic, and comprehensive initiatives beginning at the primary and secondary education levels.

The current proposal highlights two key directions in talent development. First, building upon education aligned with domestic curriculum guidelines, it is essential to collaborate with higher education institutions and related organisations to fully cultivate the potential of students with strong motivation and aptitude in science and technology, nurturing them into top-level talent capable of making meaningful contributions, both domestically and globally. Second, the proposal underscores the importance of broadening the base of students who show interest in science and technology, especially those considering academic and career paths in mathematics and the sciences.

Moreover, talent development must go beyond the mere acquisition of knowledge and technical skills. Equally important is fostering students' abilities to apply their learning skills by formulating questions, testing hypotheses, and effectively communicating their ideas. This competency, commonly referred to as inquiry and expression, is critical for cultivating individuals who can confront complex, open-ended problems with creativity and resilience.

5-2-2. Progress and Challenges in Japan's Science and Technology Education

a. Past Initiatives and Achievements

At all levels of school education in Japan, efforts have been made—beginning from the primary stage—to strengthen mathematics and science education by emphasising relevance to everyday life and society, as well as by promoting inquiry-based learning activities. Notably, under the revised domestic curriculum guidelines introduced in upper secondary schools in the fiscal year 2022, new subjects, such as Integrated Inquiry Time and Science and Mathematics Inquiry, have been established.

According to the Organisation for Economic Co-operation and Development's (OECD) Programme for International Student Assessment (PISA), Japanese students continue to perform at world-leading levels in both mathematical and scientific literacy. Similarly, the Trends in International Mathematics and Science Study (TIMSS) places Japan amongst the

top-performing economies, indicating that Japanese students possess a high level of scientific and technological proficiency.

Moreover, TIMSS data reveal a growing proportion of Japanese junior high school students who report that "studying science and mathematics is enjoyable" and that these subjects are "useful in daily life". Such trends are gradually converging with international averages, suggesting a positive shift in students' attitudes towards Science, Technology, Engineering, and Mathematics (STEM) education.

b. Enhancing and Strengthening Advanced Science and Mathematics Education

The MEXT has actively promoted advanced mathematics and science education both within and beyond school settings, in collaboration with higher education institutions and private-sector partners, the primary objective being to identify students with strong motivation and aptitude and foster the development of their talent.

One flagship initiative is the designation of 230 upper secondary schools economy-wide as Super Science High Schools (SSH). These schools are encouraged to implement advanced STEM programmes, including scientific research projects and international collaborative studies. Additionally, highly motivated students are given opportunities to participate in science and technology competitions and engage in high-level educational and research programmes at universities through the Science and Technology Challenge Programme for Next-Generation (STELLA).

These initiatives have yielded concrete outcomes. In international science competitions, Japan achieved top rankings—equivalent to first place—in the International Olympiad in Informatics in both 2022 and 2023. At the 2024 Regeneron International Science and Engineering Fair (ISEF), five research projects by Japanese high-school students received awards, including one that earned the prestigious Grand Award, demonstrating the exceptional quality of student research.

Furthermore, alumni of the SSH and STELLA programmes are now working as researchers at universities, research institutes, and in the private sector. Many have attested that their participation in these programmes significantly influenced their academic and professional trajectories. The research and development outcomes of the SSH initiative have also informed domestic curriculum reform, contributing to the creation of a new subject, namely Science and Mathematics Inquiry, in the upper-secondary-school curriculum. This, in turn, has helped advance the development and dissemination of effective models for mathematics and science education in Japan.

c. Challenges and Key Issues

Whilst notable progress has been made, several pressing challenges remain. Limited Opportunities and Regional Disparities: There is increasing recognition that the cultivation of outstanding researchers should begin at the primary education level. However, the current scale of top-tier human resource development remains insufficient. In particular, primary and junior-high-school students often face restrictions in travelling independently, and many families are unable to support their participation because of financial or time constraints. Consequently, there is a real risk that promising students may be excluded from enrichment opportunities because of accessibility barriers.

Limits of the Current Instructional Framework: Relying solely on schoolteachers at the primary, junior-high, and senior-high levels to foster top-level talent poses clear limitations. Therefore, it is essential to expand opportunities for students to receive specialised guidance from university faculty members, academic societies, subject-matter experts, and researchers with doctoral-level training.

Challenges within the SSH Programme: Since the 2002 launch of the SSH initiative, both the number and diversity of designated schools have steadily increased, leading to concerns regarding divergence from the programme's original purpose and the need for more targeted and differentiated support. Indeed, even some SSH-designated schools face financial constraints that limit their ability to offer overseas training or invest in advanced experimental equipment. These challenges are particularly acute in the case of "certified" schools, which do not receive direct funding. There is growing concern that such schools may have to scale back successful initiatives, highlighting the need for mechanisms to ensure the continuation and advancement of high-impact practices.

Dissemination of Know-How and Follow-Up Studies: There is a strong need to extend the pedagogical know-how developed in SSH-designated schools to non-designated institutions. However, many teachers in non-SSH schools lack the training or resources needed to effectively adopt these practices. Additionally, comprehensive follow-up studies on the long-term trajectories of programme participants—such as their contributions to science and society—are still in the early stages. To address this gap, further evaluation efforts are required, starting with a graduate tracking survey for SSH alumni scheduled to begin in the fiscal year 2026.

5-3. Challenges and Key Issues in STEM Education

Despite its efforts, Japan continues to face significant challenges in broadening the base of science and technology.

a. Low Enrolment Rates in STEM Fields, Especially amongst Women Students

The proportion of students enrolling in science-related disciplines—particularly engineering and technology—remains low in comparison to that of other economies. This issue is particularly pronounced amongst women students, whose enrolment in STEM fields falls well below the OECD average. Although recent years have witnessed a modest upward trend in women's STEM participation, further acceleration is needed. Meanwhile, the enrolment rate of men students has remained largely stagnant.

b. Barriers Faced by Women Students

A major factor limiting women's participation is the lack of visible and relatable career pathways in STEM. This makes it difficult for students to envision long-term goals, underscoring the importance of outreach and mentoring by role models such as women graduate students. In regional areas, there are also cases where talented women students have been discouraged from pursuing STEM pathways due to opposition from their immediate environment. Addressing this issue requires a holistic approach that targets not only students, but also parents, educators, and broader societal perceptions.

c. Need for Early Intervention

Evidence indicates that, as early as primary school, boys already tend to report higher levels of interest and confidence in mathematics compared to girls. This highlights the importance of initiating gender-sensitive STEM engagement at an earlier stage to close emerging gaps in interest and self-efficacy.

d. Strategies to Broaden Participation

Expanding students' interest in science and technology cannot be accomplished through classroom instruction alone. Outreach initiatives led by universities and other institutions are expected to be pivotal. In attempting such interest expansion, it may be effective to distinguish between students drawn to scientific research and those more interested in the practical applications of science and technology, and tailor engagement strategies accordingly. Moreover, promoting interdisciplinary approaches—such as Science, Technology, Engineering, Arts and Mathematics (STEAM) education, which integrates the said five subjects—can help foster motivation and interest amongst a wider range of students, supporting diverse pathways into the field of science and technology.

5-4. Future Initiatives: Strategic Directions for the Next Generation

5-4-1. Enhancement and Strengthening of Advanced Science and Mathematics Education

a. Promotion of the Science and Technology Challenge for Next-Generation Programme (STELLA) [Primary, Junior High, and High Schools]

The government aims to significantly expand the number of implementation sites for the STELLA programme, which is designed to nurture highly capable mathematics and science students. Specifically, the goal is to establish at least one training centre for primary and junior-high-school students in each prefecture, as well as one for high-school students in every two prefectures. Additionally, the government will ensure opportunities for participating students to engage with one another and for implementing institutions to exchange best practices and expertise.

b. Expansion and Strengthening of the Super Science High School (SSH) Support Programme [High Schools]

The government plans to expand the number of SSH-designated schools to 250, representing approximately 5% of all upper-secondary schools.

Concurrently, the SSH framework will be revised to introduce a classification system ("types") within the designated schools, based on their specific talent development strategies. Funding levels will vary according to type, thereby encouraging the further advancement and specialisation of each school's initiatives.

As part of institutional reforms, the maximum duration of continuous financial support will be adjusted to 20 years. In parallel, a new mechanism, provisionally termed Accelerated

Support, will be introduced for "certified" schools that no longer receive direct financial assistance, to help them maintain and expand their successful practices.

Beginning in the fiscal year 2026, the government will launch a graduate tracking survey of SSH alumni to evaluate and publicise the programme's long-term impact. Designated schools and their managing institutions will also be expected to share their research outcomes and instructional know-how with other schools, contributing to the overall enhancement of mathematics and science education across regions.

Indeed, a new typology, starting in the 2028 academic year, has been proposed for the SSH Support Programme.

Category 1 (SSH-Core): This category comprises designated schools that aim to cultivate highly skilled human resources in science and technology who will play active roles in society. These schools leverage both regional characteristics and their own institutional strengths to implement whole-school scientific inquiry activities. By building on and systematising their distinctive practices, they disseminate the outcomes of their initiatives within their local communities and beyond. Serving as core hubs for science and mathematics education in their respective regions, these schools foster students who are expected to become part of the next generation of scientific and technological human resources.

Category 2 (SSH-Professional): This category comprises designated schools that place particular emphasis on nurturing individuals who can apply their knowledge and skills in science and mathematics to engage in advanced scientific research activities, including preparation for research careers in both industry and academia. Through sustained research collaboration with universities, research institutes, and industry partners, these schools enhance advanced teaching practices whilst expanding opportunities for mutual stimulation and constructive competition. In doing so, they cultivate students with a deep understanding of science and technology, as well as well-developed logical and analytical thinking skills.

Category 3 (SSH-Global): This category comprises designated schools that actively cultivate highly skilled human resources in science and technology with strong international perspectives, whilst simultaneously undertaking pioneering initiatives as SSH institutions. By securing opportunities for research exchange and collaboration with overseas universities, research institutes, companies, and international organisations, these schools foster students who are capable of advancing inquiry and co-creation within the international community, with science serving as their point of departure.

c. Enhancement of Support for Science and Technology Competitions [Junior High and High Schools]

The government will continue supporting students' participation in international science and technology competitions and will also consider the possibility of hosting such competitions in Japan.

For events within Japan such as the Japan High School Science Tournament and the Junior High School Science Tournament, efforts will be made to increase participation and

elevate the level of competition by incorporating advanced content, including topics in computer science, which are becoming increasingly relevant.

5-4-2. Enrichment of Science and Mathematics Education at the Primary and Secondary School Levels

a. Enhancing Science and Mathematics Education in Schools [Elementary, Junior High, and High Schools]

Building on the economy-level curriculum, efforts should be made to enrich learning that emphasises connections between science and mathematics, daily life, and society, as well as inquiry-based learning grounded in scientific practices, in order to foster students' interest and engagement in science and technology. Furthermore, to nurture sustained interest in science and mathematics from the primary and secondary stages, teaching approaches focused on problem-solving and inquiry should be developed, and the systematic dissemination of these practices and outcomes to schools should be pursued.

b. Support for Women Junior- and Senior-High-School Students in Choosing STEM Pathways [Elementary, Junior High, and High Schools]

The government will expand the number of regional hubs for the Support Programme for Female Junior and Senior High School Students in STEM Pathways across Japan, with particular emphasis on advancing initiatives in rural and regional areas. These efforts will prioritise outreach to parents and teachers, who are critical in shaping students' career decisions. The programme will also target students currently showing limited interest in STEM fields, with the goal of encouraging broader participation. Additionally, the government will support initiatives aimed at elementary school girls to foster engagement at an earlier age.

c. Broadening the Base of Science and Technology Human Resources through Industry–Academia–Government Collaboration [Elementary, Junior High, and High Schools]

Universities and other institutions will collaborate with private-sector companies and boards of education to deliver outreach programmes and educational activities in schools. Simultaneously, the government will ensure that efforts to cultivate the next generation of science and engineering talent are steadily implemented through competitive research-funding schemes.

By leveraging programmes such as STELLA, the STEM support programme for women students, and the activities of SSH-designated schools, these initiatives aim to spark interest in science and engineering amongst a wider range of students, including boys, and expand the pipeline of future science and technology leaders.

By implementing these multifaceted initiatives, Japan seeks to build a robust pipeline of future science and technology leaders, beginning at the primary and secondary education levels and contributing to the economy's long-term development.

5-5. Framework for Budgetary Support for Human Resource Development in Science and Technology

The SSH initiative and the STELLA Programme allocated budgets of JPY 2.287 billion (approximately USD 15.8 million) and JPY 937 million (approximately USD 6.5 million) for the fiscal year 2025. Additionally, JPY 79 million (approximately USD 545,000) was earmarked for the Support Programme for Female Students in Choosing Science Courses. This funding was intended to support regionally sustained initiatives that empower women students to make informed and appropriate choices regarding STEM-related educational and career paths.

5-6. Evidence from the Field: Leading Practices in Action

a. STELLA Programme

The Next Generation Science and Technology Challenge Programme (STELLA Programme) supports the cultivation and implementation of diverse talent development programs for students in primary and secondary education (upper primary through secondary levels) who demonstrate outstanding aptitude and strong motivation in science and mathematics. Its aim is to further enhance those students' abilities and cultivate the next generation of exceptional talent capable of driving scientific and technological innovation.

Funded through government operating grants, the programme is administered by the Japan Science and Technology Agency (JST), which solicits proposals from universities, colleges of technology, public research institutions, public-interest corporations, private-sector organisations, and other relevant entities. Selected programmes provide highly motivated and capable students with opportunities to engage in research activities and academic exchange under the guidance of universities and research institutions within Japan and abroad.

Through these initiatives, the programme seeks to nurture individuals who pursue diverse forms of fulfilment and are willing to confront complex challenges. By emphasising inquiry-based learning, STEAM education, entrepreneurship, and the resolution of societal issues, the programme fosters the development of science and technology talent equipped to contribute to innovation.

As of 2025, 24 initiatives are participating in the programme, 12 of which target students at primary and lower secondary levels economy-wide, with seven programmes focused on upper secondary students, and five programmes spanning all three school levels. One institution selected to implement programmes across all school levels is the University of Tokyo's Office for the Next Generation (ONG), which is dedicated to cultivating leaders capable of creating new value and designing a society for tomorrow in an unpredictable world. Its initiatives include STEAM education, industry–academia collaborative workshops, research and development of STEAM-based inquiry programmes, and creation of educational materials. The industry–academia workshops, using engineering research as a theme, have engaged over 1,000 junior and senior high school students in exploring the connections between science, technology, school subjects, and society. The STEAM-based inquiry programme UTokyo GSC-Next enables high school students to design and conduct their own research projects, supported by the development of the "Inquiry Learning Design Method", which focuses on the process of formulating research questions. To promote and disseminate STEAM science education more widely, the ONG has developed digital teaching materials, which have been viewed more than 560,000 times.

b. Platform for Learning Innovation Japan (PLIJ)

The Platform for Learning Innovation Japan (PLIJ) is an organisation established in 2021 with the mission of accelerating innovation in primary and secondary education through close collaboration amongst industry, academia, government, and the education sector. Centred on STEAM education, the PLIJ has, since 2024, been recognising individuals and organisations that have played an outstanding role in introducing and expanding new forms of learning in STEAM and inquiry-based education at the primary and secondary levels. The awards given to the below boards of education and companies are particularly noteworthy.

In the 2024 academic year, the PLIJ launched the PLIJ STEAM and Inquiry Grand Prix. This initiative recognises outstanding individuals and organisations that undertake exemplary practices contributing to the advancement of STEAM education and inquiry-based learning, including community-engaged initiatives and school management practices that emphasise contributions to society. By honouring these efforts and widely publicising their achievements, the programme seeks to promote the dissemination and adoption of effective practices. Through these activities, the Grand Prix aims to accelerate the formation of a shared societal ethos around STEAM and inquiry-based learning whilst simultaneously fostering the evolution of learning systems through increased participation and collaboration amongst stakeholders across industry, academia, government, and education.

Five of the ten institutions awarded at the inaugural Grand Prix are introduced below:

The Oita Prefectural Board of Education: The Oita Prefectural Board of Education is fostering a comprehensive STEAM education environment that spans from elementary school to university students. This achievement reflects the shared vision amongst schools, extracurricular science centres, and Oita university, all aligned with Oita's long-term educational policy. For elementary and junior high school students, hands-on learning is offered through the O-Labo Children's Museum; high school students benefit from the prefecture's STEAM Promotion Initiative; and university students are supported by the Oita University STEAM Education Promotion Centre through various courses and events.

AFK Laboratory LLC: AFK Laboratory LLC is conducting a unique and socially impactful STEAM education programme centred around the creation of and experimentation with "Robo Fossils"—robotic models of ancient aquatic organisms. By integrating cutting-edge biology and underwater physics, the programme immerses students in an exciting inquiry process that mobilises the full scope of STEAM disciplines to explore scientific mysteries. The company collaborates with local governments, museums, and corporate organisations, in addition to creatively fostering connections with experts across fields through public social media platforms. This innovative and distinctive approach holds great promise for further expansion and transformative impacts on students' learning.

Kanazawa University Centre for Academic Management and Partner Institutions: Kanazawa University promotes interdisciplinary and STEAM education through the establishment of the Interdisciplinary Studies Division and the launch of the Pioneering STEAM Human Resource Development Programme (KU-STEAM). Drawing on innovative approaches, such as university–graduate school continuity curricula, the visualisation of learning outcomes, and personalised learning support, the university has

developed a comprehensive framework for human resource development. These initiatives are actively disseminated both within the university and to external partner institutions. Participation in related programmes has steadily increased each year, surpassing 7,000 students in the 2024 academic year. This initiative represents a scalable and transferable model for building a collaborative human resource development ecosystem that effectively bridges the continuum from school education to employment.

Environmental Pollution Research Centre Ltd. and Collaborating Institutions: The Environmental Pollution Research Centre Ltd., a company based in Kanazawa City with a core focus on environmental measurement, has implemented this project in collaboration with Ishikawa Prefectural University and a high school consortium centred on Nanao High School. The initiative provides high school students with technical guidance in environmental DNA (eDNA) analysis, enabling them to engage directly in authentic scientific inquiry. Through hands-on field surveys, students collect samples, analyse data, and systematically investigate and document fish species inhabiting rivers, lakes, and marshes across Ishikawa Prefecture. The project holds significant academic value and represents a model of external collaboration that extends students' learning beyond the classroom into meaningful engagement with professional scientific practices.

Gunma Prefectural Takasaki High School and Partner Organisations: Gunma Prefectural Takasaki High School has been designated a Super Science High School since the 2002 academic year and has pursued the integration of tradition and innovation through its distinctive educational practices. Its STEAM-based Project Research programme, which enables students to identify and address problems grounded in their own interests whilst engaging in creative production, has received significant acclaim. In particular, the programme is recognised for its effective integration of knowledge and skills into real-world applications as well as for promoting cross-curricular learning that connects concepts across multiple subject areas. Additionally, the school has made sustained efforts to establish a learning environment that effectively utilises online tools and digital devices whilst strengthening collaboration with engineers and specialists from industry and other external partners.

6. Republic of Korea

Hyun-Ju PARK, Professor, Chosun University, Republic of Korea

Summary: Republic of Korea's STEM and STEAM education has evolved through a distinctive policy trajectory characterized by high academic achievement in mathematics and science, alongside sustained efforts across Korea to promote convergence learning, creativity, and problem-solving competencies. Since the introduction of an economy-wide STEAM (convergence education) policy in 2011, Korea has systematically strengthened STEM and STEAM education across multiple levels, including government, regional education authorities, schools, public institutions, research organizations, and industry, with the shared objective of cultivating future-ready human capital. On 20 December 2024, the Ministry of Education of Korea announced the Master Plan for Science, Mathematics, Information, and Convergence Education (2025–2029) under the Act on the Promotion of Science, Mathematics, and Information Education, responding to the demands of an advanced science- and technology-driven society. The plan articulates three strategic priorities: (1) instructional innovation to enhance students' confidence in science and mathematics while strengthening core competencies; (2) personalized growth support for students and teachers through the integration of artificial intelligence and digital technologies; and (3) expanded participation and the promotion of a healthy educational culture across science, mathematics, informatics, and convergence education. The master plan is aligned with a coordinated set of strategies for the same planning cycle, including dedicated master plans for mathematics education, science education, information education, and STEAM education. Together, these interlinked policies constitute an integrated economy-wide framework that connects strong disciplinary foundations with digital transformation and interdisciplinary, convergence-oriented learning. Korea's STEAM ecosystem therefore reflects a dual emphasis: maintaining rigorous disciplinary standards through a centralized domestic curriculum, while actively promoting interdisciplinary integration and creativity to move beyond examination-driven instruction toward more authentic, problem-oriented learning. This dual approach underpins Korea's strengths in academic achievement and policy coherence, while also revealing ongoing challenges in balancing examination-oriented traditions with student-centered innovation.

6-1. Strategy and Vision

Korea's vision for STEAM education is anchored in two interrelated policy directions. First, the system places sustained emphasis on strong foundational competence in mathematics and science, supported by a centralized domestic curriculum, clearly articulated learning standards, and robust accountability mechanisms. Foundational STEM competence is viewed as a prerequisite for both individual academic success and domestic competitiveness.

Second, Korea advances convergence-oriented learning (STEAM) as a strategic approach to fostering creativity, real-world problem solving, and innovation capacity. Rather than replacing disciplinary learning, STEAM is designed to complement and extend subject-based instruction by enabling students to integrate knowledge across science, technology, engineering, arts, and mathematics in meaningful and authentic contexts.

This dual vision is formally articulated in the 3rd STEAM (Convergence Education) Master Plan (2025–2029), led by the Ministry of Education and implemented through domestic agencies such as the Korea Foundation for the Advancement of Science and Creativity

(KOSAC). The plan positions STEAM as a strategic policy response to rapid societal, technological, and industrial change, emphasizing learner-centered inquiry, interdisciplinary problem solving, and the application of knowledge in socially relevant contexts.

At the system level, the 2022 Revised National Curriculum reinforces this vision by introducing competency-based learning outcomes while maintaining clear subject structures. Within this framework, STEAM capability is understood not only as academic achievement, but also as the capacity to apply knowledge flexibly across disciplines and real-life situations, including ethical and societal dimensions.

Korea's STEAM strategy is further operationalized through a system-level implementation framework that reflects one of the most coordinated approaches among OECD economies. Guided by domestic master plans, curriculum reforms, and centrally supported implementation mechanisms, Korea has evolved from a narrow focus on academic excellence toward a broader policy orientation integrating creativity, convergence, collaboration, and societal relevance. Since the early 2010s, STEAM has been institutionalized at scale as a pedagogical reform model, rather than as an enrichment or extracurricular activity.

The 3rd STEAM Master Plan (2025–2029) structures this reform agenda around four interrelated policy pillars:

(1) strengthening STEAM implementation within schools through close curriculum alignment and the expansion of problem-based and inquiry-driven learning;

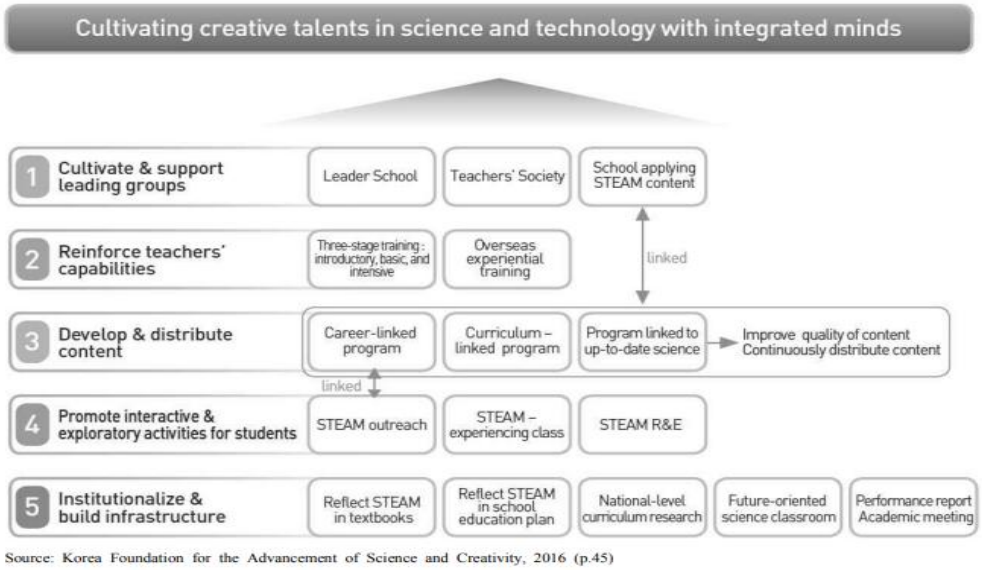
(2) promoting student-centered convergence learning through collaborative, exploratory, and project-based experiences;

(3) providing systematic support for teachers' STEAM capacity development, including professional learning networks and interdisciplinary pedagogical expertise; and

(4) building a sustainable and inclusive STEAM infrastructure through governance coordination, regional ecosystem development, and partnerships with universities and industry.

Overall, the plan reflects Korea's commitment to embedding STEAM education as a long-term structural reform, balancing disciplinary rigor with creativity and ensuring that convergence-oriented learning is scalable, inclusive, and socially relevant.

Figure 1 illustrates Korea's domestic STEAM strategy as a systemically aligned framework connecting domestic vision, policy instruments, teacher capacity building, classroom practice, and institutional infrastructure.



Source: Korea Foundation for the Advancement of Science and Creativity, 2016 (p.45)

Figure 8. Korea's STEAM Education Implementation Framework

At the top of the model, the overarching vision is articulated as "Cultivating creative talents in science and technology with integrated minds." This vision encapsulates Korea's approach to STEAM education: nurturing scientifically competent learners who are also capable of integrative thinking, creativity, and interdisciplinary problem solving. The framework operationalizes this vision through five interconnected policy pillars, forming a vertically aligned and systemically coordinated implementation structure.

The first pillar, cultivating and supporting leading groups, focuses on establishing institutional leadership and diffusion mechanisms through Leader Schools, Teachers' Societies, and schools applying STEAM content. These entities function as early adopters and innovation hubs, enabling domestically guided yet school-based experimentation.

The second pillar, reinforcing teachers' capabilities, highlights teacher professional capacity as a core driver of STEAM implementation through staged training and experiential learning, positioning teachers as curriculum designers and facilitators of interdisciplinary inquiry.

The third pillar, developing and distributing STEAM content, emphasizes high-quality, curriculum-linked resources aligned with career pathways, domestic standards, and rapidly evolving scientific knowledge.

The fourth pillar, promoting interactive and exploratory activities for students, advances inquiry-based and problem-centered learning through outreach programs, experiential classes, and research and engineering (R&E) activities.

The fifth pillar, institutionalizing STEAM and building infrastructure, embeds STEAM principles into textbooks, school plans, curriculum research, future-oriented learning environments, and performance reporting systems.

Taken as a whole, the framework reveals several defining characteristics of Korea's STEM and STEAM education:

(1) strong vertical alignment between domestic vision, policy instruments, teacher development, classroom practice, and infrastructure;

(2) centralized coordination with distributed implementation, enabling scale without fragmentation;

(3) a dual emphasis on disciplinary rigor and interdisciplinary creativity; and

(4) a clear understanding of STEAM as a pedagogical reform model, rather than merely an enrichment program.

This structure helps explain Korea's ability to maintain high international achievement in mathematics and science, while simultaneously seeking to address long-standing challenges related to creativity, student engagement, and real-world problem solving.

6-2. Key STEAM Education Programs

a. STEM Education Programs and Initiatives

Korea's STEAM education programs are characterized by a domestically coordinated, platform-based implementation model. Rather than relying solely on isolated projects or school-level initiatives, the Korean government has established a central digital platform to curate, disseminate, and support STEAM education economy-wide.



