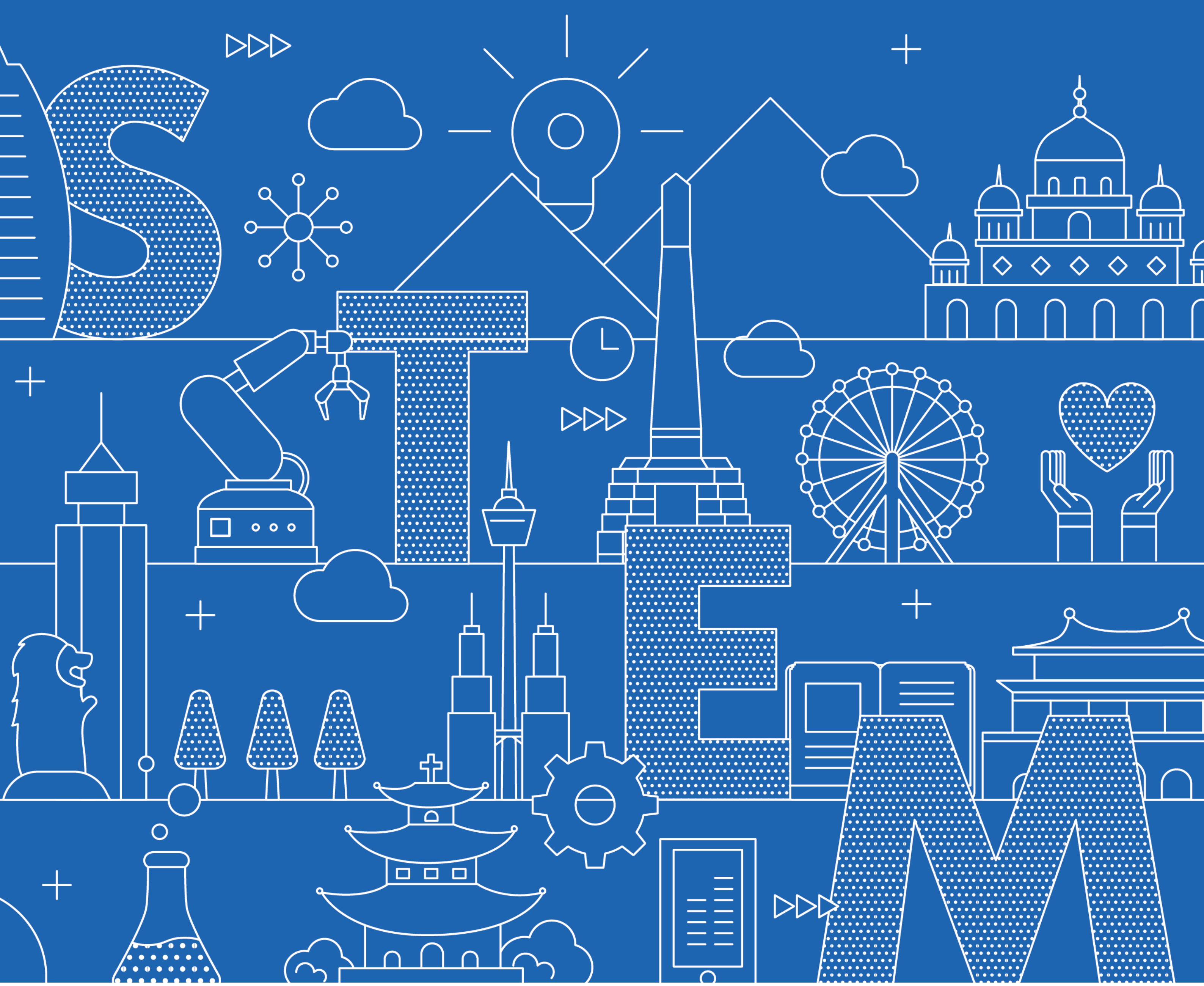

EXECUTIVE REPORT ON ENVISIONING STEM EDUCATION IN ASIA SEMINAR

STEM Leaders Programme in Asia

STEM @ NIE SINGAPORE
NIE NATIONAL INSTITUTE OF EDUCATION SINGAPORE
An Institute of
NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE
Supported by
TEMASEK FOUNDATION

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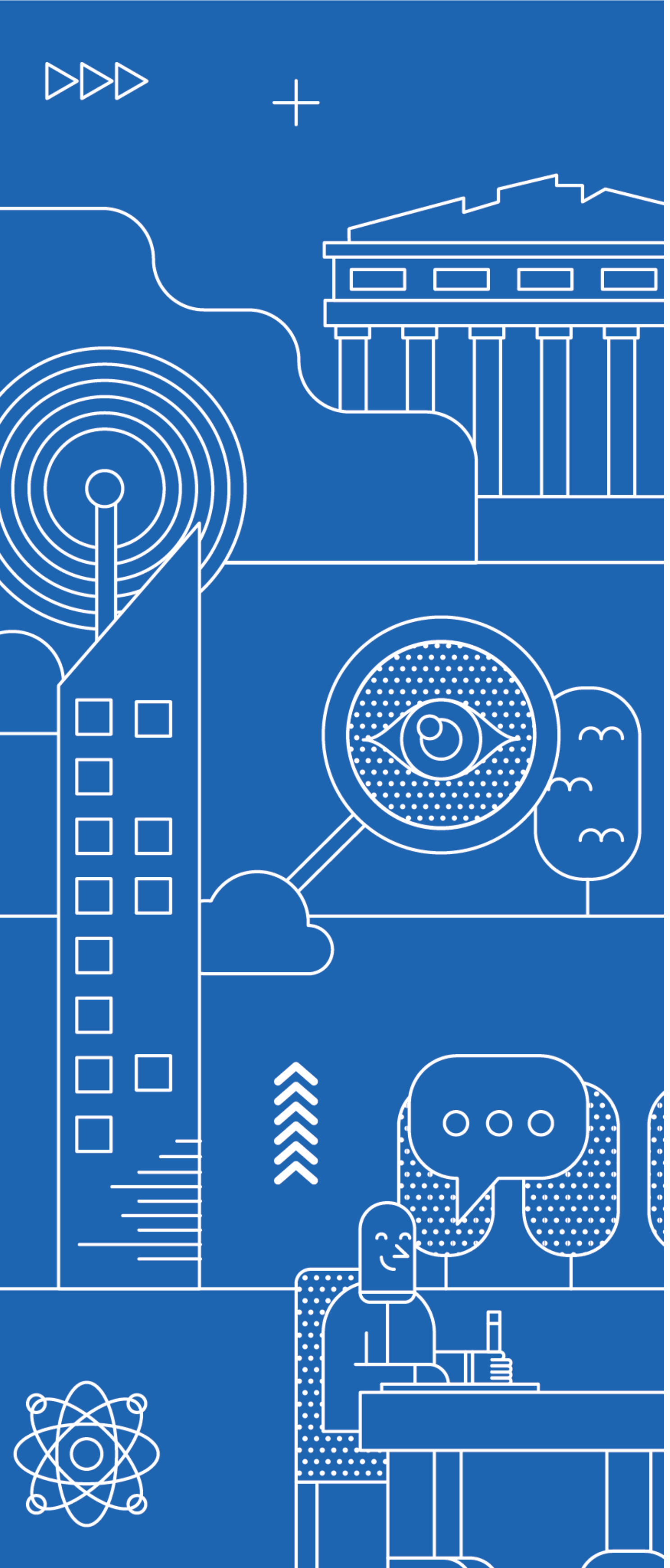
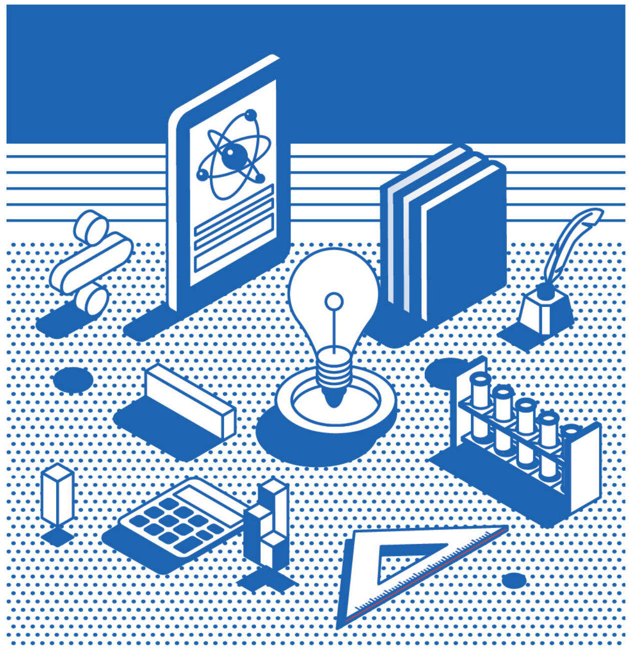




FRONT MATTERS

This executive report is an outcome of the collective effort of delegates and invited keynote speakers and panel members who participated in the three-day virtual seminar—**Envisioning STEM Education in Asia (27 to 29 July, 2021)**— organised by the Multi-centric Education, Research and Industry STEM Centre at the National Institute of Education (meriSTEM@NIE), Nanyang Technological University, Singapore, and supported by Temasek Foundation as the first seminar of the **STEM Leaders Programme in Asia**.

