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Insights

FUTURE JOBS FOR INDUSTRY 4.0

AND THE DIGITAL ECONOMY

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Expert Interviewees

(arranged alphabetically by institution)

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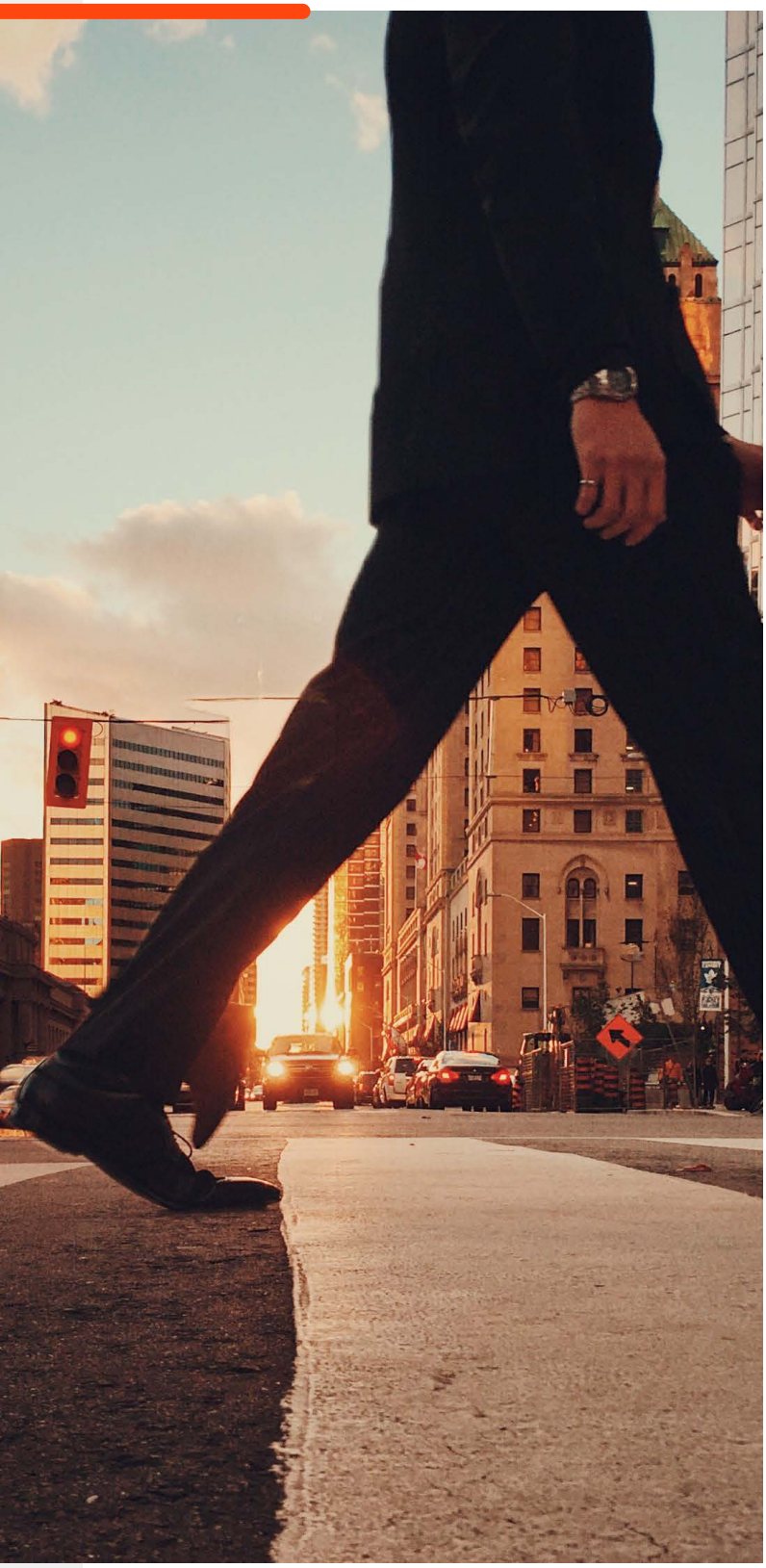
1. Introduction



Industry 4.0 describes the trend where automation powered by data may be able to perform everyday tasks. It is blurring the lines between the physical, digital and biological worlds. It also refers to the blending of two or more technologies such as genetic engineering, materials science, Artificial Intelligence (AI), advanced manufacturing and the Internet of Things (IoT) to result in innovations and solutions. Industry 4.0 has ushered in the digital economy where technology is ubiquitous, driving transformative change in the way we live and radically disrupting every business sector.

One of the biggest concerns of Industry 4.0 is its impact on the workforce. Between 400 million and 800 million jobs will be lost to automation by 2030, according to McKinsey Global Institute (MGI).[1]

There is a spot of good news: technology may destroy jobs but not work. MGI reports that only five percent of current occupations will be automated with many existing job roles redefined. Most critically, new jobs will be created. The challenge, however, is that many future jobs have not been invented or defined yet. Hence the anxieties faced by workers, employers and governments.

The reality is that tomorrow's workers must have technical skills and competence, complemented by dexterity in thinking and prowess in solving problems. The current workforce must immediately set out to upskill and reskill continually to remain competent for the Industry 4.0 era.

Governments are responding in various ways such as to expand science and technology (S&T) programmes including R&D activities; introduce new initiatives in S&T education and forge new ways of keeping the workforce relevant and ensuring employability. Private sector R&D outfits also have ongoing worker upskilling and reskilling efforts.

Against this backdrop, this Insights Paper considers the impact of Industry 4.0 and the digital economy on S&T talent development in Singapore.

[1] McKinsey Global Institute, "Jobs lost, jobs gained: What the future of work will mean for jobs, skills, and wages", November 2017 [https://www.mckinsey.com/featured-insights/future-of-work/jobs-lost-jobs-gained-what-the-future-of-work-will-mean-for-jobs-skills-and-wages]

2. Worldwide R&D Investment Landscape

Between 2007 and 2013, global gross expenditure on research and development (GERD) grew faster than the global economy. The 2015 UNESCO Science Report: Towards 2030[2] said governments continued to invest in R&D despite the 2009 global financial crisis. UNESCO studies the world R&D landscape once every five years and the next report is expected in 2020.