Figure 9. STEAM education platform by KOSAC. https://steam.kosac.re.kr/main

A representative example is the domestic STEAM education platform operated by the Korea Foundation for the Advancement of Science and Creativity (KOSAC). This platform functions as a policy delivery infrastructure, enabling systematic sharing of programs, instructional resources, and professional networks related to STEAM education.

Through this platform, the government supports STEAM education in several interrelated ways.

First, the platform serves as a repository of curriculum-linked STEAM programs. Teaching and learning materials are organized by school level (primary, middle, and high

school) and aligned with domestic curriculum objectives. These resources emphasize inquiry-based learning, real-world problem solving, and interdisciplinary integration, ensuring that STEAM is embedded within regular classroom instruction rather than treated as extracurricular enrichment.

Second, the platform facilitates economy-wide diffusion of best practices. Schools designated as STEAM-leading or innovation schools share lesson cases, instructional designs, and implementation experiences. This horizontal sharing mechanism allows successful models to spread across regions while maintaining alignment with domestic policy goals.

Third, the platform supports teacher professional learning communities. Teachers can access instructional guides, participate in training programs, and engage in professional exchange through online and blended formats. This reflects Korea's emphasis on teacher capacity as a core driver of STEAM quality.

Finally, the platform acts as a policy communication channel, providing announcements, guidelines, and evaluation materials related to domestic STEAM initiatives. In this sense, it bridges domestic policy intent and school-level practice, strengthening coherence across the system.

Overall, Korea's STEAM initiatives are distinguished not by the sheer number of individual programs, but by the institutionalized mechanism through which programs are curated, quality-controlled, and continuously updated at the economy-wide level.

b. Talent Development and Scholarship Programs

Alongside broad-based STEAM education for all students, Korea has maintained a strong policy focus on systematic STEM talent development, particularly for students with high potential in science, mathematics, and engineering-related fields.

At the secondary level, Korea operates specialized science high schools and gifted education programs, which provide advanced coursework, research-oriented learning, and mentorship opportunities. These institutions play a significant role in nurturing future STEAM professionals and researchers, forming an upper segment of the domestic STEAM pipeline.

In parallel, the government supports research- and inquiry-oriented student programs, such as STEAM research and engineering (R&E) activities. These programs allow students to engage in extended investigations, often in collaboration with universities or research institutes, thereby strengthening early exposure to authentic scientific practices.

At the postsecondary and pre-tertiary transition stages, domestic scholarship and talent support schemes contribute to STEAM pipeline continuity. Scholarships and fellowships are often targeted toward students pursuing science and engineering majors, reducing financial barriers and encouraging sustained participation in STEAM pathways. Although these schemes are administered through multiple ministries and agencies, they collectively reflect a state-led commitment to cultivating high-level STEAM human capital.

Importantly, recent policy directions emphasize that talent development should not be limited to academic excellence alone. There is increasing attention to creativity, convergence competence, ethical awareness, and social responsibility, aligning advanced STEM training with broader societal needs.

Taken together, Korea's STEAM education programs and talent development

initiatives reveal a two-tiered but integrated policy architecture.

- At the base level, universal STEAM education is supported through a domestic platform that enables curriculum alignment, teacher capacity building, and equitable access to high-quality resources.
- At the advanced level, targeted talent development and scholarship programs cultivate future STEAM leaders through specialized schooling, research experiences, and financial support.

The domestic STEAM platform plays a pivotal role in connecting these layers, ensuring that broad participation and elite talent development are not treated as separate policy tracks, but as complementary components of a coherent STEAM ecosystem.

c. Teachers' Capacity Building

A defining feature of Korea's STEAM policy is its strong reliance on teacher-led development and dissemination mechanisms. Rather than prescribing uniform instructional models from the center, Korea has invested in policy structures that position teachers as curriculum designers, innovators, and knowledge producers within the STEAM ecosystem.

A prominent example is the STEAM Education Research Council program, supported by the Ministry of Education and administered through the Korea Foundation for the Advancement of Science and Creativity (KOSAC). These councils consist of teacher teams, often working in collaboration with subject-matter experts, who design, pilot, and refine STEAM lesson models aligned with the domestic curriculum. Selected councils have typically received modest project-based funding (approximately KRW 5 million over a nine-month period), with outcomes disseminated economy-wide through workshops, publications, and online platforms.

This model reflects a core policy assumption in Korea's STEAM approach: convergence education gains legitimacy, quality, and scalability when it is professionally authored by teachers, rather than externally imposed through top-down mandates. By embedding innovation within teacher professional communities, the system supports both contextual adaptation and domestic coherence.

Beyond STEAM-specific initiatives, Korea has also strengthened teacher capacity through system-wide informatics education. Since 2018, informatics (Information) has been a mandatory subject at the middle school level, ensuring that all students—and, by extension, all schools—engage with foundational concepts such as programming, algorithmic thinking, and computational problem solving. This policy has functioned as a structural backbone for contemporary STEM capacity, reinforcing digital literacy and logical reasoning across the education system.

Teacher capacity is widely recognized in Korea as both a key enabler and a structural constraint in STEM and STEAM education. Accordingly, capacity-building efforts have emphasized professional learning communities, research-oriented teacher groups, and structured dissemination of practice, rather than reliance on short-term, one-off training sessions.

Through STEAM research councils and related initiatives, teachers are encouraged to engage in collaborative lesson design, classroom experimentation, and reflective refinement. These processes have contributed to the gradual diffusion of inquiry-based and project-based instructional practices. At the same time, policy analyses and field reports consistently point to teacher workload and time constraints as persistent challenges, particularly when convergence-

oriented learning is layered onto an already content-dense curriculum.

Korea's experience highlights that effective teacher capacity in STEAM extends beyond subject knowledge. It requires instructional design competence, assessment literacy for complex and open-ended tasks, and professional confidence in interdisciplinary teaching.

d. STEM Facilities and Learning Environments

Korea's STEAM learning environments have evolved in parallel with curriculum and pedagogical reforms. Increasing attention has been given to the creation of flexible learning spaces that support experimentation, inquiry, and collaborative problem solving, particularly in science- and technology-related subjects.

While the scale and quality of facilities vary across regions and school contexts, domestic policy discourse consistently emphasizes that learning environments should facilitate active inquiry and hands-on exploration, rather than passive content delivery. In this sense, facilities are framed not merely as physical infrastructure, but as pedagogical enablers aligned with the goals of convergence-oriented STEAM education.

e. Student STEM Participation and Pipeline Development

Korea's student STEM pipeline is notable for its system-wide reach, as most STEM-related learning occurs within the formal curriculum rather than through optional extracurricular participation alone. Strong mathematics and science requirements ensure broad participation at the foundational level, while STEAM initiatives and informatics education aim to broaden the nature of STEM engagement.

However, participation patterns reveal familiar transition challenges. While achievement levels remain high overall, maintaining student motivation and interest—particularly in relation to creative and interdisciplinary applications—continues to be a focus of policy attention.

6-3. Education Effects and Measured Outcomes

The effects of Korea's STEAM education are most clearly evidenced through international comparative assessments and equity-related indicators. In PISA 2022, Korea achieved 527 points in mathematics and 528 points in science, substantially exceeding the OECD averages of 472 and 485, respectively. These results confirm Korea's position as a high-performing STEM system.

Beyond average performance, Korea demonstrates a strong high-achievement profile. Approximately 23% of students reached the highest proficiency levels (Levels 5–6) in mathematics, compared with an OECD average of 9%. In science, 16% of students attained top proficiency levels, more than double the OECD average of 7%. At the same time, 84% of students achieved at least baseline proficiency (Level 2) in mathematics and 86% did so in science, indicating a broad and robust foundation of STEM competence across the student population.

Equity indicators provide additional insight. OECD analyses identify a 97-point gap in mathematics performance between socio-economically advantaged and disadvantaged students. Nevertheless, 11% of disadvantaged students in Korea are classified as academically

resilient, meaning they perform in the top quarter of achievement despite socio-economic disadvantage. This suggests that while equity gaps persist, the system also enables meaningful upward mobility through education.

Taken together, these outcomes indicate that Korea's STEAM policies have been highly effective in sustaining strong foundational achievement and a large pool of high performers, even as convergence-oriented reforms continue to mature.

6-4. Investment and Budgetary Patterns

Korea's investment in STEAM education is typically embedded within broader economy-wide curriculum reform budgets and targeted program-level funding, rather than presented as a single, consolidated STEAM budget line. Program-level investments—such as support for STEAM research councils—illustrate a preference for moderate, strategically targeted funding aimed at strengthening professional capacity and supporting the dissemination of effective instructional practices.

This investment pattern reflects a broader policy logic. Rather than relying on large-scale, one-time funding initiatives, Korea emphasizes continuous system refinement through curriculum alignment, sustained teacher engagement, and iterative program development. Such an approach prioritizes long-term coherence and institutional learning over short-term expansion, reinforcing STEAM education as an integral component of ongoing education reform rather than a standalone initiative.

6-5. Partnerships

Partnerships constitute a core structural component of Korea's STEAM ecosystem. Policy design and implementation are commonly carried out through coordinated collaboration among the Ministry of Education, domestic agencies such as KOSAC, universities, public research institutes, and professional teacher networks. Through these multi-level partnerships, Korea supports curriculum innovation, teacher professional learning, and the large-scale dissemination of effective instructional practices.

Within the context of STEAM education, partnerships play a particularly important role in bridging disciplinary boundaries and linking classroom learning to real-world scientific, technological, and societal contexts. Collaboration with universities and research institutes provides access to up-to-date scientific knowledge and authentic problem contexts, while teacher networks facilitate peer-based adaptation and diffusion of STEAM practices. Together, these partnerships enhance both the relevance and scalability of convergence-oriented education.

6-6. Performance Indicators

Korea's STEAM performance is monitored through a portfolio of complementary indicators, encompassing international achievement measures (such as PISA), equity indicators (including socio-economic achievement gaps and student resilience), and implementation indicators (such as teacher participation in STEAM research councils and the dissemination of instructional practices).

This multi-dimensional monitoring framework reflects a policy-level recognition that no single metric can adequately capture the complex and long-term impacts of convergence-

oriented education reforms. Instead, Korea's approach emphasizes the combined assessment of learning outcomes, inclusivity, and systemic implementation capacity in evaluating STEAM effectiveness.

6-7. Gender Inclusivity and Equity

Gender patterns in Korea's STEAM outcomes present a nuanced picture of parity and persistence gaps. According to PISA 2022, boys and girls demonstrate similar average performance in mathematics, indicating that broad gender parity in achievement has largely been achieved. However, boys remain disproportionately represented among top performers, with 26% of boys compared to 19% of girls reaching Levels 5–6.

This pattern suggests that while access to foundational STEM learning is relatively equitable, gender disparities persist at the highest levels of performance, where pathways into advanced STEAM trajectories are often formed. From a policy perspective, these findings point to the need for targeted strategies that support girls' sustained participation and confidence in advanced STEM learning, particularly in contexts emphasizing high-level problem solving, abstraction, and competition.

Equity concerns extend beyond gender. Socio-economic disparities continue to influence students' access to advanced STEAM learning opportunities, especially in systems where private education plays a significant role. Ensuring that convergence-oriented STEAM innovations are inclusive and equitably distributed therefore remains a critical policy challenge, underscoring the importance of reducing structural barriers while broadening participation.

6-8. Key Challenges

Despite its strong academic outcomes, Korea continues to face several interrelated challenges in advancing STEAM education. A central issue lies in balancing disciplinary rigor with creativity, ensuring that convergence-oriented learning deepens conceptual understanding rather than introducing superficial complexity. Closely related is the challenge of managing teacher workload, as effective STEAM implementation requires additional time for instructional design, collaboration, and reflection within an already demanding curriculum structure.

Sustaining teacher motivation and providing adequate institutional support—including time allocation, professional recognition, and collaborative infrastructure—remain critical conditions for the effective implementation of convergence-based instruction. At the system level, a persistent overemphasis on examination performance continues to shape instructional priorities, potentially constraining inquiry, creativity, and pedagogical risk-taking.

In addition, Korea's STEAM ecosystem is characterized by a high reliance on private education, particularly in advanced mathematics and science, raising concerns about equity and the capacity of public education alone to support high-level STEAM learning. Despite high achievement in international assessments, students also report relatively low levels of interest and well-being in science, highlighting a disconnect between performance and engagement.

Finally, there is growing recognition of the need to align STEAM education more closely with ethical, societal, and sustainability challenges, ensuring that scientific and technological competence is accompanied by responsible judgment and civic awareness in increasingly complex socio-technical contexts.

7. Malaysia

Pimonpan CHANTARAPIMON, National Science Museum, Thailand

Summary: Malaysia's STEM education system in 2025 reflects a strategic domestic commitment to strengthening human capital in support of economic competitiveness, digital transformation, and sustainable development. Anchored by the National STEM Movement, Malaysia integrates formal education, digital innovation, and industry engagement to promote STEM participation at all educational levels. While access and early-stage engagement in STEM learning have expanded, challenges persist in instructional quality, teacher capacity, and student retention along the STEM pipeline. Public–private partnerships and digital STEM platforms play a distinctive role in extending learning opportunities, particularly in underserved communities. Overall, Malaysia's STEM education landscape demonstrates steady progress, while highlighting the need for stronger implementation coherence and longitudinal outcome tracking to ensure sustained talent development.

7-1. Strategy and Vision

Malaysia has articulated a coherent and forward-looking domestic strategy for STEM education as a central pillar of its human capital development and economic transformation agenda. Anchored in the Twelfth Malaysia Plan (12MP, 2021–2025) and reinforced by the Malaysia Education Blueprint 2013–2025, STEM education is positioned as a strategic mechanism to enhance productivity, technological capability, and global competitiveness in the context of Industry 4.0 and the digital economy (Ministry of Education Malaysia [MOE], 2023).

At the domestic level, Malaysia's STEM vision emphasizes the development of future-ready, innovation-oriented, and digitally competent learners capable of contributing to high-value industries, including advanced manufacturing, artificial intelligence, data analytics, green technology, and biotechnology. This vision aligns closely with broader domestic aspirations articulated in Shared Prosperity Vision 2030, which underscores inclusive growth, talent-driven development, and reduced socioeconomic disparities (Prime Minister's Department, 2021). STEM education is therefore framed not only as a driver of economic advancement but also as a tool for social mobility and domestic cohesion.

The Ministry of Education plays a central coordinating role in translating this vision into policy and practice across basic and secondary education. Through curriculum reforms and the promotion of integrated STEM learning, Malaysia seeks to shift instructional approaches away from rote memorization toward inquiry-based, problem-oriented, and interdisciplinary learning models. These reforms emphasize the application of scientific and mathematical concepts to real-world challenges, fostering critical thinking, creativity, and collaboration—competencies that are increasingly emphasized in international frameworks such as the OECD Learning Compass 2030 and UNESCO's Reimagining Education agenda (UNESCO, 2021).

At the post-secondary level, the Ministry of Higher Education complements school-based STEM initiatives by strengthening alignment among higher education, research, and labor-market needs. Universities are encouraged to expand enrollment in priority STEM fields, enhance industry-relevant curricula, and promote applied research and innovation. These efforts are closely linked to Malaysia's innovation ecosystem, including the National Science, Technology, and Innovation Policy (DSTIN) 2021–2030, which identifies STEM education as a critical enabler of technological sovereignty and sustainable development (Ministry of Science, Technology, and Innovation [MOSTI], 2021).

A distinctive feature of Malaysia's STEM strategy is its strong emphasis on equity and inclusivity, particularly in addressing urban–rural disparities and socioeconomic gaps in STEM participation. Domestic policies explicitly recognize the persistent challenges of uneven access to quality STEM learning opportunities, digital infrastructure, and qualified teachers. In response, STEM education is integrated with targeted interventions for underserved communities, including rural schools, low-income students, and Indigenous populations, reflecting commitments aligned with APEC human capital development priorities and UNESCO's equity-focused education frameworks (UNESCO, 2023).

Collectively, Malaysia's strategy and vision for STEM education in 2025 reflect a whole-of-government and system-wide approach that integrates education reform, economic policy, innovation strategy, and social inclusion under a shared developmental agenda. By positioning STEM education as both an economic imperative and a social investment, Malaysia demonstrates a balanced policy orientation that seeks to cultivate a resilient, adaptable, and inclusive STEM talent pipeline capable of supporting long-term domestic transformation in an increasingly knowledge-driven global economy.

7-2. Key STEM Education Programs

a. STEM Educational Programs and Initiatives

Malaysia has implemented a range of large-scale and strategically coordinated STEM programs that serve as key operational mechanisms for translating domestic STEM policy into practice. These flagship initiatives are designed to strengthen student engagement, improve teaching quality, expand access to STEM learning, and align education with domestic innovation and workforce priorities. Collectively, they reflect Malaysia's emphasis on systemic reform, applied learning, and inclusivity within its STEM education ecosystem.

One of the most prominent domestic initiatives is the Malaysia STEM Initiative (MSI), coordinated by the Ministry of Education in collaboration with the Ministry of Science, Technology, and Innovation (MOSTI). The MSI functions as an overarching framework that integrates STEM promotion, curriculum enhancement, teacher professional development, and public engagement activities. Central to the initiative is the objective of increasing student participation in STEM streams at the upper secondary and tertiary levels, addressing Malaysia's long-standing concern over declining STEM enrollment ratios (MOE Malaysia, 2023). Through coordinated campaigns, school-based activities, and partnerships with industry and research institutions, the MSI seeks to reposition STEM as relevant, engaging, and aligned with future career pathways.

At the school level, Malaysia has institutionalized Integrated STEM Education as a core pedagogical approach within the domestic curriculum. This approach emphasizes interdisciplinary, inquiry-based learning that connects science, mathematics, engineering, and technology to real-world problems. Flagship programs such as STEM Project-Based Learning (STEM-PBL) initiatives encourage students to design solutions related to sustainability, environmental management, digital innovation, and community challenges. These initiatives are closely aligned with international best practices promoted by the OECD and UNESCO, particularly in fostering higher-order thinking skills, creativity, and collaborative problem-solving (OECD, 2019; UNESCO, 2021).

Another major pillar of Malaysia's STEM ecosystem is the National STEM Movement, a whole-of-society platform that brings together government agencies, universities, private-sector partners, and civil society organizations. Under this movement, large-scale outreach activities—including STEM carnivals, science fairs, robotics competitions, and innovation challenges—are organized economy-wide, with a particular focus on rural and underserved regions. These programs aim to democratize access to STEM learning experiences and reduce

geographic and socioeconomic disparities, reinforcing Malaysia's equity-oriented STEM agenda (MOSTI, 2021).

Digital transformation is a prominent feature of Malaysia's flagship STEM initiatives. The Digital STEM Education Platform, developed under the Malaysia Education Blueprint and reinforced during the post-pandemic period, provides students and teachers with access to virtual laboratories, coding modules, AI learning resources, and online STEM challenges. This platform supports blended and remote learning models, enhances system resilience, and expands opportunities for schools with limited physical resources to engage in high-quality STEM education (MOE Malaysia, 2023). These efforts align with UNESCO's emphasis on leveraging technology to expand equitable access to STEM learning while strengthening digital literacy economy-wide (UNESCO, 2023).

At the post-secondary and talent development levels, Malaysia has launched targeted STEM programs under the National Science, Technology, and Innovation Policy (DSTIN) 2021–2030, including research internships, industry-linked capstone projects, and innovation grants for university students. These initiatives strengthen pathways from education to employment by embedding students within domestic priority sectors such as advanced manufacturing, green technology, biotechnology, and digital services. By fostering closer alignment between academic training and industry needs, these programs contribute to workforce readiness and innovation capacity, consistent with OECD recommendations on skills ecosystems and work-integrated learning (OECD, 2021).

Overall, Malaysia's key STEM programs and flagship initiatives demonstrate a coordinated, multi-level, and inclusive approach to STEM education reform. By combining curriculum innovation, experiential learning, digital platforms, public engagement, and industry alignment, Malaysia has constructed a diverse portfolio of STEM initiatives that reinforce domestic development goals while addressing persistent challenges in participation, quality, and equity. These programs play a critical role in strengthening the STEM talent pipeline and in positioning Malaysia to compete effectively in an increasingly knowledge-intensive, technology-driven global economy.

b. Case Studies of Best Practices

National STEM Teacher Training Program (NSTTP)

- Lead Agencies: Ministry of Education (MOE), SEAMEO RECSAM, Universiti Teknologi Malaysia (UTM).
- Target Groups & Scope: Pre-service and in-service STEM teachers, especially at upper primary and secondary levels economy-wide.
- Structure & Approach: Blended learning combining workshops, online modules, and classroom mentoring, with an emphasis on inquiry-based and problem-solving instruction aligned with Malaysia's STEM curriculum.
- Outcomes & Indicators: Over 5,000 teachers trained by 2024, measurable improvements in classroom practices, and enhanced student performance in STEM subjects based on domestic and international assessments (e.g., PISA, TIMSS).
- Scalability: Designed to be adapted across ASEAN economies with flexible curriculum alignment.

STEM@Petronas Program

- Lead Agencies: Petronas (Malaysia's oil company), Ministry of Education.
- Target Groups & Scope: Secondary school students in urban and rural areas, with a focus on underserved schools.

- Structure & Approach: Distribution of STEM kits, school visits by STEM ambassadors, hands-on workshops, annual science fairs, and collaboration with teachers to integrate real-world STEM challenges into the curriculum.
- Outcomes & Indicators: More than 50,000 participants annually, and 30% of participants pursue STEM-related studies or careers.
- Scalability: Considered a replicable public–private partnership model for other economies.

Malaysia Digital STEM Learning Platform

- Lead Agencies: Ministry of Science, Technology, and Innovation (MOSTI), Malaysia Digital Economy Corporation (MDEC).
- Target Groups & Scope: Students, teachers, and lifelong learners at all levels through online access.
- Structure & Approach: A comprehensive online portal offering STEM content, virtual labs, coding instruction, and AI-supported personalized learning and collaboration with tech companies ensures up-to-date tools and content.
- Outcomes & Indicators: Over 1 million registered users in 2024, user satisfaction above 4.5/5, and documented improvement in STEM skills.
- Scalability: Content and interface can be localized for ASEAN economies.
- Shared Success Factors Across All Programs: Government and private sector funding, integration of local context and relevance, teacher development and mentorship, effective use of digital technology and data, and strong institutional collaboration.
- Shared Policy Recommendations All Programs: Institutionalize continuous STEM, teacher development, promote multi-sector collaboration and funding, expand digital access in rural and underserved areas, advance gender equity, and inclusive engagement in STEM, and strengthen data-based monitoring and evaluation systems.

c. Talent Development and Scholarship Programs

Talent development and scholarship programs constitute a central pillar of Malaysia's STEM education strategy, reflecting the economy's commitment to building a sustainable pipeline of highly skilled human capital aligned with domestic development priorities. These efforts are closely linked to Malaysia's long-term vision, including the Malaysia Madani framework and the National Science, Technology, and Innovation Policy (2021–2030), both of which emphasize innovation-driven growth and global competitiveness.

At the domestic level, the Ministry of Education (MOE) and the Ministry of Higher Education (MOHE) administer a range of scholarship and talent development schemes designed to support students across the STEM education continuum. Major public scholarship programs, such as the Public Service Department (JPA) scholarships, MOE-sponsored science stream scholarships, and MOHE-funded postgraduate fellowships, prioritize disciplines including engineering, information and communications technology, data science, biotechnology, and environmental sciences. These programs aim to increase STEM participation among high-achieving students while addressing workforce needs in strategic sectors (Ministry of Higher Education Malaysia, 2024).

A distinctive feature of Malaysia's STEM talent strategy is its strong linkage between scholarships and domestic workforce planning. Many scholarship recipients are bonded to public agencies, government-linked companies (GLCs), or strategic industries upon graduation, ensuring that public investment in STEM education translates into tangible contributions to domestic development. This approach strengthens talent retention while aligning educational pathways with labor market demand (OECD, 2021).

In parallel, Malaysia has expanded talent development initiatives beyond traditional academic excellence, incorporating innovation, entrepreneurship, and applied research components. Programs supported by agencies such as the Ministry of Science, Technology, and Innovation (MOSTI) and TalentCorp Malaysia offer grants, fellowships, and innovation challenges that target young researchers, technopreneurs, and early-career professionals in STEM fields. These initiatives encourage interdisciplinary problem-solving, industry engagement, and startup formation, thereby broadening the definition of STEM talent beyond conventional degree attainment (MOSTI, 2023).

Equity considerations are increasingly embedded in Malaysia's scholarship framework. Targeted schemes support students from low-income households, rural communities, and underrepresented groups, including Bumiputera students and women in selected STEM disciplines. These measures seek to reduce structural barriers to participation and ensure a more inclusive STEM talent pipeline, although disparities in access and completion remain an ongoing concern (UNESCO, 2023).

Despite substantial progress, challenges persist in tracking the long-term outcomes of scholarship recipients and evaluating the effectiveness of talent development programs. Monitoring systems often focus on inputs and completion rates rather than graduate employability, innovation outputs, or career progression in STEM-related fields. Strengthening longitudinal data collection and outcome-based evaluation will be critical to enhancing policy coherence and maximizing the return on investment in STEM talent development.

Overall, Malaysia's talent development and scholarship programs reflect a strategic and increasingly integrated approach to nurturing STEM capabilities. By combining financial support, workforce alignment, innovation incentives, and equity-focused interventions, Malaysia continues to strengthen its capacity to develop a competitive and future-ready STEM workforce.

d. Student Competitions and Events

Student competitions and enrichment activities play a strategically significant role in Malaysia's STEM education ecosystem by complementing formal schooling with experiential, inquiry-based, and innovation-oriented learning opportunities. These activities function as key mechanisms for nurturing interest in STEM, identifying high-potential students, and strengthening the STEM talent pipeline from an early age.

At the domestic level, the Ministry of Education (MOE) and the Ministry of Science, Technology, and Innovation (MOSTI) jointly support a wide range of STEM competitions, science fairs, innovation challenges, and enrichment programs targeting primary and secondary students. Flagship initiatives include domestic robotics competitions, science and engineering innovation fairs, coding and computational thinking challenges, and mathematics and science Olympiad pathways. These platforms encourage students to apply theoretical knowledge to real-world problems while developing higher-order thinking, creativity, and teamwork skills (Ministry of Education Malaysia, 2024).

A defining feature of Malaysia's STEM competitions is their strong alignment with domestic priorities in digital technology, sustainability, and innovation. Several enrichment programs emphasize robotics, artificial intelligence, the Internet of Things (IoT), green technology, and data-driven problem-solving, reflecting the economy's broader aspirations under the National Science, Technology, and Innovation Policy (DSTIN) 2021–2030. Through participation in these activities, students gain early exposure to emerging technologies and industry-relevant competencies, strengthening their readiness for advanced STEM studies and future careers (MOSTI, 2021).

Malaysia also actively participates in regional and international STEM competitions, enabling students to benchmark their skills against global standards. Selected high-performing

students are supported to represent the economy in international Olympiads, robotics competitions, and innovation exhibitions. These international engagements enhance students' confidence, cross-cultural communication skills, and global awareness, while also reinforcing Malaysia's commitment to producing globally competitive STEM talent (OECD, 2019).

In addition to competitions, enrichment activities such as STEM camps, innovation boot camps, maker programs, and university-led outreach initiatives provide extended learning opportunities beyond the classroom. Universities, science centers, and industry partners collaborate with schools to offer hands-on workshops, mentoring, and research exposure, particularly for students with a strong interest or aptitude in STEM fields. These programs contribute to sustained engagement and help reduce attrition along the STEM education pipeline (UNESCO, 2023).

Equity and access are increasingly emphasized in the design of student competitions and enrichment activities. Targeted initiatives aim to expand participation among students from rural areas, low-income backgrounds, and underrepresented groups by providing mobile STEM programs, subsidized participation fees, and school-based outreach. Despite these efforts, disparities in access to high-quality enrichment opportunities persist, indicating the need for more systematic scaling and monitoring of inclusive participation (Ministry of Education Malaysia, 2024).

