HEALTH & MEDTECH INNOVATION TALENT

Importance of an Innovation Training Framework

Co-authored by:

SINGAPORE BIODESIGN

DukeNUS Medical School | Centre for Lifelong Learning

Jointly endorsed by:

National Research Foundation
Prime Minister's Office
Singapore

Agency for Science, Technology and Research
Singapore

Enterprise Singapore

HEALTH & MEDTECH INNOVATION TALENT

Importance of an Innovation Training Framework

SINGAPORE BIODESIGN

DukeNUS Medical School | Centre for Lifelong Learning

Foreword

Science and technology (S&T) is pivotal to Singapore's survival and success and has helped us overcome the constraints of our small size and limited resources. Singapore's research and development (R&D) journey started in 1991, with the establishment of the National Science and Technology Board and the launch of the first five-year National Technology Plan. Singapore has a vibrant and dynamic innovation and enterprise (I&E) ecosystem. Since 2014, Singapore has ranked as a top innovative nation in the Asia Pacific according to the Global Innovation Index, an annual ranking of 130 economies compiled by the World Intellectual Property Organisation, Cornell University and INSEAD. Private sector R&D activity has increased steadily over the last two decades, with annual business expenditure on R&D growing from $1.5B in 1998 to $5.9B in 2019[1].

The Human Health and Potential (HHP) domain has its origins in the Singapore Biomedical Sciences (BMS) initiative, launched in 2000 to develop the life sciences as a pillar of Singapore's economy. Its initial focus was on establishing strong biomedical research capabilities, critical human capital and research infrastructure. Subsequently, there was a greater focus on translational and clinical research to derive positive health and economic outcomes. This latest pivot has paid off handsomely, growing the number of startups/SMEs from 60 to 300 over the past decade, with a handful starting to reach the growth stage. Singapore's talent, infrastructure, and technological advantages have attracted numerous health and medtech firms to establish a presence in Singapore, with national medtech manufacturing output surpassing S$15 billion in 2020[2].

The coming phase of capability development will further enhance the vibrant I&E ecosystem for health and medtech, building new pathways to support the translation of research discoveries for improved health outcomes and economic value. The Research, Innovation and Enterprise 2025 (RIE2025) Human Health and Potential (HHP) roadmap[3] envisages a diversified base of high-quality researchers and I&E talent, with the aim of accelerating translation of research, and adoption of innovations.

As the industry looks to the future, it is opportune to consider ways to coalesce and progress the exceptional talent and ingenuity of Singapore's health and medtech innovation ecosystem.

The report's analysis and recommendations focus on adult learners, in part due to their higher learning requirements, but also the conviction that adult learning, including workplace learning, is the most critical talent constraint. This report identifies the key gaps and unmet needs for health and medtech innovation training in the Singapore innovation ecosystem and recommends a framework for career and skills & competencies development across all ecosystem stakeholders.

This report is jointly authored by Singapore Biodesign and Duke-NUS Centre for Lifelong Learning and jointly endorsed by the National Research Foundation, Singapore, Enterprise Singapore and the Agency for Science, Technology and Research in Singapore as a coordinated approach towards developing innovation talent for the health and medtech ecosystem. We hope that the insights and recommended framework proves to be a valuable and important starting point for all members of the health and medtech community as we continue to upskill multi-disciplinary innovators towards addressing the region's many unmet healthcare needs.

Sincerely,

Professor Low Teck Seng

Chief Executive Officer,
National Research Foundation, Singapore

Acknowledgements

The authors owe a debt of gratitude to many people who made this research and publication possible.

First, we wish to thank the team at Singapore Biodesign and Duke-NUS Centre for Lifelong Learning for their hard work in coordinating, editing and supporting the production of this white paper. We also wish to thank the team at Enterprise Singapore for providing inputs and recommendations that contribute to the development of the white paper. This tri-partite involvement demonstrates the passion the team has towards talent development and coming together to develop a playbook that can be used across multi-disciplinary teams in need of innovation training.

Second, we are grateful to the National Research Foundation, Singapore and the Agency for Science, Technology and Research, who fund and host the Singapore Biodesign Programme respectively for their commitment towards manpower development in the RIE2025 plan and for the unique positioning to impact not one, but three domains i.e., human health and potential, I&E and manpower.

Finally, we offer our thanks to the team at L.E.K, all partners and individuals who graciously participated in the survey and focus group discussions to facilitate a comprehensive understanding of the landscape and providing feedback to make this a stronger and more relevant piece that can be taken back for further reference and implementation.

About Singapore Biodesign

SINGAPORE BIODESIGN

Singapore Biodesign is a national level talent development platform for healthtech innovation training and the first Asian Global Affiliate of the renowned Stanford Byers Center for Biodesign. With the aim to train and nurture the next generation of healthtech innovators for Asia, Singapore Biodesign provides high-touch development of healthtech talent centered on a needs-based approach and quality industry mentoring to accelerate health technology innovation and adoption for Asia's unmet healthcare needs.

Visit www.a-star.edu.sg/sb for more information.

About Duke-Nus Centre for Lifelong Learning

DukeNUS Medical School | Centre for Lifelong Learning

The Centre for Lifelong Learning provides a central point of access for accredited and non-accredited courses offered within Duke-NUS and the wider Academic Medical Centre. Located within Duke-NUS, the Centre facilitates the establishment and conduct of non-traditional courses and programmes geared toward professionals. The Centre aims at growing a vibrant education environment for lifelong learning with a focus on education, innovation and technology in healthcare.

Visit www.duke-nus.edu.sg for more information.

About Enterprise Singapore

Enterprise Singapore

Enterprise Singapore is the government agency championing enterprise development. We work with committed companies to build capabilities, innovate and internationalise.

We also support the growth of Singapore as a hub for global trading and startups, and build trust in Singapore's products and services through quality and standards.

Visit www.enterprisesg.gov.sg for more information.

About the National Research Foundation, Prime Minister's Office, Singapore

NATIONAL RESEARCH FOUNDATION
PRIME MINISTER'S OFFICE
SINGAPORE

The National Research Foundation (NRF) is a department within the Prime Minister's Office. The NRF sets the national direction for research, innovation and enterprise (RIE) in Singapore. It seeks to invest in science, technology and engineering, build up the technological capacity of our companies, encourage innovation by industry to exploit new opportunities that drive economic growth, and facilitate public-private partnerships to address national challenges.

About Agency For Science, Technology And Research (A*STAR)

Agency for Science, Technology and Research
SINGAPORE

The Agency for Science, Technology and Research (A*STAR) is Singapore's lead public sector R&D agency. Through open innovation, we collaborate with our partners in both the public and private sectors to benefit the economy and society. As a Science and Technology Organisation, A*STAR bridges the gap between academia and industry. Our research creates economic growth and jobs for Singapore, and enhances lives by improving societal outcomes in healthcare, urban living, and sustainability. A*STAR plays a key role in nurturing scientific talent and leaders for the wider research community and industry. A*STAR's R&D activities span biomedical sciences to physical sciences and engineering, with research entities primarily located in Biopolis and Fusionopolis.

Global Health and MedTech Innovation Trends

A confluence of global trends (Figure 1) has amplified the pressure on the health and medtech industry to reliably deliver high-quality products and services at lower cost—and on patients' terms. Healthcare innovation will experience continued compression of product development cycles and the reinvention of business models. Value-based care is fast becoming the dominant healthcare approach. Unlike fee-for-service models, value-based care focuses on the best treatment, rather than the costliest, lifting the quality of care by doing so. Value-based care is innovative in that it encourages open communication, which in turn builds new, innovative approaches to care. The shift to value-based healthcare amid budgetary pressures on health systems means that health and medtech innovations need to be competitive from the outset. Entrepreneurial health and medtech companies are pushing to bring their innovative solutions to the market faster, while less agile traditional medtech manufacturers need to pivot quickly or be left behind.

Technology convergence will generate innovation opportunities around improved user experience and service delivery. Health and medtech advances have ushered in the use of artificial intelligence (AI) and machine learning to streamline workflows. On the patient side, converging technologies will empower patients and healthcare professionals (HCPs) to access online and digitalised healthcare services that prioritise

FIGURE 1

Global Health & MedTech innovation trends influenced by COVID-19

Faster and more agile innovation cycles	Increased partnerships and multi-stakeholder engagement	Growing importance of public health awareness	Move towards supply chain resiliency
• There is a drive to bring healthcare products to the market faster • Businesses also need to transform and constantly innovate on products, service and business models to stay ahead	• With convergence of software, devices and services in healthcare, partnerships are increasingly necessary • Continual engagement of stakeholders across value chain to accelerate speed to market will be key (e.g.,public-private-partnerships)	• COVID-19 showed that public education on vaccines, regular testing and treatment is needed to dispel misinformation, enhance public adoption and healthcare administration outside the hospital • New entrant stakeholders such as insurance players, employers and public health policy makers	• COVID-19 lockdowns intensified move towards greater self-reliance or shorter supply chains • Digitalization, automation and visibility of end-to-end processes • Prioritization of product manufacture according to criticality to business/outcome

Source: L.E.K. interviews, research and analysis

schedules and treatments. Such seamless solutions require the **convergence of software, devices and healthcare services**—distinctive specialisms that make strategic partnerships a growing need and an understanding across a wide range of technology, product offerings and business models the new imperative.