The COVID-19 pandemic has highlighted the urgency for STEM (science, technology, engineering, mathematics) education to develop students' 21st century competencies necessary for thriving in a vulnerable, uncertain, complex, and ambiguous (VUCA) world amidst the backdrop of the fourth Industrial Revolution (4IR). To initiate discussions of how STEM education can develop these competencies in pre-tertiary school students, the seminar brought together STEM industry experts and STEM education leaders in Asia to co-construct a vision of STEM education. The keynote speakers and STEM industry experts provided accounts of valued STEM expertise and competencies in STEM industries. The STEM education experts—comprising education policy makers, leaders from intergovernmental education organisations, and academics from institutes of higher learning—shared insights on current and forthcoming STEM education policies and curricula in Asian economies.

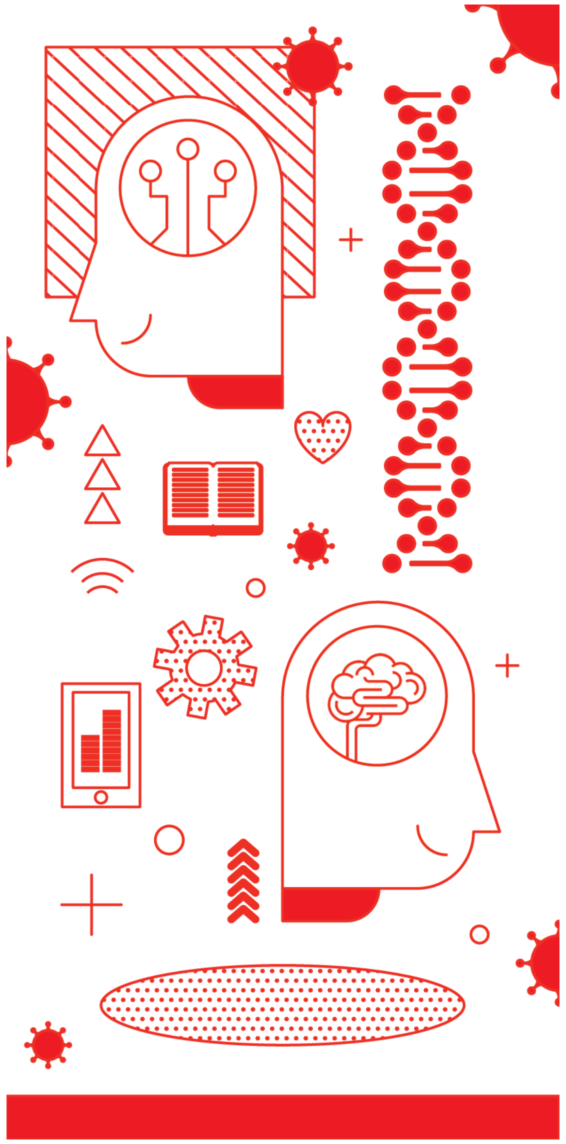
A highlight of this report is the **STEM Competencies Framework for post-COVID Asian Economies (pp. 17 to 21)**, which has been co-constructed from the collective wisdom shared by our delegates and invited experts at the **Envisioning STEM Education in Asia seminar**. In addition, this report summarises the essential ideas that emerged from various discussions throughout the seminar. We hope that readers of this report—whether you had attended our seminar or not—will find the report useful in helping you (re) conceptualise STEM education in your local context to support pre-tertiary students in achieving the necessary STEM competencies to thrive in the 21st century.

STEM Leadership in Asia Programme Organising Committee

meriSTEM@NIE
National Institute of Education (NIE)
Nanyang Technological University, Singapore

01

THE CURRENT STATE OF STEM EDUCATION IN ASIA



Throughout the pandemic, we have seen numerous innovations and attempts to establish continuity in education — and these were highlighted throughout the course of a three-day conference on STEM Education in Asia.

Nanyang Technological University (NTU) President Subra Suresh opened the conference by sharing insights on the opportunities and challenges within the context of STEM education in the Asian region. He highlighted the rapid pace of technological adoption throughout the last century and emphasised how digital transformations have accompanied not just the thrust of 4IR, but that of the COVID-19 pandemic as well.

He specified 12 disruptive technologies — mobile internet, cloud technologies, advanced materials, next-generation genomics, advanced robotics, automation of knowledge work, energy storage, advanced oil and gas exploration and recovery, autonomous vehicles, internet of things, 3d printing, and renewable energy — and brought attention to how they open up avenues for training an automation-ready workforce, but also pose a potential threat to the preservation of human core values, as machine-generated decisions could significantly alter humans' behaviour and way of life.

With many countries in Asia rapidly developing, there is a unique avenue to adopt technologies in a manner that enables large numbers of people across countries and borders to obtain an education that could not have been possible even a few decades ago. Now more than ever, it is evident that STEM education in Asia is indeed in a strong position to tap into the many opportunities that digital technologies will provide that we can benefit from.

Current policies and initiatives of Asian economies

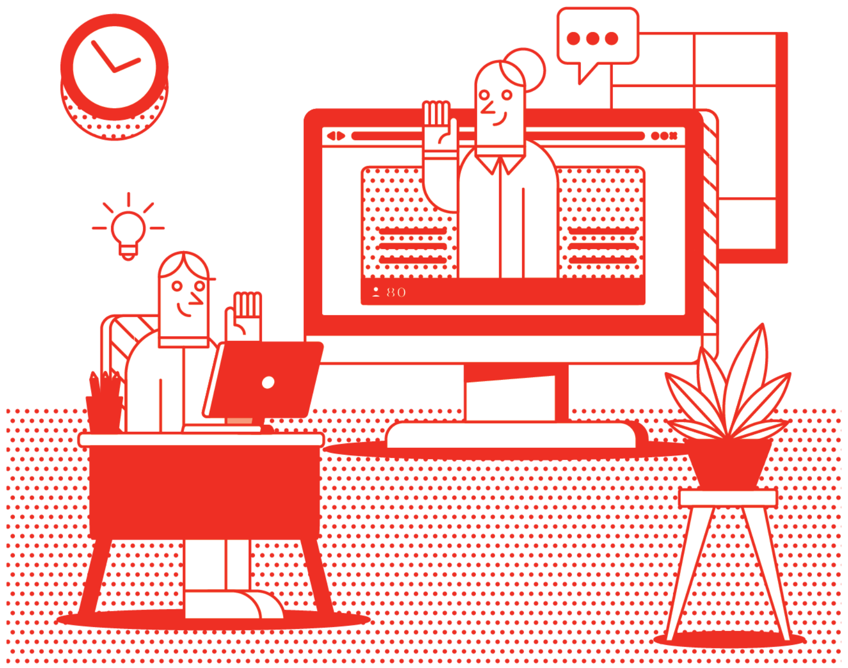
From the sharing by participants during the conference, it appeared that various Asian economies have collectively approached STEM education in a similar fashion, with a strong focus being placed on the improvement of existing curriculums to enhance the components of Science, Technology, Engineering and Mathematics that address both learner and educator needs to adapt to the impact of 4IR.

Most Asian economies have been driving STEM education as a priority as far back as mid-2000. For those that do not have existing STEM policies, existing school curriculums have instead been simplified resulting in fewer subjects but with a stronger focus on STEM oriented core competencies. Along with this comes the development of STEM educational materials as well as the implementation of quality assurance measures to gauge the effectiveness of the former.

Generally, the Asian economies' learning systems have adapted a blended modality, having both online and offline learning made available to promote STEM education. Initially, the onset of the pandemic drove the economies to focus their priorities on online education as the primary learning environment, but due to technological gaps such as lack of devices or access to the internet, some of the economies came up with workarounds, such as the creation of videos, for schools to maintain continuity of STEM education amongst their educational population.

STEM education in Asia places a lot of emphasis on the development of skills of both learners and educators, with the desire to support lifelong learning and recurrent education. This is to prepare individuals to be digitally literate and develop high-level thinking. STEM is acknowledged as a helpful tool to help build entrepreneurship skills and the preparations ensure that learners are capable of either being ready to successfully operate their own businesses or remain employable when 4IR begins triggering the creation of new jobs that require a higher level of digital savviness.

There is also a strong focus on enhancing the capabilities of educators to facilitate online learning through inquiry-based pedagogy. Teachers are assessed, trained and re-oriented on STEM to make sure they are more than able to effectively teach STEM and support an inquiry-based learning approach in a virtual environment. At the same time, independent learning is also being promoted amongst students to reduce their reliance on educators for information. Collectively, this leads to improved quality of learning because as teachers become better at teaching STEM online, students are also adding to their own educational development by asking more questions and learning to construct knowledge amidst existing technological challenges and maintaining a good momentum towards digital readiness for the impact of 4IR.



02 POST-COVID STEM EDUCATION

As countries march forward with vaccination efforts and attempt to transition to the next normal, it is becoming increasingly clear that STEM education needs to adapt, and adapt fast.

Current trends

In his introductory address, Professor Subra Suresh identified six post-pandemic core issues in STEM education that must be addressed as we rapidly move through the phases of digital advancement: (1) the time lag between job creation and job obsoletion; (2) the definition of what an educated person is post-graduation and prior to joining the workforce; (3) what it means to be human amidst these technological advancements; (4) the point of singularity where one day, machinated recommendations will be deemed as good as human decisions; (5) the unintended consequences of misuse and abuse of technology by humans; and (6) the risk of losing the aspects of beauty, truth, imperfection, and imprecision with the rise of dependencies on machine-oriented decisions and output.