Overall, student competitions and enrichment activities constitute a vital extension of Malaysia's STEM education strategy. By integrating experiential learning, innovation challenges, and international exposure, these programs not only enhance students' academic and technical competencies but also cultivate motivation, creativity, and resilience. Strengthening coordination, expanding equitable access, and linking competition outcomes more systematically to talent development pathways will be critical to maximizing their long-term impact on Malaysia's STEM ecosystem.

e. Teachers' Training

Teacher capacity building is a central pillar of Malaysia's STEM education reform, reflecting the government's recognition that effective STEM implementation depends fundamentally on teachers' pedagogical competence, interdisciplinary knowledge, and confidence in delivering inquiry-based, technology-enhanced instruction. In 2025, Malaysia's approach to STEM teacher training is characterized by a combination of structured pre-service preparation, large-scale in-service professional development, and strategic alignment with domestic curriculum reforms and digital transformation agendas.

Pre-service teacher education in Malaysia is primarily delivered through public universities and teacher education institutes under the Ministry of Education (MOE). These programs emphasize strong disciplinary foundations in science and mathematics, complemented by pedagogical training in curriculum design, assessment, and classroom management. In recent years, increasing attention has been given to integrated STEM pedagogy, computational thinking, and project-based learning, ensuring that newly qualified teachers are better prepared to implement interdisciplinary STEM curricula aligned with standards (MOE Malaysia, 2023). This shift reflects Malaysia's effort to move beyond subject silos toward holistic STEM teaching approaches consistent with OECD-recommended instructional practices (OECD, 2019).

In-service professional development (CPD) represents the most significant mechanism for strengthening STEM teaching capacity economy-wide. The MOE, in collaboration with the Institute of Teacher Education Malaysia (IPGM) and state education departments, delivers continuous training programs focused on integrated STEM instruction, digital pedagogy, and assessment of higher-order thinking skills (HOTS). These programs are closely aligned with the domestic curriculum and the Malaysia Education Blueprint, enabling teachers to translate

policy objectives into classroom practice (MOE Malaysia, 2024). Training is delivered through blended modalities, combining face-to-face workshops, online courses, and school-based coaching, thereby increasing accessibility across urban and rural contexts.

A key feature of Malaysia's STEM teacher development strategy is its emphasis on hands-on, practice-oriented training. Teachers are encouraged to engage in project-based STEM modules, design challenges, and inquiry activities that mirror student learning experiences. Through initiatives under the National STEM Movement, teachers participate in STEM camps, innovation workshops, and industry-supported training sessions, which enhance their confidence in facilitating real-world problem-solving and interdisciplinary learning (MOSTI, 2021). These experiential approaches align with UNESCO's emphasis on empowering teachers as designers of meaningful STEM learning rather than transmitters of content (UNESCO, 2021).

Digital competency development is another priority area in Malaysia's STEM teacher training framework. Following lessons learned during the COVID-19 pandemic, the MOE has expanded training in digital tools, virtual laboratories, coding platforms, and online STEM resources, enabling teachers to implement blended and technology-enhanced learning models effectively. Domestic digital learning platforms support teachers' continuous upskilling and peer learning, contributing to system resilience and instructional innovation (MOE Malaysia, 2023; UNESCO, 2023).

Malaysia also promotes Professional Learning Communities (PLCs) and collaborative learning among teachers as part of its STEM capacity-building strategy. Through lesson sharing, peer observation, and reflective practice, teachers collectively refine instructional strategies and adapt STEM content to local contexts. Research indicates that such collaborative structures enhance instructional quality and teacher self-efficacy, particularly in implementing complex interdisciplinary STEM approaches (OECD, 2019). However, implementation remains uneven, with time constraints and workload pressures limiting sustained participation in some schools.

Despite noteworthy progress, challenges persist in STEM teacher training. Shortages of qualified STEM teachers—particularly in rural and underserved areas—continue to strain the system, while variations in training quality and follow-up support affect consistency of classroom implementation (MOE Malaysia, 2024). These gaps highlight the need for more systematic mentoring, stronger school-level instructional leadership, and clearer pathways linking professional development to career progression.

Overall, Malaysia's teacher training framework for STEM education in 2025 reflects a systemic and reform-oriented approach that integrates pedagogical innovation, digital transformation, and collaborative professional learning. While continued investment and coordination are required to address capacity gaps and regional disparities, Malaysia has established a robust foundation for developing a STEM-capable teaching workforce that can support domestic aspirations for innovation-driven, inclusive growth.

f. STEM Facilities and Learning Environments

STEM facilities and learning environments play a crucial role in supporting Malaysia's STEM education agenda by enabling experiential, inquiry-based, and technology-enhanced learning. In 2025, domestic efforts focus on strengthening both physical and digital infrastructures across schools, higher education institutions, and informal learning settings to ensure alignment with Industry 4.0 and digital transformation goals.

At the school level, the Ministry of Education continues to expand STEM laboratories, maker spaces, and digital classrooms, particularly through initiatives under the National STEM Movement and Digital Education Transformation programs. These facilities emphasize hands-on experimentation, robotics, coding, and applied science, although disparities remain between

urban and rural schools in terms of equipment quality and access (Ministry of Education Malaysia, 2024).

Higher education institutions are supported by the Ministry of Higher Education and MOSTI through investments in advanced research laboratories, innovation hubs, and technology parks, especially in priority fields such as artificial intelligence, biotechnology, and green technology. University–industry-linked facilities facilitate applied research, student internships, and commercialization pathways, strengthening the connection between STEM learning and workforce readiness (Ministry of Higher Education Malaysia, 2024).

Malaysia also leverages informal and community-based STEM learning environments, including science centers, innovation labs, and mobile STEM units, to broaden access and foster public engagement. Digital platforms and virtual laboratories further extend learning opportunities beyond physical spaces, enhancing flexibility and resilience in STEM education delivery.

Overall, while Malaysia has made considerable progress in developing STEM learning environments, continued investment is needed to address regional inequalities, ensure effective utilization of facilities, and integrate digital and physical infrastructures into coherent, learner-centered STEM ecosystems.

g. Student STEM Participation and Pipeline Development

Student participation and pipeline development are central to Malaysia's long-term STEM strategy, as the economy seeks to expand and sustain a skilled workforce aligned with domestic innovation and industrial priorities. In 2025, Malaysia adopts a multi-level approach to strengthening the STEM pipeline, targeting early exposure, sustained engagement, and smoother transitions from school to higher education and employment.

At the basic education level, the Ministry of Education promotes early STEM engagement through curriculum integration, co-curricular activities, and initiatives under the National STEM Movement. Programs emphasize inquiry-based learning, problem-solving, and real-world applications to increase students' interest and persistence in STEM pathways. Domestic competitions, STEM camps, and school–industry activities function as key mechanisms for identifying talent and motivating continued participation, particularly in science, engineering, and technology-related fields.

At the upper secondary and tertiary levels, targeted interventions aim to address declining STEM enrolment and high attrition rates. These include specialized STEM streams, foundation programs, and strengthened career guidance to improve students' awareness of STEM career opportunities and labor market relevance. Universities further support pipeline development through bridge programs, applied learning models, and industry-linked training, facilitating students' transition into STEM-intensive sectors.

Malaysia also prioritizes broadening participation among underrepresented groups, including students from rural areas and lower socioeconomic backgrounds. Digital learning platforms, mobile STEM outreach, and community-based programs are increasingly used to reduce access barriers and expand the domestic talent pool. However, persistent challenges remain, particularly in sustaining student interest in mathematics and science and ensuring continuity across educational stages.

Overall, Malaysia's STEM pipeline strategy reflects a growing recognition that participation must be supported longitudinally—from early schooling through workforce entry—requiring coordinated policies, targeted interventions, and continuous monitoring to ensure both scale and quality in STEM talent development.

7-3. Education Effects and Measured Outcomes

Malaysia places increasing emphasis on measuring the educational effects and outcomes of STEM education to assess policy effectiveness and inform continuous improvement. In 2025, evaluation frameworks combine domestic assessments, international benchmarking, and program-level monitoring to capture learning quality, participation trends, and workforce relevance.

At the system level, Malaysia continues to rely on large-scale indicators such as PISA and TIMSS to benchmark student performance in science and mathematics. While overall participation in STEM-related subjects remains high, learning outcomes reveal persistent gaps in higher-order skills, including problem-solving, knowledge application, and scientific reasoning. These findings have prompted policy efforts to shift instructional practices toward inquiry-based and applied STEM learning.

Program-level evaluations focus on student engagement, progression, and transition outcomes. Flagship initiatives under the National STEM Movement and Digital STEM platforms report improvements in student awareness of STEM careers, increased participation in co-curricular STEM activities, and enhanced digital and collaborative skills. However, evidence suggests that positive short-term engagement does not always translate into sustained enrolment in upper-secondary STEM streams or STEM-related tertiary programs, indicating pipeline leakage.

At the post-secondary level, outcome measurement increasingly incorporates graduate employability and alignment with industry. Data from higher education institutions show that graduates from applied STEM programs and industry-linked curricula demonstrate stronger employment outcomes, particularly in engineering, ICT, and technology-driven sectors. This has reinforced the policy focus on work-integrated learning and industry collaboration as key levers for improving the effectiveness of STEM education.

Despite progress, challenges remain in integrating outcome data across education levels and translating evaluation findings into systematic reform. Overall, Malaysia's measured outcomes indicate incremental gains in STEM engagement and employability, while highlighting the need for stronger longitudinal tracking systems to ensure that educational effects are sustained across the full STEM talent pipeline.

7-4. Investment and Budgetary Patterns

Investment and public financing play a pivotal role in sustaining Malaysia's STEM education reform and in supporting the economy's broader transition toward a knowledge-based, innovation-driven economy. In 2025, Malaysia's investment framework for STEM education reflects a multi-ministerial and multi-level approach, combining allocations from the Ministry of Education (MOE), the Ministry of Higher Education (MOHE), and the Ministry of Science, Technology, and Innovation (MOSTI), while increasingly leveraging private-sector and industry participation.

At the basic education level, the Ministry of Education continues to allocate a substantial portion of its annual education budget to strengthening science, mathematics, and integrated STEM instruction. Funding priorities include curriculum implementation, teacher professional development, digital learning infrastructure, and the development of STEM-enabling school environments. In line with the Malaysia Education Blueprint 2013–2025, budgetary support is directed toward enhancing higher-order thinking skills, inquiry-based learning, and interdisciplinary STEM pedagogy, particularly in public schools serving diverse socioeconomic contexts (Ministry of Education Malaysia, 2024).

Digital transformation constitutes a major area of STEM-related investment. Malaysia has expanded funding for online learning platforms, virtual laboratories, and digital STEM content to support blended and remote learning models. These investments align with domestic

priorities outlined in the Digital Economy Blueprint and aim to improve access to high-quality STEM resources, enhance instructional flexibility, and strengthen system resilience in response to technological disruption (UNESCO, 2023).

At the post-secondary and workforce development levels, significant funding for STEM education is channeled through MOSTI and MOHE, particularly under the National Science, Technology, and Innovation Policy (DSTIN) 2021–2030. Public investments support research universities, polytechnics, and technical and vocational education and training institutions in priority STEM fields such as artificial intelligence, data science, biotechnology, green technology, and advanced manufacturing. These allocations seek to strengthen research capacity, modernize laboratories, and align STEM human capital development with domestic industrial strategies (MOSTI, 2021).

Malaysia's STEM investment strategy increasingly emphasizes public–private partnerships as a mechanism to extend the reach and effectiveness of public funding. Through tax incentives, competitive grants, and corporate social responsibility schemes, private-sector actors are encouraged to co-invest in STEM education initiatives, including teacher training, student competitions, industry-linked projects, and school-level innovation programs. Such co-investment enhances the relevance of STEM education to labor market demands and supports smoother transitions from education to employment (OECD, 2019).

Equity considerations are embedded within Malaysia's STEM financing framework, with targeted funding aimed at reducing urban–rural disparities. Additional resources are allocated to schools in underserved areas through infrastructure upgrades, mobile STEM initiatives, and supplementary instructional support. Nevertheless, persistent gaps in implementation capacity highlight the need for more outcome-oriented budgeting and strengthened monitoring mechanisms to ensure efficient and equitable use of resources (Ministry of Education Malaysia, 2024).

Overall, Malaysia's investment and budgeting approach for STEM education in 2025 demonstrates a sustained commitment to long-term human capital development. By aligning public expenditure with education reform agendas, digital transformation strategies, and innovation-driven economic goals—while progressively engaging private-sector partners—Malaysia has established a solid financial foundation for STEM education. Continued emphasis on efficiency, equity, and cross-sector coordination will be essential to maximize the impact of these investments.

7-5. Partnerships

Strategic partnerships among government agencies, educational institutions, industry, and international organizations constitute a central pillar of Malaysia's STEM education ecosystem. These partnerships are designed to align education with workforce needs, enhance innovation capacity, and strengthen the transition from schooling to higher education and employment. The Ministry of Education (MOE) and the Ministry of Science, Technology, and Innovation (MOSTI) play coordinating roles in fostering cross-sector collaboration to support STEM learning across formal and non-formal settings.

At the domestic level, school–industry partnerships are actively promoted to ensure that STEM curricula remain relevant to evolving technological and economic demands. Through structured collaboration mechanisms, private-sector partners contribute to curriculum co-design, student internships, mentoring programs, and the provision of real-world problem contexts for project-based learning. Industry engagement is robust in priority sectors such as advanced manufacturing, electronics, digital technology, and green innovation, reflecting Malaysia's broader domestic development agenda (Ministry of Education Malaysia, 2024).

Higher education institutions serve as key intermediaries within Malaysia's STEM partnership landscape. Universities collaborate with schools to deliver outreach programs, STEM camps, laboratory-based learning experiences, and teacher professional development. At the same time, university–industry partnerships support applied research, talent pipelines, and innovation-driven learning, enabling students to gain early exposure to research environments and industry practices. These collaborations strengthen coherence across the STEM education continuum from basic education to tertiary and postgraduate levels (OECD, 2019).

Malaysia also actively engages in regional and international partnerships to enhance STEM capacity building. Cooperation with organizations such as SEAMEO, UNESCO, and APEC supports knowledge exchange, policy learning, and regional benchmarking of STEM education practices. International collaborations facilitate joint programs in teacher training, digital STEM learning, and gender-inclusive education, while also providing Malaysian students and educators with exposure to global standards and emerging educational innovations (UNESCO, 2023).

Public–private partnerships further reinforce STEM education through corporate social responsibility (CSR) initiatives. Private-sector actors contribute funding, expertise, digital infrastructure, and learning resources to support STEM outreach, particularly in underserved communities. These initiatives include mobile STEM labs, community-based innovation programs, and technology-focused enrichment activities, which help extend STEM opportunities beyond urban centers and elite institutions (Ministry of Education Malaysia, 2024).

Despite the breadth of partnerships, challenges remain in ensuring coordination, sustainability, and equitable impact. Fragmentation across initiatives and uneven engagement across regions can limit the effectiveness of collaboration. Strengthening governance mechanisms, clarifying stakeholder roles, and embedding monitoring frameworks will be essential to maximizing the long-term value of partnerships within Malaysia's STEM education ecosystem.

Overall, partnerships function as a critical enabler of Malaysia's STEM education strategy. By leveraging cross-sector collaboration at the domestic, regional, and international levels, Malaysia enhances the relevance, quality, and inclusiveness of STEM learning while building a more resilient, future-oriented talent development system.

7-6. Performance Indicators and Monitoring

Malaysia increasingly recognizes the importance of robust performance indicators and monitoring frameworks to ensure the effectiveness, accountability, and continuous improvement of STEM education policies. Monitoring mechanisms are coordinated primarily by the Ministry of Education (MOE) and supported by agencies such as the Ministry of Science, Technology, and Innovation (MOSTI) and the Economic Planning Unit, reflecting a whole-of-government approach to human capital development.

At the system level, Malaysia employs a combination of assessment data, program-level evaluations, and international benchmarking to track STEM education outcomes. Student achievement indicators include performance in examinations at primary and secondary levels, participation and completion rates in STEM streams, and progression into science- and technology-related fields in upper secondary and tertiary education. These indicators are complemented by participation data in enrichment activities, competitions, and informal STEM learning programs (Ministry of Education Malaysia, 2024).

International large-scale assessments play an essential role as benchmarks within Malaysia's monitoring framework. Results from the Programme for International Student

Assessment (PISA) and Trends in International Mathematics and Science Study (TIMSS) are used to assess learning outcomes in science and mathematics, identify equity gaps, and inform curriculum reforms and teacher professional development strategies. While improvements have been observed in access and participation, these assessments continue to highlight challenges related to higher-order thinking skills and inquiry-based learning, reinforcing the need for pedagogical innovation in STEM education (OECD, 2023).

Teacher-related indicators form another key component of Malaysia's STEM monitoring system. These include participation rates in professional development programs, certification in STEM-related competencies, and teacher deployment in STEM subjects, particularly in rural and underserved areas. Monitoring teacher capacity supports evidence-based decisions on resource allocation, training priorities, and incentive structures to strengthen instructional quality (UNESCO, 2023).

At the program level, flagship STEM initiatives are subject to periodic evaluation based on predefined output and outcome indicators. These include student engagement levels, satisfaction surveys, school participation rates, and, in selected programs, longitudinal tracking of learners' educational pathways. However, monitoring practices remain uneven across initiatives, with some programs relying heavily on input and activity-based indicators rather than measurable learning outcomes or long-term impact (OECD, 2019).

Digitalization has begun to enhance Malaysia's monitoring capacity, particularly through centralized data systems and education management information platforms. These tools enable more systematic tracking of enrollment patterns, regional disparities, and resource distribution. Nevertheless, the integration of data across ministries and between formal and non-formal STEM education providers remains a work in progress, limiting the use of real-time analytics for policy refinement.

Overall, Malaysia's performance indicators and monitoring frameworks for STEM education are evolving toward greater coherence and greater emphasis on evidence. Strengthening outcome-based indicators, improving data integration, and expanding longitudinal tracking of STEM learners will be critical to ensuring that investments in STEM education translate into sustained improvements in quality, equity, and workforce readiness.

7-7. Gender Inclusivity and Equity

Gender inclusivity and equity remain integral components of Malaysia's STEM education agenda, particularly as it expands participation and ensures equitable access across socioeconomic and geographic groups. In 2025, domestic policies continue to emphasize inclusive human capital development, aligning STEM education with broader goals of social equity and sustainable economic growth.

At the basic education level, Malaysia has achieved balanced gender participation in science and mathematics, with female students often demonstrating comparable or higher achievement in foundational STEM subjects. However, gender disparities persist in specific STEM pathways, particularly in engineering, information and communications technology (ICT), and advanced technical fields, where female representation declines at upper-secondary and tertiary levels. These trends indicate structural and cultural barriers that influence subject choice and career aspirations rather than academic capability.

To address these gaps, the Ministry of Education and the Ministry of Higher Education promote targeted initiatives to increase girls' participation and retention in STEM. These include female-focused STEM outreach programs, mentorship schemes, and career awareness activities that highlight diverse role models in the science, engineering, and technology sectors. Universities and public agencies also support scholarships and leadership development

programs designed to encourage women's progression into advanced STEM studies and research careers.

Equity considerations extend beyond gender to include rural–urban disparities and socioeconomic inclusion. Digital STEM initiatives and school-based interventions prioritize underserved communities to ensure that girls and marginalized groups benefit equally from STEM learning opportunities. Nevertheless, monitoring frameworks indicate that implementation effectiveness varies across regions, and there is limited longitudinal data on women's retention and career outcomes in STEM.

Overall, Malaysia's approach to gender inclusivity in STEM education reflects steady progress in access and participation, while underscoring the need for stronger systemic interventions. Enhanced data tracking, sustained mentoring, and closer alignment between education and labor market policies are essential to ensuring that gender equity in STEM is translated into long-term workforce participation and leadership representation.

7-8. Key Challenges and Distinctive Features

Malaysia's STEM education landscape in 2025 is characterized by a combination of persistent structural challenges and distinctive policy features shaped by its developmental context and domestic aspirations. While the economy has made sustained efforts to promote STEM participation and digital readiness, several systemic constraints continue to affect the depth and continuity of STEM learning outcomes.

A significant challenge lies in the persistent gap between policy ambition and classroom-level implementation. Although domestic frameworks strongly advocate inquiry-based and applied STEM learning, instructional practices in many schools remain examination-oriented and content-driven. This limits opportunities for interdisciplinary integration, critical thinking, and authentic problem-solving—key competencies emphasized in global STEM education frameworks.

Teacher capacity represents another critical bottleneck. Despite ongoing professional development initiatives, uneven access to high-quality STEM training—particularly in rural and underserved areas—constrains instructional quality. Many teachers report limited confidence in integrating technology, engineering design, and computational thinking into their lessons, resulting in fragmented STEM delivery rather than cohesive learning experiences.

Pipeline sustainability is an additional concern. While early-stage student participation in STEM activities is strong, attrition increases at upper-secondary and tertiary levels, especially among female students and learners from lower socioeconomic backgrounds. This leakage undermines long-term workforce supply in high-demand STEM fields and highlights weaknesses in career guidance and transition support mechanisms.

At the same time, Malaysia exhibits several distinctive strengths in its STEM education approach. The National STEM Movement provides a unifying policy platform that integrates formal education, informal learning, and industry engagement under a shared domestic narrative. Strong emphasis on digital STEM platforms and public–private partnerships reflects Malaysia's pragmatic strategy to leverage industry expertise and corporate social responsibility to supplement public resources.

Furthermore, Malaysia's multicultural and multilingual context shapes a distinctive emphasis on inclusivity and social cohesion within STEM education. Policies increasingly recognize STEM not only as a driver of economic competitiveness but also as a tool for social mobility and regional development.

In sum, Malaysia's STEM education system in 2025 reflects a transitional phase—marked by ambitious reforms and innovative platforms, yet constrained by capacity gaps, implementation variability, and pipeline fragility. Addressing these challenges while

consolidating its distinctive strengths will be essential for achieving a resilient and inclusive STEM talent ecosystem.

8. The Philippines

Orteza RONNALEE, Executive Director, DOST-Philippines Science High School System, the Philippines

Summary: The Philippines has outlined a long-term domestic vision that prioritizes human capital development, especially via education and science-based skills, as central to inclusive growth, individual well-being, and global competitiveness. This vision is implemented through medium-term development strategies that emphasize science, technology, and innovation as essential catalysts for productivity, economic diversification, and social change. In this context, the economy has implemented a broad strategy to enhance education in science, technology, engineering, and mathematics throughout the learning continuum. Key initiatives consist of creating and increasing specialized science high schools, institutionalizing science-oriented secondary schools across the economy, and executing and improving a revised basic education curriculum that focuses on essential literacies, inquiry-driven learning, student well-being, and future-ready skills. These are supported by extensive scholarship initiatives that enhance access to science and technology education, especially for academically gifted and economically disadvantaged students, along with specific scholarships aligned with domestic workforce needs in health, agriculture, industry, and innovation. The enhancement of teacher capacity is pursued via ongoing professional development and sophisticated graduate training to elevate instructional quality, research skills, and technology dissemination. Funding for facilities, innovation hubs, and mobile labs enhances experiential learning and strengthens connections among education, research, and industry. Student involvement is additionally enhanced via participation in competitions, research immersion, entrepreneurial training, and domestic science events that foster creativity, leadership, and global standards. These initiatives are supported by growing public funding for education, collaborations with the private sector, performance evaluation systems, and gender-sensitive policies that enhance equity and inclusion. Despite these developments, ongoing challenges persist, such as backlogs due to chronic underfunding in the past, coordination issues between education agencies, limited resources, infrastructure deficits, inconsistent learning results, and obstacles to access and retention in science programs. These challenges highlight the necessity for continued investment, improved governance, and inclusive support systems to successfully achieve the economy’s science and innovation objectives.

8-1. Strategy and Vision

On 30 March 2016, the government of the Philippines launched its long-term vision known as AmBisyon Natin 2040, which describes a future where "by 2040, Filipinos enjoy a strongly rooted, comfortable, and secure life," emphasizing not only economic stability but also personal well-being and pride (NEDA, 2016). Central to this vision is the image of the Filipino as smart, innovative, and globally competitive, which underscores the state's commitment to invest in human capital development, particularly through education.

To achieve this vision, the government has pledged to be proactive in setting the domestic education agenda. This includes ensuring that Filipino learners acquire the **foundational literacies**, such as reading, numeracy, scientific and ICT literacy, economic and financial literacy, as well as civic and cultural literacy. Moreover, the formal education system is expected to nurture 21st-century competencies, including critical thinking, problem-solving, creativity, communication, and collaboration. Alongside these skills, the development of key character qualities—such as curiosity, initiative, grit, adaptability, leadership, and socio-cultural awareness—is recognized as essential for thriving in a rapidly changing global landscape (NEDA, 2016; World Economic Forum, 2015).

In line with this long-term vision, the Philippine Development Plan (PDP) 2023–2028 was approved and adopted by President Ferdinand R. Marcos Jr. through Executive Order No. 14, series of 2023, on 27 January 2023. This PDP is the second medium-term development plan anchored on AmBisyon Natin 2040, and it seeks to restore the economy to an exponential growth path while enabling transformative economic and social development. One of the plan's central pillars is the advancement of science, technology, and innovation (STI), which underscores the strategic importance of STEM education as a driver of productivity, economic diversification, and global competitiveness (NEDA, 2023).

The PDP 2023–2028 explicitly recognizes the need to strengthen the entire ecosystem of science and innovation—from foundational STEM education in basic and higher education institutions to investments in digital infrastructure and research commercialization. These efforts are in line with global frameworks and best practices, and they aim to equip the Filipino workforce with future-ready skills that match the demands of an increasingly digital and knowledge-based economy.

8-2. Overview of Key STEM Education Programs

a. STEM Education Programs and Initiatives

In recent decades, the government of the Philippines has implemented a series of strategic policies and institutional reforms to cultivate a robust pool of STEM (Science, Technology, Engineering, and Mathematics) talent, particularly among the youth. Central to this effort is the establishment of the Philippine Science High School (PSHS) through Republic Act No. 3661 in 1963, which mandated the provision of free, science-oriented secondary education for intellectually gifted students, emphasizing mathematics and the sciences to encourage the pursuit of STEM careers and strengthen the domestic science and technology (S&T) workforce.

In 1998, Republic Act No. 8496 created the PSHS System, consolidating and harmonizing the operations of the initial four campuses: Diliman (Main Campus), Eastern Visayas, Western Visayas, and Southern Mindanao. This consolidation was further reinforced by Republic Act No. 9036 in 2001, which mandated the establishment of at least one PSHS campus in every region, ensuring equitable access to high-quality STEM education economy-wide. By 2016, the system had expanded to 16 campuses under the Department of Science and Technology (DOST), serving as a strategic arm of the government in developing globally competitive S&T professionals.

Despite the presence of 16 campuses economy-wide, the DOST-Philippine Science High School (PSHS) System is able to accommodate only about 1,920 scholars annually, significantly limiting access to its highly specialized STEM education programs. In response to this capacity constraint, in October 2025, the government enacted Republic Act No. 12310, also known as the Expanded Philippine Science High School (PSHS) System Act, to further strengthen the institution. The law mandates the expansion of the PSHS System with the explicit goal of widening access to high-quality STEM education for academically gifted students, particularly those from underserved and geographically disadvantaged regions (Presidential Communications Office, 2025).

Beyond the PSHS System, a significant policy intervention was the issuance of Department of Education, Culture, and Sports (DECS) Order No. 69 in 1993, which institutionalized the establishment of science high schools across the economy. These schools offer an enriched curriculum with intensive instruction in science, mathematics, and English, going beyond the standard domestic curriculum in both content and contact hours.