The COVID-19 pandemic has compressed a decade of incremental change in **public health awareness** into a matter of months[4]. Global public health awareness has undergone a paradigm shift since the onset of the COVID-19 pandemic, including a new relationship with technology and the greater involvement of patients in all aspects of healthcare. More self-aware than ever before, healthcare consumers want affordable, accessible and personalised care; whilst healthcare systems evolve their care delivery models at an unprecedented pace

Despite its debilitating hardships, the COVID-19 pandemic has presented the healthcare industry with an opportunity to reset and build **more efficient and resilient supply chains[5].** Aligning product innovation and manufacturing needs with the post-COVID supply chain will be a significant factor in determining the future success for nations and companies—through improved costs savings and risk mitigation, all while bringing greater accessibility and improving the patient experience and patient outcomes.

The rapidly evolving technology landscape, the shift to "hospital at home", and the need for national healthcare resilience are reshaping the future of health and medtech innovation. To embrace these advances, Singapore will need to build capabilities to bring innovation to market faster while ensuring that it has the talent to manage innovation processes end-to-end, from basic and applied research to data management, supply chain optimisation, change management and adoption.

Global Innovation Training Trends

Several countries with health and medtech innovation hubs have recognised the importance of innovation training programmes to developing a sustainable foundation of innovation talent across clinicians and scientists (Figure 2). In Singapore, Singapore Biodesign (SB), a global affiliate of the renowned Stanford Byers Center for Biodesign, is one such example of a national-level talent development platform for health and medtech innovation training with capability development initiatives starting from 10 years ago with the foresight of the government.

1. **National and/or regional innovation training platforms, hubs and networks are being developed to upskill a base of scientists and HCPs entering innovation**. America's National Science Foundation's Innovation Corps (NSF I-Corps) model has supported the experiential entrepreneurial training of academic researchers across all fields of science and engineering since 2011.

FIGURE 2

Global innovation training trends

	Key Global Innovation Training Trends	Key Examples
1	**National and/or regional innovation training platforms upskill a base of scientists and healthcare professionals entering entrepreneurship**	• US National Science Foundation (NSF) I-Corps trained >5.8k clinicians and researchers in 7-week course format • EU-funded EIT Health trained >36k students, clinicians and scientists in bootcamps, Master's and various course formats
2	**Multiple ecosystem partners are involved in the delivery of innovation training**	• US NSF I-Corps partners with 45> IHLs as hubs deliver innovation training • EIT Health works with 150 partners for training, incl. government agencies, IHLs, hospitals and industry
3	**Most commonly taught methodologies are needs-based design thinking or lean start-up, training learners with market-oriented mindset to allow for adaptability for evolving healthcare needs**	• EIT Health Innovation Fellowships uses the Stanford Biodesign methodology • US NSF I-Corps uses Steve Blank's Lean Startup methodology
4	**Universities are partnering with online providers to broaden reach in training delivery**	• Wharton and Penn Medicine offers "Healthcare Innovation" course via Coursera platform • MIT offers "Drug and Medical Device Development Strategy" course via Emeritus platform
5	**Current innovation training offerings and courses are in-line with Health and MedTech innovation trends**	• In-line with recent trends of AI and health informatics: – EIT Health offers "Enabling AI Use in the Medical Environment" course – Columbia University offers "Health Informatics for Innovation, Value & Enrichment" course

I-Corps: Innovation Corps; EIT: Europe Institute of Innovation and Technology; IHLs: Institutes of Higher Learning

Source: L.E.K. analysis

From 2021, an I-Corps reorganisation promoted five regional hubs, each consisting of a regional alliance of at least eight universities. Together these will scale the National Innovation Network and rapidly advance health and medtech solutions. In Europe, European Institute of Innovation and Technology (EIT) has worked to develop knowledge and innovation communities (KICs) since 2015, each centre of innovation excellence focusing on an individual theme, such as health and ageing, or climate change and sustainable energy. Both US and European concepts are based on the premise that innovation flourishes when the right people assemble to share their expertise. On a smaller scale, the government of Japan brought together Osaka University, The University of Tokyo, and Tohoku University under the global programme of Stanford Byer's Center for Biodesign. Again, the goal is to sculpt an ecosystem that continuously delivers healthcare innovation—with a particular focus on the needs of Japan's rapidly ageing society.

2. **Outcomes are improved when stakeholder interests are aligned.** Most innovation training providers appreciate the need to collaborate with multiple ecosystem partners to leverage their full complement of strengths, including content, network, resources, and funding sources (Figure 3). Recognising the critical role of collaboration for innovation training ecosystems, the US National Innovation Network comprises

FIGURE 3

Examples of global innovation training partnership

Source: Company websites; L.E.K. interviews, research and analysis

universities, NSF-funded researchers, established entrepreneurs, local and regional entrepreneurial communities, and other federal agencies. Together they teach researchers how to translate fundamental research results to the marketplace. Building on the lessons learned through the first decade of the I-Corps initiative, the 7-week programme is designed to catalyse the commercialisation of deep technologies that emerge from discoveries in fundamental science and engineering. EIT advocates a similar collaborative approach. Working across the EU, EIT brings together approximately 150 EIT Health partner organisations, including university hospitals and other institutes of higher learning, government agencies and business (including Pharma, HealthTech and MedTech).

3. **Commonly taught methodologies include needs-based design thinking or lean startup, with an adaptable market-facing mindset.** Steve Blank's Lean LaunchPad methodology reverses the traditional approach to entrepreneurship training, which is to develop a business plan, pitch it to investors, form a team, build the product and then market it. Instead, the Lean Launchpad method hypothesises an unmet need, defines the essential building blocks for the proposed business (key partners and resources, customer segments, revenue streams, etc.), tests the assumptions and finally launches a "minimum viable product", with ensuing feedback driving product refinement. EIT adopts a needs-based design approach to healthcare innovation, which follows the maxim that innovation is a process that can be learned, practised, and perfected in an environment in which learners are brought together through a tried and tested framework: identify, invent and implement.
4. **Innovation training providers are partnering with online platforms to widen their training reach.** Battered by the COVID-19 pandemic, higher education institutions and/or institutes of higher learning (HEIs/IHLs) worldwide have rushed to leverage remote learning, exposing a fragmentation in the deployment of content for innovation learning. World-renowned HEIs specialising in healthcare are leading the way in developing short-course online programme content. Wharton Online and Penn Medicine offers a free 7-hour Health Care Innovation course on the Coursera platform. MIT offers a Drug and Medical Device Development Strategy course on the Emeritus platform, designed to explain medical product development end-to-end.
5. **Current innovation training offerings and courses are converging around the latest digital health and medtech innovation trends**. Innovating the delivery of care and moving to value-based healthcare systems, including a more proactive focus on patient outcomes, feeds into the digital revolution in acquiring, processing, and studying patient data. In line with the ascent of AI and health informatics, EIT now offers courses on Enabling AI Use in the Medical Environment. In addition, Columbia University runs a Health Informatics for Innovation, Value and Enrichment course.

Singapore's Health & MedTech Innovation Talent Landscape

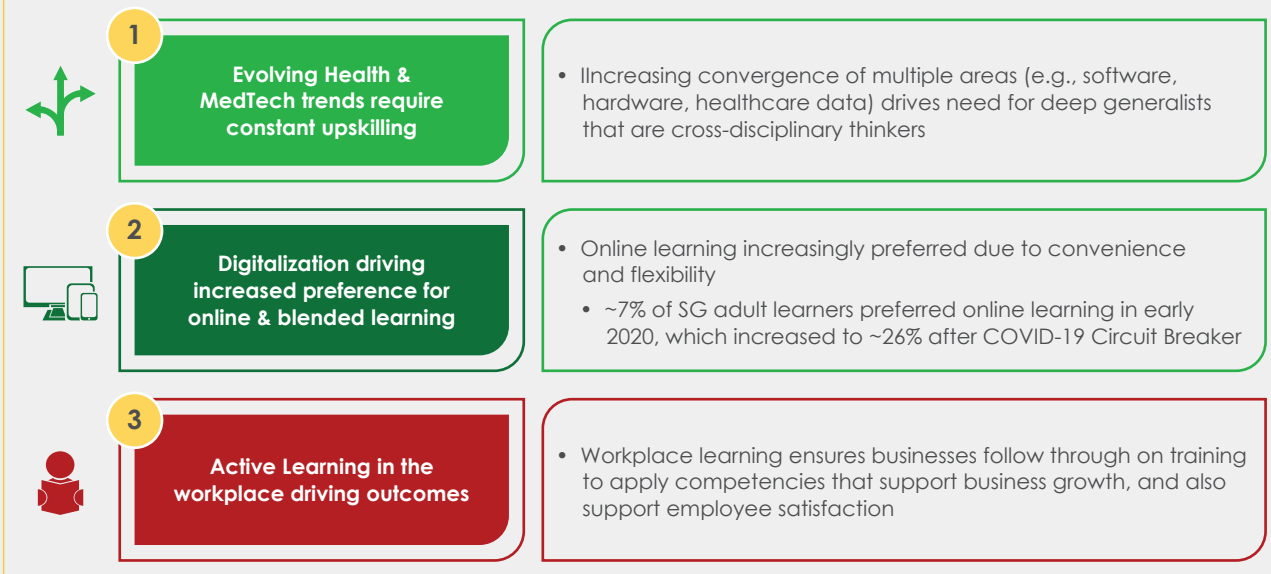
Singapore's adult learners must constantly adapt to the changing healthcare industry landscape, emerging technology trends, evolving skills and competency requirements and new modes of adult learning (Figure 4). Rapidly evolving health and medtech innovations involve the increasing convergence of multiple spheres (e.g., data science and software development, hardware and devices, diagnostics), driving a need for both deeper expertise and cross-disciplinary generalists.