In order to begin addressing these issues, NTU established the Institute of Science and Technology for Humanity which focuses on 3 main areas of priority: responsible innovation, governance, and leadership in the era of industry 4.0, and the new urban Asia. With technology becoming more advanced, the realisation of potentially losing the critical aspects of humanity has created the need to take steps to balance out STEM education with social sciences, ethics, the arts, and humanities. This ensures that the focus not only remains with the precision and speed of technological advancement but also considers the maintenance of positive human conditions to secure the influence of human characteristics within an automation-driven era. In addition, NTU has already started introducing digital literacy requirements for undergraduate students to help promote that balance between technological advancement and the preservation of humanity.

Meanwhile, Mr. Vincent Quah, Microsoft's Director of Education (Asia Pacific), reminded us of the role our post-pandemic society will play in contributing towards the implementation of STEM education in preparation for 4IR. He noted that access to education itself creates new economic opportunities for members of society as well as their own communities. This should revolutionise the way we think about educating and skilling individuals for economic success in 4IR.

The World Economic Forum has predicted that by the year 2025, an estimated 97 million new roles that are more adapted to the division of labor amongst humans, algorithms, and machines will emerge. Ultimately, this means a lot of machine processing and cloud capabilities will take on most of the simple tasks that human beings once handled. Tasks that are repetitive and without heavy need for computing will begin to decline in terms of requirement, shifting the employment focus to securing jobs that still require human intervention. With the progression of technology, the increasing level of complexity that computers and machines can handle will trigger that imbalance that cuts through the availability of work for human-dependent roles. Thus, we need to help individuals quickly shift into a state of digital savviness to become a digital consumer and even a contributor and secure their place of involvement in a digital era economy.

To give a better perspective of the shift in the nature of the roles, some of the opportunities foreseen to emerge in the coming years are as follows:

- **Cloud Computing**
- **Content Production**
- **People and Culture**
- **Product Development**
- **Data and AI**
- **Marketing**

It is imperative that STEM-driven educational support is provided at the earliest stages of learning, beginning from primary school all the way up to post-graduation where strong opportunities to reskill are also made available to those already engaged in employment or specific trades. To best prepare learners to become successful at entering a dynamic job market in a strikingly different digital world, there are three focus areas that require attention in an effective STEM education programme:

- **The ability to spark curiosity**
- **The development of productivity skills and growing knowledge and competence**
- **Improving employability with the right technical skills**

MR. VINCENT QUAH

"We want to expose all the young people to as many opportunities as possible, give them enough information to help them understand what is available, and get them to explore. We can try to be more programmatic with incentives and opportunities thrown in, but that's as much as you can do: Present them with the right set of incentives and opportunities so that you can channel more into that industry."

With that said, Asian economies also need to begin planning how to strengthen their STEM curriculums' effectiveness by considering these recommended core components of focus:

A. The prioritisation of future-ready skills, such as collaboration, critical thinking, creativity, and social and emotional skills.
B. The creation of courses that are topical, relevant, and continuously updated. It is important to ensure that courses will be continuously refreshed to reflect technological advancements that both learners and educators need to remain up to date with.
C. The ability to spark curiosity and the ability to teach learners how to ask the right questions.
D. The enhancement of the 2 competency areas for digital consumers and contributors:
   - Digital skills for consumers.
   - Computer science and coding for contributors.

Overall, economies need to envision the impact that an effective STEM curriculum can bring about during 4IR. Mr. Quah said that as early as now, Microsoft holds firm to that genuine desire to build the right learning culture and does not limit itself within the confines of being just an industry partner but rather as a proponent in the form of an educational institution - a mindset that societies also need to adapt to help their members shift from and successfully apply the principles of lifelong learning to establishing lifelong livelihood.

MR. VINCENT QUAH

"Showing that you're willing to adapt and learn along the way and pick up new tech skills, that puts you in a much, much better seat[...] The propensity to learn is something that is more important than just acquiring that [tech] skill."

To trigger that shift, Quah recommended taking the following steps:

Introduce students to computational thinking through computer science programming and STEM education.

Prepare students with industry-relevant, role-based skills to address anticipated gaps.

Evolve the curriculum to effectively attract and retain students and also be able to re-skill existing institutional staff.

Existing challenges

Based on the consolidated insights of the various participants, some of the biggest challenges in STEM education are the emergence of diverse information sources, as well as a need to solve existing STEM problems while developing essential post-COVID skills.

Educational systems must evolve to facilitate future learning and future living, to cope with the challenges of a world of volatility, uncertainty, complexity, and ambiguity (VUCA). Some important considerations in this evolution are:

TECHNOLOGY MASTERY

One of the key priorities across Asian economies is to improve on the current technological mastery levels of their learners. This ranges from the utilisation of devices, understanding how machines and computers work as well as acquiring basic programing knowledge.

MENTAL HEALTH

We need to consider the impact of the pandemic and continue to maintain virtual interactions even during learning sessions. The lack of face-to-face, human interactions is an aspect that not all individuals have fully gotten accustomed to.

STUDENT BEHAVIOUR

How students are adapting to an almost purely virtual method of teaching with the existence of technological gaps where not all learners have proper access to the internet or lack the devices needed to be able to participate in online learning.

ADAPTIVE THINKING

Some students and educators are still inclined towards the former learning methods stemming from decades of face-to-face education. This coincides with remaining familiarity with a non-STEM curriculum framework that does not encompass all core aspects of the STEM education framework. Moreover, there are learners who are not inclined towards STEM.

REMOTE COLLABORATION

There is a need to increase collaboration amongst educational institutions, educators, and stakeholders virtually and consistently towards continuity of the implementation of effective STEM programme.

Technology and blended learning platforms can enhance the learning experience, but they also necessitate new team learning and peer assessment systems. Ultimately, a mix of future-ready skills, resilience, and innovation is required.

Necessary skills and competencies

Collectively, the participants proposed a number of essential post-COVID-19 STEM education skills and competencies during the sessions, with the top 3 common priorities across the Asian economies as follows.

In recognition of our progression towards a more digitised future, there is a need for our learners to achieve digital literacy, digital fluency, and information literacy.

DIGITAL LITERACY

Includes acquiring skills such as coding, as well as knowledge of data privacy and security. Digital skills enhancement should lead to improved productivity, efficiency, effectiveness, and the simplification of complex actions such that they can be completed with less time and effort, leading to improvement in the standard of daily life.

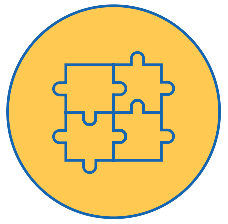
DIGITAL FLUENCY

Which is broader than digital literacy, includes notions of technology adoption in addition to usage, innovation and creation, as well as the ability to collaborate and communicate with others in the digital world.

INFORMATION LITERACY

Includes the ability to utilise digital information and interpret statistics and data.

There is also the need to continuously enhance learners' disciplinary ways of thinking, such as scientific thinking and inquiry. As we experience the post-pandemic transition to a more digital-oriented population that will encounter increasingly complex and ambiguous problems, there is a need to enhance learners' mathematical and computational thinking. Some relevant aspects of mathematical and computational thinking are highlighted as follows.



Learners need to be equipped with the ability to problem-solve within limiting parameters. Four core components of computational thinking- Decomposition, Pattern Recognition, Abstraction and Algorithm-provide a good starting point.

Learners need to know how to leverage digital tools to accomplish tasks and conduct problem-solving. This requires computational thinking and other aspects of computational literacy.

Learners must develop a growth mindset, and have opportunities to hone their employability skills.

In addition, learners need to acquire "life skills" such as problem-solving, creativity, curiosity and innovation, critical thinking, communication and collaboration, humanistic values, flexibility and agility, and value creation. Such "life skills" or 21st century skills are interdisciplinary in nature. Some specific mentions of interdisciplinary skills and their value are highlighted as follows.

A. Social empathy, the ability to discover and create value of new products, and the need for greater curiosity and inquisitiveness.
B. Self-motivated learning to address limitations with time to interact with others and to ensure students motivate themselves to continue learning and can adapt to changes.
C. Interpersonal skills such as collaborative learning, communication, respect for diversity, and inclusivity.
D. Promotion of community-oriented STEM programme for sustainable development.
E. Problem-solving inclusive of critical and creative thinking and actions
F. Digital ability to read statistical and evidence-based data.
G. Global awareness on topics such as COVID-19, vaccination, and climate change.

STEM industry experts panel discussion

STEM industry experts representing various industries were also asked to define what they felt were the top 3 STEM competencies needed to become successful in a VUCA world.

DR. ALEX LIN
Venture Builder

Dr. Alex Lin began with his insights on the importance of **Mathematics**, which he defined as the language of science and a component of all things. He stated that math has always been important in not just the creation of things but in other critical industries and areas such as finance, planning, and management.

Next was **logic and reasoning** and the importance of being able to derive something logically and to be able to present an idea or solution that will be accepted by others because it is reasonable. Dr. Lin shared his thoughts on how math and logic cannot stand alone on their own, and that this is where STEM education comes in to provide individuals the ability to learn the 3rd important skill, which is **observation**. Observation was defined as a channel and skill that people need in order for them to be able to utilise available data appropriately and derive the reasoning behind their findings.