A pivotal reform in the basic education of the Philippines came with the enactment of the Enhanced Basic Education Act of 2013 (Republic Act No. 10533), which introduced the K

to 12 curriculums. This reform aimed to align the education system of the Philippines with international standards and enhance students' readiness for higher education, employment, or entrepreneurship. The K to 12 program includes a Senior High School (SHS) component where students can select specialized STEM tracks. According to Department of Education (DepEd) Order No. 021, s. 2019, the curriculum fosters 21st-century skills such as critical thinking, information literacy, collaboration, and innovation, which are essential for success in STEM fields.

The K to 12 curriculums also promotes learner-centered and inquiry-based pedagogies, allowing for the localization and contextualization of learning experiences. It supports Mother Tongue-Based Multilingual Education (MTB-MLE) in early grades and employs a spiral progression approach in science and mathematics, ensuring progressive and deeper mastery of complex concepts over time.

Recently, DepEd has launched its new curriculum, undertaking a major recalibration of the basic education curriculum of the Philippines in response to persistent learning gaps, curriculum congestion, and misalignment between basic education outcomes and the demands of higher education and the labor market. Rather than dismantling the K to 12 frameworks, these reforms refine its structure and content to emphasize foundational competencies, learner well-being, and future-ready skills. The curriculum reform agenda is anchored on DepEd's MATATAG Basic Education Agenda, which prioritizes quality, relevance, resilience, and inclusivity in Philippine education (DepEd, 2023).

A parallel reform initiative has been undertaken by the DOST-Philippine Science High School (PSHS) System with the launch of its revised curriculum for Grades 7–8 beginning in School Year 2025–2026. Beyond updating content, the new curriculum serves as a catalyst for systemwide pedagogical alignment and continuous curriculum refinement across PSHS campuses. These efforts are intended to strengthen subject integration, ensure vertical alignment of learning competencies, and promote the coherent and consistent delivery of high-quality STEM education throughout the System (Philippine Science High School System, 2025).

b. Talent Development and Scholarship Programs

A cornerstone of the STEM talent development strategy is the Science Education Institute (SEI), an attached agency of the DOST established through Executive Order No. 128 in 1987. SEI is tasked with planning, designing, and implementing programs to promote and develop S&T education and training. In close coordination with academic institutions, SEI plays a pivotal role in strengthening the S&T workforce through scholarships, capacity-building programs, and learning innovation.

As of 2025, SEI has supported 10,907 new qualifiers under the RA 7687 Scholarship Program (for students from economically disadvantaged families) and the Merit Scholarship Program (for academically outstanding students). These programs exemplify the government's commitment to making STEM opportunities accessible and merit-based. Additionally, the Junior Level Science Scholarships (JLSS) support third-year college students pursuing degrees in S&T fields, thereby ensuring a steady pipeline of qualified STEM professionals.

Furthermore, the Commission on Higher Education (CHED) administers targeted scholarship programs designed to address specific workforce needs. In 2023, it launched the list of priority programs for the CHED Merit Scholarship Program (CMSP), which include programs aligned with global innovation platforms of Science, Technology, Engineering, Agri-fisheries and Mathematics (STEAM) as well as the priorities of the government in key growth areas such as semiconductor and electronics, business process outsourcing, tourism, general infrastructure and other priority manufacturing industries (Department of Budget and Management, 2022). Another notable example is the Scholarship Program for Future Medical

Technologists and Pharmacists (MTP-SP), which provides financial assistance to qualified students pursuing degrees in medical technology and pharmacy. This program supports the development of essential health professionals, particularly those committed to serving underserved areas upon graduation, thereby contributing to improved healthcare access and the development of a robust science-based workforce (CHED, 2025). CHED has also expanded its scholarships for agriculture, fisheries, and science courses, responding to declining enrollment in sectors critical to food security, environmental sustainability, and scientific advancement. By realigning scholarship slots with domestic development priorities, CHED aims to incentivize students to pursue courses that contribute directly to community resilience, scientific innovation, and economic progress (Philippine Information Agency, 2025).

Another key agency that administers a range of scholarship and educational assistance programs is the Department of Agriculture (DA), which focuses on developing human capital in agriculture, fisheries, and related sectors. These programs are designed not only to reduce financial barriers to higher education but also to cultivate a new generation of agricultural professionals, researchers, extension workers, and agripreneurs whose competencies are critical to achieving domestic objectives such as food security, rural development, and sustainable agricultural innovation. Among the major initiatives are the Educational Assistance for the Youth in Agriculture (EAsY Agri) Program, implemented through the Agricultural Training Institute (ATI); the DA Biotechnology Undergraduate Scholarship Program; and the Fisheries Scholarship Program (FSP) administered by the Bureau of Fisheries and Aquatic Resources (BFAR).

c. Teachers' Capacity Building

Teacher capacity building is a foundational pillar of effective STEM talent development, as the quality of instruction, mentoring, and learning experiences is closely linked to teachers' content mastery, pedagogical competence, and continuous professional development (UNESCO, 2021; World Bank, 2020). In the Philippines, agencies such as the Department of Science and Technology–Science Education Institute (DOST-SEI) play a critical role in strengthening STEM education beyond scholarship provision by implementing sustained capacity-building initiatives for teachers across basic and secondary education.

Beyond scholarships, DOST-SEI enhances the quality of STEM education through various teacher development programs, including e-training courses for science and mathematics teachers, hands-on workshops on robotics and microcontrollers, and investigative science and mathematics workshops that emphasize inquiry-based and problem-centered learning (DOST-SEI, 2022). These initiatives are designed to improve both subject matter expertise and instructional practices, enabling teachers to integrate emerging technologies, experimentation, and real-world applications into classroom instruction. Such approaches are widely recognized as effective in cultivating higher-order thinking skills and sustained student interest in STEM disciplines (OECD, 2019).

In addition, DOST-SEI advances curriculum innovation through the development of digitized and interactive learning modules that support e-learning and blended learning modalities (DOST-SEI, 2022). These digital resources help address persistent shortages in instructional materials, improve access to quality STEM content—particularly in geographically isolated areas—and support teachers in adopting flexible and technology-enabled pedagogies. The integration of digital tools in teacher practice is aligned with global recommendations for building more resilient and inclusive STEM education systems (UNESCO, 2021).

Beyond undergraduate education, sector-specific agencies also contribute to teacher and research capacity building. The Department of Agriculture (DA), for example, supports graduate education and advanced research training through its Degree Scholarship Program (DSP), which provides financial assistance for Master's and Doctoral degrees in agriculture, fisheries, and related scientific fields (Department of Agriculture, 2023). The program aims to develop a pool of highly competent researchers, educators, and extension professionals who can strengthen instruction, research productivity, and technology transfer across academic institutions and government research agencies.

This graduate-level capacity-building initiative forms part of the DA's broader strategy to strengthen research and development (R&D) systems, enhance innovation, and support human resource development in key scientific and technical areas of the agricultural sector (Department of Agriculture, 2023). By investing in advanced training for educators and researchers, the DA contributes to a more robust STEM ecosystem in which knowledge generation, teaching quality, and applied innovation mutually reinforce STEM talent development in the Philippines.

d. STEM Facility

Developing a robust pipeline of science, technology, engineering, and mathematics (STEM) talent in the Philippines hinges not only on curriculum and scholarship programs but also on physical infrastructure and research facilities that allow learners, educators, and researchers to engage in meaningful, hands-on science and innovation.

To extend the reach of STEM engagement, SEI operates a mobile science laboratory that visits underserved communities, offering hands-on STEM activities and career guidance to senior high school students.

The Department of Science and Technology (DOST), in partnership with the Philippine Economic Zone Authority (PEZA) and other stakeholders, has established Knowledge, Innovation, Science, and Technology (KIST) ecozones and parks as strategic platforms to strengthen the Philippines' innovation ecosystem, bridge research and industry, and support economic development through science and technology (DOST, PEZA, & PASUC, 2023; PIA, 2025). KIST ecozones are special economic zones designated within academic institutions—particularly state universities and colleges (SUCs) and increasingly private universities—that integrate research and development (R&D), commercialization, and industry collaboration into a single ecosystem. The KIST designation enables campuses to attract investors, stimulate entrepreneurship, and accelerate the commercialization of technologies developed through academic research.

e. Student STEM Competitions and Events

Furthermore, SEI facilitates Filipino students' participation in prestigious international competitions such as the International Olympiads in Mathematics, Physics, Chemistry, Biology, and Informatics, enabling Filipino talent to be benchmarked against global standards.

SEI also leads the Scholars Technopreneurs Training Program (STTP), which equips scholars with entrepreneurial knowledge and skills to convert research outputs and innovations into viable enterprises. This initiative underscores the growing synergy between STEM education and entrepreneurship in advancing domestic development.

In addition to formal education and scholarship programs, the Philippines promotes STEM through youth-centered science engagement activities. Presidential Proclamation No. 264, issued in 2002, declared September as National Science Club Month (NSCM), mandating DepEd, DOST-SEI, CHED, the Philippine Society of Youth Science Clubs (PSYSC), and the Science Club Advisers Association of the Philippines (SCAAP) to spearhead related initiatives.

NSCM has evolved into an economy-wide celebration with programs such as "I Teach Science" teacher training seminars, MathSciAKA interdisciplinary science workshops, the National Science Clubs Summit, and the Philippine Science Olympiad.

The DOST also launched the National Youth Science, Technology, and Innovation Festival (NYSTIF), a platform that raises awareness on S&T's role in domestic development. NYSTIF features interactive exhibits, seminars, journalism contests, and youth fora, all of which showcase DOST's achievements and inspire the youth to pursue STEM careers.

Another key DOST initiative is the Regional Invention Contests and Exhibits (RICE), implemented by the Technology Application and Promotion Institute (DOST-TAPI). RICE recognizes innovation and creativity among Filipino inventors, particularly students. It provides a professional venue for showcasing investigatory projects, facilitating feedback from experts, and encouraging the transformation of scientific ideas into real-world applications.

The DOST-Philippine Council for Industry, Energy and Emerging Technology Research and Development (PCIEERD) implements the Young Innovators Program (YIP) to engage promising high school students in hands-on research. The program offers students the opportunity to undertake a research project for up to one (1) year, under the guidance of a dedicated research mentor who provides technical assistance and coaching. To support the development and implementation of their project, participating students or teams also receive a research grant from the program.

A similar Innovation Competition tagged as "iMake.weMake: Create. Innovate. Collaborate." is also run by DOST-SEI in partnership with C&E Publishing, Gokongwei Brothers Foundation (GBF), and Honda Cars Philippines, Inc (Parel, 2024). This provides a platform for young innovators to develop practical solutions to domestic and community challenges using science and technology (S&T). According to Sec. Renato U. Solidum, Jr., during the awarding ceremony on 26 July 2024, "This competition is more than just a platform to showcase your talents. It is a training ground for developing competencies such as project proposal-making, communication skills, critical and analytical thinking, engineering, and technical skills. Equally important, it teaches the value of taking risks and learning from failures" (Parel, 2024).

Meanwhile, the DOST-National Academy of Science and Technology (NAST) supports youth STEM engagement through the Meet Your Scientist (MYS) program. This initiative enables students to interact with leading Filipino scientists who share their research and personal journeys. A highlight of the program, MYS: Women in Science, promotes gender inclusion by spotlighting the achievements of Filipina scientists and encouraging young women to pursue STEM careers.

Within the Philippine Science High School (PSHS) System, student support programs play a vital role in enhancing STEM education. The Alternative Learning Program (ALP) nurtures student-led STEM clubs that cultivate leadership, creativity, and innovation beyond the classroom setting. The Science Immersion Program (SIP) provides Grade 10 to 12 students with the opportunity to engage in real-world scientific work through two- to three-week placements in partner institutions. Additionally, international student exchange programs expose scholars to diverse global learning environments, enriching their scientific outlook. To further strengthen innovation and research commercialization, the PSHS System, in collaboration with the DOST-Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development (PCAARRD), has conducted capacity-building initiatives on Intellectual Property (IP) and technology transfer for both students and teachers. These efforts aim to encourage the development of research projects that address societal needs and have potential economic impact.

Collectively, these policies and programs reflect a holistic, inclusive, and future-ready strategy for STEM development in the Philippines. From institutionalizing science high schools and reforming the domestic curriculum to expanding region-wide access and integrating hands-on scientific experiences, the economy demonstrates a strong commitment to building a critical mass of STEM professionals. These efforts align with broader trends among APEC economies in investing in youth STEM capacity-building and preparing the next generation of innovators, researchers, and technopreneurs who will drive domestic competitiveness in an increasingly knowledge-based global economy.

8-3. Investment and Budget

In its 2025 domestic budget, the government allocated PhP 1.06 trillion to the education sector as its priority. This includes PhP 7.33 billion for DOST-SEI scholarship programs and PhP 2.71 billion for the DOST-PSHS System (DBM, 2024).

On 5 January 2026, President Ferdinand R. Marcos Jr. signed the PhP 6.793-trillion budget for Fiscal Year 2026 into law, reaffirming education as the government's top budget priority in compliance with the Constitution (Philippine Star, 2026; Reuters, 2026). Under this new budget, the education sector received the largest allocation in the Philippines' history—approximately PhP 1.345 trillion, representing about 4.36 percent of GDP—surpassing previous funding levels and meeting key international benchmarks for educational investment (Philippine Star, 2026; Reuters, 2026).

8-4. Partnerships

The government of the Philippines has also become proactive in securing private sector partnerships to augment limited public resources through the National Priority Plan (NPP), which includes flagship projects in education, science, culture, and related sectors. Private donors to these projects—including major organizations like Unilab Foundation, Cebu Pacific, J&T Express, BPI, Hyundai Philippines, Aboitiz Foundation, 3M, and Samsung—are eligible to claim full tax deductions for their contributions, provided the initiative is certified under the NPP.

8-5. Performance Indicators

DepEd has been monitoring some indicators, which include PISA, TIMSS, and assessments (National Achievement Test and National Career Assessment Examination) (DepEd, 2016).

The Philippines assesses teachers using the Philippine Professional Standards for Teachers (PPST) and the Results-Based Performance Management System (RPMS), which help evaluate teacher competence, guide professional development, and ensure quality education.

Other KPIs include the cohort survival rate, participation of students in international and domestic competitions, research outputs, STEM promotion activities conducted, and the number of beneficiaries for the different STEM initiatives.

8-6. Key Challenges

According to findings from the Education Commission 2 (2023), several systemic challenges continue to hinder the quality of education in the Philippines, particularly in STEM fields. These include the overloading of teachers with administrative and ancillary tasks, which limits their time and capacity to focus on effective instruction and mentorship. There is also a lack of strong coordination among the three major education agencies—DepEd, CHED, and TESDA—resulting in fragmented policies, misaligned curricula, and weak continuity in STEM learning pathways. Persistent issues such as shortages of textbooks and learning materials,

mismatches between teacher specialization and assigned subjects, overcrowded classrooms, and inadequate laboratory and digital infrastructure further constrain the delivery of quality STEM education.

Beyond these structural concerns and despite the education sector getting the biggest chunk of annual domestic budget and meeting key international benchmarks for educational investment with the 2026 budget (Reuters, 2026), there was chronic underfunding as allocation for the sector chronically fell short of global standards in the past years, creating a critical barrier to meaningful reform and innovation. Insufficient financial support affects teacher training, curriculum modernization, research opportunities, and the maintenance of STEM facilities, particularly in public schools and state universities. This funding gap also limits investments in emerging STEM areas such as artificial intelligence, data science, biotechnology, and advanced engineering, which are essential for global competitiveness.

These challenges are reflected in the consistently low performance of Filipino students in international large-scale assessments such as the Programme for International Student Assessment (PISA) and the Trends in International Mathematics and Science Study (TIMSS). Results from these assessments point to gaps in foundational skills in mathematics and science, as well as weaknesses in problem-solving and critical thinking, which are competencies vital for STEM careers.

At the postsecondary level, access and retention pose additional concerns. In the study by Alvarez (2024), many students who initially enrolled in STEM programs were unable to complete their courses due to limited scholarship opportunities, financial constraints, inadequate academic support, and lack of parental encouragement. These factors disproportionately affect students from low-income and marginalized backgrounds, leading to high attrition rates and a narrowing of the STEM talent pipeline. Collectively, these challenges underscore the need for sustained investment, better governance, and more inclusive support mechanisms to strengthen STEM talent development in the Philippines.

8-7. Gender Inclusivity and Equity Measures

Gender inclusivity and equity are critical dimensions of sustainable STEM talent development in the Philippines. Government institutions such as the Department of Education (DepEd) and the DOST-Philippine Science High School System (DOST-PSHSS) align their programs, policies, and institutional practices with the provisions of Republic Act No. 9710, also known as the Magna Carta of Women. This landmark legislation mandates the integration of gender-responsive principles across institutional planning, curriculum development, human resource management, and service delivery to address systemic gender disparities and promote equal opportunities for women and girls in all sectors, including science and technology.

In compliance with the Magna Carta of Women and related guidelines issued by the Philippine Commission on Women (PCW), government agencies are required to allocate at least 5% of their annual budget to Gender and Development (GAD) programs. These GAD funds support a wide range of initiatives relevant to STEM talent development, including gender sensitivity and gender mainstreaming trainings for teachers and administrators, advocacy campaigns to encourage girls' participation in STEM fields, mentoring and leadership programs for female students, and the establishment of safe, inclusive, and gender-sensitive learning environments. In science-focused institutions such as the PSHS System, GAD initiatives also extend to the development of inclusive laboratory facilities, dormitories, and support systems that address gender-specific needs and promote student well-being.

Beyond access, gender equity measures aim to address persistent gender gaps in STEM participation and career progression. While female participation in basic education in the Philippines is relatively high, studies show that women remain underrepresented in certain STEM disciplines—particularly in engineering, information and communications technology (ICT), and advanced research careers. Gender-responsive STEM programs seek to counteract these trends by addressing socio-cultural stereotypes, improving female students' self-efficacy in science and mathematics, and providing role models and institutional support that enable women to persist and excel in STEM pathways. Such measures are aligned with international evidence indicating that inclusive policies and targeted interventions significantly improve gender balance and talent retention in STEM fields.

Overall, the integration of gender inclusivity and equity measures into STEM education and talent development strengthens not only social justice outcomes but also domestic innovation capacity. By ensuring that women and girls are fully supported and represented across the STEM pipeline, the Philippines enhances its ability to harness a broader and more diverse pool of scientific talent essential for inclusive growth, technological advancement, and sustainable development.

9. Singapore

Pimonpan CHANTARAPIMON, National Science Museum, Thailand

Summary: Singapore's STEM education system is internationally recognized for its coherence, rigor, and strong alignment with domestic economic and innovation strategies. Anchored in a long-term vision of human capital development, STEM education in Singapore integrates curriculum excellence, teacher professionalism, digital learning infrastructure, and industry relevance across all education levels. Domestic initiatives emphasize applied learning, inquiry-based pedagogy, and early exposure to science, technology, engineering, and mathematics to cultivate problem-solving and innovation skills. Substantial investment in teacher training, digital platforms such as the Student Learning Space (SLS), and world-class STEM facilities enhances instructional quality and learning equity. Through sustained partnerships with industry and research institutions, Singapore ensures seamless talent pipelines from school to workforce. Collectively, these systemic strengths position STEM education as a cornerstone of Singapore's global competitiveness and innovation-driven growth.

9-1. Strategy and Vision

Singapore's strategy for STEM education is closely integrated with its long-term vision for innovation-driven growth, economic competitiveness, and societal resilience. Rather than treating STEM as a standalone policy area, Singapore embeds STEM education within its broader domestic development and workforce strategies, particularly through the Research, Innovation and Enterprise (RIE) 2025 Plan, which positions human capital in science and technology as a key driver of domestic productivity and technological leadership (National Research Foundation [NRF], 2020).

The Ministry of Education (MOE) translates this vision into a coherent education framework that emphasizes strong foundational competencies, applied problem-solving, and lifelong learning. STEM education aligns with domestic priority sectors such as artificial intelligence, advanced manufacturing, clean energy, and biomedical sciences, ensuring coherence between education outcomes and future labor-market needs (MOE, 2023).

A defining feature of Singapore's STEM vision is its emphasis on applied and interdisciplinary learning. Through curriculum reforms and school-based initiatives such as the Applied Learning Programme (ALP), students are encouraged to engage in inquiry-based learning and real-world problem solving, strengthening both scientific literacy and innovation capacity. At the same time, inclusivity and system resilience are supported through multiple learning pathways and lifelong learning initiatives under SkillsFuture, extending STEM development beyond formal schooling. Collectively, Singapore's integrated and forward-looking approach demonstrates how strong policy alignment and sustained investment can support the development of a future-ready STEM workforce.

9-2. Key STEM Education Programs

a. STEM Educational Programs and Initiatives

Singapore's STEM education system is underpinned by a suite of well-structured and domestically coordinated flagship programs that emphasize applied learning, industry alignment, and future-oriented competencies. Central to this ecosystem is the Applied Learning Programme (ALP), implemented across all primary and secondary schools economy-wide. The ALP is designed to move STEM learning beyond traditional classroom instruction by engaging students in real-world, interdisciplinary problem-solving across areas such as sustainability, robotics, data science, environmental engineering, and smart city technologies. Significantly,

ALP operates outside high-stakes examinations, allowing schools flexibility to foster creativity, inquiry-based learning, and authentic application of STEM knowledge (Ministry of Education [MOE], 2023).

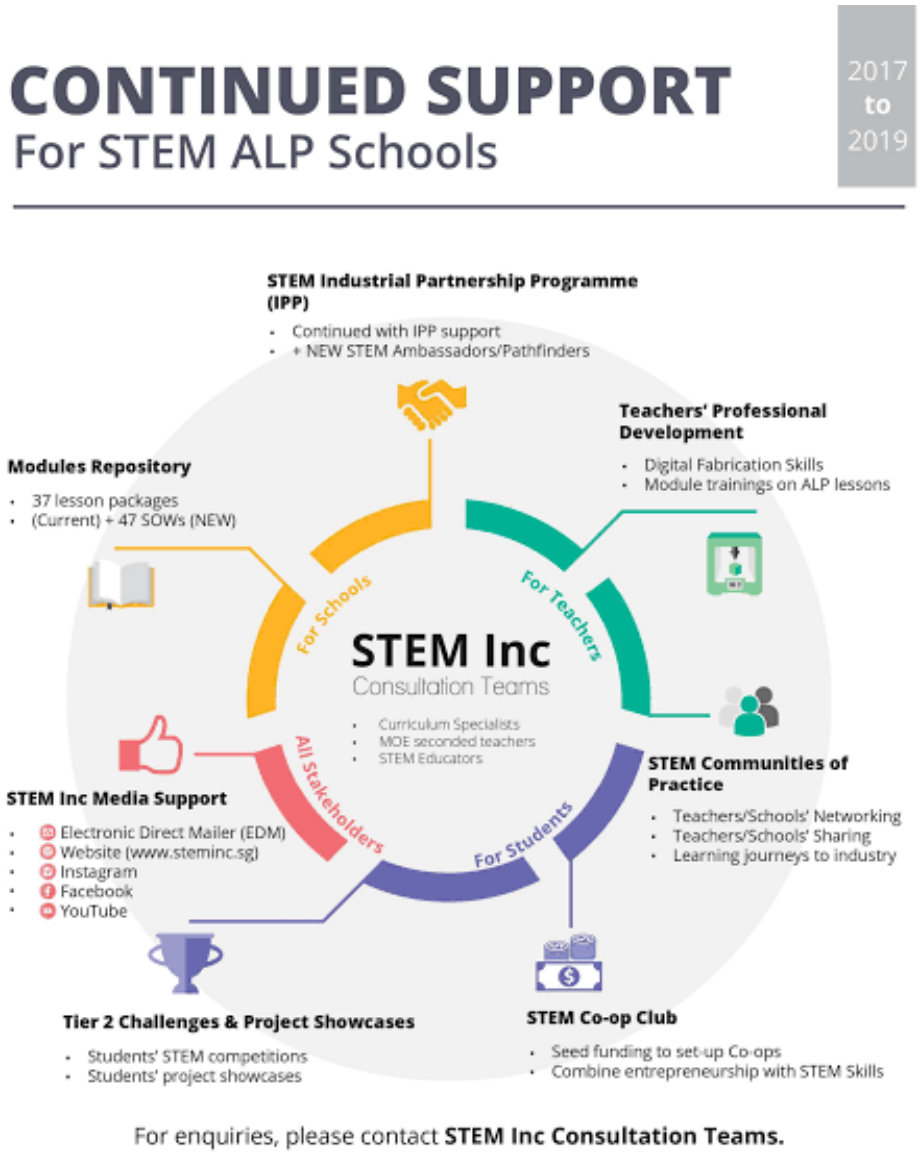


Figure 10. Continued Support for STEM ALP Schools, 2017–2019. Science Centre Singapore, STEM Inc.

In addition to school-based and institution-led initiatives, the Singapore Student Learning Space (SLS) serves as a critical domestic digital platform supporting STEM education delivery and innovation. Launched by the Ministry of Education, SLS functions as a centralized online learning ecosystem that provides students and teachers with access to high-quality digital resources, interactive STEM content, simulations, and inquiry-based learning modules aligned with the domestic curriculum (MOE, 2023). Through SLS, STEM learning extends beyond physical classrooms, enabling blended and self-directed learning while supporting differentiated instruction for diverse learner profiles.

The platform plays a particularly strategic role in strengthening computational thinking, data literacy, and digital STEM competencies by integrating virtual laboratories, coding activities, AI-enabled learning tools, and problem-based scenarios. Teachers are encouraged to

curate and co-create STEM lessons within SLS, fostering pedagogical innovation and professional collaboration while ensuring curriculum coherence economy-wide. Moreover, SLS enhances system resilience by maintaining STEM learning continuity during disruptions and by supporting equitable access to high-quality educational resources for all students, regardless of school context or location (OECD, 2021).

By embedding the Singapore Student Learning Space within its broader STEM education architecture, Singapore reinforces a digitally enabled, scalable, and future-ready learning environment. SLS complements applied learning programs, vocational pathways, and research-oriented initiatives by providing the digital backbone that supports personalized learning, instructional innovation, and the sustained development of STEM competencies essential for participation in a technology-driven economy.

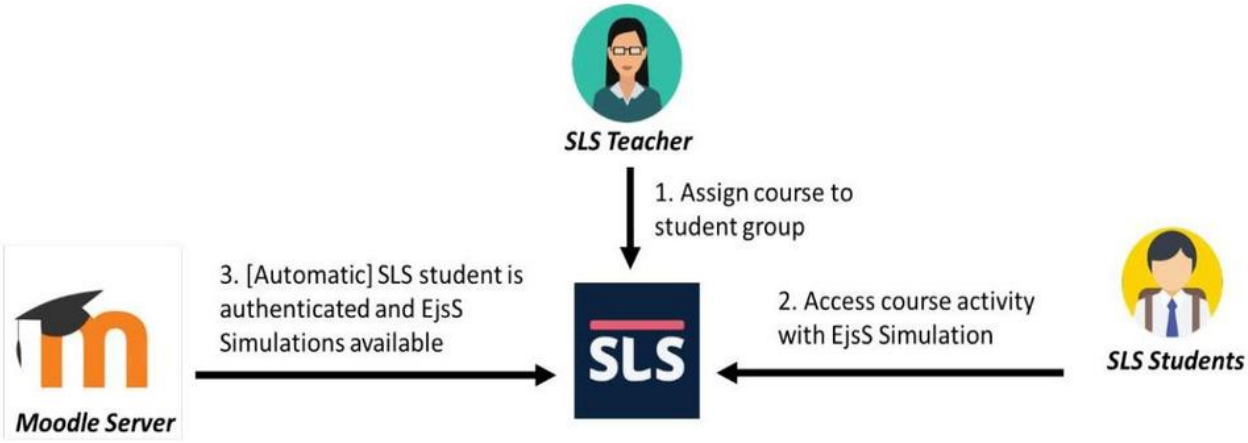


Figure 11. Integration of Easy JavaScript Simulation (EJSS) with Singapore Student Learning Space (SLS).