Singapore's Push for Adult Learning and Upskilling

Workforce SG (WSG) and SkillsFuture Singapore (SSG) are key proponents of adult and lifelong learning. They share the conviction that the workforce can be trained to adapt to evolving industry needs and evolving career roles. Online learning, fully actuated by digitalisation and its inherent advantages in convenience and flexibility, is the critical enabler. Since the implementation of Singapore's COVID-19

FIGURE 4

Adult learning influencers in Singapore



Source: Institute for Adult Learning Singapore (IAL) 2020 report; National Centre of Excellence for Workplace Learning (NACE); Trade press; L.E.K. research and analysis

Circuit Breaker in April 2020, there has been a fourfold increase in the preference for 100% online learning (up from 5.6% to 26.4%); only 7% of adult learners preferred classroom over online[6].

A theme advocated by SkillsFuture Singapore is the need for active learning in the workplace to complement classroom and tech-enabled learning. Using experiential learning and personalised learning platforms, many enterprises are adopting workplace learning to drive the higher rates of employee satisfaction that support business growth. Already gaining acceptance, the coronavirus pandemic has accelerated the adoption of active learning techniques in the workplace.

An overarching theme for skills and competency training is the need to better define career development roadmaps, and the associated key competencies and skills training at every level. To this end, SSG has worked with ecosystem stakeholders since 2016 to develop a core skills and industry specific skills framework. As a result, more than 30 sector-specific skills frameworks underpin Singapore's Industry Transformation Maps for a relevant and competitive workforce.

Current Health & MedTech Innovation Training Gaps

All the evidence suggests that innovation is a powerful economic driver, and a harmonised approach to talent development for health and medtech innovation can accelerate and yield higher returns. According to the Milken Institute's 2012 report, "*Estimating Long-Term Economic Returns of NIH Funding on Output in the Biosciences,*" a one dollar increase in National Institutes of Health (NIH) funding will increase the size (output) of the bioscience industry by at least $1.70. Investments in NIH research also spur job creation. United for Medical Research estimates that in fiscal year 2012, NIH funding supported more than 402,000 jobs and $57.8 billion in economic output in the USA[7].

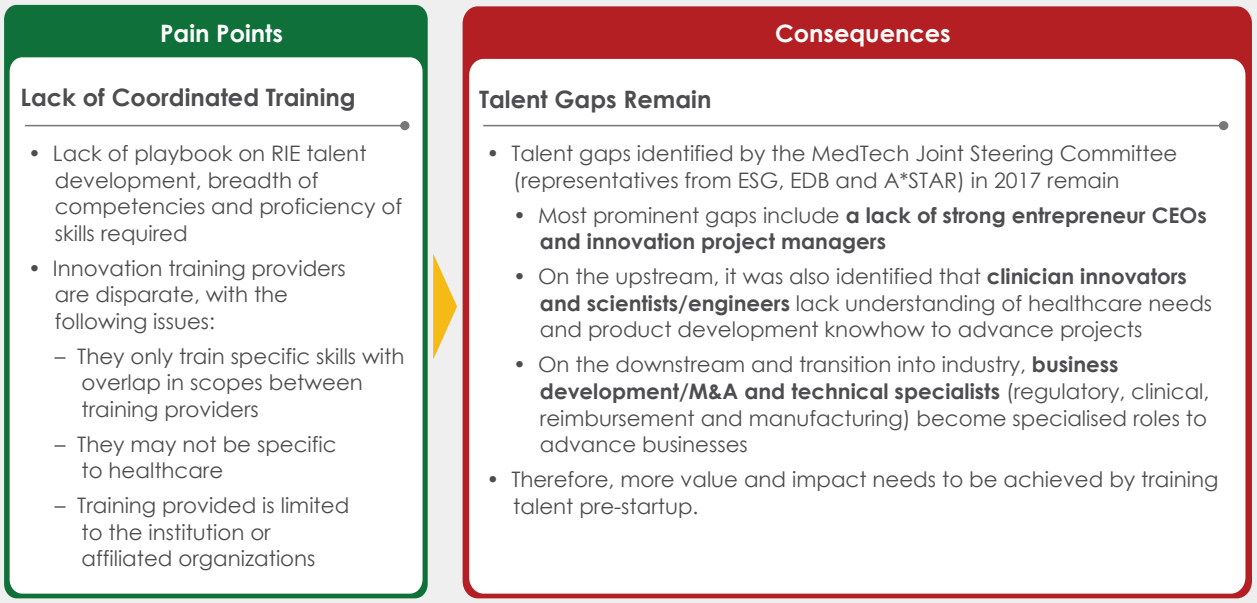
Unlike the process undertaken for mapping skills competencies in other sectors, the Singapore health and medtech RIE ecosystem is more complex due to its multi-disciplinary nature and is not defined by one industry career path alone. Health and medtech innovation requires the combined expertise of HCPs, scientists/engineers, innovation managers and entrepreneurs. This study sets out to understand the training needs of all the key innovation stakeholders—institutes of higher learning (IHLs), public healthcare institutions (PHIs) and research institutions so as to create a detailed mapping and analysis of the talent gaps and future innovation and enterprise competencies required for health and medtech innovation. For this report, L.E.K. interviewed 41 professionals across key learner segments to obtain a "top-down" perspective with organisation-level views, and 90 respondents in the same learner segments, for a 'bottom-up" individual participant perspective. Some 85-90% of survey respondents were Singapore healthcare ecosystem stakeholders, the balance coming from the US, the EU and Asia (Appendix Figure 3).

Challenges in the health & medtech industry that could fuel demand for a savvy and adaptable innovation talent workforce include the shift of business models towards value-based care, the rapid growth of the startup landscape and the constant pressure to maintain Singapore's competitive positioning for medtech industries through shorter innovation and development life cycles. One important step towards the RIE2025 objectives is to address current talent and competency gaps in the development and commercialisation of innovations (Figure 5). As such, a coordinated and comprehensive talent development plan, with relevant innovation training offerings as indicated by stakeholders, is needed.

The identified talent gaps constraining health and medtech innovation reflect inadequate awareness or insufficient exposure and experience (Figure 6). HCPs and scientists do not yet sufficiently understand the innovation and development health and medtech product cycle. Innovation competencies remain ill-defined and poorly integrated into existing career paths, a condition exacerbated by the lack of appropriate innovation training.

FIGURE 5

Problem statements for Singapore's Health & MedTech innovation talent landscape



RIE: Research, Innovation and Enterprise; ESG: Enterprise Singapore; EDB: Economic Development Board; A*STAR: Agency for Science, Technology and Research

Source: L.E.K. analysis; Extracted from SG Medtech Joint Steering Committee Update 10 Jul 17

Alongside this lack of innovation intelligence, there is a shortage of multidisciplinary talent, CEOs, business development managers and engineers with a strong biomedical background. For regulatory, government regulatory professionals in developing markets may not receive sufficient exposure and training to new products and trends to evaluate recent technologies.

Singapore's entrepreneurial health and medtech market- and product-experienced talent pool is also relatively shallow. In the absence of dedicated health and medtech job matching services or relevant job databases, startups continue to struggle to find talent. Health and medtech companies also report difficulty in hiring sufficient numbers of technology and data-related professionals. Data-related undergraduate cohorts are too small. Many students lack exposure to health and medtech innovation in their computer science and bioinformatics studies, and remain unaware of career options in health and medtech innovation. Moreover, the local public and private RIE sector must compete with demand from traditional medtech MNCs and new healthcare market entrants.

The innovation training stakeholder survey conducted for this report revealed a critical need for enhanced innovation training for HCPs, scientists, and the startup community. HCP and scientist/engineer innovators may have some access to in-house training, but the training provided may be institution-specific and inconsistent across institutions, and thus these innovators may have limited exposure to a broader set of important skills. Conversely, larger SMEs and MNCs report having adequate in-house training.

N.B. Skills are defined as the learned abilities needed to perform a given job role while competencies are typically defined as behaviours required to perform a job role. For the purpose of this white paper, gaps in training will be presented as a combination of skills and competencies with detailed descriptions typically defining the skills

FIGURE 6

Key Health & MedTech talent gaps in Singapore ecosystem

Stage of Innovation	Key Gaps	Key Issues and Reasons
Ideation/ Prototyping	a **HCPs and scientists** do not sufficiently understand how to **articulate an unmet clinical need and knowhow to develop a health and medtech product, niche career path, part-time job for some**	• Lack of awareness and understanding of innovation competencies needed that fits with existing career tracks • Lack of sufficient innovation training and protected time
Design & Development: POC/POV	b **Difficulty hiring sufficient numbers of technology and data-related professionals who are passionate and understand healthcare needs**	• Limited supply of data-related professionals in undergraduate training • Lack of early exposure to HMT innovation in computer science and bioinformatics studies, thus unaware of career options
	c Startups need to spend **significant amount of time to find talent for roles**	• Shortage of right mix of talent knowhow for small startup teams • Lack of a job database or job matching services
Commer-cialization	d **Health and medtech companies need multi-disciplinary talent** (especially startup CEOs, business development managers with biomedical understanding; technical specialists in regulatory, QMS and market access)	• Few experienced serial entrepreneurs in Singapore • Business professionals and engineers moving into healthcare industry lack understanding of HMT markets and products • Lack of specialised talent in downstream needs (within regulatory, QMS, market access), which may affect strategies in earlier stages of innovation

Source: L.E.K. analysis

required for the job role while corresponding competency attributes and behaviours may be implied and interpreted from these descriptions (e.g., confident, adaptable, responsive, positive, proactive, resilient etc.)