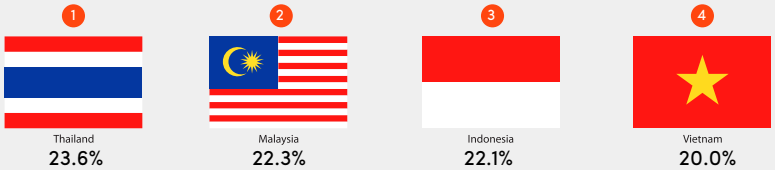
The 2015 report also pointed out that the majority of countries acknowledge the role S&T plays in their economic growth. They believe income levels will be raised, allowing them to hold their own in an increasingly competitive global marketplace.

Globally, the report stated that there were over 7.8 million researchers, up 21% since 2007. The European Union has the highest number of researchers with a 22.2% share of the total number. Since 2011, China (19.1%) has overtaken the US (16.7%). The report also highlighted that international mobility for talent was the highest at the doctoral level while the Internet had facilitated international scientific collaboration.

In its review of ASEAN countries, the report pointed out that the strongest concentration of researchers is in Singapore. Its 6,438 full-time researchers per million inhabitants in 2012 was well ahead of countries like Canada, Germany, Japan, France and the US. Singapore and Malaysia also happened to have the greatest share of PhD candidates among university students. Given that manufacturing is a big part of the economy in both countries, engineering jobs were dominant.

In the SGInnovate survey[3], titled "Understanding the Science and Technology Talent Landscape in Singapore", slightly more than a fifth of respondents indicated that Thailand (23.6%) is likely to be Singapore's biggest competitor in attracting S&T talent in Southeast Asia. The respondents also highlighted that Malaysia (22.3%), Indonesia (22.1%) and Vietnam (20%) are the other top contenders for S&T talent in the region.

Competitiveness of Singapore's Science & Technology Industry



In Southeast Asia, professionals in the science and technology industry indicated that Thailand (23.6%) will be Singapore's biggest competitor in attracting R&D and technical talent.

This is followed by Malaysia (22.3%), Indonesia (22.1%) and Vietnam (20.0%).

[2] UNESCO, "UNESCO Science Report: Towards 2030", 10 November 2015 [https://en.unesco.org/node/252273]

[3] The SGInnovate survey captured the views of 150 respondents, on the S&T talent landscape in Singapore. All responses were received in 2019, and this survey was undertaken in conjunction with this Insights Paper.

3. Singapore Science and Technology Strategy

Singapore's investments in S&T focus on keeping the Republic competitive and relevant globally, as well as seeding exciting new opportunities for the digital economy. Additionally, the spending on science and technology must have a positive impact on GDP growth. Thus, the country's twin efforts are in developing S&T capabilities to strengthen its industries and to grow its S&T talent base. Ultimately, it is to enhance Singapore's position as the tech node in Asia-Pacific as well as to be one of the most research-intensive, innovative and entrepreneurial economies in the world.

Indeed, nearly half of the respondents in the SGInnovate survey support the Government's lead to build the S&T talent together with the national science and technology agencies.

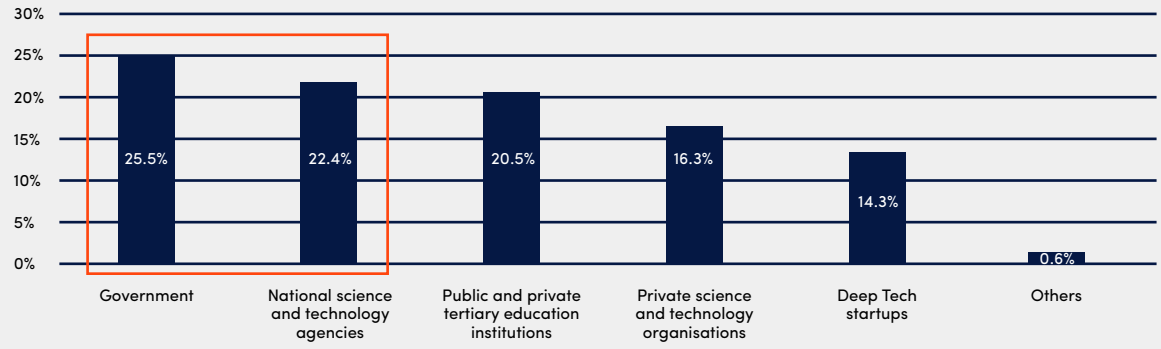
Initial S&T efforts focussed on strengthening the manufacturing sector. Gradually, as the country's economy became more sophisticated and advanced, the policy expanded to focus on other areas, especially biotechnology and biomedical sciences, cybersecurity, and computer science.

Singapore's science and technology efforts are best seen through its R&D investment lens where it has spent about US$44 billion since 1985 to build research and manpower capabilities, and grow leading-edge research institutions. The results are impressive. There are about 20 research institutes under the Agency for Science and Technology Research (A*STAR)[4] employing a total of about 5,000 scientists and engineers. Several technological centres of excellence have been established in the National University of Singapore (NUS), the Nanyang Technological University (NTU) and other tertiary institutions. Joint laboratories between the government, university and private sector organisations have also been set up to do translational research.

Between 2009 and 2013, the national S&T efforts gathered faster momentum as the Government raised R&D spending to more than 1% of GDP in a bid to develop intellectual capital and provide researchers for the R&D community.

Developing Singapore's Science & Technology Industry

Close to half of the respondents indicated that **Singapore's government (25.5%)** and **national science and technology agencies (22.4%)** should take the lead in developing Singapore's R&D and technical talent in the science and technology industry.



[4] Agency for Science, Technology & Research, "Research Entities Capabilities" [https://www.a-star.edu.sg/language/en-SG/Research/Research-Entities-Capabilities]

Several national research institutions were grouped into two centres of excellence: Biopolis for biomedical research opened in 2003 and Fusionopolis for ICT in 2008. In recognition of Singapore's efforts, the 2015 UNESCO report credited the Republic to be the international hub for R&D in the Asia-Pacific region.

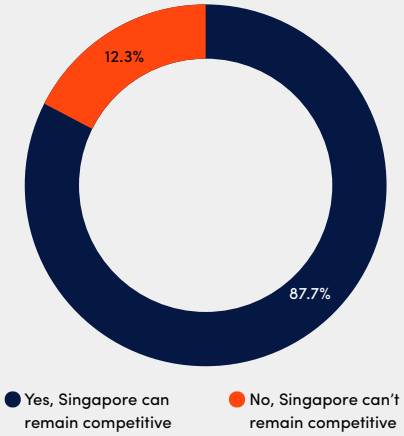
The nation's current five-year R&D masterplan is the US$13.8 billion Research Innovation Enterprise 2020 Plan (RIE2020). Spearheaded by the National Research Foundation (NRF), it is injecting more funds in expanding fields like advanced manufacturing, synthetic biology, supercomputing, robotics, cell therapy and sustainable urban food production. It will also support the translational research to address national issues like urban congestion and ageing population. RIE2020 also aims to build up innovation and technology adoption in companies and drive economic growth.