In the earlier point highlighting the importance of mathematics, it is critical to be able to utilise math to avoid the inability to quantify things. This inability will lead to a logical trap that impacts one's decision-making ability because instead of making logic-based decisions, emotions or assumptions will take precedence over actual statistics and facts. What might seem to be true at the onset might turn out to be only a portion of the overall situation. We need math in order to define real numbers, ratios, and percentages. Logic is a skill that is built on math because of the aspect of quantification.

Observation is deemed a skill not being fully learned because it is something that doesn't happen in books or on digital screens since it requires the use of the 5 senses. In the case where a lab experiment is conducted, someone can smell, see, hear, feel or taste to get a clearer perspective of what is being studied. While reading a book may allow an individual to come up with a mental image of an object, it still would not provide every essential level of detail vs having a learner be able to physically sense and feel, to eventually synthesise and comprehensively understand and eventually arrive at a solution. One major point of further consideration is to think about how observation skills can still be acquired via virtual learning by providing individuals the ability to conduct full observations in a virtually oriented era.

Dr. Lin closed his response by highlighting the importance of the interrelation of the 3 skills (i.e. mathematics, logic and reasoning, and observation) in an example related to our understanding of vaccine efficacy. Pfizer and Moderna boast of 95% efficacy while AstraZeneca is at 80%. But taking a closer look at the trials being done, the efficacy testing for AstraZeneca took a longer period of time vs. those of the MRNA (messenger ribonucleic acid) vaccines (Pfizer and Moderna). It was also done at a point where there was a peak in the time period covered, thus resulting in a different range and set of data being used. Comparing these using the 3 skills then shows that it is not an apples-to-apples comparison. Clearly, this means that being able to observe through mathematics then utilising derived logic is essential to help us notice the variables and underlying factors to understand what the statistics really mean and be able to come up with a more accurate conclusion.

"A lot of times, if you can't quantify things, it becomes a logical trap."

MR. ONG ZHONG LIANG

Senior Engineer (Platform), Rakuten Viki

Mr. Ong spoke of the 3 important skills from the perspective of a software engineer and what he found to be helpful for him in the course of his career.

The first was the procedural skill of reasoning about complex systems. He highlighted that in school, subjects are being taught from a concept-based perspective, primarily because of time constraints resulting from a semestral structure. Learners are then tested on their knowledge through examinations or completion of projects. But if we were to take a look at software and real-world systems, the complexities surrounding these such as the rules and a myriad of moving pieces make the environment too challenging to simply learn every single detail, and an incomplete understanding of a system's concrete rules could result in errors in decision making. Learning through interfaces and abstractions allow for the complexities to be better managed and for learners to conduct work on systems safely. It also gives them the ability to focus on their own conditions, as opposed to being tested on knowledge through an examination or a project.

The second skill he spoke of is an attitude built on a foundation of curiosity and technical literacy to continue learning. It is important to learn how new developments in a field of expertise take place so that individuals can remain relevant and benefit from these developments thus making their tasks easier, allowing them to be more productive. And to do so, it is critical to have that strong foundation and understand the major sources of these new developments in a specific STEM field. In the context of STEM, this means that curiosity would also involve something that is tangible about the new concepts, similar to utilising observation to be able to internalise the learning. For example, instead of settling with just reading a post about a new software library, someone can run snippets of code to test them and gain a better appreciation of the library and how it functions in conjunction with other libraries.

Lastly, Mr. Ong presented on the ability to communicate precisely with an audience as the third important competency. It helps reduce ambiguity at the onset as we always look towards the help of others to get a task done. In his role as an engineer, he cited that he would not be able to commit a single line of code into the code base without first having a code review done by a colleague, where his work is checked to see if his contribution is of the expected quality. For his colleague to effectively conduct the review, he needs to ensure he communicates clearly, reducing confusion, allowing the colleague to spot mistakes or find a better approach that can save the rest of the team time, all the while considering several other contributors who will be contributing code at the same time. With multiple sources of various code, the chances for ambiguity increase. Therefore, clear communication ensures that mistakes and confusion are avoided to bring a project of such scale to success.

"My colleagues sometimes say we write tomorrow's legacy code today. It is important to learn how new developments in our field take place so that we can stay relevant and benefit from these developments to make our job easier and to be more productive."

MS. KATHARINA UELTSCHI

Director, BERNINA (Singapore) Pte Ltd

Ms. Ueltschi was quick to point out that **creativity, critical thinking**, and **collaboration** are the key qualities that a workforce needs to remain agile when responding to uncertain times. Referencing Bernina, she mentioned that innovation has been one of the key drivers that enabled her organisation to stay ahead in a VUCA world.

The speed of change is influencing society to become more creative and collaborative, and Ms. Ueltschi defines her belief in maintaining a multidisciplinary approach by linking the aspect of **creativity with technology**. One of the steps Bernina has taken to fuel this belief was to collaborate with meriSTEM@NIE on a STEM programme for primary and secondary school students that focuses on the cultivation of both soft and hard skills. The programme is inclusive of coding, design thinking, the science of materials, software linking, real-world problem solving skills, as well as physical prototyping for their machinery used in sewing and embroidery. The programme aims to expand educators' portfolios and enable the participants to begin exploring skills that are linked to lifelong learning.

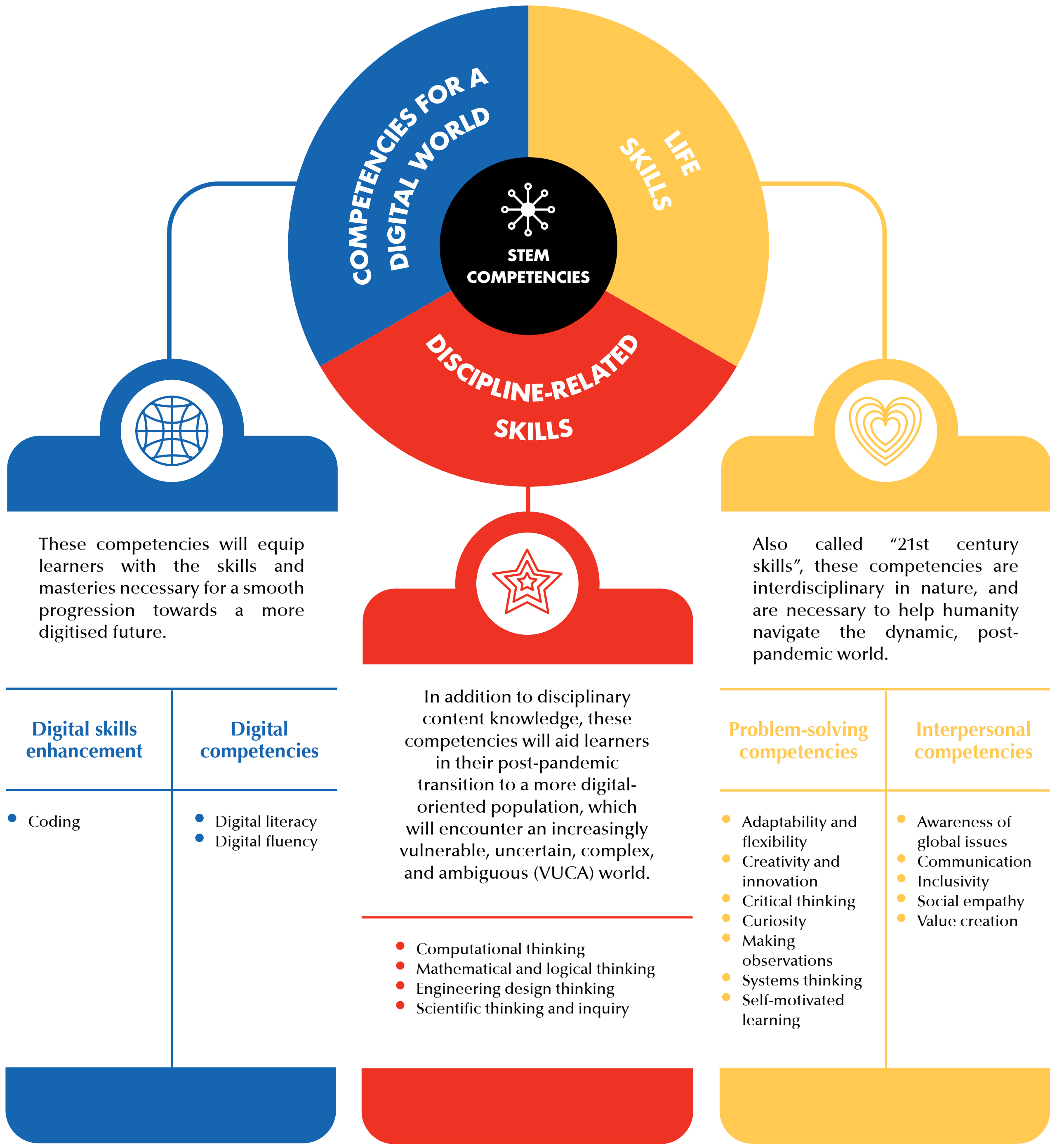
There is also a cultural and emotional aspect to the programme that develops these qualities in their learners, where the goal in mind is to break down existing gender biases where the customary way of thinking is sewing is limited to the list of tasks that only females can do and coding is exclusive learning for members of the male population. The overall goal would be to encourage all students to develop an ample level of curiosity about science, technology, engineering, and mathematics regardless of gender through the use of a multidisciplinary approach.

Lastly, this is also a great way to introduce the concept of environmental sustainability to students, and this is achieved through hands-on activities where students work with a wide range of material to gain a deeper understanding of their sources. Students will also develop an appreciation for resources and the environment and will be empowered to contribute to more sustainable methods of income generation in the future.