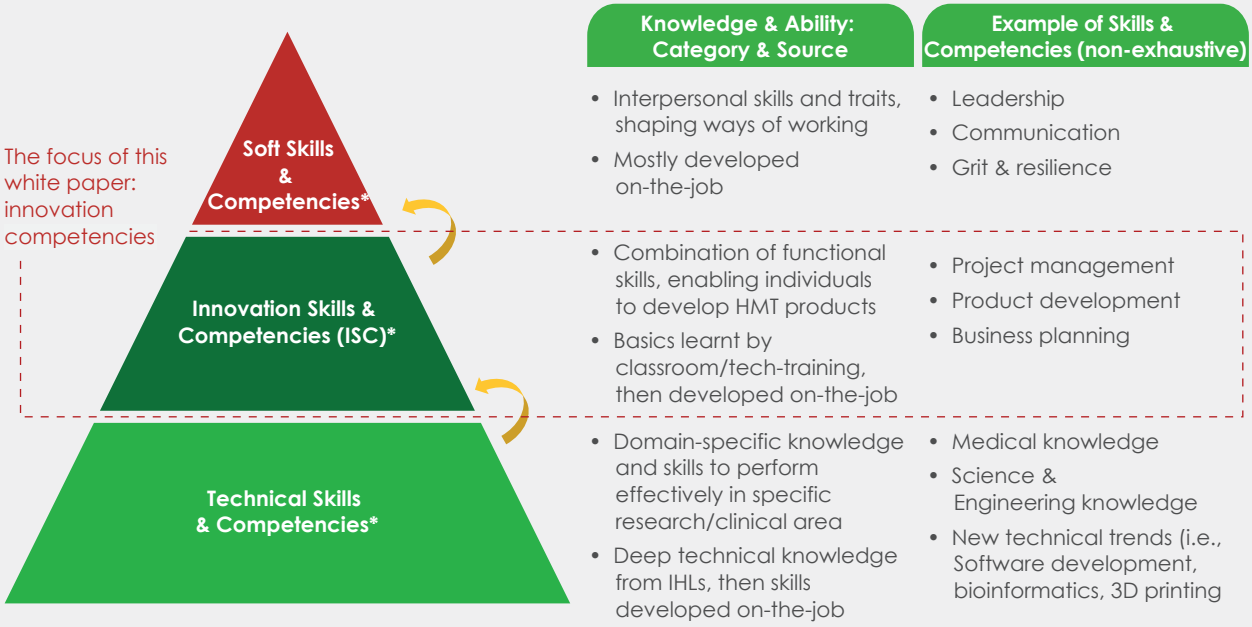
Key Health & MedTech Innovation Training Providers

Ideally, health and medtech talent should comprise foundational technical skills and competencies, learned innovation skills and competencies (ISC), and 21st Century soft skills and competencies (Figure 7). Technical capabilities are the domain-specific knowledge and skills needed to perform effectively in specific job roles. IHLs are instrumental in developing this deep technical competence, skillsets that are refined through workplace and on-the-job training. (e.g., medical knowledge, engineering know-how and software development skills).

Complementary innovation and enterprise skills and competencies are critical for the realisation of health and medtech products, blending technical capabilities with functional innovation and translational skills and competencies such as product development, business planning and project management. Innovation training may be delivered through any of the following three strategies: tech-enabled learning, classroom learning and workplace learning; although a blended learning approach is highly recommended. Through these delivery strategies and corresponding assessment strategies, the principles of innovative practice can be coupled with implementation through learning-on-the-job. Finally, interpersonal skills and traits—soft skills and competencies such as leadership, communication, resilience—are also best internalised in the workplace, with occasional internal or external classroom

FIGURE 7

Categories of skills & competencies needed for Health & MedTech innovation



HMT: Health and medical technologies; *Innovators may embark on any of these skills trainings anytime instead of in a sequential manner

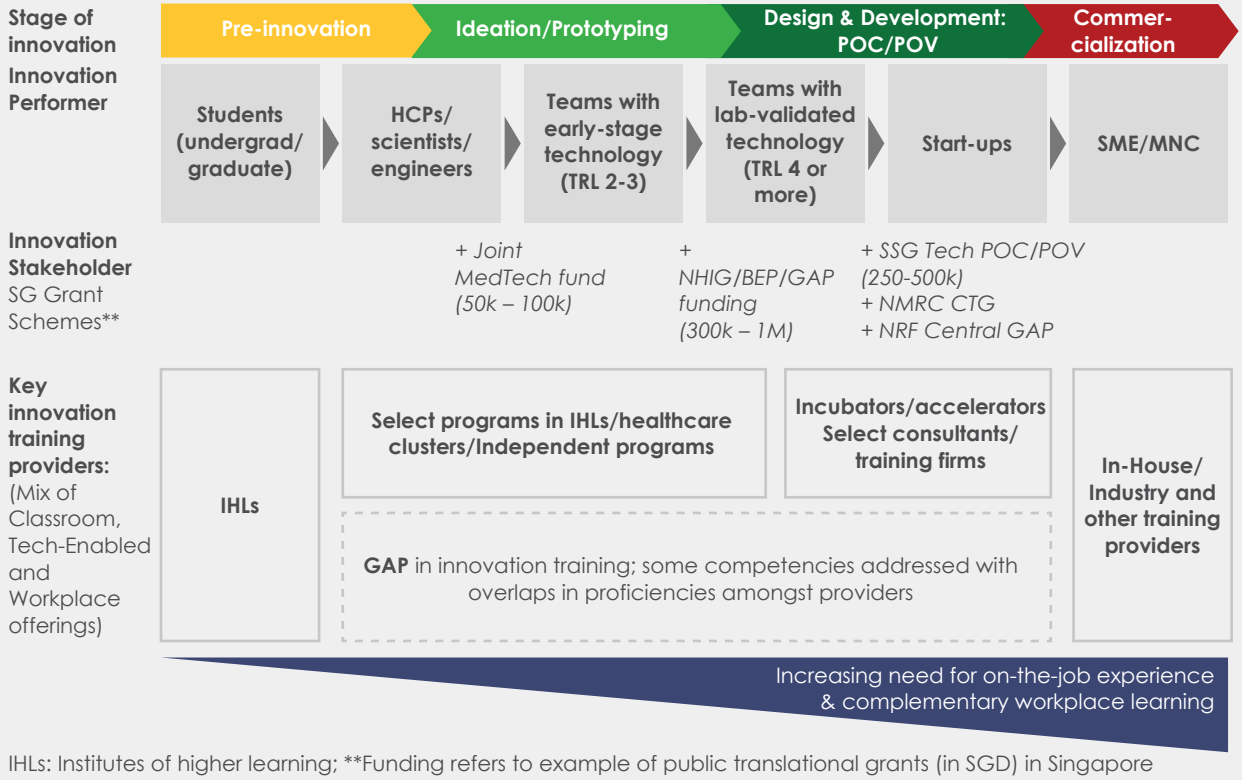
Source: L.E.K. interviews, research and analysis

and tech-enabled training support. There is no sequence to how these trainings should be undertaken. New trends in technical skills could surface and require relearning whilst on-the job training for soft-skills and developing future-orientedness can go hand-in-hand with technical and innovation skills and competencies trainings.

This paper focuses on the innovation skills and competencies (ISC) that can be applied across all learner segments in the health and medtech innovation space, noting where skillsets can be armonised and delivered through current training methods to achieve the greatest return on innovation. Singapore's innovation ecosystem, comprising high-quality infrastructure, world-class IHLs, a growing base of startups, and a well-trained (albeit shallow) local talent pool backed by effective policy support, is a conducive operating environment for health and medtech enterprises. While a number of excellent Singapore-based organisations already offer well-structured innovation training programmes, these can often overlap in their scope and coverage (Figure 8). Moreover, it is increasingly evident that HCPs, scientists and recipients of public sector translational grants generally remain underserved and in need of more targeted innovation training support. In addition, there is little coordination among Singapore's disparate group of RIE training providers, many of which are too narrowly focused—the training provided by some institutions is also confined to its affiliated organisations—and provide insufficient domain context.

FIGURE 8

Singapore's innovation training ecosystem



IHLs: Institutes of higher learning; **Funding refers to example of public translational grants (in SGD) in Singapore ecosystem provided for the innovators to progress to the next stage of the innovation pathway
Source: L.E.K. interviews, research and analysis

The Health and MedTech Innovation Skills & Competencies Framework

Based on health and medtech innovation stakeholder feedback, eight distinct functional innovation skills and competencies are required to drive innovation in health and medtech: project management, product development, business planning, clinical trial planning, regulatory understanding, market access acumen, intellectual property know-how and operational planning (Figure 9). The relative importance of each skill & competency varies according to the target learner group (e.g., HCPs, scientists/ engineers, innovation managers, regulatory professionals and startups) and the learning each requires to carry out their innovation job scopes effectively.

The *Health and MedTech Innovation Skills & Competencies (ISC) Framework* (Figure 10) is a means by which organisations and individuals can appreciate the skillsets and attributes required for developing health and medtech innovation capabilities. The attainment of these skills and competencies will, in turn, increase the ability of individuals to deliver quality innovation outcomes and subsequently advance their careers and receive corresponding recognition for their effort and outputs. The Health and MedTech ISC framework delineates a common set of skills and competencies. It provides an innovation toolkit to help HCP innovators, scientists and engineers, innovation managers, regulatory professionals and startups teams develop a clear understanding of organisational values, training requirements and performance expectations around innovation. To this end, the Health and MedTech ISC framework stratifies learners by their prior innovation experience (ranging from little or no prior project exposure to being able to take a leadership role) and their desired competency proficiency (ranging from basic knowledge and understanding of concepts and their application to deep and comprehensive knowledge and skills, to perform tasks and adapt to changing dynamics). Expectations for proficiency (capability and performance) are mapped against the eight critical ISC which details the key knowledge and abilities expected of each ISC's proficiency level (Appendix Figure 1).