Technology consortia have also been set up by NRF in areas like photonics, synthetic biology and biofilms to bring together local pockets of research expertise and capabilities.

Talent development is a crucial pillar in RIE2020. Currently, there are over 35,000 research scientists and engineers in Singapore, according to A*STAR. Undoubtedly, S&T investments will generate economic opportunities here, including creating new exciting jobs in cutting edge technology and leading-edge applications.

The majority of respondents (87.7%) from the SGInnovate survey are confident that Singapore will continue to remain a competitive R&D and product development global hub in the next five to 10 years. Their confidence is based on the Government's continued efforts to provide leadership, direction and financial support for the science and technology industry.

Competitiveness of Singapore's Science & Technology Industry



- Majority (87.7%) of S&T professionals feel Singapore can still remain competitive as a global science and technology R&D and product develpment hub in the next 5-10 years.
- Amongst these respondents, **clear direction and strong support from government** was noted as the top reason why the respondents believe Singapore will remain competitive in the near future.

4. Future Jobs

Pursuing a career in S&T and taking on advanced technical jobs can be satisfying. On average, more than three out of five respondents from the SGInnovate survey perceive that R&D professionals here in computer science, science and engineering are well-qualified. They point to the tremendous upward growth curve for the technology industry as an indicator for the slew of exciting careers that will open up over the next few years.

There are three S&T disciplines – computer science, science and engineering – which form the foundational technologies on which leading-edge applications are developed and where talent is most urgently needed as Singapore advances into Industry 4.0.

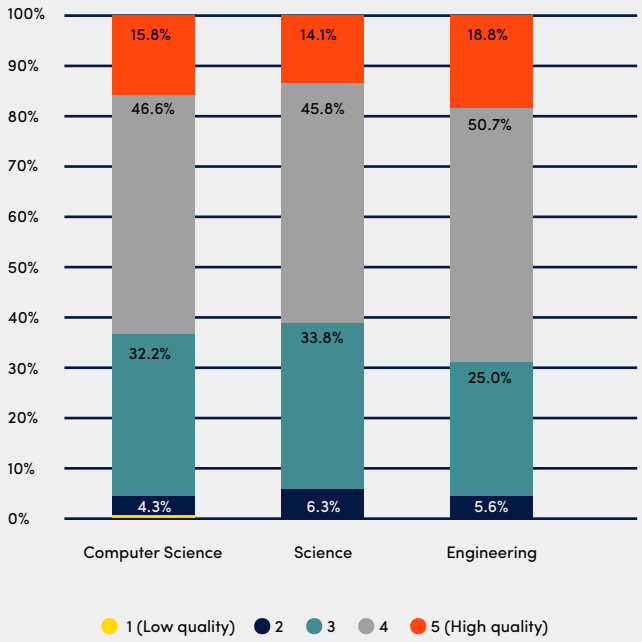
Computer science disciplines

A digital economy needs ICT professionals. In 2017, NUS, NTU and other tertiary institutions produced over 8,000 graduates in computer science, engineering, science, medicine and related disciplines.[5] As organisations proceed with digital transformation, more expertise in this field is needed. Southeast Asia's largest bank DBS for example, tripled the headcount in its technology and operations department to 10,000, hiring software engineers, data scientists and cloud specialists among others.[6]

Data scientists and cybersecurity specialists are the fastest-growing occupations in Singapore. According to a Linkedin report[7] in 2018, demand for data scientists grew the fastest at 17 times the previous year. Demand for cybersecurity specialists grew 5.5 times.

Opportunities are aplenty in these two areas. Insights gleaned from the data can help companies in various ways from more

Confidence in the Quality of Talent in Singapore's Science & Technology Industry



- Overall, respondents are confident about the quality (i.e., technical skill sets and mindsets) of talent across all three disciplines within Singapore's science and technology industry, particularly in engineering.
- Nearly 7 out of 10 [69.5%] respondents indicated that the current Engineering R&D and technical talent working in Singapore have high quality technical skill sets and mindsets.*
- This is followed by talent in the Computer Science [62.4%] and the Science [59.9%] disciplines.

(*For mindset, we are referring to attributes such as continuous learning, risk-taking and the willingness to experiment, and openess to new ideas.)

[5] Ministry of Education Singapore, "Education Statistics Digest", 2018
[https://www-moe-gov-sg-admin.cwp.sg/docs/default-source/document/publications/education-statistics-digest/esd_2018.pdf]

[6] Today Online, "The Big Read: Nerds and geeks no more, computing graduates now rule the roost", 10 March 2018
[https://www.todayonline.com/singapore/big-read-nerds-and-geeks-no-more-computing-graduates-now-rule-roost]

[7] Today Online, "Data scientists, cyber-security specialists among top emerging jobs in S'pore: LinkedIn report", 6 September 2018
[https://www.todayonline.com/singapore/data-scientists-cyber-security-specialists-among-top-emerging-jobs-spore-linkedin-report]

efficient use of manpower to improved customer engagement. Demand for cybersecurity professionals is also exploding as organisations seek new ways of protecting and defending themselves against the exponential growth of online threats and attacks.

But there are other fast-rising domains such as computational science to support supercomputing capability. It combines computer science with other domain-specific areas in biology, chemistry and other sciences to design simulations of physical phenomena to run on supercomputers. Another is quantum computing which approaches computation from a fresh approach – not based on classical computing – to crunch data much faster.

Although not new areas of study, computational science and quantum computing are coming to the fore partly due to the expansion and commoditisation of computing power in the last decade and the explosion of data. This confluence allows data to be mined and analysed quickly and more affordably for their useful insights.

Artificial intelligence has deep roots in Singapore. Among the earliest AI application worldwide was expert systems which trained computers to solve problems following an "as if-then" rules. In the mid-1980s, the then Port of Singapore Authority faced a challenge in the planning of loading/unloading containers. It required 25 ship planners around the clock to do this. The Port worked together with a government research agency called Information Technology Institute (closed in 2000) to roll out the Ship Planning Expert System in 1987.[8] This system won the Innovative Application Award from the American Association for Artificial Intelligence at its inaugural conference in 1989 at Stanford University. This award placed Singapore's AI engineers alongside teams which had developed expert systems such as the US National Aeronautics and Space Administration's space shuttle mission control system.