At the secondary and post-secondary levels, Singapore emphasizes differentiated STEM pathways through its polytechnics and Institutes of Technical Education (ITEs). These institutions serve as key vehicles for delivering practice-oriented STEM education closely aligned with labor market needs. Programs offered by polytechnics and ITE integrate classroom learning with hands-on laboratory work, industry-sponsored projects, and structured internships in priority sectors such as advanced manufacturing, artificial intelligence (AI), cybersecurity, biomedical sciences, and green technologies. Through Work-Study Programmes and industry certification tracks, students acquire both technical competencies and workplace readiness, thereby strengthening the transition from education to employment (SkillsFuture Singapore [SSG], 2022).

In parallel, research-intensive talent development is supported through initiatives led by the Agency for Science, Technology, and Research (A*STAR). Programs such as the A*STAR Science Award (Junior College), research attachments, and talent development schemes provide high-performing students with early exposure to scientific research environments, mentorship by professional scientists, and participation in innovative projects. These initiatives are strategically aligned with Singapore's domestic research priorities under the Research, Innovation and Enterprise (RIE) 2025 plan, reinforcing the linkage between STEM education, domestic innovation capacity, and economic competitiveness (A*STAR, 2023).

Informal STEM education and public engagement constitute another critical pillar of Singapore's flagship initiatives. The Science Centre Singapore plays a central role in promoting scientific literacy and broad-based STEM participation through exhibitions, maker programs, STEM camps, teacher support initiatives, and domestic competitions. These activities

complement formal schooling by cultivating curiosity, experimentation, and lifelong interest in STEM among diverse learner groups, including young children and underrepresented populations (Science Centre Singapore, 2023).

Collectively, Singapore's key STEM programs and flagship initiatives demonstrate a coherent and vertically integrated approach to STEM education. By combining inquiry-based learning in schools, industry-aligned vocational pathways, research-focused talent nurturing, and strong informal learning ecosystems, Singapore sustains a robust STEM talent pipeline that supports innovation-driven growth and long-term domestic competitiveness.

b. Case Studies of Best Practices

STEM Inc. – Science Centre Singapore (Applied Learning Programme – ALP)

- Lead Agencies: Science Centre Singapore, in partnership with MOE.
- Target Groups & Scope: Secondary school students (ages 13–15) in government schools; expanded to the primary level in 2023–2024.
- Structure & Approach: Hands-on, project-based learning in eight themes (e.g., robotics, food science, environment, health), STEM specialists co-design lessons with teachers and co-teach in classrooms, and a non-examinable structure emphasizes interest and skills, not test performance.
- Outcomes & Indicators: Launched in 2014 with 19 schools, expanded to 60–80 schools by 2017, significant improvements in engagement and collaborative learning, and global recognition (e.g., Shell Bright Ideas Competition).
- Scalability: Designed to be adapted across ASEAN economies with flexible curriculum alignment.
- Success Factors: Strong support from MOE, reduced pressure from exams, and industry partnerships with Micron and Broadcom for real-world integration.
- Scalability: Expandable to more schools and adaptable to the primary level, and suitable for international adaptation under the applied learning model.
- Policy Recommendations: Scale non-examinable ALP to all education levels, strengthen school–industry collaboration, and use qualitative data to improve long-term STEM pedagogy.

STEM Train-the-Trainer Programme – Science Centre Singapore Global

- Lead Agencies: Science Centre Singapore Global, in collaboration with MOE and STEM experts.
- Target Groups & Scope: Teachers (Grades 5–8) seeking to enhance STEM skills and curriculum design.
- Structure & Approach: Four stages: introduction to STEM pedagogy, mindset and activity design, hands-on skills (build, code, fabricate), and curriculum development with expert mentoring.
- Outcomes & Indicators: Increased STEM teaching competency, custom lesson plans tailored to school contexts, and alignment with domestic and regional programming.
- Success Factors: Mentorship from STEM professionals, a balance of theory and practice, and an emphasis on essential tools and mindset.
- Scalability: Adaptable to all schools and transferable across ASEAN with contextual adjustments.
- Policy Recommendations: Integrate into domestic CPD frameworks, provide micro-credentials for STEM teaching, and adopt as a sustainable teacher development model.

STEAMunity – SUTD & Science Centre Singapore

- Lead Agencies: Singapore University of Technology and Design (SUTD) and Science Centre Singapore, supported by MOE and Domestic Research Foundation (NRF).
- Target Groups & Scope: Students aged 13+ across schools in Singapore, emphasizing cross-school and community collaboration.
- Structure & Approach: Two phases: design coursework and peer-to-peer learning at SUTD, followed by real-world problem-solving (e.g., reducing smoke from traditional paper offerings), culminating in prototyping and stakeholder pitching.
- Outcomes & Indicators: Real-world prototypes (e.g., air pollution filters) and improved interdisciplinary thinking, teamwork, and entrepreneurial skills.
- Success Factors: High-level support from domestic leaders, real-life community issues that engage and motivate students, and inclusion of diverse learning styles and regions.
- Scalability: Expansion to other institutions (e.g., Temasek Polytechnic, Ngee Ann Polytechnic) and adaptable to international and regional contexts with access to makerspaces and community partnerships.
- Policy Recommendations: Promote problem-based STEAM in domestic policy, develop school-based makerspaces connected to community needs, and provide seed funding for impactful student prototypes.

c. Talent Development and Scholarship Programs

Talent development and scholarship programs constitute a central pillar of Singapore's STEM education and human capital strategy, reflecting the economy's long-standing commitment to nurturing a highly skilled, innovation-driven workforce aligned with domestic economic priorities. In 2025, these programs continue to operate within an integrated policy ecosystem that links education, research, and industry, underpinned by Singapore's Research, Innovation and Enterprise (RIE) 2025 framework and broader workforce development strategies.

At the pre-university level, talent development is systematically embedded within the education system through specialized pathways such as the Gifted Education Programme (GEP), Science and Mathematics Olympiad training schemes, and school-based talent development initiatives under the Applied Learning Programme (ALP). These pathways identify high-potential students early and provide enriched learning experiences, advanced curricula, mentorship, and exposure to research-oriented and industry-relevant STEM domains. Such early-stage interventions are designed not only to accelerate academic achievement but also to cultivate scientific curiosity, innovative mindsets, and sustained engagement in STEM fields.

At the post-secondary and tertiary levels, Singapore operates a comprehensive and highly competitive scholarship ecosystem to support STEM talent development. Major government-administered schemes include the Public Service Commission (PSC) Scholarships, the Agency for Science, Technology and Research (A*STAR) National Science Scholarships (NSS), and scholarships administered by statutory boards such as the Economic Development Board (EDB) and Infocomm Media Development Authority (IMDA). These programs provide full financial support for undergraduate and postgraduate studies in priority STEM disciplines, both domestically and at leading international universities, in exchange for service commitments that contribute directly to domestic capacity building.

A distinctive feature of Singapore's scholarship model is its strong alignment with domestic research and industry needs. A*STAR scholarships, for example, explicitly link academic training with research attachments, overseas doctoral training, and postdoctoral placements in strategic domains such as biomedical sciences, artificial intelligence, advanced manufacturing, and data science. Scholars are embedded within research institutes and innovation clusters, ensuring that talent development is closely integrated with applied

research, technology commercialization, and industry collaboration. This model strengthens the STEM talent pipeline while supporting knowledge transfer and innovation outcomes.

Industry-linked talent development programs further complement government scholarships. Through partnerships with multi-economy corporations and local enterprises, Singapore offers co-funded scholarships, bonded internships, and structured work–study programs that provide students with authentic workplace learning experiences. These initiatives facilitate smoother school-to-work transitions, enhance employability, and ensure that STEM graduates possess industry-relevant skills alongside strong theoretical foundations.

Equity and inclusivity considerations are increasingly incorporated into talent development and scholarship policies. Targeted bursaries, needs-based scholarships, and outreach programs aim to broaden participation among students from lower-income backgrounds and underrepresented groups, ensuring that access to high-quality STEM pathways is not limited by socioeconomic status. These measures align with Singapore's broader commitment to social mobility and inclusive growth within a high-performance education system.

Overall, Singapore's talent development and scholarship programs for STEM education in 2025 exemplify a strategically aligned and future-oriented approach to human capital development. By integrating early talent identification, rigorous academic training, research immersion, and industry engagement within a coherent scholarship ecosystem, Singapore ensures a steady pipeline of globally competitive STEM talent capable of sustaining innovation, economic resilience, and technological leadership in an increasingly complex global landscape.

d. Student Competitions and Events

Student competitions and enrichment activities constitute a central pillar of Singapore's STEM education ecosystem, serving as critical extensions of formal schooling and as mechanisms for cultivating innovation, applied problem-solving skills, and talent identification. Under the leadership of the Ministry of Education (MOE), in close collaboration with the Science Centre Singapore, higher education institutions, and industry partners, Singapore has developed a coherent system of STEM competitions and enrichment platforms that span primary, secondary, and pre-university levels.

A defining feature of Singapore's approach is the strong integration of competitions with curriculum-aligned applied learning. Programs such as the Applied Learning Programme (ALP) in STEM embed inquiry-based projects, design challenges, and real-world problem-solving tasks into school-based learning. At the same time, competitions function as advanced pathways for students to deepen their engagement. Domestic-level competitions—including the Singapore Science and Engineering Fair (SSEF), National Robotics Competition, Domestic Coding Championships, and AI and data science challenges—provide structured opportunities for students to apply interdisciplinary STEM knowledge in authentic contexts. These competitions emphasize design thinking, experimentation, collaboration, and communication, rather than rote technical performance alone.

Enrichment activities are further strengthened through Science Centre Singapore's flagship initiatives, such as STEM Inc programmes, maker education workshops, and innovation bootcamps. These initiatives offer sustained mentorship, modular learning resources, and access to industry expertise, enabling students to develop advanced competencies in robotics, digital fabrication, artificial intelligence, sustainability technologies, and engineering design. Tiered challenge models allow students with varying levels of readiness to participate, promoting broad access while still nurturing high-potential talent.

International exposure is another distinctive component of Singapore's enrichment strategy. Students are actively supported to participate in international Olympiads, robotics

competitions, innovation fairs, and global STEM exchanges, reinforcing Singapore's emphasis on global competence and benchmarking against international standards. Such experiences cultivate adaptability, cross-cultural collaboration skills, and awareness of global scientific and technological trends—competencies that align closely with Singapore's broader talent development and innovation agenda.

Digital platforms also play an enabling role in scaling enrichment opportunities. The Singapore Student Learning Space (SLS) supports competition preparation and enrichment through curated STEM content, virtual simulations, and collaborative tools, allowing students to engage in extended inquiry beyond classroom hours. This digital infrastructure enhances equity by ensuring that enrichment resources are accessible across schools, regardless of location or institutional capacity.

Collectively, student competitions and enrichment activities in Singapore serve as strategic tools to strengthen the STEM talent pipeline. By systematically linking applied learning, mentorship, industry engagement, and international exposure, Singapore ensures that students develop not only strong disciplinary foundations but also creativity, resilience, and real-world problem-solving capabilities essential to participation in future STEM careers and to innovation-driven economic growth.

e. Teachers' Training

Teacher capacity building remains a central pillar of Singapore's STEM education strategy, reflecting the economy's strong emphasis on instructional quality and future-ready pedagogy. The Ministry of Education (MOE) ensures that STEM teachers receive continuous professional development through a coherent system linking pre-service preparation, in-service training, and career-long learning pathways. The National Institute of Education (NIE) plays a key role in equipping teachers with strong subject mastery, inquiry-based instructional design, and assessment literacy aligned with domestic curriculum priorities.

In response to rapid technological change, professional development increasingly focuses on applied STEM pedagogy, computational thinking, artificial intelligence, data literacy, and interdisciplinary problem-based learning. Teachers are supported through structured programs such as STEM Inc consultation teams, Communities of Practice (CoPs), and industry-linked training that connects classroom teaching with real-world applications. These mechanisms promote collaborative lesson design, reflective practice, and the effective integration of emerging technologies into STEM classrooms.

Overall, Singapore's teacher training framework ensures that educators remain adaptive, innovative, and professionally supported, enabling consistent implementation of high-quality STEM education across schools and sustaining strong student learning outcomes in international benchmarks.

f. STEM Facilities and Learning Environments

Singapore places strong emphasis on providing high-quality STEM facilities and learning environments as a foundation for effective talent development and innovation-driven education. In 2025, STEM learning spaces are deliberately designed to support inquiry-based, applied, and interdisciplinary learning across all levels of education, closely aligned with domestic priorities in science, technology, and industry.

At the school level, institutions are equipped with well-resourced science laboratories, maker spaces, and technology-enabled classrooms that support hands-on experimentation, computational thinking, and project-based learning. These facilities are further complemented by domestic platforms such as the Singapore Student Learning Space (SLS), which enables blended and personalized STEM learning through digital simulations, data-driven activities, and collaborative online tools.

Beyond schools, domestic STEM hubs such as the Science Centre Singapore, A*STAR research institutes, and university-based innovation labs provide extended learning environments that connect formal education with real-world scientific practice. These facilities provide students with access to advanced equipment, research mentorship, and industry-linked problem-solving experiences, thereby strengthening the integration of education, research, and innovation.

Collectively, Singapore's STEM facilities and learning environments form a coherent ecosystem that supports deep learning, technological fluency, and sustained engagement in STEM, reinforcing the economy's capacity to develop future-ready talent within a highly digital, innovation-oriented education system.

g. Student STEM Participation and Pipeline Development

Singapore adopts a structured, early-stage approach to student STEM participation and pipeline development, ensuring sustained engagement from primary education through higher education and into the workforce. STEM exposure begins early through inquiry-based curricula, Applied Learning Programmes (ALP), and co-curricular activities that cultivate interest, confidence, and foundational competencies in science, technology, engineering, and mathematics.

At the secondary and post-secondary levels, specialized pathways—such as STEM-focused schools, applied diplomas, and university-industry-linked programs—provide students with progressive opportunities to deepen technical expertise and apply STEM knowledge to real-world challenges. Domestic initiatives and enrichment platforms further support talent identification, mentoring, and differentiated learning for high-potential students.

Overall, Singapore's STEM pipeline is characterized by strong continuity, clear progression pathways, and close alignment with domestic economic and innovation strategies, enabling students to transition smoothly from education into advanced study, research, and STEM-related careers.

Overall, Malaysia's STEM pipeline strategy reflects a growing recognition that participation must be supported longitudinally—from early schooling through workforce entry—requiring coordinated policies, targeted interventions, and continuous monitoring to ensure both scale and quality in STEM talent development.

9-3. Education Effects and Measured Outcomes

Singapore's STEM education system demonstrates consistently strong educational effects and measurable outcomes, reflecting the economy's long-standing emphasis on evidence-based policy, system coherence, and outcome-oriented governance. Learning outcomes in STEM are systematically monitored through a combination of domestic assessments, international benchmarking, and longitudinal tracking of student progression, enabling policymakers to evaluate both academic performance and broader competencies relevant to innovation and workforce readiness.

At the student learning level, Singapore continues to perform at the top tier of international large-scale assessments such as the Programme for International Student Assessment (PISA) and Trends in International Mathematics and Science Study (TIMSS). These results indicate not only high levels of achievement in mathematics and science literacy but also strong problem-solving, analytical reasoning, and application of knowledge in unfamiliar contexts. Importantly, Singapore's assessment frameworks increasingly emphasize higher-order thinking, inquiry, and applied learning outcomes aligned with 21st-century STEM competencies, rather than rote content mastery alone.

Beyond standardized testing, measured outcomes of STEM education are closely linked to students' engagement in applied and experiential learning. Evaluations of Applied Learning Programmes (ALP), STEM enrichment activities, and school–industry collaboration initiatives demonstrate positive effects on student motivation, conceptual understanding, and interest in STEM-related pathways. Schools report increased student confidence in tackling interdisciplinary problems, particularly in computational thinking, data literacy, environmental science, and engineering design. These outcomes suggest that applied STEM learning enhances both cognitive and non-cognitive dimensions of student development.

At the post-secondary and workforce transition levels, outcome indicators focus on enrollment patterns, completion rates, and employability in STEM-related fields. Singapore maintains a strong pipeline from secondary education to polytechnics, universities, and research institutions, with high participation in STEM disciplines aligned with domestic priority sectors such as artificial intelligence, advanced manufacturing, biomedical sciences, and clean energy. Graduate employment surveys consistently show high employability rates for STEM graduates, reflecting effective alignment between education, skills development, and labor market demand.

System-level evaluation further examines the effectiveness of STEM teacher professional development, digital learning platforms, and curriculum reforms. Data collected through school reviews, teacher appraisal systems, and platform analytics (such as those from domestic digital learning environments) inform continuous improvement and policy adjustments. These monitoring mechanisms enable the Ministry of Education to refine instructional strategies, scale successful practices, and address emerging gaps, ensuring that STEM education remains adaptive to technological and economic change.

Overall, the educational effects and measured outcomes of STEM education in Singapore illustrate a mature, highly integrated system in which learning quality, equity, and relevance are rigorously assessed. By combining international benchmarking, domestic performance indicators, and applied learning evaluations, Singapore sustains a high-performing STEM education ecosystem that not only produces strong academic results but also supports innovation capacity, economic competitiveness, and long-term human capital development.

9-4. Investment and Budgetary Patterns

Sustained and strategic public investment underpins Singapore's STEM education system, aligning education policy closely with domestic innovation and economic priorities. STEM education funding is closely aligned with the Research, Innovation, and Enterprise (RIE2025) framework, which channels substantial domestic resources into priority domains such as artificial intelligence, digital technologies, sustainability, and advanced manufacturing. Education-related STEM investments are integrated across the Ministry of Education (MOE), Smart Nation initiatives, and sectoral innovation agencies.

Budget allocations support curriculum innovation, digital learning infrastructure, applied learning programs, and teacher professional development. Platforms such as the Singapore Student Learning Space (SLS) and Applied Learning Programme (ALP) receive continued funding to enable inquiry-based, technology-enhanced STEM learning at scale. Additional investments target school–industry collaboration, student competitions, and talent development pathways that connect education with workforce needs.

Overall, Singapore's investment approach emphasizes long-term returns, system coherence, and scalability, ensuring that STEM education remains responsive to technological change while maintaining high quality and equity across schools.

9-5 Partnerships

Strategic partnerships among government agencies, educational institutions, industry, and international organizations form a foundational pillar of Singapore's STEM education ecosystem. The Ministry of Education (MOE) plays a central coordinating role, ensuring that partnerships are systematically aligned with domestic priorities in innovation, workforce development, and economic transformation, as articulated in the Research, Innovation and Enterprise (RIE) 2025 framework and SkillsFuture agenda.

At the domestic level, MOE collaborates closely with statutory boards such as Science Centre Singapore, SkillsFuture Singapore (SSG), and the Infocomm Media Development Authority (IMDA) to design and implement applied STEM learning initiatives. These partnerships support curriculum enrichment, teacher professional development, and student engagement in emerging domains such as artificial intelligence, data science, cybersecurity, sustainability technologies, and advanced manufacturing. Science Centre Singapore, through initiatives such as STEM Inc and school-based Applied Learning Programme (ALP) partnerships, serves as a key intermediary connecting schools with industry expertise and real-world problem contexts.

Industry–education partnerships are a defining strength of Singapore's STEM model. Multi-economy corporations and local enterprises actively participate in co-developing learning modules, providing mentorship, hosting workplace learning experiences, and sponsoring competitions and innovation challenges. Through structured mechanisms, industry partners help ensure curricular relevance and expose students to authentic STEM applications, thereby strengthening school-to-work transitions. These collaborations also support early talent identification and align STEM education with evolving labor-market needs across sectors such as semiconductors, biomedical sciences, green technologies, and digital services.

Higher education institutions play a complementary role by partnering with schools and government agencies to support outreach, enrichment, and research-informed pedagogy. Universities contribute expertise in advanced STEM fields, offer access to laboratories and mentorship programs, and collaborate on talent development pipelines spanning secondary, pre-university, and tertiary education. These vertical partnerships enhance continuity in STEM learning and reduce fragmentation across educational stages.

International and regional partnerships further reinforce Singapore's STEM ecosystem. Engagement with organizations such as APEC, OECD, and UNESCO enable Singapore to benchmark its policies against global best practices, participate in cross-border STEM initiatives, and contribute to regional capacity-building efforts. International collaborations also facilitate student exchanges, joint competitions, and knowledge-sharing platforms, thereby strengthening global competence and an international outlook among learners.

Overall, Singapore's partnership-driven approach to STEM education reflects a highly coordinated and system-level strategy. By institutionalizing collaboration across government, industry, academia, and international networks, Singapore ensures that STEM education remains dynamic, future-oriented, and closely aligned with domestic innovation and human capital development goals. These partnerships not only enhance the quality and relevance of STEM learning but also contribute to the sustainability and global competitiveness of Singapore's STEM talent pipeline.

9-6. Performance Indicators and Monitoring

Singapore employs a highly structured, evidence-based monitoring and evaluation framework to ensure the effectiveness, quality, and long-term relevance of STEM education. Central to this system is the Ministry of Education's (MOE) emphasis on outcomes-oriented

governance, where policy implementation, curriculum delivery, and student learning outcomes are closely aligned through coherent performance indicators and continuous feedback mechanisms. Rather than relying solely on summative examination results, Singapore adopts a balanced approach that integrates academic achievement, applied learning outcomes, and future-ready competencies.

At the student level, STEM learning outcomes are monitored through a combination of domestic assessments, school-based evaluations, and applied learning assessments under initiatives such as the Applied Learning Programme (ALP) and Learning for Life Programme (LLP). These mechanisms assess not only content mastery in science and mathematics but also higher-order competencies, including problem-solving, inquiry skills, collaboration, and the application of STEM knowledge to authentic, real-world contexts. Performance data are used formatively to guide instructional improvement and support differentiated learning pathways, rather than serving purely as accountability instruments.

International benchmarking plays a strategic role in Singapore's STEM monitoring framework. Participation in large-scale assessments such as the Programme for International Student Assessment (PISA) and Trends in International Mathematics and Science Study (TIMSS) provides external validation of system performance. It offers comparative insights into strengths and emerging gaps. Findings from these assessments are systematically analyzed and translated into policy and curriculum refinements, particularly in scientific literacy, computational thinking, and applied problem-solving. This evidence-informed approach enables Singapore to remain responsive to global trends while maintaining alignment with domestic priorities.

Digital technologies further enhance Singapore's monitoring capacity. The Singapore Student Learning Space (SLS), a digital learning platform, functions not only as a teaching and learning environment but also as a data-rich ecosystem that supports learning analytics and formative assessment. Through SLS, educators can track student engagement, learning progress, and competency development in STEM subjects, enabling timely instructional adjustments and personalized support. At the system level, aggregated data from digital platforms contribute to policy analysis and program evaluation, strengthening the feedback loop between classroom practice and domestic decision-making.

School-level accountability is reinforced through structured review mechanisms such as the School Excellence Model (SEM) and regular external school evaluations. These reviews examine leadership effectiveness, curriculum coherence, pedagogical innovation, and student outcomes, including the quality of STEM implementation. Importantly, evaluation frameworks emphasize professional learning, innovation, and reflective practice rather than punitive accountability, fostering a culture of continuous improvement across schools.

Collectively, Singapore's performance indicators and monitoring frameworks reflect a mature and integrated governance model for STEM education—one that combines robust data systems, international benchmarking, digital analytics, and school-level quality assurance. By aligning monitoring practices with domestic innovation strategies and workforce development goals, Singapore ensures that STEM education remains adaptive, future-oriented, and closely connected to the skills and competencies required in a rapidly evolving global economy.

9-7. Gender Inclusivity and Equity

Gender inclusivity and equity are integral to Singapore's STEM education policy framework, reflecting the economy's broader commitment to social inclusion, meritocracy, and human capital optimization. While Singapore demonstrates relatively balanced gender participation in STEM education compared to many OECD economies, policymakers continue to address persistent gendered patterns in subject choices, career trajectories, and representation

in advanced STEM fields. As such, gender equity in STEM is approached not only as an access issue but also as a matter of sustained participation, progression, and leadership development.

At the foundational education level, Singapore has largely achieved gender parity in student performance and participation in mathematics and science. International assessments such as PISA and TIMSS consistently show minimal gender gaps in achievement, indicating that children receive comparable opportunities to develop core STEM competencies. This outcome reflects a strong domestic curriculum, standardized quality assurance, and inclusive pedagogical practices that emphasize conceptual understanding, inquiry, and problem-solving across all student groups.

Despite parity in early STEM learning outcomes, gender differences become more pronounced at later stages of the education and career pipeline, particularly in engineering, information technology, and advanced computing fields. Recognizing this trend, Singapore has implemented targeted initiatives to sustain girls' interest and confidence in STEM beyond compulsory education. Programs such as Girls in Tech, university-supported Women in STEM initiatives, and outreach campaigns coordinated with industry partners aim to counter gender stereotypes, provide role models, and highlight diverse STEM career pathways. These initiatives emphasize mentorship, experiential learning, and exposure to real-world applications, which research suggests are critical for retaining female participation in STEM.

At the institutional level, higher education institutions and research agencies actively integrate gender equity considerations into recruitment, scholarship allocation, and talent development strategies. Universities and polytechnics increasingly monitor gender-disaggregated data on enrollment, progression, and completion in STEM disciplines, using this evidence to inform targeted interventions. Scholarship schemes and leadership development programs also emphasize supporting women in high-demand STEM sectors, particularly those aligned with domestic priorities such as artificial intelligence, biomedical sciences, and sustainability technologies.

Workforce-oriented STEM policies further reinforce gender inclusivity by addressing structural barriers that affect women's long-term participation in STEM careers. Flexible learning pathways, continuing education programs, and reskilling initiatives enable women to re-enter or transition within STEM fields across different life stages. Complementary policies on work–life balance, parental support, and inclusive workplace practices—though broader than education alone—indirectly strengthen the sustainability of female STEM talent development.

From a governance perspective, Singapore's data-driven monitoring frameworks play a critical role in advancing gender equity. Gender-disaggregated indicators are embedded within education statistics, workforce surveys, and talent development reports, allowing policymakers to track trends, identify bottlenecks, and evaluate the effectiveness of interventions. This systematic use of evidence aligns with OECD recommendations on equity-oriented STEM policy and ensures that gender inclusivity remains a measurable and accountable policy objective.

Overall, Singapore's approach to gender inclusivity and equity in STEM education reflects a mature and multidimensional strategy. By combining early achievement parity, targeted enrichment and mentoring, institutional accountability, and workforce-aligned support mechanisms, Singapore seeks not only to equalize access but also to ensure sustained participation and leadership of women in STEM. This comprehensive approach strengthens the resilience, diversity, and innovation capacity of the domestic STEM talent ecosystem, positioning gender equity as a strategic asset for long-term economic and technological competitiveness.

9-8. Key Challenges and Distinctive Features

Singapore's STEM education system is highly effective and internationally competitive. Yet, it faces ongoing challenges in keeping pace with rapid technological change and increasingly complex skill demands in fields such as artificial intelligence, data science, and sustainability. Continuous curriculum renewal and teacher upskilling are required to ensure relevance, while maintaining academic rigor without exacerbating student stress within a performance-oriented education culture.

Equity remains another challenge, as differences in socioeconomic background can affect access to advanced STEM enrichment opportunities, despite strong domestic support mechanisms. In addition, rapid shifts in industry needs pose risks of skills mismatch, highlighting the importance of lifelong learning and flexible reskilling pathways.

At the same time, Singapore's STEM education is distinguished by strong policy coherence across education, innovation, and workforce development, as well as a clear emphasis on applied and experiential learning through programs such as the Applied Learning Programme and school–industry partnerships. Robust, data-driven monitoring and accountability frameworks further enable continuous system improvement, positioning Singapore to sustain high-quality, future-ready STEM education.