Ms. Ueltschi strongly believes in collaboration between industries and institutions to ensure that skills, values, and needs are aligned for future generations. She looks forward to having more female leaders in the future, not only in the creative fields but as well as within STEM education as well. Based on her experiences from the pilots they've run, she has come to observe that in schools, it is the teachers that are key to driving the environment in education besides the parents of the learners.

> ***"I strongly believe in collaboration between industries and institutions, to ensure skills, values, and needs are aligned for our future generations."***

STEM Competencies Framework for Post-COVID Asian Economies



Glossary of Competencies

COMPETENCY	DESCRIPTION
DIGITAL SKILLS ENHANCEMENT	These competencies are relevant for enhancing learners' digital skills.
Coding	Process of creating instructions for computers using programming languages to tell computers what to do. Coding enables the creation of computer software, applications (apps), and websites.
DIGITAL COMPETENCIES	These competencies support learners to be wise consumers and producers of content in a digital world.
Digital literacy	Ability to use information and communication technologies to find, evaluate, create, and communicate information, including data and statistics. Digital literacy involves both cognitive ("how to think") and technical skills ("how to do"). It also involves the knowledge of data privacy and security.
Digital fluency	A step up from digital literacy, digital fluency includes notions of technology adoption (in addition to usage), innovation and creation, as well as the ability to collaborate and communicate with others in the digital world.

LIFE SKILL	DESCRIPTION
PROBLEM-SOLVING COMPETENCIES	These competencies are relevant for solving real-life, complex problems.
Adaptability and flexibility	Willingness to respond according to the situation and the ability to deal positively with feedback and criticism and incorporate them effectively to solve a problem.
Creativity and innovation	Seeking different and relevant ways to solve problems.
Critical Thinking	Rational, unbiased and skeptical analysis of evidence related to an issue to form a judgement.
Curiosity	Desire to explore the environment and question what is observed or known.
Making observations	Making observations is the noticing of something and may include utilising all of a learner's senses. It forms the basis for drawing inferences based on what is noticed. Making observations is the channel and skill that enables learners to utilise available data appropriately and derive the reasoning behind findings.
Systems thinking	A set of analytic skills used to identify and understand systems, predict their behaviours, and propose modifications to (parts of) a system in order to produce desired effects. These skills work together as a system.
Self-motivated learners	Self-motivated learners are able to take initiative and action to pursue goals and complete tasks, including learning new conceptual knowledge or acquiring new skills relevant to solving a problem.
INTERPERSONAL COMPETENCIES	These competencies are relevant for positive interactions with others in real-life contexts.
Awareness of global issues	Being aware and updated on global issues e.g. COVID-19 and climate change.
Communication	Articulate thoughts and ideas effectively in various forms and contexts to achieve intended purpose; listen effectively to interpret meanings.
Inclusivity	Practice of providing equal access to opportunities and resources for all, embracing people from various backgrounds, promoting a sense of belonging, and respecting diversity.
Social empathy	Ability to understand how someone else is thinking and feeling and their situations, and the ability to see from different points of view.
Value creation	Creating something of value to others or a community beyond self.

COMPETENCY	DESCRIPTION
Computational thinking	Computational thinking is a problem-solving process that involves attempting to solve a complex problem (a problem that we don't know how to solve immediately) by computation and breaking it down into a series of small, more manageable problems or sequence of solution steps (decomposition). Each of these smaller problems can be looked at individually, considering how similar problems have been solved previously (pattern recognition) and focusing only on the important details, while ignoring irrelevant information (abstraction). Simple steps or rules to solve each of the smaller problems can then be designed (algorithms). These simple steps or rules can be used to programme a computer to help solve the complex problem in the best possible way.
Mathematical and logical thinking	Mathematical thinking is not the same as doing mathematics--at least not the typical kind of mathematics presented in schools. Instead, it can be seen as a set of actions, ways of working, or habits of mind of a mathematician. To think mathematically is to be able to see a problem or the world through a mathematical lens. Doing this involves looking at special cases or examples and looking at them inductively to generate new insights (specialising), which may lead to identifying patterns and relationships that can help solve the problem or model the problem (generalising). The generalising process often leads one to hypothesise possible relationships and results from the examples (conjecturing). The hallmark of mathematical thinking lies in the ability to prove and convince others about the hypothesised conjectures (justifying). Reasoning is the heart of mathematical thinking and this is dependent on a system of coherent linking of premises and results, or what we commonly term as logic. To think logically is to establish the truth of a statement by drawing on the evidence and constructing a sequence of thoughts and ideas to convince others.
Engineering design thinking	Engineering design thinking refers to the ways of thinking that engineers engage in during the engineering design process in order to solve a problem a client wishes to solve, which essentially involves how to make "stuff" (any thing of interest) that works or make "stuff" work better. The engineering design process typically includes problem definition, model development and use, investigation, analysis and interpretation of data, application of mathematics and computational thinking, determination of solution, and presentation of solution to client. Engineers also consider criteria and constraints, as well as optimisation and trade-offs in order to reach the best solution.

Scientific thinking and inquiry	Scientific thinking and inquiry describe the ways of thinking and doing that scientists engage in to achieve various purposes such as developing scientific theories that provide explanations to questions about natural phenomena. Theories and explanations have to meet criteria or standards valued by the scientific community (such as reliability, validity, and coherence) in order for them to be accepted as scientifically sound or trustworthy. Scientific inquiry involves a variety of approaches (experimentation is just one approach) that scientists (and anyone who has adopted scientists' ways of thinking) would take to answer questions.

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What else needs to change?

Through the sharing and discussions, various ideas for changes in STEM education were highlighted as necessary for supporting students to acquire the necessary competencies to thrive in a VUCA world. The proposed key areas of changes are highlighted.

Existing STEM curricula must be redesigned to become more seamless and connected.

There needs to be greater emphasis on and the inclusion of problem-solving skills, technical competencies. and increased connectivity. Additionally, digital literacy standards must be raised.

Humanities courses must be developed alongside STEM.

There must be an increased emphasis on IT and medical sciences, as well as a reduction in over regulation of subjects to be considered in the STEM curriculum.

Teacher education and professional learning for teaching and learning in the digital world.

There should be digital technology retraining programme made available for existing professionals to help them remain employable.

Teachers must be provided supplementary professional development on STEM-oriented subjects as well as how to conduct online classes effectively.

Technology-related enhancements and supportive actions.

Schools should explore BYOD (bring your own device) policies for students.

There must be a transition to greater adoption of technologies.

There should be more university scholarships for STEM students.

Alternative learning systems should be established.

In addition, educators can work on existing opportunities in the following ways:

Encouraging students to engage in learning activities by assigning them in various activities, such as discussion rooms or Flipped classroom approach Students would need to study before coming into the classroom for them to remain engaged.

Developing and/or recommending online instructional resources. Government agencies need to support teachers by inviting discipline experts or educational practitioners to synthesise existing online resources.

Designing or introducing easily accessible hands-on activities that can be done at home. Examples of these would be kitchen chemistry, baking soda, paper airplanes.

Transform the assessment formats. This means providing alternative assessment strategies or materials such as an e-portfolio or shifting from produce to process-oriented testing.

Institutions can also respond to pandemic-era STEM education concerns through the following initiatives:

Enhancement of STEM competencies for students and teachers.

Providing online resources for students and teachers.

Remote/hybrid training courses for teachers.

Ready to use and affordable STEM kits that can be sent to students' homes.

Developing STEM Competencies through Education for Thriving in a VUCA World

PANEL 2A

PROF. CHIU MEI-HUNG

Professor, National Taiwan Normal University, Taiwan

Professor Chiu began with an overview of the impact of the pandemic on learners and spoke of the number of learners affected as well as the average time that schools were closed (an average of 15 weeks, or about 4 months worldwide). Such statistics clearly define that we need to be ready to deal with these situations and highlights the need for educators to adopt various courses, activities, and strategies to accommodate students who will learn online, as this transition from face-to-face learning to virtual learning will result in an entirely different experience for both students and teachers.

Professor Chiu highlighted the following challenges in Taiwan:

a. Lack of teacher-student interaction.
b. Lack of useful resources and guidelines to select materials.
c. Lack of opportunities to conduct hands-on experiments.
d. Lack of alternative assessments.

She ended her presentation by stating that economies need to think out of the box to remain creative in coming up with solutions for addressing challenges that have resulted from the pandemic.

As a post-reflection, Professor Chiu added that although they confronted the challenges in teaching and learning during the pandemic period, fortunately, Taiwan did not lockdown schools or universities for a long period of time and school teachers and university faculty members were competent to find alternative ways to cope with the unpredictable situation within a limited time frame.

DR. IHSAN BIN ISMAIL

Deputy Director, Digital Education Secretariat,
Ministry of Education, Malaysia

Dr. Ihsan opened his segment with an overview of the STEM activities that had been planned by the Malaysian Ministry of Education when the pandemic first came about. They had already launched inquiry-based education for both science and mathematics, with the plan to conduct a nationwide launch to train their teachers on those concepts.

The main element of this training was the promotion of hands-on activities, where students would conduct investigations, exploration, and experiments, instead of remaining reliant on their teachers or from reading to acquire answers. Students were expected to collaborate on activities inside the classroom or laboratory. But these plans were halted when the pandemic began and the ministry had to re-assess and switch training to happen virtually instead.