From this pocket of AI engineers, Singapore had built out its AI capabilities in areas like machine learning, deep learning, decision making, computer vision, natural language processing and others. AI has been identified by the Government as a core technology essential to the country's push to become digitally ready. To spur the development of local AI talent and ecosystem in Singapore, AI Singapore was set up by the National Research Foundation.

With this push into AI, many job opportunities will become available, said Dr Leong Tze Yun, Practice Professor at the School of Computing, NUS, and Director of AI Technology at AI Singapore. Various AI scientists, experts and technologists will be needed in various areas, including inventing new solutions, integrating AI to solve complex problems and managing AI teams. To help users apply AI-powered applications in problem-solving, AI application specialists will have to be trained.

According to AI Singapore, AI researchers here are strongest in machine learning followed by computer vision, robotics and natural language processing.[9] AI Singapore is collaborating with various tertiary institutions to build expertise. For example, with NTU, it is collaborating on machine learning, data mining, computer vision as well as applying AI in ageing and healthcare solutions. With the Singapore Management University, it is zooming in on AI for urban and social sensing.

[8] Infocomm Development Authority of Singapore, "Innovationation: 25 Years of Infocomm in Singapore", 2006

[9] AI Singapore, "AI Research" [https://www.aisingapore.org/research]

In the coming years, AI experts will be needed to assume roles such as:

- AI research and engineering scientists to invent new AI theories, methodologies and systems.
- AI technology engineers to design, develop or integrate AI methodologies and systems to solve complex problems. They would need systems engineering and translational skills for this role.
- AI application engineers to integrate, apply and use AI technologies and systems to solve new problems. They need not be trained in computing science but must be trained to use AI techniques.
- AI system managers to plan, budget and manage AI talent, resources and operations.

Cybersecurity is a pre-requisite for every organisation. It is a long and never-ending journey. No organisation including government agencies will have cyber defence capabilities that are absolutely impregnable against attacks. Attackers are using the same technologies employed for cyber protection to launch their attacks.

Singapore is one of the most connected nations in the world. Reliance on technology, however, also opens up organisations to cyber threats and attacks which are becoming increasingly sophisticated. Symantec's Internet Security Threat Intelligence Report 2019[10] show that globally, web attacks have risen 56% and mobile ransomware is up 33%. Many of the attacks steal information including intellectual property or are designed to bring down critical infrastructure like healthcare and power generation.

Singapore started its cybersecurity strategy in 2005 with its first Infocomm Security Masterplan which focussed on building basic capabilities within the public sector to mitigate and respond to cyber threats. The current National Cybercrime Action Plan 2016 spells out priorities to fight against cybercrime including public education and strengthening international collaborations.

In 2020, the Government expects there will be a potential shortage of up to 3,400 cybersecurity professionals[11] here. Many different types of jobs from cyber risk analysts, security engineers to security operations manager and forensics experts are available. Many organisations are also beginning to hire chief cybersecurity officers to provide corporate guidance and governance.

Job opportunities in this sector are immense. Talent is needed to detect, defend and protect, as well as to predict potential threats and attacks. According to LinkedIn, cybersecurity specialists are the second most in-demand profession in 2018 after data scientists.[12]

Examples of cybersecurity job roles include:

- Forensics experts who are similar to crime scene investigators. They are called in to analyse and determine the masterminds behind security breaches.
- Threat hunters' aim is to uncover cyberattacks that are hidden, waiting to be activated. They need a good understanding of businesses and their operations to be able to detect abnormal behaviours.
- Security architects design systems to develop and test the security vulnerabilities of organisations.
- Cryptanalysts/cryptographers are code makers who build special algorithms to encrypt and hide sensitive information from cyber attackers. They secure critical data from being copied, edited or deleted by unauthorised users as well as test ICT systems for weaknesses.

[10] Symantec, "Internet Security Threat Report", February 2019
[https://www.symantec.com/content/dam/symantec/docs/reports/istr-24-2019-en.pdf]
[11] The Straits Times, "Cyber-security contest aims to attract young people to sector", 17 July 2019
[https://www.straitstimes.com/tech/cyber-security-contest-aims-to-attract-young-people-to-sector]
[12] LinkedIn, "Emerging Jobs Report 2018"
[https://business.linkedin.com/talent-solutions/talent-intelligence/emerging-jobs/sg-emerging-jobs-report#]

Data science can be used in various industries from advertising to utilities. This discipline is geared towards providing meaningful information based on large amounts of complex data. It combines statistics and machine learning in order to interpret data for decision-making purposes. With the insights provided, businesses obtain a better understanding, among other things, of customer behaviour and transactions.

Data scientists are in great demand especially by organisations undergoing digital transformation. They can "unlock" the value of the data embedded in business processes that can lead to greater efficiency and savings in cost and time as well as uncover new business and revenue potential.

Queen of Figures

In the mid-2010s, when the term "data science" was emerging as a discipline, Serene Ow left her job in applied defence research in DSO National Laboratories for a data science role with consulting firm EY.

Data science is a multi-disciplinary field, and while she was experienced in some of the areas, she also took up online courses to learn the additional skills. At EY, she gained exposure to various sectors such as banking, healthcare, security and public service, where she applied data science to improve business operations. Serene is currently leading Grab's data science team for transport.

"Data science is about algorithms; the knowledge is transferable and can be applied across all domains. With a technical background, it's easier to pick up. As it is software-based, if I want to develop a model, I can do it on a computer and see the outcome directly."

Data science is more than just analytics, she explained, adding that it also involves techniques such as optimisation and simulation. To be a good data scientist, technical skills coupled with a questioning mind and good communication skills are important.

"Technical background is one thing. We need someone who is logical and willing to ask questions.

Serene Ow, Head, Data Science, Transport, Grab

Why does this model look weird, is the data skewed; why are there unexpected results; and so on.

We cannot take data results at face value; we have to verify and validate."

Good communication skills are needed to explain to decision makers and executives the outcome of the modelling.

What kind of team members does she look for?

"I look for people who can quickly understand the problems in a certain context and apply their technical knowledge to solve problems in that domain. They must also be motivated self-learners who demonstrate flexibility and adaptability."

Science

Rapid developments in scientific knowledge – from finding a cure for cancer to inventing a new clean form of energy – will improve living standards. However, science fundamentals such as the science of materials, will remain foundational, said Dr Jeffrey Tung, Head of R&D, Greater China Area, 3M.

"For instance, a very smart device with cutting-edge software featuring AI capabilities can be designed. However, if the material used cannot enable this device by way of overheating prevention, improving durability or waterproofing, technological and scientific advancement would be severely limited."