10. Chinese Taipei

Orteza RONNALEE, Executive Director, DOST-Philippines Science High School System, the Philippines

Summary: Chinese Taipei has a cohesive and progressive strategy for nurturing talent in science, technology, engineering, and mathematics that integrates education, innovation, and industry within a unified domestic vision of competitiveness and growth driven by innovation. A cornerstone of this approach is a domestic talent initiative aimed at enhancing local skills while drawing in and keeping international talent, especially in key areas like artificial intelligence, semiconductors, digital technologies, and advanced manufacturing. This is supported by a progressive industrial framework that connects research, entrepreneurship, and industry partnerships, ensuring that the development of talent is tightly aligned with new economic opportunities. At the educational level, extensive reforms focus on inquiry-based education, critical thinking, digital literacy, and research initiated by students, backed by significant investment in digital infrastructure and learning technologies. Student contests, hands-on programs, and global exchanges enhance traditional education by fostering practical problem-solving abilities, innovative thinking, and international competence. Teacher quality is emphasized as a strategic priority via thorough pre-service training, ongoing professional growth, collaborative learning networks, and rewards that connect career progression to teaching effectiveness and innovation. Ongoing public investment supports these initiatives, featuring focused funding for artificial intelligence education, interdisciplinary learning, digital access in disadvantaged regions, and bilingual instruction to boost global involvement. Robust collaborations among government, industry, academia, and international organizations better align education with workforce demands, enhance work-based learning, and bolster talent retention through public–private partnerships. Performance metrics, such as consistently excellent results in international evaluations, strong enrollment in enrichment activities, and achievements in worldwide contests, demonstrate the effectiveness of these approaches. However, obstacles still exist, such as disjointed policy execution, inadequate training for integrated STEM instruction, challenges in providing experiential learning in digital settings, and ongoing gender disparities in higher STEM domains. Chinese Taipei is working to close these gaps through legal structures and specific initiatives that encourage gender equity and inclusion. Its cohesive and investment-focused strategy showcases how effective governance, high educational standards, and alignment with industry needs can support a competitive and inclusive STEM workforce worldwide.

10-1. Strategy and Vision

Chinese Taipei has articulated a clear and forward-looking domestic strategy for STEM talent development, anchored on strengthening human capital to sustain economic competitiveness, technological leadership, and innovation-driven growth. Through its Key Talent Cultivation and Recruitment Program (2021–2024) launched by the National Development Council (NDC), Chinese Taipei aims to position itself as a global talent hub amid intensifying international competition for high-skilled workers (Chinese Taipei government, 2025). The program emphasizes the development, attraction, and retention of STEM talent as a strategic priority, recognizing human capital as a key driver of industrial upgrading and digital transformation.

Under this program, the government advances STEM capacity-building through a multi-pronged approach that spans education reform, labor market alignment, and internationalization. Key strategies include expanding STEM enrollment in universities, particularly in priority fields such as artificial intelligence, semiconductors, information and communications technology (ICT), and advanced manufacturing (Chinese Taipei government, 2025). To ensure relevance and employability, the program strongly promotes industry–academia collaboration, enabling universities to co-develop curricula, research agendas, and applied training programs with industry partners. These partnerships facilitate the translation of academic knowledge into real-world applications and strengthen innovation pipelines.

Another important pillar of the economy-wide talent strategy is the promotion of bilingual education, particularly in higher education and research institutions. By enhancing English proficiency among students and researchers, Chinese Taipei seeks to increase the global mobility and competitiveness of its STEM workforce while also making the economy more attractive to international scholars and professionals (Chinese Taipei government, 2025). Complementing this effort are policies that streamline visa processes, improve working conditions, and provide incentives for foreign STEM professionals and Chinese Taipei talent overseas to work, conduct research, or establish startups in Chinese Taipei.

Complementing the Key Talent Cultivation and Recruitment Program is the Asia Silicon Valley Development Plan (ASVDP), which provides an industrial and innovation-oriented framework for STEM talent development. First introduced in 2016, the plan was expanded under its 2.0 (2021–2024) and 3.0 (2025–2028) phases to respond to emerging technological trends and global economic shifts (Chinese Taipei government, 2025). The ASVDP aims to position Chinese Taipei as a global leader in Artificial Intelligence of Things (AIoT) by integrating hardware excellence with software innovation, data analytics, and intelligent systems.

The ASVDP supports high-potential industries such as biotechnology, smart machinery, green energy, and digital services, creating sustained demand for highly skilled STEM professionals (Chinese Taipei government, 2025). Through investments in research infrastructure, startup incubation, regulatory sandboxes, and innovation ecosystems, the plan nurtures entrepreneurship and strengthens linkages among universities, research institutions, startups, and multi-economy firms. These ecosystem-based approaches ensure that STEM talent development is closely aligned with domestic industrial strategies and future-oriented economic goals.

Collectively, these domestic initiatives reflect Chinese Taipei's coherent and integrated approach to STEM talent development—one that aligns education, innovation, and industry policy under a shared long-term vision. By simultaneously cultivating domestic talent, attracting global expertise, and embedding STEM development within innovation-driven industrial ecosystems, Chinese Taipei demonstrates how strategic governance and sustained investment can build a resilient and globally competitive STEM workforce.

10-2. Key STEM Education Programs

a. Educational Programs and Initiatives

Chinese Taipei has implemented comprehensive education reforms and targeted initiatives to strengthen STEM talent development from basic to secondary education. Between 2011 and 2014, Chinese Taipei introduced its 12-Year Basic Education Curriculum Reform, which places strong emphasis on creative problem-solving, critical thinking, digital literacy, and hands-on, inquiry-based learning (Ministry of Education [MOE], 2014). A distinguishing feature of this reform is the requirement for senior high school students to undertake personal research projects, which are designed to cultivate independent inquiry, research skills, and deeper engagement with STEM disciplines.

The effectiveness of these reforms is reinforced by empirical studies examining collaborative STEM implementation in schools in Chinese Taipei. Research by Lin, Ku, and Wei (2025a) highlights that successful STEM talent development is strongly associated with teacher collaboration, flexible and performance-based assessment systems, and cross-disciplinary learning environments that integrate science, technology, engineering, and mathematics in authentic contexts (Lin et al., 2025b). These findings underscore the importance of institutional support and professional learning communities in translating curriculum reforms into meaningful classroom practices.

To further support these pedagogical shifts, the Ministry of Education has made substantial investments in digital learning innovation and infrastructure. Significant public funding has been allocated to enhance school connectivity, digital platforms, and instructional technologies. Notably, an estimated USD 672 million was earmarked for digital education initiatives, including USD 188 million specifically dedicated to K–12 STEM content and digital tools, which are essential for supporting bilingual education and digitally integrated learning environments (Trade.gov, 2024). These investments ensure that students and teachers have access to high-quality digital resources that reinforce STEM learning, facilitate personalized instruction, and strengthen alignment with Chinese Taipei's broader domestic innovation and talent strategies.

Collectively, these educational programs and initiatives reflect Chinese Taipei's systematic approach to STEM talent development, which combines curriculum reform, evidence-based pedagogical practices, and sustained investment in digital infrastructure to prepare learners for participation in a knowledge-intensive and innovation-driven economy.

b. Student Competitions and Events

Student competitions and enrichment events play a strategic role in Chinese Taipei's STEM talent development ecosystem by providing authentic, experiential learning opportunities that complement formal education. The Youth Development Administration (YDA) under the Ministry of Education leads domestic efforts to empower young people through programs that integrate career guidance, entrepreneurship education, and STEM skill-building, with a strong emphasis on innovation, digital competence, and global engagement (MOE, 2023b).

YDA-supported initiatives include STEM-focused experiential learning camps, domestic and international competitions, creative innovation workshops, hackathons, and student exchange programs, which are designed to cultivate problem-solving, teamwork, and applied technical skills. These activities expose students to real-world challenges in areas such as robotics, artificial intelligence, digital design, environmental technology, and entrepreneurship, thereby strengthening their interest and persistence in STEM pathways (YDA, 2023). Competitions, in particular, serve as talent identification platforms, enabling educators and policymakers to recognize high-potential students and provide them with further

mentoring and development opportunities.

In addition to technical skills, YDA programs emphasize digital literacy, innovation mindset, and international competence, reflecting Chinese Taipei's broader domestic vision of developing globally competitive STEM talent. Through international exchanges and cross-border competitions, students gain exposure to diverse perspectives, emerging technologies, and global standards of excellence, which enhances their adaptability and readiness for participation in international research, industry, and innovation ecosystems (Chinese Taipei government, 2025). These global engagement opportunities also support bilingual education goals and help students build communication and collaboration skills essential for STEM careers in a globalized economy.

Overall, student competitions and events organized or supported by YDA function as critical extensions of classroom learning, reinforcing inquiry-based education and strengthening the STEM talent pipeline. By integrating experiential learning, innovation challenges, and international exposure, Chinese Taipei ensures that young learners are not only academically prepared but also creatively empowered and globally connected, which are key attributes for sustaining long-term STEM excellence and innovation leadership.

c. Teachers' Training

Chinese Taipei places strong and sustained emphasis on teacher capacity building as a cornerstone of its STEM talent development strategy, particularly in response to rapid technological change and the evolving demands of 21st-century education. Its MOE ensures that teachers are continuously equipped with both deep subject-matter expertise and innovative pedagogical competencies through a coherent system of pre-service preparation, in-service professional development, and career-long learning pathways (MOE, 2023a).

A key feature of Chinese Taipei's teacher development framework is its rigorous pre-service training, delivered through accredited teacher education universities. Future educators receive systematic training in instructional design, subject mastery, assessment literacy, and inclusive education, with increasing emphasis on inquiry-based STEM teaching, digital pedagogy, and interdisciplinary learning approaches (NAER, 2021). This strong foundation ensures that newly licensed teachers enter the profession with both disciplinary competence and readiness to implement modern STEM curricula.

Equally important is the economy's robust in-service professional development system, which supports teachers throughout their careers. Professional learning opportunities are facilitated by Regional Education Resource Centers, universities, and the National Academy for Educational Research (NAER), offering regular workshops and certification programs focused on digital literacy, interdisciplinary STEM integration, artificial intelligence (AI) education, computational thinking, and innovative teaching methodologies (MOE, 2023a). These programs are aligned with domestic curriculum reforms and emerging technology trends, enabling teachers to continuously update their knowledge and classroom practices.

Chinese Taipei also strongly promotes Lesson Study and Professional Learning Communities (PLCs) as core mechanisms for teacher learning and instructional improvement. Through collaborative lesson planning, peer observation, and reflective practice, teachers engage in evidence-based dialogue on curriculum implementation and student learning outcomes. Research indicates that these collaborative structures enhance instructional quality, teacher efficacy, and the successful integration of STEM concepts across disciplines (OECD,

2019b).

Domestic initiatives further reinforce teacher capacity building in STEM education. Programs such as the High-Scope Program and the SMART Education Project provide hands-on training in coding, computational thinking, AI applications, and the effective use of digital tools in classroom instruction (MOE, 2023a). These initiatives support the development of future-ready teaching practices and ensure that STEM education remains responsive to technological innovation and industry needs.

To sustain high standards, Chinese Taipei employs incentive and accountability mechanisms that link teacher promotion and career advancement to demonstrated professional growth, instructional effectiveness, and the integration of technology-enhanced and inquiry-based learning approaches (MOE, 2023a). This alignment of professional development with career progression reinforces a culture of excellence and continuous improvement within the teaching workforce.

Collectively, this comprehensive teacher capacity-building system has contributed to Chinese Taipei's consistently strong performance in international large-scale assessments such as the Programme for International Student Assessment (PISA) while also sustaining a highly skilled, adaptive, and future-oriented teaching workforce capable of nurturing the next generation of STEM learners and innovators (OECD, 2023).

10-3. Budget and Investment

Sustained public investment is a central pillar of Chinese Taipei's strategy for STEM talent development, reflecting the government's recognition that human capital is essential to domestic competitiveness, digital transformation, and innovation-led growth. For the upcoming fiscal year, Chinese Taipei's MOE proposed a total budget of TWD 362.3 billion (approximately USD 870 million), representing an increase of TWD 27.8 billion compared to the previous year (Lin & Yeh, 2024). This budget expansion underscores the prioritization of education—STEM in particular—as a long-term domestic investment.

A significant portion of the proposed budget is allocated to strengthening artificial intelligence (AI) and information and communications technology (ICT) education, with TWD 7.25 billion earmarked to support curriculum development, teacher training, and the integration of emerging technologies across basic and higher education institutions (Lin & Yeh, 2024). These investments aim to ensure that learners acquire future-ready competencies in data science, AI applications, and digital systems, which are aligned with Chinese Taipei's broader industrial strategies, such as the Asia Silicon Valley Development Plan.

In parallel, the MOE allocated TWD 2.7 billion to enhance digital learning in schools, supporting the expansion of digital infrastructure, online platforms, and blended learning models (Lin & Yeh, 2024). This funding enables schools to modernize instructional delivery, improve access to quality STEM resources, and build system resilience in response to technological disruption and future crises. Digital learning investments also complement Chinese Taipei's bilingual education policy by facilitating access to global STEM content and international collaboration.

To promote integrative and innovative learning, TWD 990 million has been designated for interdisciplinary technology education, encouraging the convergence of science,

engineering, technology, and applied research (Lin & Yeh, 2024). These funds support project-based learning, cross-disciplinary curricula, and collaboration between schools, universities, and industry partners. These approaches have been shown to strengthen problem-solving skills and innovation capacity among students (OECD, 2019a).

Equity considerations are also embedded in Chinese Taipei's STEM investment strategy. Approximately TWD 410 million is allocated for digital empowerment initiatives in rural and underserved areas, aiming to reduce the digital divide and ensure that students outside urban centers have access to modern STEM learning environments (Lin & Yeh, 2024). This includes improving broadband connectivity, providing digital devices, and offering targeted teacher support, thereby promoting inclusive STEM talent development economy-wide.

Overall, these budgetary allocations demonstrate Chinese Taipei's comprehensive and forward-looking approach to STEM talent development, which balances excellence, innovation, and equity. By aligning financial investments with strategic priorities in AI, digital learning, interdisciplinary education, and regional inclusion, Chinese Taipei reinforces its capacity to develop a globally competitive and socially inclusive STEM workforce (Chinese Taipei government, 2025).

10-4. Partnerships

Strategic partnerships among government, industry, academia, and international organizations form a core component of Chinese Taipei's STEM talent development framework. Through active participation in regional and global cooperation platforms, Chinese Taipei leverages partnerships to align education systems with labor market needs, foster innovation, and strengthen talent pipelines. Notably, APEC initiatives hosted in Chinese Taipei, such as the Industry–Academia Collaboration for Talent Development and the APEC STEM-PLUS Scientific Literacy Workshops, reinforce synergies between education and industry by promoting applied learning, entrepreneurship, and innovation-oriented STEM education (Asia-Pacific Economic Cooperation [APEC], 2022; Chinese Taipei government, 2023).

These APEC-supported programs actively engage students and young professionals in hands-on STEM activities, startup-oriented challenges, and cross-border collaboration, with particular attention to inclusive participation, including initiatives that encourage girls and young women to pursue STEM and entrepreneurial pathways (APEC, 2022). By embedding applied STEM practices and industry-relevant competencies into educational programs, these regional partnerships contribute to workforce readiness while also facilitating knowledge exchange and capacity building across the Asia-Pacific region (OECD, 2019a).

At the domestic level, Chinese Taipei's education and labor policies strongly encourage school–industry partnerships, particularly in key growth sectors such as semiconductors, artificial intelligence, advanced manufacturing, finance, and green technologies. Through structured collaboration mechanisms, schools and universities work closely with industry partners to co-develop curricula, offer internships and apprenticeships, and provide students with authentic workplace learning experiences (MOE, 2023a). These partnerships ensure that STEM education remains responsive to rapidly evolving technological and economic demands while supporting smoother transitions from education to employment.

A flagship example of public–private partnership in STEM talent development is the INTENSE Program, launched by the Chinese Taipei government in collaboration with private

sector organizations. The program provides full financial support for STEM education and industry internships, including a minimum monthly stipend of TWD 10,000, with a strategic focus on priority industries such as semiconductors, finance, and artificial intelligence (Chinese Taipei government, 2024). In return, program beneficiaries are expected to work in Chinese Taipei after graduation, thereby directly contributing to the economy's talent retention and workforce sustainability strategy (National Development Council [NDC], 2024).

Collectively, these partnerships demonstrate Chinese Taipei's integrated approach to STEM talent development, which links education, innovation, and employment through sustained collaboration. By leveraging international platforms, fostering robust school–industry linkages, and incentivizing public–private cooperation, Chinese Taipei strengthens its ability to develop, attract, and retain STEM talent essential for long-term economic growth and global competitiveness.

10-5 Performance Indicators

Chinese Taipei's strong performance in international large-scale assessments serves as a key indicator of the effectiveness of its STEM talent development strategies. In assessments such as the Programme for International Student Assessment (PISA), Chinese Taipei students consistently perform above the OECD average in mathematics and science, reflecting solid foundational competencies and the positive impact of sustained curriculum reforms and teacher capacity-building initiatives (OECD, 2023; Wu, 2020). These outcomes demonstrate the system's ability to develop analytical thinking, scientific reasoning, and problem-solving skills essential for advanced STEM learning and innovation.

At the postsecondary level, STEM enrollment rates provide insight into the economy's capacity to sustain its STEM talent pipeline. While Chinese Taipei has faced challenges related to demographic decline and fluctuating student interest in certain STEM disciplines, government interventions continue to promote enrollment in priority areas such as artificial intelligence, semiconductors, and engineering through targeted incentives and industry-aligned programs (Huang & Liu, 2023). Monitoring enrollment trends enables policymakers to assess the attractiveness, accessibility, and labor-market relevance of STEM pathways.

Gender balance in STEM is another important performance indicator. International data indicate relatively narrow gender gaps in mathematics and science achievement at the basic education level, suggesting progress toward equitable learning outcomes (OECD, 2023). However, disparities remain in higher education and specific STEM fields, particularly engineering and technology, highlighting the continued need for gender-responsive interventions to strengthen female participation and retention in advanced STEM programs (Fillmore et al., 2024).

The scope and effectiveness of STEM talent cultivation programs further reflect system performance. Chinese Taipei implements a wide range of enrichment initiatives—including research projects, industry internships, and innovation challenges—that bridge education and workforce development. Participation rates, program completion, and post-program employment outcomes serve as indicators of how well these initiatives translate educational experiences into tangible career pathways in high-growth sectors.

Investment levels in digital education also function as a measurable indicator of STEM

readiness. Substantial public spending on digital infrastructure, learning platforms, and STEM-related educational technologies demonstrates Chinese Taipei's commitment to future-oriented education and equitable access to learning opportunities. These investments support blended learning, computational thinking, and AI-related competencies, which are increasingly critical to STEM talent development.

Equally important is teacher professional development, as teacher quality directly influences student learning outcomes. Indicators such as participation in continuous professional development, engagement in lesson study and professional learning communities, and demonstrated integration of inquiry-based and technology-enhanced pedagogy reflect the system's instructional strength and adaptability (OECD, 2019b). Chinese Taipei's structured approach to teacher development contributes to sustained instructional quality across STEM disciplines.

Beyond standardized assessments, student competency growth—including improvements in creative thinking, scientific inquiry, and applied problem-solving—provides a more nuanced measure of STEM education impact. PISA's expanded assessment domains highlight Chinese Taipei's growing emphasis on higher-order competencies that extend beyond rote knowledge and align with innovation-driven economic needs (OECD, 2023).

Finally, participation and achievement in international competitions and exchanges serve as qualitative and quantitative indicators of elite STEM capability. Chinese Taipei students consistently perform well in international science and mathematics Olympiads, robotics competitions, and innovation expos, signalling the effectiveness of talent identification and enrichment mechanisms within the education system (Wu, 2020). Collectively, these performance indicators demonstrate Chinese Taipei's holistic and results-oriented approach to STEM talent development, combining excellence, equity, and global competitiveness.

10-6. Key Challenges

Despite its strong performance in international assessments and substantial investment in education, Chinese Taipei continues to face several structural and pedagogical challenges that affect the long-term sustainability of its STEM talent development pipeline. One major concern identified by Ku and Lin (2022b) is the lack of clearly articulated, system-wide STEM education goals and a unified domestic policy framework. While various initiatives promoting AI, digital learning, and industry–academia collaboration exist, these programs are often implemented in parallel rather than under an integrated STEM roadmap. This fragmentation can lead to inconsistencies in curriculum focus, uneven implementation across regions, and difficulties in evaluating long-term outcomes related to STEM workforce readiness (Ku & Lin, 2022b).

Another persistent challenge lies in the absence of systematic STEM teacher education programs within higher education institutions. Pre-service teacher preparation in Chinese Taipei remains largely discipline-based, with limited emphasis on interdisciplinary STEM integration, design thinking, or real-world problem solving. As a result, many teachers enter the profession with strong subject knowledge but insufficient preparation to design and facilitate integrated STEM learning experiences that reflect authentic scientific and technological practices (Ku & Lin, 2022b; Lin et al., 2025). This gap constrains the ability of schools to fully implement inquiry-driven and innovation-oriented STEM curricula.

The rapid expansion of online and blended learning has further exposed teachers' difficulties in implementing hands-on and experiential STEM activities in virtual environments. Ku and Lin (2022b) note that many educators struggle to translate laboratory experiments, engineering design challenges, and collaborative problem-solving tasks into effective online formats. Limited access to digital tools, uneven student connectivity, and insufficient training in virtual pedagogy have compounded these challenges, potentially reducing student engagement and weakening the development of practical STEM competencies.

In addition, the lack of diverse and well-developed interdisciplinary STEM modules remains a significant concern. Although curriculum reforms encourage cross-disciplinary learning, many schools continue to rely on isolated subject-based lessons rather than fully integrated STEM units that combine science, technology, engineering, and mathematics in meaningful contexts. This limitation reduces opportunities for students to develop systems thinking, creativity, and applied problem-solving skills—competencies essential for innovation-driven economies (Ku & Lin, 2022b). The uneven availability of high-quality instructional materials further exacerbates disparities in STEM learning experiences across schools.

Finally, diversity-related challenges within classrooms pose both instructional and equity concerns. Increasing cultural, socioeconomic, and learning diversity among students requires differentiated instruction and inclusive pedagogical strategies, yet many teachers report limited preparation and support in addressing these needs within STEM contexts (Ku & Lin, 2022b). Without deliberate efforts to design inclusive STEM learning environments, certain student groups—particularly those from rural areas or underrepresented backgrounds—may face barriers to participation and achievement, undermining broader domestic goals for inclusive talent development.

Collectively, these challenges highlight the need for Chinese Taipei to move beyond strong performance outcomes toward a more coherent, inclusive, and future-oriented STEM education system. Addressing policy alignment, teacher preparation, instructional innovation, curriculum integration, and learner diversity will be critical to sustaining the economy's global competitiveness in STEM and ensuring equitable access to talent development opportunities.

10-7. Gender Inclusivity and Equity Measures

Chinese Taipei has institutionalized gender inclusivity in education through a strong legal and policy framework, most notably the Gender Equity Education Act, which was enacted in 2004 and subsequently amended, with the latest revision in 2018. This law mandates the integration of gender-balanced and gender-sensitive curricula across all levels of education—from basic education to higher education—and requires the establishment of Gender Equity Education Committees in schools and universities. These mechanisms aim to eliminate gender stereotyping, prevent discrimination, and actively encourage students, particularly girls, to pursue fields traditionally dominated by males, including science, technology, engineering, and mathematics (MOE, 2018).

Beyond formal legislation, Chinese Taipei advances gender equity in STEM through targeted regional and international initiatives, such as the APEC STEM-PLUS Scientific Literacy Workshops and entrepreneurship programs that specifically engage girls and young women. These initiatives emphasize applied STEM learning, leadership development, and innovation, while also addressing gender gaps in participation by creating supportive environments for female learners. Such programs reinforce the role of international cooperation

in promoting inclusive STEM education and expanding opportunities for women in science- and technology-related careers (APEC, 2020).

Despite these efforts, challenges persist. A report by the Industrial Development Bureau (2021) indicates that female students remain underrepresented in several STEM disciplines, particularly in engineering, information technology, and advanced manufacturing. In response, the Ministry of Science and Technology (MOST) launched the Gender in Science and Technology Program, which focuses on early intervention and sustained engagement of girls in STEM. This program supports a wide range of activities—including science camps, hands-on workshops, mentoring sessions, and career talks—for K to 12 students, with the goal of sparking interest, building confidence, and strengthening girls' STEM identity at an early age (Industrial Development Bureau, 2021; MOST, 2021).

Collectively, these demonstrate Chinese Taipei's recognition that broadening participation in STEM is essential to talent sustainability and innovation capacity. While legislative support and targeted programs have laid a strong foundation, continued efforts are needed to address persistent gender disparities, particularly in higher education and STEM workforce transitions, to ensure that women are fully represented in the economy's future STEM talent pool.

11. Thailand

Pimonpan CHANTARAPIMON, National Science Museum, Thailand

Summary: STEM education has become a strategic priority in Thailand's development agenda as the economy seeks to strengthen human capital, enhance innovation capacity, and remain competitive in a rapidly evolving global economy. Domestic policies, particularly under the Thirteenth National Economic and Social Development Plan (2023–2027), emphasize STEM skills, digital transformation, and workforce readiness aligned with future labor market demands. Government agencies and educational institutions have advanced curriculum reform, teacher professional development, and student enrichment initiatives across formal and informal learning systems. However, persistent challenges, including teacher shortages, regional inequities, and exam-oriented pedagogical constraints, continue to limit effective implementation. This policy context underscores the need for coherent, evidence-based approaches to strengthening STEM education as a foundation for inclusive and sustainable development in Thailand.

11-1 Strategy and Vision

Thailand's current domestic strategy for STEM education centers on strengthening human capital and fostering innovation to support economic transformation and competitiveness in the 21st century. Recognizing the strategic importance of STEM, the government has integrated STEM objectives into key policy frameworks—most notably the Thirteenth National Economic and Social Development Plan (2023–2027)—which emphasize digital literacy, problem-solving skills, and alignment with evolving labor market demands. Education reforms led by the Ministry of Education and the Ministry of Higher Education, Science, Research, and Innovation aim to enhance the quality and relevance of STEM learning across formal, informal, and non-formal systems through curriculum enhancement, teacher development, and cross-sector partnerships. Initiatives such as experiential science projects in rural schools and the establishment of futuristic learning centers exemplify efforts to broaden access and foster learner engagement. However, persistent challenges such as regional disparities, teacher capacity, and the need for greater integration of inquiry-based and interdisciplinary pedagogies continue to shape implementation. Thailand's vision remains focused on developing an inclusive, resilient STEM ecosystem that prepares learners for global challenges and contributes to domestic innovation goals.

11-2. Key STEM Education Programs

a. STEM Educational Programs and Initiatives

STEM education has been widely recognized as a structural foundation for human capital development in the twenty-first century, particularly in the context of knowledge-based economies, digital transformation, and global sustainability challenges. In Thailand, the domestic strategy and vision for STEM education in 2025 reflect a concerted effort to elevate the education system to respond effectively to rapid economic, technological, and social changes by embedding STEM education within the economy's broader strategic development agenda (NESDC, 2022).

At the macro-policy level, STEM education has been positioned as a key mechanism for domestic development under Thailand's 13th National Economic and Social Development Plan (2023–2027), which emphasizes enhancing domestic competitiveness through innovation-driven growth, productivity enhancement, and structural economic resilience (NESDC, 2022).

Within this framework, STEM is no longer viewed merely as a cluster of academic disciplines, but rather as an integrated system for competency development, linking education, research, technological advancement, and targeted industrial sectors. Particular emphasis is placed on strategic fields such as artificial intelligence, electric vehicles, semiconductors, advanced electronics, and modern medical industries, all of which are critical to Thailand's long-term economic transformation.