With this sudden shift of environment, there were challenges that were encountered involving students lacking the needed devices and students and teachers having to quickly adapt to a virtual learning setup. There was also a problem with connectivity. ne of the surveys they conducted showed that 37% of students did not have any device and 40% did not have internet access. But because the pandemic did not allow for any other option, the switch to online learning was made. They began conducting training for their teachers to facilitate online learning for an inquiry-based education method. Since there was no way to put a lot of emphasis on hands-on activities, most of the focus remained on content that could easily be taught online instead.

There were positive outcomes amidst this rapid educational response to the pandemic where students became more interested to study and there was also a higher teacher participation rate for a colloquium.

PROF. SHERYL LYN C. MONTEROLA

Professor, University of the Philippines-Diliman,
College of Education; Executive Director, Center for
Integrated STEM Education (CISTEM), Philippines

Professor Monterola highlighted that the Philippines' educational response to the pandemic is the result of a collaboration between the University of the Philippines College of Education and the Center for integrated STEM education.

Some of their achievements included the implementation of a teacher upskilling programmed where they were able to successfully skill 320k teachers and the co-organisation of the 2nd Integrated STEM Leadership Summit in Asia. There were also webinar series created that focused on STEM education. Her team is currently in collaboration with the ILO (International Labor Organisation) with the aim to further the training of trainers and curriculum planners on the integration of STEM in technical vocational education and training.

They recently transitioned their face-to-face STEM teaching facility into an online environment where teachers and science teachers undergo immersion with a manufacturing company to gain a perspective of STEM careers within the manufacturing sector. Amongst other endeavours, other activities related to the promotion of STEM-oriented education such as the creation of an activity booklet and storybook on urban agriculture in partnership with their local Department of Agriculture, the assembly and distribution of labs-in-a-box, the production of video tutorials to help parents participate in the science experiments being conducted by their children, the production of a series of shows for the junior high school level and the broadcasting of radio programme.

There are still other up-and-coming initiatives in collaboration with UNICEF with the aim to establish alternative learning systems, a growth mindset, and employability skills for learners. It is all a matter of thinking of the big picture connecting various perspectives and synergising ideas to be able to solve problems. All these initiatives are a clear testament to the ability to remain innovative in promoting STEM education despite an event as globally impacting as the COVID-19 because of the desire to work on the opportunities that arose amidst the pandemic.

DR. NGUYEN THI THU TRANG

Director, STEM Education Center; Lecturer, Department of Chemistry, Ho Chi Minh City University of Education, Vietnam

Dr. Nguyen spoke of the situation of STEM education in Vietnam amidst the pandemic. A city as popular and robust as Ho Chi Minh that once flourished with people but in the social distancing paints scenes of an exactly opposite scenario. And this gives a good perspective of the gravity of the situation that people need to adapt to, as well as its impact on sectors as influential as that of education.

Some of the impacts on STEM education caused by the pandemic have materialised into challenges such as shifting from activities that thrived with face-to-face interactions to activities that are now bound within the confines of a virtual environment, where a lot of thought had to be put into how these will all get transposed to having participation happen from either a laptop or mobile device. Another challenge would be the rising demand of parents for STEM activities to be conducted at home and not all students having the needed devices to participate in online learning.

Overall, and similar to the other economies, Vietnam has remained agile amidst the pandemic to work on the learnings and challenges they encountered to ensure that they are supporting the continuation of improvement of STEM education through innovative methods and alternatives in a virtual environment.

PANEL 2B

MR. ROBERT GARDINER

Founder & Management Advisor, Prestasi Junior Indonesia Foundation (PJI), Indonesia

Mr. Gardiner began the presentation for Indonesia with an overview of Prestasi Junior Indonesia, an organisation that works directly with various representatives across the country on the development of STEM initiatives. Hel spoke from the perspective of an educational practitioner and what his observations were about working towards the development of STEM competencies through education.

Indonesia's student population is around 800% larger than that of Singapore's and is the world's 4th largest educational system. There are approximately 3 million teachers and 300,000 schools accommodating the roughly 50 million members of the student population. These statistics speak of both great opportunities and unique challenges.

Over a decade ago, entrepreneurship was not a primary consideration for school leavers as a means of viable livelihood. Compared to the present, that viewpoint has significantly changed and many of the younger generation are equally aware that having the needed STEM skills are key to operating their own businesses. This means that as an education-oriented institution, it was important for PJI to view STEM not only as a prerequisite for finding employment but also as a good foundation to running a successful trade.

In relation to some of the key points that were discussed during the seminar, the following objectives were highlighted by Robert to achieve greater depth and breadth of STEM education implementation:

a. Create a highly capable STEM workforce.
b. Prepare students for advanced degrees and technical studies.
c. Contribute to the nation's competitive participation in the global economy.
d. Prevent the loss of valuable human resources.
e. Develop 21st-century competitiveness.
f. Develop STEM literate citizenry.
g. Contribute to personal well-being.

Some of the current undertakings to bring these objectives to fruition involve the following STEM implementation programme in Indonesia:

MICROSOFT DIGITAL ANALYTICS

Working with Microsoft to engage 10,000 individuals (select top students) in an opportunity to undergo comprehensive digital analytics training.

USAID SAFETY AND CYBERSECURITY

An endeavour working outside educational institutions to provide safety and cybersecurity training to 4000 young entrepreneurs located in East Java to ensure business operators are fully aware of the risks and be capable of safeguarding themselves from potential threats.

JOHNSON AND JOHNSON WISTEM2D

Working with young female students to introduce them to STEM engineering through the development of a simple robot via online training. Specialists are also asked to participate to further support this endeavour with the goal to cultivate the desire to enter university to young female learners.

WHATSAPP FOR BUSINESS

Platform being used to help entrepreneurs build their businesses.

While there are a significant number of impactful initiatives set up for helping learners become digitally skilled, an ample amount of focus is also being given to building educator capacity in Indonesia as well. It is of equal importance to also build on the STEM competencies of the individuals who deliver the knowledge and materials to the classroom. PJI is working closely with Nanyang Technological University (NTU) to train 200 teachers to become effective at delivering a technology-focused curriculum, which is embedded into the national curriculum and the STEM components of physics, chemistry, biology and mathematics.

DR. DATO NORAINI

President, National STEM Association, Malaysia

Dr. Noraini presented Malaysia's STEM framework by providing an overview of the curriculum inclusions and how STEM education is embedded in all levels of education from nursery all the way up to the tertiary level. The overall aim is to embed the culture with STEM knowledge and develop STEM-oriented thinkers.

The challenges surrounding the incorporation of technology is present because of a lack of technological access, specifically in rural areas, so much so that some teachers still need to send assignments and projects to the learner's parents just so they can be completed.

Dr. Noirani proceeded to talk about the National STEM Organisation whose mission is promoting and attracting interest from all levels of the community in the field of science, technology, engineering, and mathematics. A more granular view of the overall mission can be seen with these 5 objectives:

a. Cultivate interest and understanding about STEM among pre-school, primary and secondary, and university level students.
b. Strengthen the effectiveness of teaching and

learning techniques in STEM education.

c. Encourage innovation and STEM creativity in the classroom through projects and activities based on smart and interactive learning.
d. Recognition of excellent STEM programme, industries, and staff.
e. Be the medium of support to the STEM ecosystem to produce innovative and competitive human capital.

The National STEM Association (NSA) School Network was introduced to further support these objectives that involve participation from educators and educational institutions. School principals are to join the network to provide a ready avenue for collaboration and availability of updates, especially during the pandemic to keep everyone aligned to the goals of proper STEM education establishment and promotion.

SCHOOL

Early childhood education, primary education, secondary education

ACADEMIC

Tertiary education

INDUSTRY LINKAGES

Local industry, international industrial linkages, STEM ambassador, STEM careers

COMMUNITY LINKAGES

Parents and community/NGO

A virtual STEM internship programme was also launched to allow students to go through a video tour related to engineering, agriculture, or other related industries, and as NSA is also focused on industry linkages, they are working closely with the Education Alliance of Finland to ensure that the online work being done is properly accredited.

Learning science and its components is now a bit more challenging because the pandemic took away the capability for face-to-face interactions. Thus, it has become essential for online sessions and classes to cultivate a sustained interest in science and math and gradually become a fun, learning environment despite the impact of the pandemic.

Another project of NSA is the mini-theater system, where students were required to come up with a simple, innovative invention related to STEM to begin training them to become STEM entrepreneurs. The participants included 100 students from 40 schools being guided by 80 facilitators resulting in 35 product innovations being invented.

Dr. Noirani closed her segment by reiterating that one goal in mind is to keep learners excited about learning STEM during the pandemic and that collaboration amongst teachers and the involvement of leadership and administrators will help solidify this goal.

DR. PORNPUN WAITAYANGKOON

Director, SEAMEO Regional Center for STEM Education (SEAMEO STEM ED), Thailand

Dr. Pornpun Waitayangkoon began with redefining what STEM education is for the Thai economy - teaching and learning approach, which emphasises the connections among the integration of knowledge and skills in science, technology, engineering, and mathematics. These are the critical skills needed to address the problems being encountered by the community, as well as other larger global issues that require a skilled workforce and knowledgeable citizens.

The implementation of STEM in Thailand did not move as quickly as anticipated due to students, and at times, even teachers, lacking the basic knowledge of science, math, and reading, which will hinder the integration of the needed knowledge into the educational foundation of these individuals.