Nanomaterials, neurotechnology and synthetic biology are the other key emerging technology trends, he added.

To work in top-tier R&D labs that undertake basic research, it is important to have PhD qualification with postdoctoral fellowship experience. Scientists can aspire to become principal investigators to run their own labs.

Some private sector R&D programmes are open to hiring research officers with masters degrees. They also offer professional and managerial tracks. For the professional track, the highest rank obtainable is a chief scientist or something akin to this role.

Entrepreneurial scientists can start their own companies by acting on their passions. Cardiologist Dr Philip Wong of the National Heart Centre was a gadget enthusiast. He started Web Biotech on a part-time basis to develop a wearable to detect heart arrhythmia.

Other scientists licence a technology for commercialisation. Dr Rosemary Tan, chief executive of homegrown Veredus Lab, licensed disease testing technology from A*STAR where she had worked before. This technology allowed Veredus to detect malaria, dengue, SARS (Severe Acute Respiratory Syndrome) and other diseases. When STMicroelectronics and a French-Italian semiconductor company invested in Veredus, she developed its lab-on-a-chip technology.

Engineering

In the digital economy, engineering is more important than ever. They are needed for Singapore's R&D efforts in climate change mitigation, green manufacturing technology, engineering solutions to improve food security, electrification of the transportation system, enhanced water and energy production, biofuels and emissions control technology.[13] In the SGInnovate survey, about seven out of 10 respondents indicated that the current engineering researchers have good technical expertise.

Engineers make science and technology invented workable. Their expertise is in improving the technology readiness of a product or solution including its components, measuring manufacturing performance, costings, testing and packaging. The universities hope to enhance the effectiveness of future advanced engineering manpower by introducing a new type of graduate engineering programme especially in translational research.

The Doctor of Engineering (EngD) is a new research degree at the doctoral level to develop master engineers who not only can innovate but also translate the new ideas into commercialised products. This master engineer will have a deeper industrial focus and will have mandated technology management coursework. This is most appropriate for those pursuing professional rather than academic careers. NUS has introduced this programme in 2018.

Professor C.C. Hang of the Engineering Faculty, NUS, said of the EngD course, "The engineering landscape in Singapore has become more sophisticated and knowledge-intensive. Many of our top engineers are interested in gaining greater expertise but are not interested in PhD programmes because they don't want to become professors or to do basic research in universities."

"The EngD thus allows them to gain greater expertise while working full-time in industry on applied R&D, but at the same time they learn about the business aspects, so that they are better prepared to take an invention or research result into commercialisation."

[13] Academy of Engineering Singapore, "Engineers for the future" [https://www.saeng.sg/key-projects/engineers-for-the-future]

Entrepreneurial King of the Lab

Managing a scientific lab is akin to founding a startup. The founder is the lab's principal investigator. He finds the funds to finance his research programme and to recruit the best scientific minds. He also has to look for business partners with whom he can test his research theses. At the same time, he must actively continue with his own research so as to keep up to date with the science and to publish his scientific findings to maintain his credibility.

Dr Adrian Teo is a principal investigator (PI) at the Institute of Molecular and Cell Biology (IMCB), A*STAR. His lab, Adrian Teo Lab, focusses on the use of stem cell technology to model human pancreas development and to study diabetes disease mechanisms. He leads a 14-man team of scientists, postdoctoral fellows, PhD students and research officers.

The route to running his own lab started with a PhD programme at the University of Cambridge followed by postdoctoral fellowship at the Harvard Medical School. While at Harvard, he obtained two seed grants from the Harvard Stem Cell Institute and a Juvenile Diabetes Research Foundation fellowship to pursue his research interests in stem cell for diabetes.

It was during his PhD days that he decided he wanted to run his own lab. It will give him autonomy over his research and let him set his own research agenda. He had already begun to develop an interest in stem cells and diabetes. With this in mind, he set out to learn how to run a lab by observing the way his professors and mentors manage their research and scientists as well as integrate with the scientific community. He also wrote up applications for scientific grants to gain experience in this area. He interacted with other scientists and the R&D community to build contacts.

Dr Adrian Teo (seated on the right) runs the Adrian Teo Stem Cells and Diabetes Laboratory to research the potential treatment of diabetes using stem cell technology.

"I was preparing myself, so the hard work that came with my lab didn't come as a cultural shock."
A typical day at the lab starts with him doing some experiments for a few hours. Later in the day, he holds a lab meeting with his staff for about an hour or two. Every week he spends a few hours meeting potential collaborators and companies interested in his work. He also puts aside time to meet every team member once a week. "This is what my mentors did for me, I learnt a lot through this way. I want to continue this, training and guiding the other researchers."

Running a lab is hard work, said Dr Teo. "Each research project runs for three to four years at any one time." The satisfaction is seeing results and his team growing in scientific stature, maturity and experience.

Apart from these courses, engineers can also consider postgraduate programmes in management of technology, supply chain management, materials science and engineering and postdoctoral fellowships.

At the undergraduate level, new modules have been added to provide future skills. NUS Engineering for example, has introduced new specialisations in robotics, Internet of Things, digitalisation in urban infrastructure and data science in its 2019 academic year. Top students will have a chance to accelerate their education, obtaining in four years, a Masters in Science degree – in any area including business and computing – in addition to their basic engineering degree.

Ministry of Education Singapore, "Education Statistics Digest", 2018
[https://www-moe-gov-sg-admin.cwp.sg/docs/default-source/document/publications/education-statistics-digest/esd_2018.pdf]
Today Online, "The Big Read: Nerds and geeks no more, computing graduates now rule the roost", 10 March 2018
[https://www.todayonline.com/singapore/big-read-nerds-and-geeks-no-more-computing-graduates-now-rule-roost]

5. Jobs from Technology Convergence

When ideas and technologies converge, new types of jobs emerge. This is occurring rapidly in ICT and AI. X-Informaticians are new job roles where two disciplines converge, said NUS' Dr Leong Tze Yun. This is when domain experts like lawyers and doctors acquire AI skills to integrate, apply and use the technology to solve complex problems such as disease management, healthcare and risk stratification.

Another profession at the intersection of disciplines is a geospatial expert, a specialist who understands data that identifies the geographic location of features and boundaries on Earth. Needed in various industries including healthcare, education, transport and energy, they will grapple with issues that have no precedents, some of which do not even exist yet. Through visualisation and analysis, they will help to make sense of complex issues and phenomenon by integrating different types of information from a variety of sources. They will be at the cutting edge of technological advances in the collection, visualisation and analysis of data.