From an educational system perspective, Thailand's STEM strategy in 2025 signals a paradigm shift from content-heavy, rote-learning approaches toward competency-based and interdisciplinary learning models. This transition aligns closely with the OECD Learning Compass 2030, which underscores learners' capacities to create new value, manage complexity, and engage constructively in society (OECD, 2020). Domestic initiatives such as the Ministry of Education's "Learning Well, Living Happily" policy and the 2025 annual operational plans reflect these principles through curriculum reform, the reduction of non-instructional teacher workload, and the purposeful integration of digital technologies into teaching and learning processes (Ministry of Education, 2024).

Teacher and educator development is identified as a critical systemic factor underpinning the success of Thailand's STEM education agenda. Continuous professional development, enhancement of pedagogical competencies in integrated STEM instruction, and the promotion of Professional Learning Communities (PLCs) are central to current policy directions. These priorities are consistent with OECD findings highlighting teacher quality and support systems as decisive variables influencing long-term learning outcomes (OECD, 2021). Nevertheless, persistent structural challenges remain, particularly disparities in teacher capacity, resources, and access to professional development opportunities between urban and rural areas.

Beyond formal education, Thailand places increasing importance on non-formal and informal STEM learning as complementary mechanisms for fostering a science-literate society. The National Science Museum (NSM) plays a strategic role in expanding access to STEM learning for youth, educators, and the general public through interactive exhibitions, mobile outreach programs, digital platforms, and the professional development of science communicators (National Science Museum, 2024). Such efforts are strongly aligned with UNESCO's framework on lifelong learning and science communication for sustainable development (UNESCO, 2021).

Equity and inclusion constitute integral dimensions of Thailand's STEM strategy in 2025, with explicit linkages to the Sustainable Development Goals (SDGs), particularly SDGs 4 (Quality Education), 5 (Gender Equality), and 8 (Decent Work and Economic Growth). Policy measures increasingly focus on promoting the participation of women and underrepresented groups in STEM fields, narrowing access gaps in learning resources, and strengthening international collaboration through multilateral platforms such as APEC, OECD, and UNESCO (APEC HRDWG, 2023; UNESCO, 2023).

In conclusion, Thailand's strategy and vision for STEM education in 2025 demonstrate a clear commitment to developing an integrated education ecosystem that aligns learning, innovation, and economic development within regional and global policy frameworks. While challenges related to learning quality, equity, and systemic monitoring persist, the strategic direction underscores Thailand's potential to leverage STEM education as a cornerstone for sustainable human capital development and long-term domestic competitiveness.

b. Case Studies of Best Practices

Thai-US Joint Degree Sandbox for STEM Teacher Education

- Lead Agencies: Teachers' Council of Thailand (TCT), SEAMEO STEM ED, NXPO, in collaboration with 7 Thai universities and the University of Illinois Urbana-Champaign / Arizona State University.
- Target Groups & Scope: Undergraduate teachers and recent graduates in science, mathematics, and technology education across the economy; initially piloted in 7 Thai universities.
- Structure & Approach: Joint-degree program between Thai and U.S. institutions, English as the medium of instruction, and the curriculum redesigned for practical, globally aligned pedagogy.
- Outcomes & Indicators: Improved STEM teaching competencies among Thai teachers, professional standards elevated to international benchmarks, and designed as a model for regional scale-up.
- Success Factors: Strong support from MOE, MHESI, and U.S. academic experts, robust international partnership networks, and integration of language and professional skills into the curriculum.
- Scalability: Designed as a pilot program for adoption by additional institutions in Thailand and abroad, and an adaptable team-teaching model for diverse regional contexts
- Policy Recommendations: Expand financial and professional accreditation pathways and integrate international collaboration into Thailand's STEM teacher strategy.

SEA TEP (Southeast Asian Teacher Education Program)

- Lead Agencies: SEAMEO STEM ED in collaboration with IPST, TCT, Chevron, and regional partner organizations.
- Target Groups & Scope: Pre-service and in-service teachers from Thailand and neighboring Southeast Asian economies.
- Structure & Approach: Workshops on core instructional practices (e.g., eliciting student thinking, integrated lesson planning) and hands-on training with teaching templates and models.
- Outcomes & Indicators: Teachers apply new teaching strategies such as student thinking analysis, enhanced practical teaching skills for STEM educators, and pilot programs implemented in 10–12 schools in Thailand.
- Success Factors: Adoption of research from the Core Practices Consortium (USA), regional collaboration and teacher network for knowledge exchange, and ongoing training and mentoring support.
- Scalability: Expandable from Thailand to other SEAMEO member economies and applicable to educators across all levels and regions.
- Policy Recommendations: Establish domestic STEM teacher training standards based on Core Practices, promote a culture of continuous training as a professional norm, and implement quality assessment through PLC (Professional Learning Community) and mentoring systems.

Futurium of the National Science Museum, Thailand

- Lead Agency: National Science Museum, Thailand (NSM).
- Target Groups & Scope: The content is specifically designed for youth aged 13–15. The educational experiences are crafted to be impactful by using simple, clear language and communication.
- Structure & Approach:

- Innovation World Exhibition: An immersive space where visitors explore how innovations in science and technology—from the past to the present—form the foundation of life and work transformation, including envisioning the role of young Thais in the Thailand 4.0 era.
- Job World: Future Careers in Science, Technology, and Innovation: Hands-on exhibitions and workshops simulate future career paths, cultivating a scientific spirit, academic capabilities, and awareness of emerging industries. The area provides youth with experience in future workplaces and helps them envision how they can build a better future in a world reshaped by technological advancement.

- Outcomes & Indicators: Focuses on inspiring and stimulating motivation among youth, enhances technological competencies, and prepares students for future industries through the lens of STEM education frameworks.
- Success Factors: Strong government support and expert collaboration from both public and private sectors, international partner networks, and integration of language and career-related skills within the program.

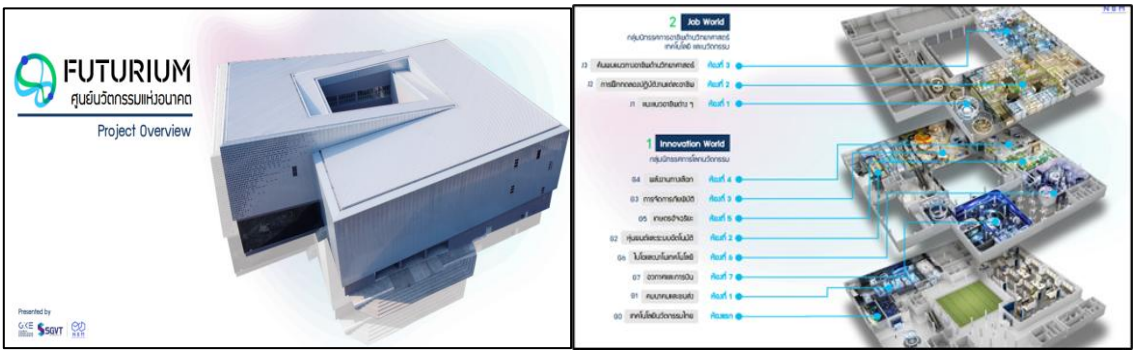


Figure 12. Perspective image of the Futurium of the National Science Museum, Thailand

Science Caravan of the National Science Museum, Thailand

- Lead Agency: National Science Museum, Thailand (NSM).
- Target Groups & Scope: The Science Caravan aims to inspire youth and the general public in regional areas by providing enjoyable science learning experiences. Through engaging exhibitions and hands-on activities, the program promotes scientific, technological, and innovative literacy across diverse demographics.
- Structure & Approach: Operated as a mobile science museum, the Science Caravan comprises the following key components:
  - Mobile Science Exhibitions (Hands-on Exhibits): “Science for Fun” features interactive displays that allow visitors to explore and discover answers through tactile experimentation. Topics include mechanics, mathematics, neuroscience and perception, magnetism and electricity, and logic puzzle games.
  - Science Shows: Live performances that demonstrate everyday scientific concepts in an entertaining, exciting, and informative manner, presented by skilled science communicators.
  - Science Laboratories: Workshops where participants transform into scientists by conducting various experiments, enhancing cognitive processes, and scientific instrument skills.
  - Science Games & Toys: Activities involving the construction, testing, and imaginative use of scientific toys and games, with challenges and rewards to stimulate creativity.

- Mobile Planetarium: A portable dome that allows immersive astronomy experiences, including learning about stars, constellations, spatial orientation, Earth's positioning, and imaginative journeys through space.
- Maker Space: A creative zone for young inventors to develop their ideas and innovations using STEM Education principles. Activities emphasize teamwork, planning, idea-sharing, and collaborative problem-solving.
- Enjoy Science Careers Exhibition: An interactive showcase of STEM careers that allows youth to explore exciting professional paths. Emphasis is placed on core STEM skills essential for innovation and international competitiveness.
- Science Competitions: Competitions aimed at stimulating learning motivation, creativity, scientific awareness, and systematic thinking. They help cultivate essential 21st-century skills and prepare students for future technological industries.
- Teacher Training Workshops: Practical workshops for educators focused on improving science instruction using scientific methods. The training supports the integration of STEM Education principles and promotes the development of effective learning materials to make science education more engaging and enjoyable.

- Outcomes & Indicators: Focuses on inspiring and stimulating motivation among youth, enhances technological competencies, and prepares students for future industries through the lens of STEM education frameworks.
- Success Factors: Strong government support and expert collaboration from both public and private sectors, international partner networks, and integration of language and career-related skills within the program.

c. Talent Development and Scholarship Programs

Talent development and scholarship programs play a pivotal role in Thailand's efforts to strengthen STEM capacity and prepare a future-ready workforce capable of driving innovation and economic competitiveness. In 2025, Thailand's approach to developing STEM talent encompasses both scholarship schemes to expand learning opportunities and platform-based mechanisms to align education with labor market needs, reflecting a comprehensive strategy that integrates access, quality, and relevance

A cornerstone of Thailand's scholarship support for STEM learners in 2025 is the Outstanding Development Opportunity Scholarship (ODOS), enabled by government policy to widen access to education and technology training across the economy. This initiative, supported through a charity lottery funding mechanism approved by the Cabinet, allocates substantial resources to scholarships at various educational levels—including secondary, vocational, and university—specifically in science and technology fields. The ODOS program includes provisions for international study in economies such as Australia; the United States; and the United Kingdom, as well as scholarships for domestic STEM study, with thousands of places designated to expand access and diversify the talent pipeline economy-wide.

Beyond traditional scholarship awards, Thailand is also strengthening its talent development infrastructure through platforms like STEMPlus, which is developed under the Thailand Plus Package framework led by the Office of the National Higher Education, Science, Research and Innovation Policy Council (NXPO) in collaboration with MHESI. STEMPlus functions as a workforce development hub that connects students and job seekers with industry needs, offering skill assessment tools, accredited training courses aligned with future skill sets, and internship and employment placement support. Its integration of certified training offerings and employer matching mechanisms underscores a strategic shift toward demand-driven talent development, bridging the gap between STEM education and industry requirements.

In addition to domestic programs, institutional and organizational scholarship initiatives further contribute to nurturing STEM talent. For example, the National Science and Technology Development Agency (NSTDA) implements targeted programs such as the Junior Science Talent Project (JSTP), which identifies and supports high-potential students through scholarships, mentorship, and professional development from secondary through doctoral education levels. These initiatives not only provide financial assistance but also cultivate research capabilities and scientific leadership among emerging STEM professionals, creating long-term pipelines of talent for both academic and industry sectors.

Higher education institutions in Thailand also play an increasingly significant role in talent development through scholarship offerings that attract top learners globally and locally. While Thailand's policy environment prioritizes STEM fields, many universities extend fully funded scholarships for master's and doctoral studies in science and engineering disciplines. These institutional scholarships complement domestic programs by promoting advanced study, research engagement, and international academic cooperation, further enhancing Thailand's attractiveness as a STEM education hub in Southeast Asia.

Collectively, these scholarship and talent development programs reflect Thailand's multi-pronged strategy to build a competitive and inclusive STEM workforce. By combining broad access scholarships, platform-based workforce alignment, and institution-level support, Thailand seeks not only to expand participation in STEM education but also to ensure that graduates are equipped with the competencies required by evolving technological and economic landscapes. Going forward, continued coordination among government, academia, and industry will be essential to scale these efforts and monitor impact through robust performance indicators.

d. Student Competitions and Events

Student competitions and enrichment events constitute a strategically significant component of Thailand's STEM education ecosystem in 2025, functioning as experiential learning platforms that complement formal schooling while supporting domestic goals in human capital development, innovation, and workforce readiness. Within Thailand's broader STEM policy framework—aligned with the 13th National Economic and Social Development Plan and Thailand 4.0—such activities are increasingly recognized as mechanisms for cultivating higher-order competencies, including problem-solving, creativity, teamwork, and applied technological skills (NESDC, 2022).

Domestic-level agencies play a central role in organizing and coordinating STEM competitions and student-focused events. Key actors include the Ministry of Education (MOE), the Ministry of Higher Education, Science, Research and Innovation (MHESI), the Institute for the Promotion of Teaching Science and Technology (IPST), the National Science and Technology Development Agency (NSTDA), and the National Science Museum (NSM). Together, these institutions support a wide range of domestic and international competitions, science fairs, innovation challenges, and STEM camps that target students across primary, secondary, and tertiary education levels (MHESI, 2024).

Flagship activities include domestic science fairs, robotics and coding competitions, maker and innovation challenges, mathematics and science Olympiads, youth research exhibitions, and interdisciplinary STEM contests linked to real-world problem contexts. Programs such as the Thailand Science Fair, Thailand Robotics Competition, Young Scientist Competition, and STEM Innovation Challenges emphasize inquiry-based learning and hands-on experimentation, exposing students to emerging fields such as artificial intelligence, automation, digital fabrication, renewable energy, and environmental technology. These competitions serve not only as learning experiences but also as talent identification

mechanisms, enabling educators and policymakers to recognize high-potential students and channel them into advanced training, mentorship, and research-oriented pathways (IPST, 2023).

Beyond technical skill development, Thailand's STEM competitions increasingly integrate transversal competencies and innovation mindsets. Many events incorporate teamwork, design thinking, entrepreneurial elements, and presentation skills, reflecting international frameworks promoted by the OECD and UNESCO that emphasize creativity, collaboration, and societal relevance in STEM learning (OECD, 2020; UNESCO, 2021). Students are frequently required to propose solutions to authentic challenges related to sustainability, public health, smart cities, and climate resilience, reinforcing the relevance of STEM knowledge to domestic and global development agendas.

International exposure represents another growing dimension of Thailand's student competitions and events ecosystem. Thai students regularly participate in regional and global competitions such as international science Olympiads, robotics championships, and innovation showcases, often supported by government agencies and public–private partnerships. These opportunities enhance students' global awareness, intercultural communication skills, and familiarity with international standards of excellence, aligning with Thailand's objectives to strengthen global competitiveness and cross-border collaboration under APEC and ASEAN frameworks (APEC HRDWG, 2023).

Nevertheless, challenges persist in ensuring equitable access to STEM competitions and enrichment activities. Participation remains uneven across regions, with students in urban and well-resourced schools benefiting disproportionately from competition-based opportunities. Resource constraints, limited coaching capacity, and disparities in infrastructure continue to affect rural and underserved communities, highlighting the need for more systematic outreach mechanisms such as mobile STEM programs, digital competition platforms, and teacher capacity-building initiatives (MHESI, 2024).

Overall, student competitions and events in Thailand function as critical extensions of classroom-based STEM education, reinforcing inquiry-oriented learning and strengthening the domestic STEM talent pipeline. By integrating experiential learning, innovation challenges, and international engagement, Thailand's approach mirrors best practices observed in advanced STEM ecosystems while reflecting local development priorities. With further investment in equity, scalability, and longitudinal talent tracking, student competitions can play an even more transformative role in sustaining Thailand's STEM capacity and innovation-driven growth in the long term.

e. Teachers' Training

Thailand is placing an increasing strategic emphasis on teacher capacity building as a foundational element of its domestic STEM education agenda, recognizing teachers as key agents in translating policy aspirations into effective classroom practices. In response to rapid technological change, digital transformation, and evolving workforce demands, the Thai education system in 2025 prioritizes the continuous development of STEM teachers' disciplinary expertise, pedagogical innovation, and professional adaptability through a combination of pre-service preparation, in-service professional development, and lifelong learning pathways (Ministry of Education [MOE], 2023).

At the pre-service level, teacher education institutions under the supervision of the Teachers' Council of Thailand (TCT) and the Ministry of Higher Education, Science, Research and Innovation (MHESI) provide foundational training in subject-matter knowledge, educational psychology, curriculum design, and assessment. Recent reforms increasingly incorporate STEM-oriented pedagogies, including inquiry-based learning, project-based instruction, and interdisciplinary integration, with greater attention to digital literacy and

educational technology. These reforms aim to ensure that newly qualified teachers enter the profession with both conceptual understanding of STEM disciplines and readiness to implement integrated STEM curricula aligned with domestic standards (TCT, 2023; MHESI, 2024).

In parallel, Thailand has expanded its in-service professional development system to support practicing teachers in adapting to curricular reform and emerging technologies. The Institute for the Promotion of Teaching Science and Technology (IPST) plays a central role in designing and delivering economy-wide STEM-focused training programs, including workshops, modular courses, and blended learning formats that emphasize STEM integration, engineering design processes, computational thinking, and formative assessment strategies. These programs are aligned with domestic curriculum revisions and aim to support teachers in shifting from content-centered instruction toward learner-centered and problem-oriented pedagogies (IPST, 2023).

Beyond curriculum-based training, experiential and practice-oriented professional development has gained prominence. Agencies such as the National Science and Technology Development Agency (NSTDA) and the National Science Museum (NSM) offer teacher immersion programs, laboratory-based training, and science center–based learning experiences that expose educators to real-world scientific research, innovation processes, and emerging technologies. These initiatives strengthen teachers' ability to contextualize STEM concepts, connect classroom learning with real-world applications, and foster student engagement through authentic learning experiences (NSTDA, 2023; NSM, 2024).

Thailand also promotes collaborative professional learning through mechanisms such as Professional Learning Communities (PLCs), lesson study, and school-based mentoring systems. While implementation varies across regions and school contexts, these collaborative structures are increasingly recognized as critical for sustaining instructional improvement and supporting reflective practice. Through peer collaboration, teachers share instructional strategies, analyze student learning evidence, and collectively refine STEM lesson design, contributing to incremental improvements in teaching quality and coherence across disciplines (OECD, 2019).

Digital transformation constitutes another important dimension of STEM teacher training in Thailand. Domestic policies encourage the use of online platforms, MOOCs, and digital repositories—such as Thai Science Cloud—to support continuous professional development and reduce geographic disparities in access to training. These digital modalities enhance scalability and flexibility, particularly for teachers in rural and underserved areas, though challenges remain regarding digital readiness, instructional support, and sustained pedagogical change (MOE, 2023).

In terms of incentives and professional recognition, Thailand is gradually strengthening mechanisms that link teacher development to career progression and professional standards. While not yet as tightly coupled as in some high-performing systems, ongoing reforms seek to align professional development participation, instructional innovation, and competency-based evaluation with promotion pathways, thereby reinforcing a culture of continuous improvement within the teaching profession (TCT, 2023).

Collectively, Thailand's approach to teachers' training for STEM education in 2025 reflects a system in transition—from fragmented training initiatives toward a more coherent, multi-level capacity-building framework. By strengthening pre-service foundations, expanding in-service professional learning, integrating experiential and digital training models, and promoting collaborative practice, Thailand is progressively enhancing the quality and adaptability of its STEM teaching workforce. Sustained investment, stronger coordination across institutions, and robust monitoring mechanisms will be essential to ensure that teacher training reforms translate into consistent, high-quality STEM learning outcomes and contribute

effectively to domestic innovation and human capital development goals.

f. STEM Facilities and Learning Environments

In 2025, Thailand's STEM education ecosystem is supported by a combination of domestic-level science institutions, school-based innovation spaces, and emerging digital learning environments. Key facilities such as the National Science Museum (NSM) and Thailand Science Park (TSP) play a central role in providing informal and experiential STEM learning, linking scientific knowledge with real-world applications and industry practices. These institutions complement formal education by fostering curiosity, scientific literacy, and awareness of STEM careers.

At the school level, the expansion of maker spaces, innovation labs, and digital STEM classrooms, supported by agencies such as IPST and NSTDA, reflects a policy shift toward inquiry-based and project-based learning. These environments enable students to develop problem-solving, creativity, and technological skills aligned with domestic STEM and innovation strategies. However, disparities in access to modern laboratories and digital infrastructure persist, particularly between urban and rural schools.

Overall, Thailand's STEM facilities and learning environments demonstrate progress toward experiential and future-oriented education, yet continued investment and equitable expansion remain essential to ensure economy-wide access and sustainable STEM capacity development.

g. Student STEM Participation and Pipeline Development

In 2025, Thailand's development of student participation and STEM education pipelines reflects a multifaceted effort involving domestic policy directives, school-level programs, private partnerships, and targeted enrichment activities designed to engage learners across diverse contexts. STEM participation is increasingly emphasized not only in formal curricula but also through experiential learning, competitions, and initiatives that foster sustained interest and progression toward STEM pathways.

A key feature of Thailand's STEM engagement landscape is the proliferation of domestic and regional events that encourage broad participation among students of varying backgrounds. For example, dedicated STEM promotion projects—such as the secondary-school-level STEM promotion program organized in March 2025—provide structured opportunities for students to interact with integrated science and technology learning activities that stimulate curiosity and problem-solving skills, directly contributing to pipeline development from early schooling onward.

Partnerships with international organizations and private sector actors also support expanded access to STEM participation. Collaborative initiatives like the BMW Group and UNICEF program aim to reach tens of thousands of secondary students across rural and urban areas, offering STEM bootcamps, after-school programming, science fairs, and mentorship opportunities that strengthen pathways from basic education into more advanced STEM engagement. Similarly, corporate efforts such as "Women Made: Girl in STEM" target historically underrepresented groups, empowering female students to explore STEM careers and build confidence through hands-on experiences alongside professionals. These activities not only increase participation rates but also help broaden the pipeline by addressing equity issues that influence long-term engagement and retention in STEM fields.

Equally important for pipeline sustainability are structured learning environments and participation contexts. School-based integrated STEM activities and research-oriented projects have been shown to raise both student interest and achievement in STEM disciplines, contributing to deeper engagement and reinforcing the progression of learners into STEM majors and careers. However, domestic assessments and educational research continue to

highlight challenges related to systemic readiness and equitable access, suggesting that expanded participation must be coupled with improved pedagogical support, resource allocation, and curriculum alignment to sustain long-term pipeline development.

Overall, student participation in STEM within Thailand in 2025 reflects a strategic mix of policy-aligned interventions, community engagement efforts, and cross-sector partnerships designed to build a resilient and diverse STEM talent pipeline. Continued emphasis on inclusive programming, enriched experiential opportunities, and evidence-based evaluation will be crucial to strengthening pathways from early learning through higher education and into the workforce.

11-3. Education Effects and Measured Outcomes

In 2025, the effects of STEM education in Thailand are increasingly reflected in both empirical research and large-scale assessment data, providing a nuanced picture of learning outcomes and areas for improvement. Several local studies demonstrate positive impacts of STEM-oriented instructional models on student learning achievement and cognitive skills. Meta-analytic evidence from research conducted from 2016 to 2020 indicates that participation in STEM education significantly improves students' overall learning outcomes and critical thinking skills compared to control groups, suggesting that STEM pedagogies contribute to deeper conceptual understanding and analytical ability.

Targeted classroom interventions further highlight the potential of STEM learning. For example, research applying STEM instructional models with assessment-as-learning approaches shows that students exposed to STEM education frameworks achieve higher competency scores than those in traditional instruction, indicating enhanced mastery of integrated STEM concepts. Similarly, studies focusing on physics and science learning at secondary levels report that STEM instructional methods elevate students' problem-solving abilities and learning outcomes in science subjects when compared to conventional teaching methods.

Despite these positive micro-level effects, domestic and international assessments paint a more complex macro-level picture. Thailand's results in the Programme for International Student Assessment (PISA) 2022 show that Thai students continue to lag behind OECD averages in mathematics and science literacy, with scores substantially below global benchmarks and a small proportion reaching top performance levels. Moreover, socioeconomic and digital divides play a role in shaping observed learning outcomes; recent research reveals that digital inequality—particularly in access and use of technology—diminishes the positive effects of ICT on student learning outcomes once socioeconomic factors are accounted for.

Together, these findings suggest that while STEM education initiatives in Thailand can produce meaningful improvements in individual and classroom-level outcomes, systemic challenges remain that constrain domestic performance on standardized measures and equitable access to high-quality STEM learning. Continued investment in teacher capacity, infrastructure, and inclusive instructional design is essential to translate localized STEM successes into sustainable domestic results.

11-4. Investment and Budgetary Patterns

Sustained public investment constitutes a critical pillar of Thailand's strategy to advance STEM education and develop a future-ready workforce capable of supporting domestic competitiveness, technological upgrading, and innovation-driven growth. In 2025, the Thai government continues to prioritize STEM education within its broader human capital and science, technology, and innovation (STI) agenda, as articulated in the 13th National Economic

and Social Development Plan (2023–2027) and the National Education Plan (2017–2036). These frameworks recognize STEM investment not merely as an educational expenditure, but as a long-term strategic investment essential for economic resilience, industrial transformation, and social inclusion (NESDC, 2023; MOE, 2024).

Public funding for STEM education in Thailand is distributed across multiple ministries and agencies, reflecting a whole-of-government approach. The Ministry of Education (MOE) allocates a substantial share of its annual budget to strengthen science, mathematics, digital literacy, and technology education at the basic education level, with emphasis on curriculum reform, teacher professional development, and digital learning infrastructure (MOE, 2024). In parallel, the Ministry of Higher Education, Science, Research and Innovation (MHESI) channels significant resources toward STEM capacity building in higher education, research universities, and vocational institutions, particularly in priority fields such as artificial intelligence (AI), advanced electronics, biotechnology, clean energy, and medical technology (MHESI, 2024).

A defining feature of Thailand's STEM investment strategy in 2025 is the integration of public funding with private-sector incentives. Through mechanisms such as the Thailand Plus Package, the government offers tax incentives of up to 250 percent for corporate spending on workforce training and 150 percent for hiring STEM-skilled personnel, thereby mobilizing private investment in human capital development (NXPO, 2023). This blended financing model aims to align educational outputs with labor market demand, reduce skills mismatches, and strengthen industry–education linkages in high-growth sectors.

Digital transformation represents another major area of STEM-related investment. Government funding supports the expansion of digital platforms such as Thai Science Cloud, domestic learning management systems, and virtual STEM laboratories, enabling blended and remote learning across schools and regions (NSTDA, 2023). These investments are particularly significant for enhancing system resilience and ensuring continuity of learning, while also supporting the development of data literacy, computational thinking, and digital competencies aligned with global STEM standards.

Equity and regional inclusion are increasingly embedded in Thailand's STEM budget allocations. Targeted funding is directed toward Opportunity Expanded Schools (OES), rural and border-area schools, and informal learning initiatives such as science caravans and mobile laboratories operated by the NSM. These programs aim to reduce geographic and socioeconomic disparities in access to quality STEM learning experiences and to broaden participation among underrepresented groups (NSM, 2024). Complementary investments in teacher training and digital infrastructure further support inclusive STEM education delivery economy-wide.

Overall, Thailand's investment and budgetary approach to STEM education in 2025 reflects a pragmatic and multi-dimensional strategy that balances excellence, relevance, and equity. By combining public expenditure, private-sector incentives, digital innovation, and targeted inclusion measures, Thailand seeks to build a sustainable STEM education ecosystem aligned with domestic development priorities and international frameworks such as APEC, OECD, and UNESCO. While challenges related to funding efficiency and outcome alignment remain, the strategic orientation of Thailand's STEM investments underscores a clear commitment to nurturing a skilled, adaptable, and innovation-oriented STEM workforce for the future.