To solve this, Dr. Pornpun recommended that the changes should begin with the structure of education in Thailand which should give students and educators opportunities to try new instructional technologies and learning. Though the pandemic has not spared education from disruption, it has also triggered a number of positive changes in the economy, becoming a catalyst for the digital transformation of the educational system which the economy has to adapt to. Leaders and policymakers will be playing an important role to keep the momentum of the digital transformation in motion to increase the level of quality and quantity of reach to ensure effectiveness and sustainability.

More initiatives are needed to equip learners with the skills and knowledge to meet the demands of a changing job market as every country will have a unique strategy to address local priorities and issues. For Thailand, the essential competencies to thrive are similar to what other economies have mentioned, such as:

a. Problem-solving - be able to quickly work through problems and come up with solutions.
b. Creativity - STEM teaches individuals to look at a solution from different perspectives and come up with varying approaches towards that solution.
c. Inquiry skills - require hands-on participation to effectively solve problems. With students being the drivers of solutions, they should learn how to ask effective questions and be able to test their solutions.
d. Critical thinking - effective STEM learning requires you to analyse information, evaluate designs, reflect on your thinking, synthesise new ideas and propose creative solutions. All these skills are vital to becoming an independent critical thinker.
e. Collaboration - there is an existing challenge to promote collaboration for the enhancement of current capabilities which can be gained by learning from one another.
f. English proficiency.

The discussion ended with the caregiver industry in Thailand being highlighted as a trade that showed how additional improvements in STEM education can potentially help produce better caregivers and boost the interest of others to venture into the field. A lot of concerns surrounding healthcare make this career viable, but the job will require an individual to be properly equipped with the right set of science, communication and math skills to thrive and become successful. This ties in with improving the capabilities of STEM educators and the importance of ensuring that teachers are able to teach the basic concepts of STEM effectively to help the learner develop the appropriate skill sets.

PROF. DONG YAN

Vice Dean of School of Educational Technology, Beijing Normal University, China

China's STEM educational environment is undergoing expansion, with the goal of attracting more qualified teachers while also expanding the interdisciplinary connections between students and society.

For the summer of 2021, Chinese authorities launched a relatively new policy known as "double reduction" in an attempt to effectively reduce the burdens of heavy homework and off-campus tutoring for students. Thus, innovative programme like STEM education are encouraged to launch in Chinese schools. As a result, innovative programme, such as STEM education, are being promoted and are gaining popularity.

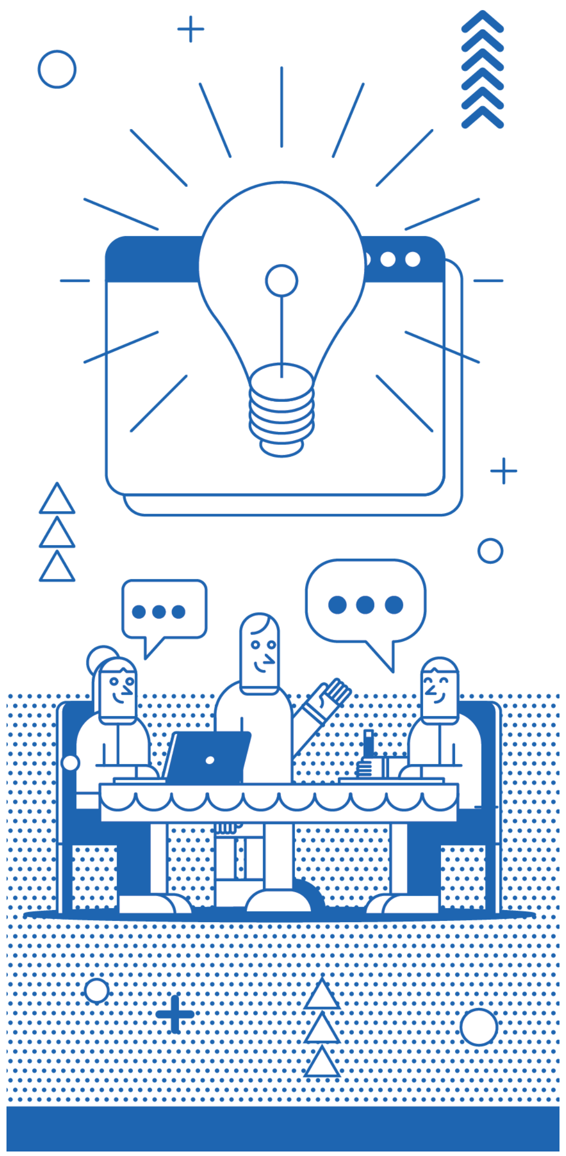
Because learners' attention will be drawn to STEM education as a result of the projected impact of this policy, it is possible that a greater interest or enthusiasm for STEM education may result. This means that STEM initiatives should not be a grassroots effort spearheaded by STEM-related companies and industries, but rather something that the government takes the lead on and implements.

China has also prompted a shift away from a teacher-centred pedagogical style and toward one that is more student-initiated or directed. An emphasis is being put on empowering students to take charge of their own learning. It is about students assuming greater responsibility for their own learning rather than merely relying on their teachers to provide them with the necessary knowledge.

Currently, focus is also being placed on the professional development needs of teachers in order to assist them in implementing the STEM curriculum, which would include developing STEM learning materials as well as building a truly integrated STEM curriculum that is culturally appropriate in the context of China's education system. Additionally, China is attempting to learn from the best practices and great ideas in STEM education from Western cultures in order to better tailor existing STEM curricula to Chinese educational contexts.

03

THE WAY FORWARD



As a final segment of the seminar, Dr. Ong Yann Shiou took the lead on discussing the plans moving forward after the seminar. This was initiated by a summary of the common shared experiences as well as personal reflections on learnings and takeaways from the seminar.

The keynotes of the seminar set the context of education in Asia and the trends and areas of needs in STEM industries, with focus on the balance between humans and machines, learners being on the spectrum of technological contributors and consumers as well as overall digital literacy.

The panelists comprising STEM industry experts and STEM education experts provided insights on how STEM education could support learners to thrive in a VUCA world. The need to be effective at communicating, such as students being able to communicate with experts, and fostering communication to help individuals work better with teams and learn to collaborate and through collaboration. A good portion of the sessions also highlighted sparking curiosity among learners to motivate them to pursue STEM education, remain innovative and be better prepared for the future that will be brought about by 4IR.

There are three main points that encompass the key learnings from the seminar. The first being the development of a transformative way of thinking. Next would be the emphasis on interdisciplinary thinking or the ability to see among the different STEM disciplines, and lastly, on transdisciplinary thinking or breaking down of silos. Collectively, these three key learnings point to the resounding theme of having a transformative mindset, the idea that we can always be better and finding more than one way to solve a problem.

Some of the invited speakers also shared their key takeaways:

01 The solutions for the development of STEM education will be unique to each economy even across similar issues. Sharing these unique experiences helps the rest gain additional insights on how to derive the best solutions within an economy's own context. A solution for one economy might not be a good solution for another.

02 Prior to the pandemic, economies were already looking at specific STEM competencies of focus. But since the pandemic, a priority that commonly stands out among various economies is that of digital literacy. The STEM competency framework is thus heavily grounded with the need for digital literacy.

Delegates from the economies also shared some of their planned or recommended measures for their priority STEM competencies, the ones common among various economies being:

1. Establishment of harmonised STEM frameworks that:

   a. Define and integrate the STEM priority competencies.
   b. Remain agile to adapt to the changing times and industry while the economies leverage on industry partners.
   c. Enhance the competencies of STEM educators.
   d. Is supportive of a curriculum inclusive of ethical values.

2. Transformation of the assessment formats. This means providing alternative assessment strategies or materials such as an e-portfolio or shifting from product to process-oriented testing. A process-oriented assessment is comprised of 3 steps, specifically:

   a. The description of performance expectations.
   b. The implementation of process-oriented assessment.
   c. Feedback on student's performance - this is important because it supports the learner's growth.

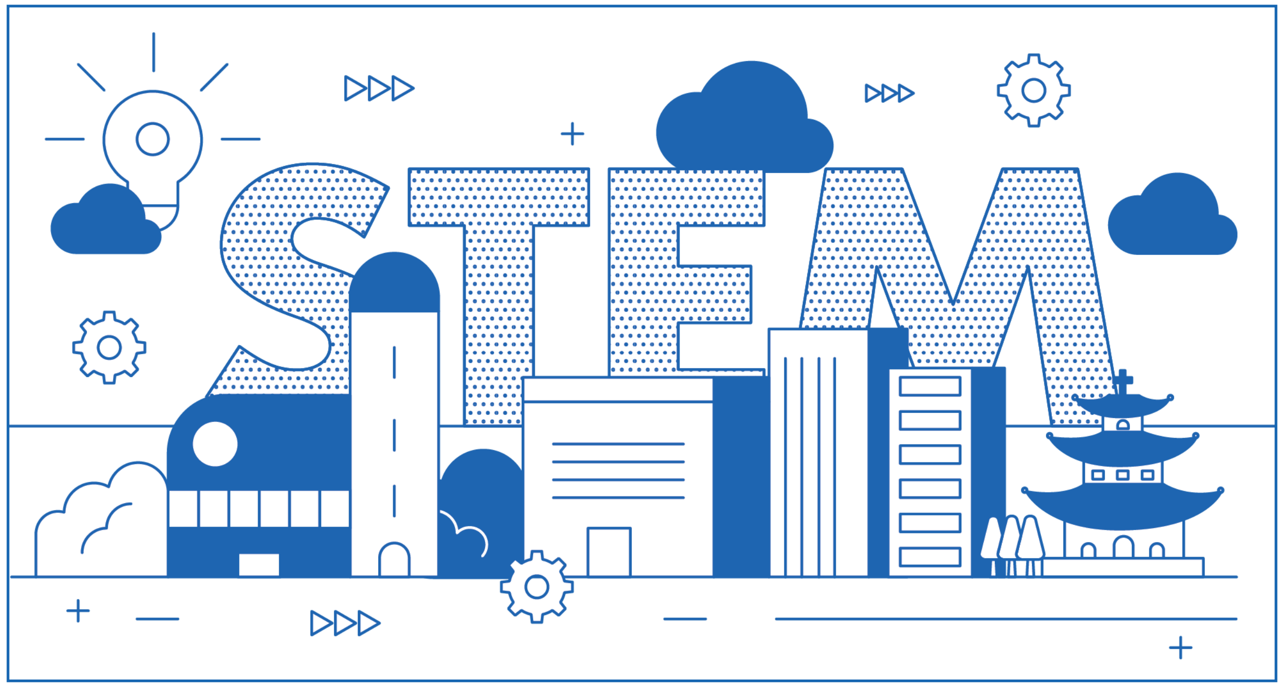
3. Building of student portfolios to track and measure progress along STEM competency development.