The proficiency levels used in the ISC framework (Figure 10) corresponds to the proficiency levels used by SkillsFuture Singapore's Skills Framework (SFw)[8], with '*Basic*' corresponding to level 3, '*Intermediate*' corresponding to level 4, '*Advanced*' corresponding to level 5, and '*Expert*' corresponding to level 6. Subsequent proficiency maps for each career path (Figure 12 to 16), may be coupled with the existing SFw's Technical Skills and Competencies (TSC) map developed for healthcare workers[8] to provide opportunities for expansion of capabilities into innovation. The list of core and optional knowledge and capabilities within innovation that are required at every proficiency level (Appendix Figure 2) can subsequently help inform the curriculum progression.

One important caveat is that this is not a one size fits all method; the move to innovation can occur at different career stages and may not be a linear trajectory. Correspondingly, it is possible to accelerate innovation learning through the different proficiencies with dedicated protected time given to learning and by applying these competencies to real-world projects.

FIGURE 9

Key functional innovation skills & competencies

Innovation Skills & Competencies	Description
Project management	• Formulate and implement a HMT innovation project plan, including HMT product development timelines, risk assessment & mitigation, manage stakeholders in healthcare ecosystem, resources and budgets
Product development	• Bring a HMT innovation through the entire development process from identifying unmet needs in healthcare system with design thinking, to technology assessment and developing proof-of-concept prototypes, verification and validation, systems engineering and designing for manufacturing
Business planning	• Plan, validate and execute HMT business models and go-to-market strategies in relevant healthcare markets, tailor business pitches to stakeholders, raise funds & conduct financial analysis
Clinical trial (CT) planning	• Design clinical trial plan and strategy, design and coordinate different types of clinical trials for HMT products, and identify and manage CROs as needed
Regulatory	• Build regulatory strategy for HMT products to fulfil regulatory requirements in different markets, and ensure compliance to standards for new innovative HMT products to secure approval
Market access	• Assemble and propose strategy to broaden patient/stakeholder access to HMT's product/service, based on understanding of healthcare systems, value chain and reimbursement landscape in relevant markets
Intellectual property	• Analyze the different IP instruments and basic regulations as relevant to HMT products/service, business significance of IP and analysis of prior art
Operational planning	• Develop operational plans, quality management systems and implement change management for the business to optimise processes, people and resources (e.g., supply chain, infrastructure)

The same 8 ISCs may generally be applied across the RIE ecosystem for other industries. For the three ISCs, CT planning, regulatory & market access understanding, which are specific to HMT, they may be replaced and nuanced for specific industry sectors needs i.e., industry standards and industry-specific descriptions.

This list does not cover technical competencies that may be specific to different careers and soft skills (e.g., perseverance). Please refer to the Appendix in this report for more details of each functional innovation competency

Source: L.E.K. interviews, research and analysis

ISC Recommendations for Key Learner Segments

Public healthcare clusters and research/technology institutions are motivated to drive innovation. All key healthcare clusters and the public health institutions have set up dedicated innovation offices in hospitals to cover a variety of healthcare innovations, be they in biotech, medtech, operational efficiency, or digital health, likewise in the academic and translational research institutes. A survey of different learner segments comprising of healthcare professionals (physician, nurse, allied health), research scientist/engineer, innovation & commercialization managers and even regulatory professionals (Figure 11), suggests the need for better knowledge in project management and product development would improve the structure of their innovation projects. The ability to assess unmet clinical needs and articulate key innovation product

FIGURE 10

Health & MedTech innovation skills and competency framework

Key Innovation Skills & Competencies	• Project management • Product development • Business planning • Clinical trial planning	• Regulatory • Market access • Intellectual property • Operational planning

	Level 0	Level 1	Level 2	Level 3	Level 4
Learner's prior innovation exposure	No prior exposure to innovation process	Learners have attended innovation training workshops and are **familiar with design thinking**, up to needs identification and concept development	Learners have attended bootcamps and incubators and/or are part of a team with an ongoing **innovation project**	Learners who have **deep appreciation of the full cycle of an innovation project, and have demonstrated experience in part of cycle through an innovation project**	Learners who have **executed the iterative end-to-end cycle of an innovation project**, from needs identification to design for manufacturing, and are **able to lead/guide others to implementation**

	Basic	Intermediate	Advanced	Expert
Proficiency level by skill & competency	Basic knowledge and understanding of concepts and their application	More innovation knowledge and ability sufficient to distinguish, analyze, infer and deliver baseline tasks independently	Deep knowledge and ability sufficient to evaluate, review and integrate more complex tasks independently	Deep and comprehensive knowledge and ability to formulate and adapt strategies and tasks to a changing environment and risks

Source: L.E.K. interviews, research and analysis

requirements from a clinical, usability and business angle would improve their ability to critique ideas and communicate needs to their technology collaborators. Knowledge of clinical trial planning and execution is always a priority. Properly designed trials allow for more accurate determination an innovation's commercial impact. The following ISC proficiency maps for each career path (Figure 12 – 16) provide a suggested approach to how individual innovators and organisations can align themselves, however, it is noted that innovation exposure may not always reflect the career pathway. Similarly, acquiring all innovation skills may favour a career development but does not guarantee it as there are also other considerations involved and an individual should have a regular, open discussion with his/her career supervisor to assess his/her progression. Finally, formalizing the ISC proficiency maps may seem daunting to innovators and the communication of this framework should also explain that the time commitment required for the training of these individuals will also be spread out over a period of 2 – 3 years each level in tandem with their career development plans in consultation with their direct reporting officer (Figure 11).

Undergraduates and graduate students (reading subjects such as medicine, engineering, business, and computer science) typically have lower awareness of and exposure to health and medtech innovation. Nonetheless, as an important

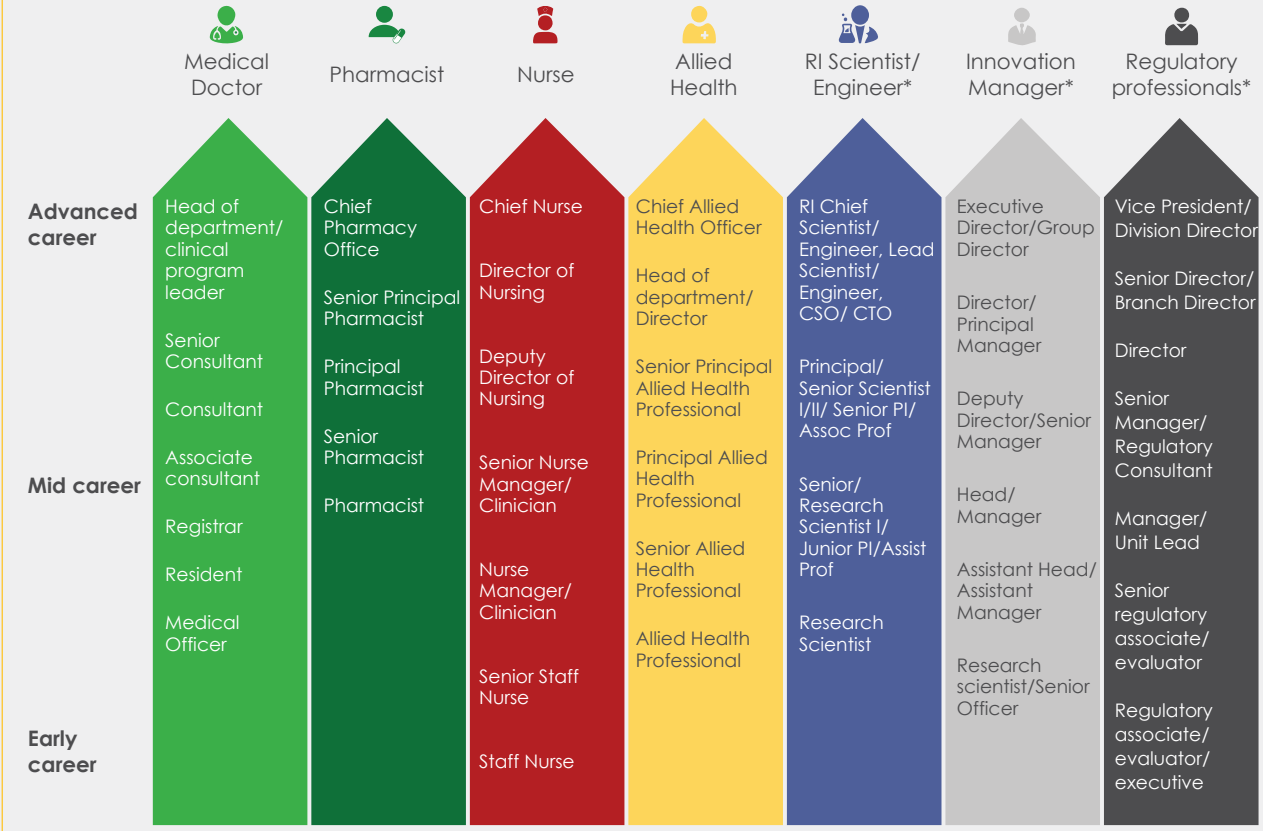
segment for the future of innovation in Singapore, they should not be overlooked. Key recommendations include:

1. Relevant IHLs should offer a health and medtech innovation module starting at the undergraduate level with corresponding coursework on a real-world problem
2. IHLs and ecosystem partners (e.g., accelerators) can organise innovation challenges and associated events to promote networking and multi-disciplinary exposure (e.g., medical grand challenges, intensive collaboration hackathons)
3. Companies (SMEs, MNCs) and public sector partners (e.g., government agencies, healthcare clusters) should continue to offer relevant internships to develop passion for the industry
4. IHLs should increase the number of data, statistics and tech-related graduates in health and medtech, with input from government agencies and companies on job market demand.