11-5 Partnerships

Strategic partnerships among government agencies, educational institutions, industry, and international organizations constitute a central pillar of Thailand's STEM education

ecosystem in 2025. Recognizing that no single sector can independently address the complex challenges of workforce development, technological transformation, and innovation-led growth, Thailand has increasingly adopted a multi-stakeholder partnership model to align STEM education with domestic development priorities and global competitiveness agendas (NESDC, 2023; MHESI, 2024).

At the domestic level, inter-ministerial collaboration provides the foundation for STEM partnerships. The Ministry of Education (MOE) and the Ministry of Higher Education, Science, Research and Innovation (MHESI) jointly coordinate policies that link basic education, higher education, research, and workforce development. This coordination is institutionalized through mechanisms such as the National Higher Education, Science, Research and Innovation Policy Council (NXPO), which acts as a policy integrator, ensuring coherence between education reform, innovation policy, and industrial strategies in priority sectors, including artificial intelligence, advanced electronics, biotechnology, and clean energy (NXPO, 2023).

Industry–academia collaboration plays a particularly prominent role in Thailand's STEM partnership landscape. Universities, vocational institutions, and research centers collaborate with domestic and multi-economy companies to co-develop curricula, offer work-integrated learning opportunities, and conduct applied research. Programs supported by MHESI and the private sector facilitate internships, cooperative education, and project-based learning that expose students to real-world technological challenges while enhancing employability and innovation skills (MHESI, 2024). These partnerships are further incentivized through fiscal mechanisms such as the Thailand Plus Package, which encourages private-sector investment in STEM training and talent development through tax deductions and employment incentives (NXPO, 2023).

Public–private partnerships are also evident in informal and non-formal STEM education. The NSM collaborates extensively with industry partners, universities, and international organizations to deliver science caravans, mobile laboratories, exhibitions, and experiential learning activities economy-wide. These initiatives extend STEM learning beyond formal classrooms, particularly to rural and underserved communities, and promote public scientific literacy, innovation awareness, and youth engagement in STEM careers (NSM, 2024). Partnerships with technology firms and energy companies further enhance the relevance and sustainability of these outreach programs.

International and regional cooperation constitutes another critical dimension of Thailand's STEM partnership. Thailand actively engages with multilateral platforms such as APEC, SEAMEO, OECD, and UNESCO to exchange best practices, develop regional capacity-building programs, and align domestic STEM initiatives with international standards. Through APEC-sponsored workshops, policy dialogues, and joint research activities, Thailand contributes to and benefits from regional efforts to strengthen STEM education, teacher professional development, and gender inclusivity (APEC, 2022; OECD, 2019). Collaboration with organizations such as the British Council and participation in initiatives like the Newton Fund further support curriculum innovation, teacher training, and global competency development.

Collectively, these partnerships reflect Thailand's evolving and increasingly integrated approach to STEM education governance. By leveraging cross-sector collaboration, aligning education with labor market and innovation needs, and engaging actively in international cooperation frameworks, Thailand strengthens the effectiveness, relevance, and inclusiveness of its STEM education system. While challenges remain in scaling partnerships uniformly across regions and ensuring long-term sustainability, the strategic emphasis on partnerships in 2025 underscores Thailand's commitment to building a resilient STEM ecosystem capable of supporting sustainable development and global competitiveness.

11-6. Performance Indicators and Monitoring

The development and use of robust performance indicators are essential components of Thailand's strategy for enhancing STEM education outcomes, reflecting a recognition that measurable evidence is needed to guide policy, assess impact, and inform continuous improvement. In 2025, Thailand has advanced its performance measurement framework to encompass a blend of input, process, output, and outcome indicators that align with domestic priorities in human capital development, innovation capacity, equity, and global competitiveness (Ministry of Education [MOE], 2024; OECD, 2023).

Thailand's performance indicators are designed to track system-wide progress across multiple levels and dimensions of STEM education. At the input level, indicators focus on resource allocation and capacity building, including per-student investment in STEM learning, teacher qualification rates in STEM subjects, and the availability of digital infrastructure, laboratories, and instructional technologies in schools and higher education institutions (NESDC, 2023). These inputs are foundational to ensuring learning environments that support 21st-century competencies and provide equitable access to quality STEM education.

Process indicators capture the dynamics of teaching and learning within STEM education. These include measures of instructional practice adoption, such as the proportion of schools implementing inquiry-based STEM curricula, frequency of collaborative and project-based learning activities, and integration of digital tools into classroom instruction (OECD, 2019). Teacher professional development participation rates, reflective practice engagement (e.g., Professional Learning Communities), and industry–education partnership activities also fall under process indicators, offering insights into the extent to which systemic reforms influence day-to-day educational experiences.

Output indicators reflect proximate student performance and engagement outcomes. Thailand employs standardized student assessment results in mathematics and science, such as O-NET and domestic benchmark assessments, to monitor learning achievements at key stages of basic education (OBEC, 2024). Additional outputs include participation rates in STEM competitions, rates of STEM course completion, and enrollment in STEM-related postsecondary programs. These outputs provide critical early signals of system performance and student interest in STEM pathways.

Outcome indicators focus on longer-term results that demonstrate the broader impacts of STEM education reform. Key outcome measures include domestic scores on international large-scale assessments such as the Programme for International Student Assessment (PISA) and Trends in International Mathematics and Science Study (TIMSS), which enable Thailand to benchmark its performance relative to global peers (OECD, 2023). In addition, indicators related to postsecondary STEM degree attainment, workforce entry rates in STEM fields, industry–academia mobility, and innovation outcomes—such as patent activity and participation in research and development—are increasingly incorporated into evaluation frameworks to assess Thailand's contributions to domestic economic and innovation goals.

Thailand's indicator framework also places a strong emphasis on equity and inclusion. Performance measures are disaggregated by gender, socioeconomic status, and geographic region to highlight participation and achievement gaps, particularly among students in rural and underserved areas. Digital access indicators—such as broadband connectivity, availability of devices, and participation in online STEM learning—are monitored to assess progress in bridging the digital divide and ensuring that all learners benefit from STEM advancements (UNESCO Bangkok, 2023).

To support evidence-based policy adjustment, data from these indicators are increasingly synthesized into domestic dashboards and annual policy reports that inform decision-making at multiple governance levels. This integration supports a feedback loop

between performance evidence and strategic planning, enabling Thailand to respond adaptively to both internal challenges and external benchmarks. While challenges remain—such as ensuring data quality, longitudinal tracking, and alignment across multiple data systems—the expanded set of performance indicators represents a significant advancement in Thailand's capacity to monitor and improve STEM education systematically.

11-7. Gender Inclusivity and Equity

Thailand's strategy for gender inclusivity and equity in STEM education in 2025 reflects a growing recognition of the crucial role that equitable participation plays in building a resilient and innovative workforce. While Thailand has achieved relatively higher female participation in some STEM-related domains compared to global averages, persistent gender imbalances remain in specific fields such as engineering, information and communication technology (ICT), and advanced manufacturing, necessitating targeted policy interventions and systemic equity measures (supply-side data suggest wider male dominance in technical STEM majors).

At the institutional level, several initiatives have emerged to address gender disparities in STEM education. Universities such as Walailak University have undertaken proactive gender equity policies that include diagnostic tracking of female student applications, acceptance rates, and graduation outcomes—especially in traditionally male-dominated fields like engineering and technology—alongside targeted outreach and partnerships with secondary schools to raise awareness and participation among girls and young women. Such measures also include scholarships and financial support tailored to female students, which are designed to mitigate economic barriers and encourage sustained participation in STEM pathways.

Complementing these efforts, equity frameworks in higher education institutions such as Mahidol University emphasize fairness, non-discrimination, and inclusive environments that support all genders equally in academic and professional development contexts. These institutional policies extend to anti-harassment protocols and awareness-raising initiatives aimed at dismantling systemic barriers within campus cultures that may unconsciously disadvantage women and other underrepresented groups.

At the domestic policy level, broader educational equity agendas led by multi-sector bodies such as the Equitable Education Fund (EEF) and policy dialogues aligned with Sustainable Development Goal 5 (Gender Equality) contribute to framing inclusion across all levels of education, including STEM. These domestic discussions highlight the importance of flexible learning pathways and outreach strategies that ensure girls and young women remain engaged in education and do not exit prematurely due to socioeconomic or cultural constraints, which disproportionately affect female learners.

Thailand also engages with regional and international frameworks to strengthen gender-inclusive practices in STEM education. Collaborative projects supported by organizations such as the British Council and SEAMEO focus on leadership with gender equity, diversity, and inclusivity, fostering networks and shared practices across institutions in Southeast Asia that aim to elevate the status and representation of women in science and technology fields while actively supporting SDG 4 (Quality Education), SDG 5 (Gender Equality), and SDG 17 (Partnerships).

Despite these developments, challenges in fully realizing gender equity in STEM persist. Structural and cultural norms that influence educational choices remain influential in early stages of schooling, and the transition from secondary to tertiary STEM programs continues to show gender segmentation in technical disciplines. Furthermore, limited longitudinal data and systematic tracking of gender-disaggregated outcomes in key performance indicators complicate efforts to evaluate the effectiveness of equity initiatives and

to tailor interventions based on evidence. Addressing these gaps requires enhanced data systems, stronger institutional accountability frameworks, and sustained collaboration between government, academia, civil society, and industry to ensure that equity strategies translate into meaningful and measurable outcomes across all stages of STEM education.

Overall, gender inclusivity and equity measures in Thailand's 2025 STEM education landscape demonstrate a multifaceted approach that integrates institutional policy reforms, targeted programs, domestic advocacy, and international collaboration. While progress is evident, deepening and scaling these measures through evidence-based policy design and implementation remains essential for ensuring that STEM education systems support equitable participation and enable all learners—including girls and women—to contribute fully to Thailand's innovation-driven future.

11-8. Key Challenges and Distinctive Features

Despite Thailand's articulated policy commitment to strengthening STEM education within its broader human capital and innovation agendas, significant challenges and implementation barriers persist in 2025, hindering the effective translation of policy into sustained educational transformation. These challenges span structural, institutional, and socio-cultural dimensions, and require coordinated multi-level responses to ensure that STEM education reforms achieve intended outcomes.

One of the most persistent barriers to effective STEM implementation in Thailand is the inadequate capacity and preparation of teachers. Research indicates that many science and mathematics teachers report limited training in integrated STEM pedagogies, a lack of confidence in implementing inquiry-based instruction, and insufficient institutional support for professional learning (Boonying et al., 2025). These gaps in professional development exacerbate difficulties in classroom practice, particularly when teachers are expected to deliver cross-disciplinary and student-centered learning experiences without adequate preparation.

Another structural challenge is the inconsistency between curriculum aspirations and classroom practices. Document analysis and teacher interviews have pointed to ambiguity in the operational definition of STEM education across schools and regional education centers, which undermines coherence in implementation (Khogkhao et al., 2025). This inconsistency often translates into a fragmented approach where STEM subjects remain siloed rather than integrated, impeding efforts to cultivate holistic problem-solving and innovation skills.

Resource constraints constitute a further major barrier, particularly in schools located in rural and underserved areas. Uneven access to instructional materials, laboratory facilities, digital infrastructure, and up-to-date technology disproportionately affects disadvantaged regions, creating inequitable learning environments that impede the full realization of STEM opportunities (ERIC report; Sangnapaboworn, 2018; Yangkeaw & Siputta, 2023). In many contexts, teachers struggle to implement active learning pedagogies without adequate physical and digital resources, further widening gaps between urban and rural schools.

The broader socioeconomic and systemic disparities embedded within Thailand's education system also complicate STEM reform. Socioeconomic inequities shape access to quality learning experiences, career guidance, and pathways into STEM tertiary education and careers, leading to a misalignment between student aspirations and labor market needs (OECD, 2019; OECD Skills Strategy Thailand report). For example, career counseling services remain limited in poorer and remote schools, reducing students' awareness of STEM opportunities and contributing to uneven participation in advanced STEM pathways.

Cultural and pedagogical traditions also present challenges. Deeply rooted practices of rote learning and teacher-centered instruction often conflict with the inquiry-based, hands-on learning approaches advocated by STEM policies (Nascimento et al.; JEIM research on

education reform). Teachers, students, and even parents may default to traditional modes of instruction that prioritize content memorization over critical thinking and problem-solving, limiting students' engagement with authentic STEM tasks.

At the system level, gaps in institutional coordination and policy coherence hinder implementation. While multiple agencies are responsible for aspects of STEM education, overlapping mandates and limited mechanisms for integrated monitoring and evaluation contribute to fragmented efforts and inconsistent accountability. This governance challenge exacerbates difficulties in sustaining long-term reform momentum and scaling successful practices across regions.

Collectively, these barriers—encompassing teacher capacity, resource inequities, curricular coherence, sociocultural norms, and governance fragmentation—highlight the complexity of transforming Thailand's STEM education landscape. Addressing these challenges requires a multi-dimensional strategy that aligns professional development with classroom needs, invests equitably in infrastructure, strengthens policy coordination, and supports cultural shifts toward student-centered learning and innovation.

12. United States

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Summary: The United States approaches STEM education through a federal system of shared authority, in which the federal government provides strategic coordination, investment priorities, and evidence frameworks, while states and local education agencies retain primary responsibility for curriculum standards, instructional design, and implementation. Rather than pursuing a single domestic STEM curriculum, the United States has developed a policy ecosystem that links education, research, workforce development, and equity through coordinated but decentralized action. This governance structure has enabled substantial innovation and regional diversity, while also generating persistent challenges related to equity, coherence, and continuity across the STEM pipeline. As a result, STEM education in the United States is best understood not as a unified program, but as a multi-level, partnership-driven strategy spanning early learning, K–12 education, postsecondary pathways, workforce entry, and lifelong upskilling.

12-1. Strategy and Vision

At the federal level, the primary organizing framework for STEM education policy is provided by the Committee on STEM Education (CoSTEM) under the National Science and Technology Council. Rather than functioning as an implementing authority, CoSTEM serves as a strategic coordination body, aligning priorities and actions across federal agencies involved in education, science, labor, defense, health, and energy.

The 2024 CoSTEM Annual Report articulates a domestic vision that frames STEM education as a continuum of talent development, extending from early childhood through K–12 education, postsecondary learning, workforce participation, and lifelong learning. Within this vision, STEM education is positioned as essential to:

- economic competitiveness and innovation,
- domestic security and technological leadership, and
- social mobility and inclusive opportunity.



Figure 13. Framework of the United States Federal Strategic Plan for Advancing STEM Education and Cultivating STEM Talent (Committee on STEM Education, CoSTEM). https://www.stem.gov

Federal STEM policy does not prescribe curriculum or pedagogy. Instead, CoSTEM advances three cross-cutting principles—access and opportunity; partnerships and ecosystem development; and transparency and accountability—to guide coordinated action across agencies and sectors. In this framework, STEM success is defined not only by academic achievement, but by whether learners can enter, persist, and thrive across successive stages of the STEM pipeline.

STEAM, in the United States context, is not articulated as a domestic policy category. Arts-integrated and interdisciplinary approaches are implemented primarily at the state, district, and school levels, often through project-based learning, design thinking, maker education, and creativity-oriented STEM instruction. These approaches are commonly used to broaden participation, enhance engagement, and connect STEM learning to human-centered and real-world problem solving, particularly for learners historically underrepresented in STEM fields.

12-2. Overview of Key STEM and STEAM Education Programs and Initiatives

a. STEM Education Programs and Initiatives

Federal Coordination: STEM as an Ecosystem

Federal STEM education efforts in the United States are intentionally distributed across multiple agencies, with CoSTEM providing coordination rather than direct program delivery. This structure reflects a core policy assumption: challenges such as participation, persistence, and workforce transitions cannot be addressed by any single institution or sector.

Accordingly, partnerships among schools, higher education institutions, research organizations, industry, non-profit organizations, community groups, and families are treated as structural features of the STEM system rather than optional enhancements. Federal policy therefore prioritizes ecosystem coherence and evidence alignment, rather than uniform domestic programs.

Why Vermont as a State-Level STEAM Case

Within this federal coordination framework, states play a decisive role in translating STEM and STEAM priorities into concrete educational practice. Vermont is highlighted in this report not because it is representative of all states in the United States, but because it offers a conceptually explicit and policy-coherent example of how STEAM can be operationalized at the state level.

The Vermont STEAM Education: Essential Elements and Strategy Guidelines (2025) define STEAM not as a replacement for disciplinary STEM learning, but as an integrative approach designed to broaden participation and deepen understanding. STEAM is framed as student-centered, inquiry-driven learning that intentionally integrates science, technology, engineering, arts, and mathematics to address authentic and locally relevant problems.

A distinctive feature of Vermont's approach is the Program Architecture Tool, which

supports schools and districts in designing, evaluating, and refining STEAM initiatives across five dimensions:

- vision and purpose,
- access and equity,
- school culture and sustainability,
- instructional design, and
- assessment practices.

Rather than promoting a single model, Vermont conceptualizes STEAM implementation as a developmental continuum, encouraging schools to identify their current stage of practice and plan realistic, context-sensitive next steps. This approach reduces the risk of symbolic or superficial integration and aligns well with the broader United States emphasis on local adaptation within shared strategic principles.

Education Recovery as a STEM Enabler

The Vermont ARP ESSER State Plan (2023) illustrates how STEM capacity in the United States is often shaped indirectly through broader education system investments. Although not a STEM-specific policy, the plan prioritizes academic recovery, student engagement, and mental health and social-emotional learning—conditions that strongly influence the effectiveness of STEM instruction.

This example highlights a defining feature of the U.S. approach: STEM outcomes depend not only on curriculum and content reforms, but also on the learning environments and support systems that enable students to engage meaningfully with rigorous STEM learning.

Expansion of Computer Science in K–12

A prominent recent development in the United States STEM pipeline is the rapid expansion of computer science education, particularly at the secondary level. According to College Board data (2024):

- 175,261 students took the AP Computer Science Principles exam (34% female),
- 98,136 students took the AP Computer Science A exam (26% female), and
- approximately 51% of United States high schools offered foundational computer science courses.

These data indicate substantial growth in access to advanced computer science learning, while also revealing persistent gender disparities at higher levels of specialization.

b. Talent Development and Scholarship Programs

Talent development in the United States is supported through a federally coordinated but institutionally distributed system of scholarships, fellowships, research experiences, and workforce-linked training programs. Rather than operating a single domestic STEM talent pipeline, the United States advances talent development through multiple, overlapping pathways spanning secondary education, postsecondary study, research training, and early career stages.

A defining feature of the United States model is the central role of federal research

agencies—including the National Science Foundation, National Institutes of Health, Department of Energy, and Department of Defense—as anchors of talent development. These agencies support undergraduate research experiences, graduate fellowships, early-career awards, and mission-oriented training programs linked to domestic priorities.

Importantly, many federal funding mechanisms incorporate broader impacts criteria, requiring attention to education, mentoring, outreach, and societal relevance. As a result, talent development is framed not only as individual advancement, but as a contribution to the inclusiveness and resilience of the STEM ecosystem.

Equity is embedded directly into United States talent development policy. Programs targeting women, first-generation students, low-income learners, and racial and ethnic minorities emphasize early exposure, sustained mentoring, and support at key transition points. In this model, equity is treated as a talent optimization strategy, recognizing that domestic STEM capacity depends on widening and sustaining the pool of learners who can persist and succeed.

c. Teachers' Capacity Building

Teacher capacity building in the United States is characterized by decentralized, partnership-based professional learning, rather than a single domestic training system. States, districts, universities, non-profit organizations, and industry partners play central roles, while federal policy supports this work indirectly through funding, coordination, and evidence-building.

Across contexts, STEM professional learning emphasizes:

- project-based and inquiry-oriented instruction,
- design thinking and problem-based learning,
- culturally responsive pedagogy, and
- career-connected learning linked to local contexts.

State-level STEAM initiatives such as Vermont's provide concrete illustrations of this approach, framing teacher capacity as instructional design competence rather than compliance with prescribed models. Teachers are positioned as designers of interdisciplinary learning experiences, with professional learning embedded in collaborative planning and continuous refinement.

d. STEM Facilities and Learning Environments

In the United States, STEM learning environments are increasingly defined in holistic terms that extend beyond physical laboratories and equipment. Federal policy emphasizes that effective STEM environments must also support psychological safety, inclusion, and a sense of belonging, recognizing these as essential conditions for persistence in STEM pathways.

CoSTEM explicitly identifies inclusive and supportive environments as foundational across the STEM continuum—from classrooms and laboratories to higher education and workplaces—reflecting evidence that exclusionary climates contribute to attrition, particularly among women and historically underrepresented groups. The United States approach underscores a key policy insight: STEM facilities and learning environments function not only

as sites of instruction, but as critical determinants of who enters, persists, and succeeds in STEM pathways.

e. Student STEM Participation and Pipeline Development

Student participation in United States STEM education spans core K–12 instruction, advanced coursework, out-of-school programs, and community-based STEAM initiatives. While access has expanded, a central policy concern remains pipeline leakage at key transition points, particularly from secondary to postsecondary education and from education to the workforce.

Workforce data illustrate these challenges. According to NSF/NCSES (2024), approximately 24% of the United States workforce is employed in STEM occupations. Women account for about 35% of the STEM workforce, yet only 18% of employed women work in STEM occupations, compared with 30% of men. These patterns indicate cumulative attrition shaped by educational transitions, institutional supports, and workplace environments.

12-3. Education Effects and Measured Outcomes

Domestic assessment data reveal persistent challenges in foundational STEM learning. NAEP Long-Term Trend results show declines in mathematics performance among 13-year-olds between 2020 and 2023, with larger declines among lower-performing students. These trends suggest that STEM expansion efforts are unfolding amid weakened foundational skills and widening disparities.

At the same time, participation in emerging fields such as computer science has expanded, though inequities remain at advanced levels. Workforce data further indicate that increased educational participation does not automatically translate into proportional employment outcomes, underscoring the importance of retention, transitions, and inclusive environments.

12-4. Investment and Budgetary Patterns

Federal STEM investment in the United States is distributed across multiple agencies and funding streams, rather than consolidated into a single budget line. Post-pandemic recovery funding, particularly through ARP ESSER, has played an important indirect role by strengthening learning conditions—academic recovery, student engagement, and mental health—that shape STEM outcomes.

This pattern reflects a core United States policy assumption: STEM performance is inseparable from overall education system health.

12-5. Partnerships

Partnerships are a foundational mechanism of United States STEM strategy. CoSTEM explicitly frames families, communities, schools, higher education institutions, industry, non-profit organizations, and government agencies as co-producers of STEM talent. State-level STEAM strategies, such as Vermont’s, operationalize this principle through career-connected

learning, community partnerships, and culturally responsive approaches.

12-6. Performance Indicators and Monitoring

United States STEM performance is monitored through multi-layered indicators, including:

- domestic achievement measures (NAEP),
- participation in advanced coursework,
- workforce representation and equity statistics, and
- environmental indicators related to safety and inclusion.

This reflects recognition that no single metric can capture STEM system performance within a decentralized ecosystem.

12-7. Gender Inclusivity and Equity

Equity is an explicit, cross-cutting priority in United States STEM policy. CoSTEM coordinates interagency efforts that emphasize inclusive participation and safe environments, recognizing that representation gaps reflect structural and cultural barriers as well as preparation differences. Despite gains in access, gender equity in advanced study and STEM employment remains incomplete, reinforcing the need for sustained attention to transitions and workplace conditions.

12-8. Key Challenges

Despite sustained policy attention, the United States continues to face:

- uneven and declining foundational achievement in mathematics and science;
- pipeline leakage at key transition points;
- persistent gender and racial disparities in advanced study and STEM careers; and
- coordination and data challenges inherent in a decentralized system.

Addressing these challenges will require integrated strategies that strengthen foundational learning, support transitions, improve inclusivity, and enhance coordination and evidence use across levels of governance.

Acknowledgements

Science, technology, engineering, mathematics (STEM) education and the cultivation of youth potential have become increasingly central to the APEC region's shared agenda for inclusive growth, resilience, and innovation. Across APEC economies, young people are expected not only to acquire foundational scientific and mathematical literacy but also to apply STEM knowledge to complex, real-world challenges that transcend domestic borders. Such challenges include climate change mitigation and adaptation, the energy transition, disaster risk reduction, food and water security, emerging infectious diseases, the rapid diffusion of artificial intelligence, and advanced manufacturing. In each of these fields, the capacity to generate evidence, interpret data, design solutions, and collaborate across disciplines is closely linked to economic competitiveness and social wellbeing. At the same time, APEC economies are increasingly recognising that broadening participation in STEM and ensuring equity must go hand in hand with the systematic development of highly capable and motivated learners – students whose advanced interests and talents, when appropriately supported, can meaningfully contribute to scientific progress and generate public value.

It is in this context that this APEC Report on STEM Capacity Building was prepared. This report represents a collective effort to identify concrete policies, institutional mechanisms, and practice-based models that strengthen STEM capacity from the school level to the wider ecosystem of universities, research institutes, industry partners, and community organisations. We believe that the most meaningful progress in STEM capacity building emerges when economies learn from one another's approaches while carefully adapting them to local contexts, whether cultural, institutional, or socioeconomic. The collaborative process behind this report was designed to embody that principle: an evidence-driven synthesis rooted in economy-specific realities, enriched through dialogue and oriented toward actionable insights.

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In addition, this report includes a dedicated section of Selected Cases (Presentation Slides) to capture practice-rich materials, as presented in their original slide format. We express our sincere appreciation to Dr. Yong ZHANG (Chair of the Department of Robotics Engineering, Zhejiang University of Science and Technology, China), who prepared the case for China, and to Dr. Anh Tuan NGUYEN (Acting Head of the Department of Science and Technology, University of Economics - Technology for Industries (UNETI), Ministry of Industry and Trade, Viet Nam), who prepared the case for Viet Nam. By retaining the presentation format, these cases preserve the specificity and immediacy of the original

communications, offering readers concrete examples of approaches, programmes, and enabling conditions.

We also acknowledge the significance of the field-informed learning process that underpins this report. Following the easing of COVID-19 restrictions, our team was finally able to initiate in-person collaboration and convene in the Republic of Korea for the Best Practice Workshop on Youth STEM Capacity Building, alongside study visits to leading institutions supporting talented youth in STEM, including the Korea Science Academy of KAIST and KAIST. These engagements provided valuable opportunities to observe institutional design, learner support systems, and research-practice linkages while enabling candid discussions on implementation challenges and transferability across contexts. Importantly, our collaboration did not end with the workshop. After returning to our respective economies, we continued our exchanges online, maintaining regular dialogue to share updates, verify emerging information, and refine the report's framework. We are honoured that this sustained process enabled us to consolidate timely insights and concrete practical examples into a coherent report.

At the same time, we would like to note a key limitation of this study. As this project started in earnest only after the pandemic subsided, we were unable to conduct economy-wide interviews and large-scale questionnaire surveys with STEM education stakeholders to the extent originally envisioned. While we have sought to ensure accuracy through careful sourcing and expert review, further empirical data collection, especially through systematic interviews, surveys, and longitudinal follow-ups, would strengthen the evidentiary base for cross-economy comparisons. Therefore, we view the present report not as an endpoint, but as a foundation. To support the sustained promotion of high-quality STEM education across APEC economies, we hope to continue fostering collaborative investigation and analysis and develop subsequent reports that deepen the empirical grounding and expand the comparative scope.

We also recognise that although this report primarily contains information related to primary and secondary education, STEM education is inherently a lifespan endeavour spanning early childhood through adulthood. Many APEC economies have advanced initiatives at the upper-secondary and higher-education levels, such as specialised STEM high schools, research internships, industry-university partnerships, and talent pipelines into emerging fields, that merit closer examination. Future work should therefore incorporate a broader developmental perspective, capturing how STEM learning pathways are designed and supported across transitions and how policies align across educational stages and sectors.

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We hope this report will serve as a practical reference for policymakers, educators, researchers, and stakeholders across APEC economies. More importantly, we hope it will contribute to the creation of learning environments and innovation ecosystems in which learners with diverse backgrounds, interests, and talents can thrive, and in which STEM

capacity building becomes a shared pathway toward sustainable and inclusive futures.

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