4. Intensive collaboration between stakeholders and educational systems to improve the understanding and application of STEM education in schools.

5. The development of hybrid/ blended methods of learning, both offline and hands-on.

It was also evident in the discussions that a lot of importance will be given to shifting the mindset of students to have an appreciation for self-learning so they can adapt to the existence of lifelong learning which in turn, will better prepare them for IR 4.0.

CONCLUSION



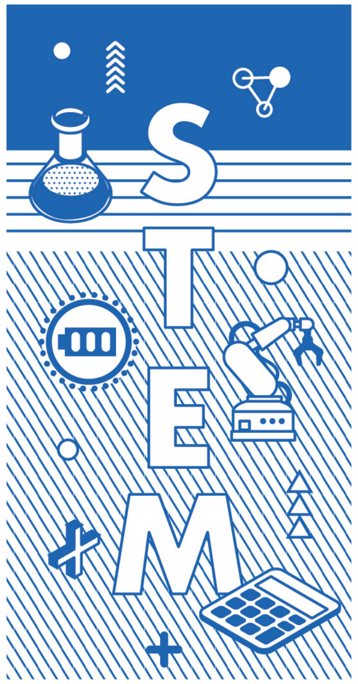
Through the contributions and fruitful participation of everyone at the **Envisioning STEM Education in Asia** seminar,the 3-day event brought about a lot of insightful takeaways from the speakers and panel discussions that highlighted the similarities and differences across the economies when it comes to their existing STEM educational programme, as well as their approaches to continue promoting STEM education amidst the pandemic.

All across Asia, it is evident that the various economies have been putting a lot of focus and effort into the promotion and cultivation of STEM education for their respective countries. Although beset by existing challenges primarily stemming from technological gaps, where there is either a lack of devices or limited access to the internet, the economies have remained agile by considering these gaps in their planning to come up with viable workarounds and proposed projects to counter them.

Clearly, the similarities across the economy's priorities are striking, as the common priorities focus on the development of not just the students but also teachers' skill sets. There is a lot of consideration being put into the professional development of educators to ensure that they are able to deliver teaching with a better level of quality that supports the proper promotion of a STEM-oriented culture.

It is also evident that the preservation of human aspects remains a top priority among the economies. It is inevitable that with the thrust of 4IR0, many important tasks and even decision making will begin to be made either primarily or solely by machines, and it is up to the economies to ensure that they are able to achieve optimal human development and adaptation by becoming technologically savvy while balancing it by maintaining our human characteristics amidst a fast-paced and dynamic progress towards being ready for a digital age.

END MATTERS



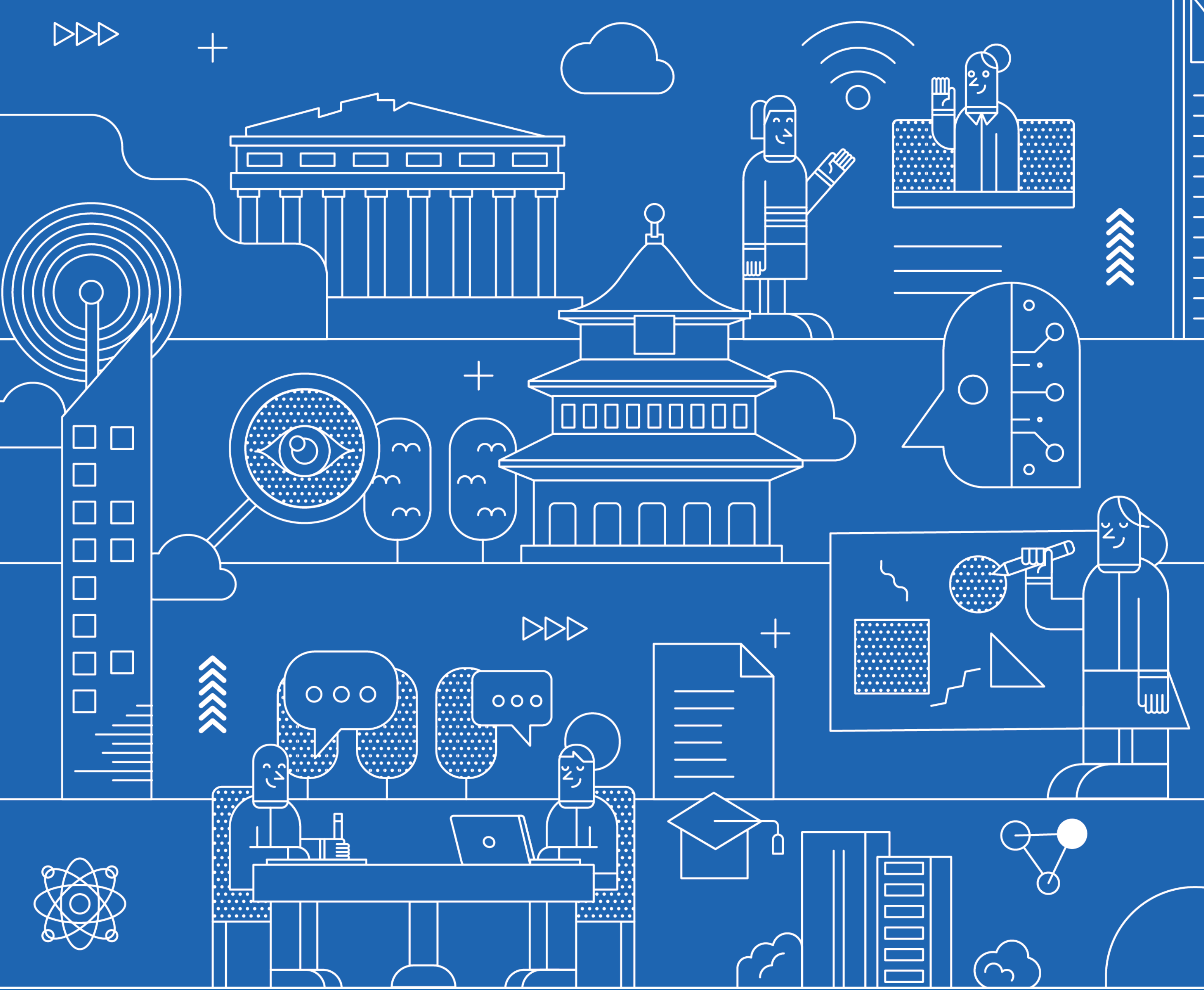
This report summarises the outcomes of the **Envisioning STEM Education in Asia seminar**, the first seminar of the **STEM Leaders Programme in Asia** organised by the Multi-centric Education, Research and Industry STEM Centre at the National Institute of Education (meriSTEM@NIE), Nanyang Technological University, Singapore, and supported by Temasek Foundation. It also paves the way for the second seminar of the programme: Sharing **STEM Competencies Practices in Asia** to be held in early 2022.

As mentioned in the Front Matters, the **STEM Competencies Framework** is a highlight of this report. The **STEM Competencies Framework** for post-COVID Asian Economies features three broad categories of competencies identified by participants of the **Envisioning STEM Education in Asia** seminar as necessary and important for Asian economies to emphasise in K-12 STEM education, post-COVID. The three categories are: **Discipline-related Skills, Life Skills** (comprising problem-solving competencies and interpersonal competencies), and **Skills for a Digital World** (comprising digital skills enhancement and digital competencies). In the second seminar, **Sharing STEM Competencies Practices in Asia**, STEM pedagogical leaders (e.g. K-12 STEM expert teachers, STEM programme leaders) from various Asian economies will be invited to share their experiences and reflections on designing, implementing, and/or evaluating STEM curriculums or activities aligned with the **STEM Competencies Framework**.

We hope that readers of this report—whether you attended/will be attending our seminars or not—will find the report as well as the STEM Competencies Framework useful in helping you (re)conceptualise STEM education in your local context. We look forward to hearing from you about how this report has been helpful for you.

STEM Leadership in Asia Programme Organising Committee

meriSTEM@NIE
National Institute of Education (NIE)
Nanyang Technological University, Singapore



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