Medical Doctors/Physicians need stronger focus on innovation skills and competencies and how these capabilities align with clinician innovator career paths. At its current state, 'innovation' is not one of the core pillars for a healthcare provider. Clinicians therefore mostly treat innovation as a past time. To become more serious at innovation, clinicians need to be better trained, and the ISC proficiency map (Figure 13) serves as goalposts for clinicians to aim towards. This will address the innovative growth mindset required for practitioners in the care economy to foster collaborations

FIGURE 11

Career development roadmap for assessed learner segments



AHP: Allied Health Professional; RI: Research Institute; PI: Principal investigator; CSO: Chief Scientific Officer; CTO: Chief Technology Officer; *As AHPs cover a wide variety of professions, the proposed is an indicative generic path, but may need further elucidation for each profession; **RI Scientist/Engineer may often cross over to Innovation Assistant Manager role or Regulatory Associate roles

Source: L.E.K. interviews, research and analysis

across disciplines and roles (e.g., key skills for care economy are collaborative practices, interprofessional collaboration). The focus on innovation, technology, and data in a multi-disciplinary environment also goes beyond the traditional tenets of medical education and is aligned to the digitalisation efforts of the sector.

In general, medical doctors' expected level of proficiency does not depend on their job title or career progression, rather it depends on the level of prior innovation exposure they have had. In other words, the time expected to achieve a level of proficiency is not fixed and might vary for each medical doctor. Budding clinician innovators are likely to have very limited exposure to health and medtech innovation and their proficiency is generally not expected to rise above the 'Basic' level ('Intermediate' level for clinical trial planning). For majority of clinician-innovators track, they will need 'Advanced' proficiency across almost all the functional competencies (Figure 12 and Appendix Figure 1). Although clinicians are often less interested in the commercialization phase, stakeholders across have echoed the importance of having basic understanding in the commercialization-related competencies to communicate with their co-founders and improve the adoption of their innovation.

The National Medical Research Council (NMRC)'s Clinician Innovator Award (CIA) and Singapore Translational Research Investigator Award (STaR), which support clinicians with

FIGURE 12

Sample innovation skills & competencies and proficiency map for medical doctors

Innovation Skills & Competencies	Level of Innovation Exposure			
	Level 1	Level 2	Level 3	Level 4
	Expected Proficiency Level			
Project Management	Basic	Intermediate	Advanced	Advanced
Product Development	Basic	Intermediate	Advanced	Advanced
Business Planning	Basic	Intermediate	Advanced	Advanced
Clinical Trial Planning	Intermediate	Advanced	Expert	Expert
Regulatory	Basic	Intermediate	Advanced	Advanced
Market Access	Basic	Intermediate	Advanced	Advanced
Intellectual Property	Basic	Intermediate	Advanced	Advanced
Operational Planning	Optional	Basic	Basic	Basic
Typical Corresponding Career Path	*For clinicians in innovator track; mostly corresponds to on prior innovation exposure rather than job title*			
Typical Clinical Innovator Award Level	*RTF/TA*	*CIA - INV*	*CIA-SI*	*STaR*

RTF: Research Training Fellowship; TA: Transition Award; CIA-INV: Clinician Innovator Award for Investigator; CIA-SI: Clinician Innovator Award for Senior Investigator; STaR: Singapore Translational Research Investigator Award. Taken from: https://www.nmrc.gov.sg/grants/talent-development

Source: L.E.K. interviews, research and analysis

healthcare innovation breakthroughs (e.g., in disease diagnosis, medical treatment, and improvement of human health and quality of life), are relevant to see through Level 2, 3 and 4 in their career development pathways.

As with physicians, the level of innovation proficiency required by nurses and allied health practitioners (AHPs) rise across all eight skills and does not depend on their job title or career progression, rather it depends on the level of prior innovation exposure they have had. In other words, the time expected to achieve a level of proficiency is not fixed and might vary for everyone. Nevertheless, for serious innovators or those in leadership tasked to effect change transformation, they are generally expected to have 'Advanced' or 'Expert' proficiency respectively, with the exception of operational and business planning (Figure 13 andAppendix Figure 1). In addition, as most developing nurse and AHP innovators are mostly involved with health services innovation due to their proximity and care towards patients, there is less of an emphasis for clinical trial planning and regulatory knowledge for earlier proficiency levels. However, the competencies in the ISC framework is still broadly applicable to nurses and AHPs. Importantly, for all HCPs including medical doctors, nurses and AHPs, market access skills can also be interpreted as aiding local deployment and adoption into their healthcare institution.

The **Scientist/Engineer** segment of innovators includes post-graduate students, research fellows and principal investigators. For research

FIGURE 13

Sample innovation skills & competencies and proficiency map for nurses and, allied health professionals and pharmacists

Innovation Skills & Competencies	Level of Innovation Exposure			
	Level 1	Level 2	Level 3	Level 4
	Expected Proficiency Level			
Project Management	Basic	Intermediate	Advanced	Advanced
Product Development	Basic	Intermediate	Advanced	Advanced
Business Planning	Basic	Basic	Intermediate	Advanced
Clinical Trial Planning	Basic	Intermediate	Expert	Expert
Regulatory	Basic	Basic	Intermediate	Advanced
Market Access	Basic	Intermediate	Advanced	Advanced
Intellectual Property	Basic	Intermediate	Advanced	Advanced
Operational Planning	Optional	Basic	Basic	Basic
Typical Corresponding Career Path	*For AHPs/ nurses in innovator track; mostly depends on prior innovation exposure rather than job title*			
Typical Clinical Innovator Award Level	*RTF/TA*	*CIA - INV*	*CIA-SI*	*STaR*

AHP: Allied Health Professionals; RTF: Research Training Fellowship; TA: Transition Award; CIA-INV: Clinician Innovator Award for Investigator; CIA-SI: Clinician Innovator Award for Senior Investigator; STaR: Singapore Translational Research Investigator Award. Taken from: https://www.nmrc.gov.sg/grants/talent-development
Source: L.E.K. interviews, research and analysis

FIGURE 14

Sample innovation skills & competencies and proficiency map for scientists/engineers

Innovation Skills & Competencies	Level of Innovation Exposure			
	Level 1	Level 2	Level 3	Level 4
	Expected Proficiency Level			
Project Management	Basic	Intermediate	Advanced	Expert
Product Development	Intermediate	Advanced	Expert	Expert
Business Planning	Basic	Intermediate	Advanced	Advanced
Clinical Trial Planning	Basic	Intermediate	Advanced	Advanced
Regulatory	Basic	Intermediate	Advanced	Advanced
Market Access	Basic	Intermediate	Advanced	Advanced
Intellectual Property	Basic	Intermediate	Advanced	Advanced
Operational Planning	Optional	Optional	Basic	Basic
Typical Corresponding Career Path	*Graduate student (Masters/PhD)*	*Research Fellow/ Postdoctoral fellow*	*Senior Research Fellow*	*Principal Investigator/ Research institute executive directors*

Source: L.E.K. interviews, research and analysis

scientists and product engineers, knowledge of the health and medtech innovation pathway is essential for the translation of ideas into viable products. Scientific and engineering professionals are suggested to aim for advanced or expert proficiency across all competencies, with strong project management being particularly important as seniority rises (Figure 14 and Appendix Figure 1). Product development skills and high-level business comprehension are also important skills and competencies for scientists in addition to their primary technical specialities, as they move further along the translation pathway from research to applied research and product. To further support on-the-job training, learners are advised to consider rotations and secondments to other related functions and/ or industry to develop the workplace exposure on top of classroom-based learning skills.

Innovation/Commercialisation Managers support research scientists/HCPs and early startup teams in developing health and medtech innovations. They should be at intermediate to advanced proficiency levels to appropriately guide and support scientists and HCPs (Figure 15 and Appendix Figure 1). Project management will be key as they often manage innovation projects directly, especially when working with HCPs. Business planning, market access and regulatory understanding are also important because scientists and HCPs typically need more support in these areas. Innovation/commercialisation managers typically support patent filing/ assessments as well as licensing negotiations and technology transfer activities in research institutes or healthcare institutions and need advanced IP expertise.

While **regulatory professionals** are not directly involved in the development of HMTs, the

FIGURE 15

Sample innovation skills & competencies and proficiency map for innovation/commercialization managers

Innovation Skills & Competencies	Level of Innovation Exposure		
	Level 1-2	Level 3	Level 4
	Expected Proficiency Level		
Project Management	Intermediate	Advanced	Expert
Product Development	Basic	Advanced	Expert
Business Planning	Intermediate	Advanced	Expert
Clinical Trial Planning	Basic	Basic	Advanced
Regulatory	Intermediate	Advanced	Advanced
Market Access	Intermediate	Advanced	Expert
Intellectual Property	Intermediate	Expert	Expert
Operational Planning	Basic	Basic	Advanced
Typical Corresponding Career Path	*Assistant Manager/Senior Officer*	*Manager/ Senior Manager*	*Deputy Director/ Director and above*

Source: L.E.K. interviews, research and analysis

approval for commercial sales and availability of the HMTs to patients is dependent on the fulfilment of regulatory professional requirements. Delays in obtaining approval can be minimised by ensuring a competent regulatory professional workforce (both public and private) and system that is efficient and effective, thus supporting innovation and timely access. Competency frameworks from recognised global organisations are available for regulatory professionals. Initiatives to train regulatory professionals are ongoing, although opportunities to optimise these efforts exist.

Translational grant recipients and startup teams usually receive some innovation training from grant administrators, associated incubators and accelerators. These grant administrators, incubators and accelerators may conduct innovation training themselves or bring in external partners. Teams that are committed to translation and/or early-stage startups need robust innovation training to develop their initial ideas and overcome the obstacles to commercialisation. Strength in all eight functional competencies is a prerequisite for these entrepreneurs (Figure 16 and Appendix Figure 1).