To qualify as experts, they will study courses such as remote sensing, spatial information science, geographic information technology and geoinformatics.

In medicine, clinician-scientists are carving new career paths. They are medical doctors interested in using research and science to improve medical treatment. With the explosion of new scientific knowledge reaching the desks of doctors, they can quickly translate the new scientific developments into clinically useful products through tests and experiments and finally into procedures or products.

> **"X-Informaticians are new job roles where two disciplines converge."**
>
> **Dr Leong Tze Yun,**
> *NUS*

6. Transitioning to Deep Tech

Job opportunities are continuing to expand in the S&T fields. The majority of respondents (84.3%) in the SGInnovate survey say that pursuing R&D and technical jobs in Singapore's S&T is rewarding. This is due to the fast expansion of the technology industry and the chance to create new technologies for the benefit of society.

Job opportunities are good for mid-career professionals seeking to switch to the S&T sector. While digital literacy and digital fluency will be needed, deep technical skills will not be required especially in areas like intellectual property management, manufacturing operations, sales and customer support.

Moreover, executives with several years of work experience can leverage their background and know-how just like how Paul Sun of biotech firm Veredus Laboratories did.

To make the switch to the S&T sector, these tips can help.

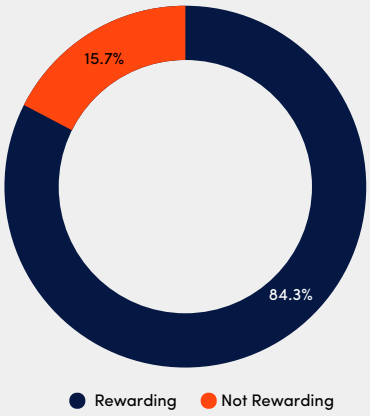
First, translate the work experience into useful skills. Paul Sun, COO of biotech firm Veredus Laboratories made the transition from the consumer and lifestyle goods industry to the biotech field by leveraging his experience in product design, people management and communication skills to lead new teams.

Second, persistence and perseverance to learn a new domain knowledge are important. If Sun did not pick up knowledge of molecular biology and clean room manufacturing he would not have succeeded in Veredus. Of course, employers have to play their part too by making an effort to educate and guide these transition employees.

Third, picking up new skills to layer on top of experience is important. Coding comes to mind, but not everyone likes programming. Consider managing intellectual property which is vital to any S&T company's success. Knowledge in this area can be obtained by taking executive or degree courses in intellectual property at the IP Academy. Shorter courses in IP law and issues in areas like R&D collaboration and procurement are also available at the Academy. The NUS also offers a postgraduate programme in IP Management.

Fourth, get a placement as a Senior Intern. Of course, it comes with no pay, or the usual pay of an intern which is a fraction of what a professional would earn. But learning new disciplines and different types of workplaces could make up for the financial loss. The experience will prepare them for potential full-time employment when the opportunity arises. Some roles that Senior Interns can fill include market research, marketing and customer engagement.

Opportunities and Rewards in Singapore's Science & Technology Industry



- Majority of respondents (84.3%) feel that pursuing R&D and technical jobs in Singapore's science and technology industry is rewarding.
- Amongst these respondents, the tremendous growth trajectory for the technology industry, and the chance to experience and create cutting-edge technology are the top two reasons why the respondents believe a career in this sector is rewarding.

The Big Switch

Mechanical engineer Paul Sun's ability to leverage his experience and willingness to learn helped him succeed as COO at Veredus Laboratories where he has to ensure that the biotech firm's innovative solutions for the detection of pathogens reach customers in a timely manner. The company's Lab-On-Chip platform can be used in areas such as bio surveillance, food testing and detecting infectious diseases.

As Veredus Chief Operating Officer, Sun joined a company where almost all employees are molecular biologists and chemists. Sun is the exception. He is a mechanical engineer who has worked in various industries including automotive, oil and gas, homeland security and luxury services.

Yet he has succeeded at Veredus as a senior executive. Veredus CEO Dr Rosemary Tan attributed it to Sun's willingness to pick up new knowledge and his ability to translate his experience in engineering product design, development and marketing into useful skills for a biotech company.

She said: "It took a lot of learning on both parties and a lot of patience. But he succeeded and is now an invaluable member of our team."

With Sun, Dr Tan can now spend more time working with her scientists to identify new innovations and to look at new business opportunities.

To do his job effectively, Sun threw himself into the biotech world. He learnt about molecular biology and picked up scientific jargon. Gradually, he became more comfortable and he could start to actively contribute by mapping out product development plans including manufacturing operations.

Three years into Veredus, Sun recalled those early days: "It's up to me to learn. I spent a lot of time with

the scientists, product marketing, production and manufacturing staff, learning the science, technology and the operations."

"I was working for a CEO who is a specialist in the field and very good at what she does. So I play to that strength, supporting her work and leveraging my experience to help scale the company."

He guided the scientists to focus on the research that would result in new solutions to expand the business. He introduced processes to ensure the solutions reached the market in a timely manner.

Sun is an example of a mid-career executive who successfully transitioned from one industry to the next. The secret of his successful transition was his willingness to step out of his comfort zone and to learn totally new skills. Adaptability and flexibility were two crucial traits needed for this.

Originally from Taiwan, Sun worked in the US with General Motors' Delphi unit and Exxon Mobil before moving to Singapore to join General Electric, Smith Detection and SUTL. Now a Permanent Resident in Singapore, he was headhunted to join Veredus. "I was attracted to Veredus because it makes innovative products that have a positive impact on people's lives. I want to be part of that."

7. Observations

Industry 4.0 and the digital economy open doors to new career and work opportunities yet to be identified. A basic STEM education prepares tomorrow's workforce but there are developing trends that tomorrow's workforce and employers should be aware of.

R&D professionals here are recognised for their technical expertise. However, soft skills in communication, critical thinking, collaboration, creativity and computational thinking are lacking. These skills are needed because technology is becoming ubiquitous, moving across all departments. The norm tomorrow is that organisations will have employees and customers located in different countries with different cultures and languages. Having the ability to communicate and explain to colleagues and business partners are crucial factors for success.

Besides, R&D professionals must be able to communicate the relevance and value of their work to business leaders. It is worthy to note that less than half of respondents (48%) for the SGInnovate survey believed that there is a high prevalence of soft skill sets amongst Singapore's current S&T talent.

Juliana Lim, Head of Talent Networking at SGInnovate, singled out critical thinking and teamwork as the top skills needed for the digital economy. "It is no point having the best technical knowledge if you cannot think out of the box to apply the expertise to solve problems."