Startups/Grant recipient teams with insufficient innovation training experience may be unprepared to be grant recipients and unable to compose convincing strong feasibility proposals. There is a general shortage of multidisciplinary talent, with health and medtech entrepreneurs and technical teams needing more extensive training in the basics of innovation as well as more hands-on mentoring. Startups struggle to find the talent and skillsets to match vacant roles, similar translational project teams also find it a challenge to find a right mix of collaborators particularly data scientists and other data-related professionals, as well as suitable founding CEOs to bring projects out of the public sector.

FIGURE 16

Sample innovation skills & competencies and proficiency map for translational grant recipients and startups (collectively as a team)

Innovation Skills & Competencies	Level of Innovation Exposure		
	Level 2	Level 3	Level 4
	Expected Proficiency Level		
Project Management	Advanced	Advanced	Expert
Product Development	Basic	Advanced	Expert
Business Planning	Advanced	Advanced	Expert
Clinical Trial Planning	Basic	Intermediate	Expert
Regulatory	Advanced	Advanced	Expert
Market Access	Advanced	Advanced	Expert
Intellectual Property	Advanced	Advanced	Expert
Operational Planning	Intermediate	Advanced	Expert
Typical Corresponding Startup Stage	*Pre-startup incorporation/ Translational Grant Recipients*	*Angel to seed funding*	*Series A and above*

For grant recipients/start-up members collectively as a team, should make up the desired requisites

Source: L.E.K. interviews, research and analysis

Translational grant bodies, innovation & enterprise offices and other startup-support bodies/venture capitalists should recommend complementary innovation training when giving out grants and funding for Proof-of-Concept (POC) and Proof-of-Value (POV) development. For example, grant bodies could coordinate with incubators and (pre-) accelerators to identify the most appropriate courses for inexperienced to advanced innovators, leaving it to the incubators/ accelerators to determine if they can provide the appropriate training and coaching using in-house expertise, or whether they need to hire external training providers. External ecosystem training partners, including IHLs, national training platforms, and private training providers, can provide basic innovation training as needed. Incubators/accelerators and other startup-related stakeholders can create job databases and improve job matching services. Incubators/accelerators and Translational and tech marketplace agencies could also take a leading role in attracting talent via roadshows and other marketing efforts to attract talent into health & medtech careers.

All translational grant recipients and startup teams (i.e., founding team/PIs and employees) need the full complement of the ISC, and incubators/accelerators should assess entrepreneurs' prior innovation exposure and provide the necessary training and on-the-job training based on that level. Core team members who are unable to fulfil all the required competencies, may augment their team by looking to advisors, mentors, board members and consultants to shore up these gaps and develop themselves alongside this guidance.

Finally, training institutions should collaborate at the national level to create a standardised curriculum to address the ISC. It is advisable to avoid duplication amongst training providers as much as possible given Singapore's relatively smaller population size and catchment of trainees. For more basic courses, national agencies may be more suited to streamline and standardise the training programmes by consolidating the demand from the disparate multi-disciplinary learner segments. To facilitate adult learning, courses should be workshop-based, with discrete modules for various capabilities in each competency coupled with technology-enabled learning and workplace learning. In the longer term, in line with a standardised curriculum, having an advanced graduate degree or diploma equivalent comprising these modules would help standardise the training received by the RIE ecosystem stakeholders, enhanced further with high-touch mentoring and advanced courses to suite the diverse range of health and medtech innovation endeavours more advanced courses will require domain experts (e.g., regulatory, IP, clinical trial experts, companies experienced in developing products) to be involved in the training to meet the bespoke needs of individual healthcare products types and their business models.

Recommendations for Implementation

For city-state Singapore, a coordinated national effort is needed to upskill a significant contingent of HCPs, scientists and researchers from different disciplines to support their growth as innovators, melding proactive needs-based learning with the latest in health technology trends. Such an initiative must entail innovation training inputs from multiple ecosystem partners.

Singapore's IHLs are largely responsible for the basic technical training of the multi-disciplinary professionals involved in health and medtech innovation. They should also continue to work with government and industry partners to increase awareness of health and medtech innovation and related career pathways among their undergraduates. Graduate programme and medical school students should be similarly made aware of health and medtech job prospects. Local universities offer a variety of health and medtech innovation courses and host innovation opportunity events that provide the necessary exposure to keep prospective talent for the industry engaged. Companies and public agencies can also be more deliberate in providing relevant internships and job placements.

At the adult professional level, HCPs and healthcare scientists and engineers who are involved with innovation need the most support, which can be achieved using a two-pronged approach (Figure 17). **Top-down**, the government and RIE policymakers can do their part to message the importance of innovation training to support the ecosystem. Measures could include:

- Endorse the innovation skills and competency framework and enhance communications via roadshows
- Consolidate innovation training providers and provide a whole-of-Singapore approach across the skills map and proficiency levels
- Provide and make available training budgets for HCP innovators and scientists
- Incorporate training provisions and budget into public translational grants
- Introduce defined training metrics as and KPIs for teams to work towards
- Include innovation training for continuing medical education credits and/or accredited courses

From the **bottom-up**, public healthcare and research institutions employing the target learners should:

- Incorporate innovation competency frameworks into career development and learning roadmaps by working closely with management, HR, Leadership & Organisation Development (L&OD) and heads of departments
- Identify champions from HQ-level innovation units as well as department/specialist level units to spearhead training efforts
- Locate, earmark, and make available funds and resources for training for individual career development
- Identify and endorse relevant training courses and providers that can add on to continuing medical education credits and/or accredited specialist skills
- Augment with workplace learning
- Track participation, learning and other performance outcome metrics to assess suitability and efficacy of training.

In addition, following the examples of EIT and NSF I-Corps, existing innovation training providers in Singapore should work together to maximise public manpower training resources to deconflict their training offerings to cover the spectrum of innovation competencies and proficiencies along the value chain.

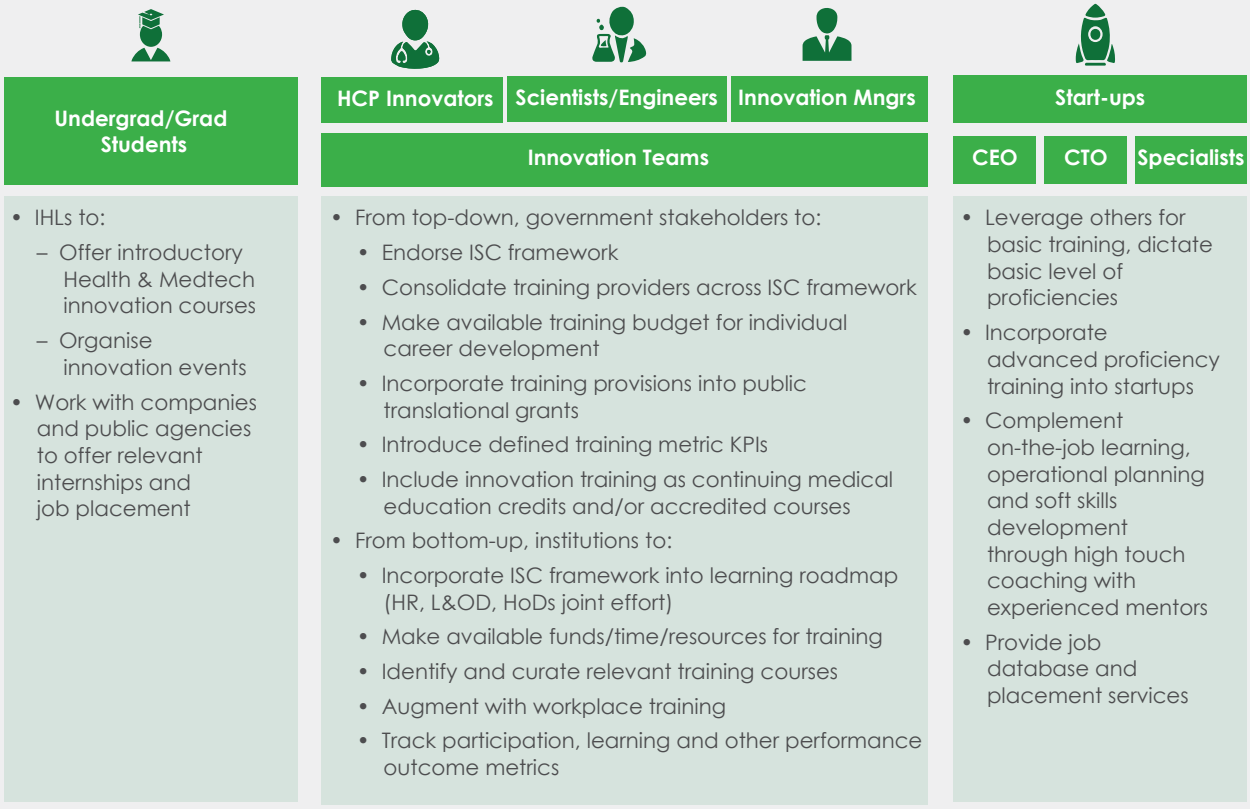
For independent innovation training providers who typically focus more on classroom- and tech- enabled learning, they could also partner organizations/employers to take proactive steps to integrate training into the workplace, for example, a set of universal SOPs/tools and playbooks coupled with job observations and coaching. In addition, training providers and organisations can co-organise regular communities of practice to encourage sharing of a learner's journey and get guidance and feedback to refine and further improve the application of skills. If workplace support is not forthcoming, incubators and accelerators can actively coach startups using experienced mentors while leveraging training partners for foundational innovation training. They can also provide job database and job matching services, and assistance with placement.