Professor C.C. Hang emphasised that broadening the education of engineers with social science subjects is essential. "A blend of engineering and humanities is good, especially for students who may become public servants or industry leaders who could influence policymaking for nation-building. It's healthy cross-fertilisation, taking a step back to consider policies and their impact on society."

Interpersonal skills are equally important. Introverts are not good for a research group because in carrying out experiments, everyone is required to help. Dr Manas Mukherjee, principal investigator at the Centre for Quantum Technologies, said: "Each scientist has unique skill sets. It takes everyone to make a research project work. It is essential to be able to get along with other people, to be a team player."

Computational thinking is an increasingly major skill to have. It is about systematically approaching a problem, breaking the problem down into components, followed by assessing and identifying the patterns causing the problem, then creating solutions. Generally, solutions have to be represented in a form that can be effectively carried out by computers.

For undergraduates, taking electives in these areas will complement their STEM education. For those already working, identifying role models to observe the way they manage professional relationships and solve emerging problems would be helpful.

Technology will influence job descriptions not once, but many times in any individual's career. Tomorrow's career path may not be an upward trajectory but sideways and then onward and up again. The ability to navigate these changes require flexibility and adaptability.

> **"It is no point having the best technical knowledge if you cannot think out of the box to apply the expertise to solve problems."**
>
> **Juliana Lim,**
> *SGInnovate*

Postgraduates are needed

STEM graduates considering a career in research should have at the minimum a PhD qualification. Postdoctoral fellowships are vital for those who want to hone their specialisations. To bolster scientific experience, overseas stints with reputable research labs and postdoctoral work with well-known scientists are also essential.

Being entrepreneurial is critical

Entrepreneurship is a buzz word but it is no hype. To be entrepreneurial, it does not mean that researchers and scientists must spin out startups. Entrepreneurship is a mindset. It means the ability to identify new areas for innovation, nimbleness in decision making and willingness to take a bet. For S&T organisations to succeed, its technical staff must have this attitude and mindset that will aid them to do their jobs better and more effectively.

Coding and digital fluency are life skills

The ability to code or write a software program helps workers construct a set of instructions to implement an algorithm to solve a problem. Every profession from microbiologists and pharmacologists to psychologists and marketers all need to know coding. There is no escape from this skill.

Linked to this is digital fluency, tomorrow's non-technical workers must be able to discover meaning from data and communicate ideas with digital tools. Ability to do this is an advantage when seeking jobs in the S&T sector.

Go for apprenticeships to get a head start

The challenge for employers has been to get fresh hires in their first job up to speed quickly. Apprentices who have learnt new skills during their apprenticeships provide this leg-up for both employers they can get to work immediately and there is little or no handholding needed.

Hire people who have the ability to acquire new skills

For employers and organisations, hiring practices have to evolve. Hiring managers should look for people who have the ability to acquire new skills continually because job scopes will always evolve, and formal educational requirements will no longer be sufficient to assess a potential candidate.

Continuous learning is a must-have ability. Workers today and tomorrow must be prepared for a skill upgrading marathon which does not end. They have to learn new skills to add to their baseline education to remain relevant.

New approaches to hiring are already in place. Tufts Medical Center in Boston has substituted a healthcare-oriented assessment, rather than a degree or prior work experience, as the first filter for 22 different job titles. This accounts for about 25% of its workforce. The result has been a far more diverse pool of vetted new hires.[14]

Training the trainers

The hunger of skills has taxed the specialists. Academia has been extensively tapped to provide executive and customised courses especially in computer science and AI. This has overwhelmed academic staff. To alleviate this problem, a "train the trainers" initiative will see the computer science academics design programmes to train experts who can then train others.

Non-computing programmes could also be set up where X-Informaticians in health, law, finance and other areas can be trained jointly by the computing and non-computing domain experts.

[14] Institute for the Future, "A Nation Upside Down"
[http://www.iftf.org/fileadmin/user_upload/futureskills/downloads/ANationUpsideDown_Innovate_Educate.pdf]

Update your skills inventory

This is a checklist of organisational capabilities that is helpful to identify gaps in competencies and to help plot what is needed for the next three or more years. With Singapore moving to zero manpower growth, it is even more urgent to understand the future skills needed.

In tomorrow's automation- and data-driven workplace, the skill needs of organisations will evolve often. Job descriptions will change; some roles will become obsolete while new types of work will surface. It is impossible to predict exactly the technical skills businesses require five years or more from now. The time to act is now. Human resource managers should spend time with their business leaders to draw up future skills needs.

Retaining talent remains challenging

According to the SGInnovate survey, talent retention is the biggest challenge for Singapore's S&T sector. Employers are fighting a global war for talent. Small companies are disadvantaged because they do not have deep pockets nor the reputation to attract talent.

Instead of big salary increments, startups and organisations including public sector agencies are known to dangle juicy carrots in the form of a technical challenge to attract talent.

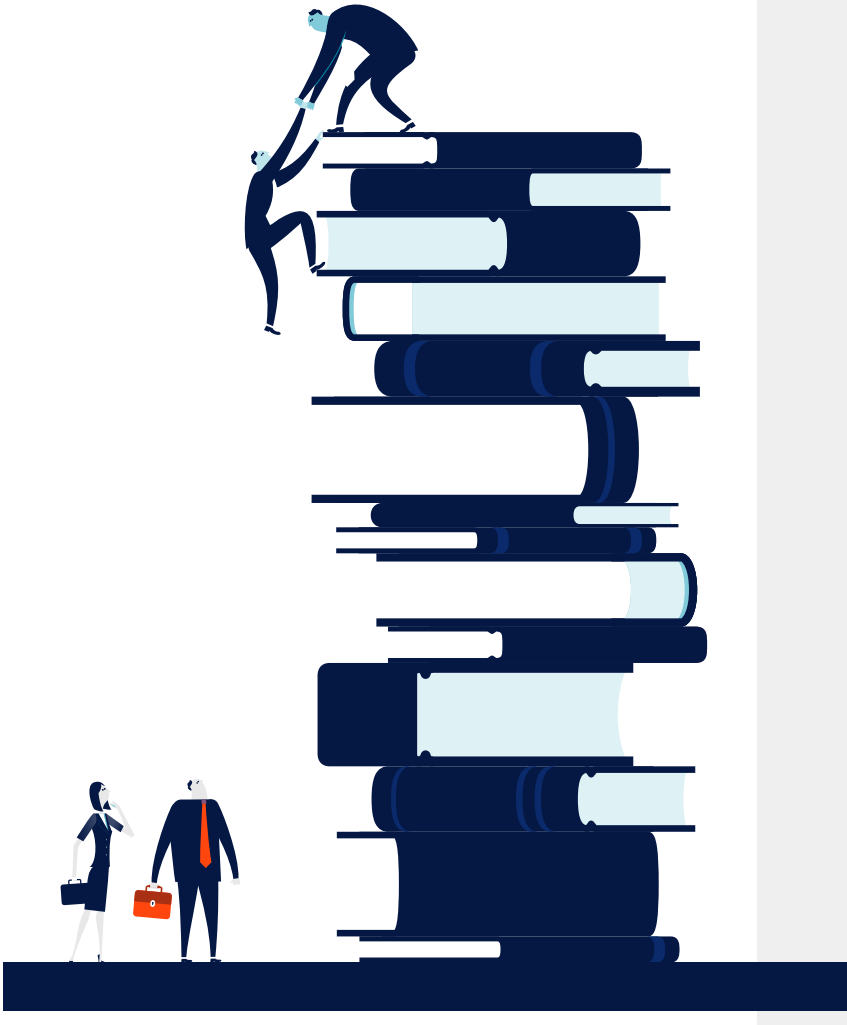
Visenze, a Singapore startup in machine learning and deep learning, retain its talent by offering them seemingly intractable problems to solve. Visual search problems are provided by its customers like Samsung, Rakuten and Uniqlo.

"They tell me their challenges, and I give them to my software engineers as problems to fix. They are interested in solving the problems because they can list in their CVs, the three to four projects they have successfully undertaken. This way, they get to increase their value if they want to move to another company. But in the process, they stay longer with Visenze doing important and relevant work," said CEO Oliver Tan.

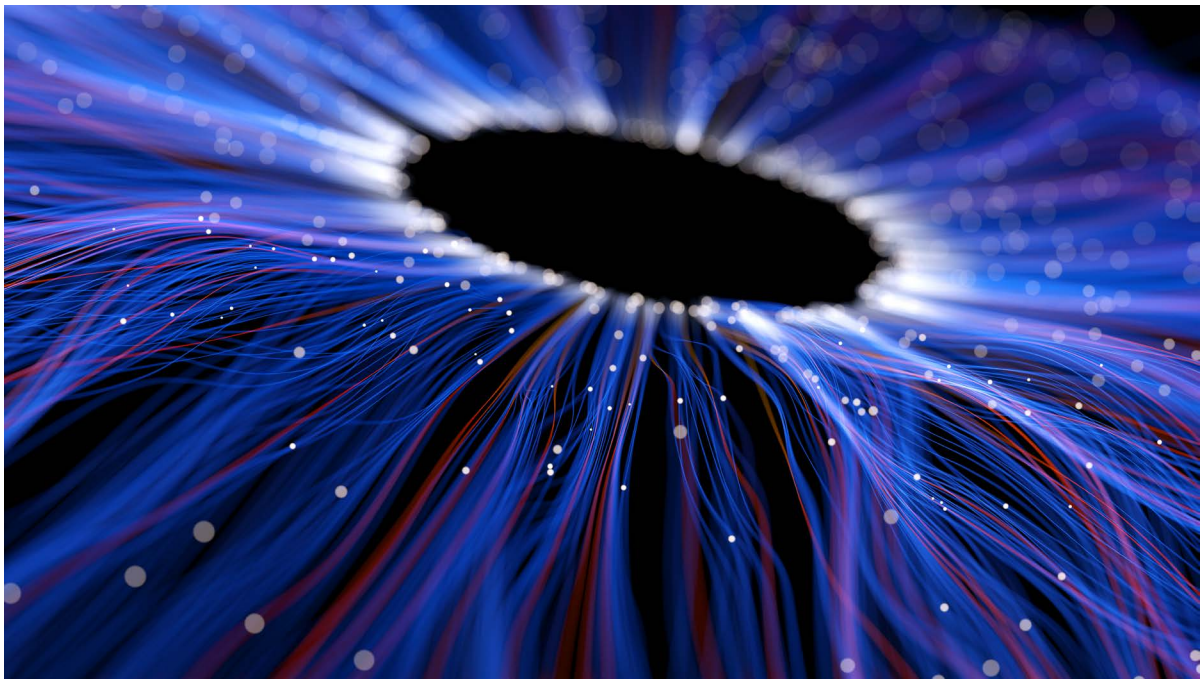
Emphasis on intellectual property

Industry 4.0 and the digital economy emphasise innovation and enterprise. IP leaders are crucial for organisations so that there is a focus and strategy around managing IP which includes registration of patents, copyrights, trademarks; managing IP portfolio and licensing. Currently, these tasks could be within the purview of the legal counsel, founder or a researcher.

Executives with technical education is preferred but not necessary. This is a job that needs familiarity with IP rules and regulations. It is well-suited for executives who are thinking of switching to a deep tech industry or who want to enhance their capabilities further.



8. CONCLUSION



Emerging technologies and future discoveries will accelerate Industry 4.0 and the digital economy further. The forecast for S&T companies which will drive and power many future innovations and inventions is looking good. For example, the global pharmaceutical industry is forecasted to hit about US$1,170 billion in 2021, according to The Business Research Company[15] while research company Gartner predicts the enterprise AI market will be worth US$6.14 billion by 2022[16].

To support this growth, technical expertise and skills in the physical, biological and engineering fields will rapidly explode, creating many jobs. While some job descriptions will change, new roles will appear and never-seen-before professions will emerge.

Knowledge and skill acquisition remain key for people who want to enter the S&T sector. Continuous learning to remain competitive will become second nature for such workers. Individuals will have to upskill and reskill on their own while organisations will step up training for employees to ensure their capabilities remain up-to-date. At the same time, the Government will advance skill capability development with new initiatives. Funding schemes for worker upskilling and reskilling will also be boosted.

More importantly, digital fluency should be taught across the board in all schools so that tomorrow's workers understand the tools and how to use them to communicate effectively.

Talent in science and technology is critical in Singapore's future economy journey. It will impact every industry and sector as the nation becomes a digitally connected society and a major technology node in Asia-Pacific.

[15] The Business Research Company, "The Growing Pharmaceuticals Market: Expert Forecasts and Analysis", 16 May 2018 [https://blog.marketresearch.com/the-growing-pharmaceuticals-market-expert-forecasts-and-analysis]

[16] May 2018 [https://blog.marketresearch.com/the-growing-pharmaceuticals-market-expert-forecasts-and-analysis]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