Accessing Innovation Training Budgets

Due to a greater focus on technical skills and competencies development, general lack of awareness of the ISC, and the adequate provision of accompanying curated courses, innovation training is often a lower priority when departments and individuals are faced with limited training budgets. Alternative mechanisms for working training provisions and subsidies into the mix could include leveraging

FIGURE 17

Overall recommendations for Singapore's Health & MedTech innovation ecosystem



ISC: Innovation Skills and Competencies; IHL: Institute of Higher Learning; HR: Human Resource; L&OD: Learning and Organisational Development; HoD: Head of Department

Source: L.E.K. interviews, research and analysis

upskilling subsidies to train the increasing need for a health and medtech innovation workforce to alleviate healthcare needs as well as provide economic returns through innovations. In addition, budget-constrained departments could make provisions from their research budgets, either directly or indirectly, through core manpower budgets or translational grant mechanisms available for public sector project teams or startup and SME teams as well as provisions through private funding mechanisms.

Currently, translational grant funding proposals in Singapore may lack an appreciation of the wider market conditions and market value, a clear signal that HCP and scientist grant recipients need better innovation training to pass muster with grant reviewers. A range of strong competencies, from project management and product development to business planning and clinical trial set up would be required so that small teams (~4 people) can perform multiple functions. Grant recipient teams currently receive partial and sporadic training, the scope of which is mainly dependent on their initiative.

Outcome Metrics & Integration into the Workplace

It is important to create a set of outcome metrics that will:

1. Improve the effectiveness of innovation training and non-training initiative
2. Enhance organisational learning, implementation, and review in a structured way
3. Identify and monitor problems or obstacles during the implementation of the competency framework
4. Align the learning, and the assessment of learning, to its objectives.

Some of the desired outcomes of innovation training can be measured with short-term and longer-term indicators using *Kirkpatrick's 4 levels of Evaluation*[9] for learning, namely: (1) Reaction, (2) Learning, (3) Application, and (4) Business (Figure 18). Short-term indicators in level 1 and 2 are those that can be immediately tracked by trainers or training providers (e.g., NPS, project plan robustness). Longer-term indicators, however, require co-tracking by training providers and workplace supervisors and innovation managers to quantify impact of innovation training in real-world environment (e.g., level of technological readiness of submitted proposals, number of start-ups advancing to series B funding). Tracking of these indicators are important as a feedback loop to refine training programs, better training outcomes, and ultimately, demonstrate their satisfactory return of investments.

Example of outcomes out of a structured training programme can be drawn from the 1-year full-time Stanford Biodesign Innovation Fellowship Programme[10]. In a comparative career tracking, it was assessed that those with a structured training programme (i.e., Fellows) were more likely to choose careers in the health technology field in greater numbers and hold leadership positions at a higher rate than the those who did not receive formal training (i.e., candidates who interviewed for the fellowship but were not selected). In addition, the cumulative outcome of the fellows to date has shown measurable impact to the ecosystem, which includes 97 companies founded with an aggregate fund raise of $1.9 billion in funding, 1850 new full-time positions and >3.35 million patients helped by technologies initiated by fellows during the program. 91 percent reported that the fellowship was influential on their chosen career trajectory and 91 percent of the responding fellows have formally or informally trained or coached others on aspects of the biodesign innovation process, with an average of 154 trainees per alumna/-us.

Ultimately, one should not lose sight of the desired end goal and over-engineer the steps required to get there. As the Health and MedTech ISC framework straddles across multi-disciplinary roles, individual institutions can further tailor the desired outcomes according

FIGURE 18

Desired outcomes for Health & MedTech training

Kilpatrick's Evaluation Level	Assessment Criteria	Stakeholder Responsible for Outcome Tracking
4 (Impact on Business)	**Project/Company, commercial & economic outcomes** • Career development and progression: maintain healthy and sustainable talent pool • Successful delivery of projects • Ability to move on to next phase of funding (e.g., no. of startups in series B), secure industry partnerships, licensing/spin-off • New products and adoption of products into healthcare setting	• Workplace Supervisor, HR, L&OD • Grant admin/ innovation manager • Research units and research policy holders • Investors • Healthcare provider/receptacle
3 (Application)	**On –the-job training and feedback** • Achieve 70% satisfaction on job performance from RO to confidently manage project management • Project on track 70% of the time according to timeline, budget, resource and deliverables • Communities of practice to check in and provide feedback on ability to apply skills	• Workplace Supervisor for individual performance and/or • Grant admin/innovation manager/investor for project/startup performance
2 (Learning)	**Group breakout sessions and individual assessment** • Able to contribute and confidently demonstrate learming methods in group breakout assessments (peer review at least 7 of 10) • Individual assessment: ability to demonstrate learning outcomes (trainer assessment at least 7 of 10)	• Trainer
1 (Reaction)	**No. of People Trained (enrollment & satisfaction)** • >80% trainees are satisfied with course (i.e., 4 out of 5 rating) • Net promoter score	• Trainer • Trainees

to the needs of their institutions. Corresponding workplace training and application can also be further contextualised according to job roles. For example, scientists/engineers can be seconded to health and medtech companies and venture capitals whilst HCPs can be rotated into roles in healthcare transformation to get the downstream implementation experience.

The ISC should also be complemented with technical skills and competencies, as well as soft skills and competencies, in a holistic approach to achieve its outcomes and should be considered from the big picture too. Embedded in the ISC is also a means to develop a forward-thinking approach that allows the innovator to adapt to market trends and user needs to deliver their innovation.

Conclusion

With the health and biomedical industry a key pillar for Singapore's economic growth and the need to cater to Singapore's ageing population and workforce needs, a harmonised whole-of-Singapore foundational innovation training approach coupled with workplace learning to actualise these skills and competencies would greatly expand Singapore's health and medtech I&E talent base and improve commercial outcomes for enhanced economic impact. Any organisation's stock of human capital is a key determinant of its ability to innovate. As such, any resulting increase in the quality of human capital through government-sponsored training initiatives should lead to greater innovation.

Admittedly, the adoption of above recommendations will require a coordinated effort between training providers and the hiring organisations to overcome a few challenges echoed across stakeholders:

1. **Time constraints** due to limited protected time by hiring organisations and individual time commitments can be addressed through digital learning tools (e.g., on-demand videos) and early alignment conversations with organisation heads to set aside time for training
2. **Budget constraints** can be addressed by finding alternative mechanisms of funding (e.g., subsidies, grants) and by engaging in early conversations with organisations (e.g., to offer tailored training programs)
3. **Training impact and relevance concerns** can be improved through early alignment around most pressing skill and competency gaps, industry placement opportunities, and tailored training programs (e.g., coaching participants on innovation projects that they are currently working on). Moreover, impact and relevance can be monitored by setting and tracking impact indicators (e.g., NPS, job placement and progression rates, etc.)
4. **Sustainability of training efforts** by an organisation can be achieved by appointing a dedicated person in HR team, who will be responsible for adapting the ISC framework to the organisation's needs, in turn providing a structured roadmap for each individual to progress along. Dedicated roles will also be responsible for sourcing and managing training budgets, engaging training providers, as well as tracking training outcome metrics and providing feedback to training providers
5. **Time to Implement and Train**: The recommended 4 levels of proficiency may seem daunting and ambitious initially but serves as an ideal state to work towards to level up the talent gaps in the ecosystem as we strive towards I&E excellence. Ways to manage this could include organizations running roadshows to better communicate the importance of complementary innovation training and also adding on acceptable timelines towards achieving each level of proficiency.

Nevertheless, innovation training can stimulate the strategic thinking that improves team performance, making it a source of disruptive technologies and business models rather than being vulnerable to them. Not only does innovation training drive organisational growth, but it also enhances employee engagement and retention. The knowledge and techniques learned from innovation training can help organisations respond to new opportunities and potential threats as they emerge.

The Health and MedTech ISC framework is not unique only to health and medtech. On a broader level, the ISC may also be expanded to all other RIE-focused industries with some

adjustment of the regulatory components for specific industries' standards and practices (e.g., clinical trials, regulatory, reimbursement/ market access). Similarly, the Health and MedTech ISC framework and map provide a starting playbook for nations wanting to build a vibrant health and medtech innovation sector as the world moves towards improved healthcare outcomes for all.

Appendix

Figure note: A further Supplementary Dataset (Fig. S1 – S31) of the breakdown of survey profile and results from 71 local respondents will be uploaded separately at https://www.a-star.edu.sg/sb/resources.

APPENDIX FIG 1

Detailed proficiency description of each innovation skill & competency

	Basic	Intermediate	Advanced	Expert
Project management	Identifies main project stakeholders in a healthcare innovation project and defines project scope and milestones that align with them Has the ability to develop a clear project charter, form basic resource budgeting plan, communicate between stakeholders, and track and report activity status Define and prepare early project risk assessment	Demonstrates good understanding of a healthcare project development cycle to define distinct planned activities and key indicators to track, with detailed estimates of manpower, financing, and duration needed of each Develops and coordinates internal stakeholder communication plan, holding cross-functional teams accountable for timely delivery, and can tackle project roadblocks Application of QMS, product safety and efficacy requirements to propose deliverables for project management	Manage a healthcare project development cycle end-to-end, from definition to successful completion, with indicators tracked Effectively manages resources and teams, maintains clear line of communication with stakeholders Analyze potential project risks, develop a mitigation plan and manage risks	Anticipates and prepares effective risk statement, generating mitigation strategies to deal with critical risks. Has the ability to make decisions under uncertainty and risks Formulate multiple contingency plans from a milestone and funding standpoint Effectively manages multiple or global projects, coordinates communication with both internal and external stakeholders
Product development	Demonstrates ability to apply design thinking and needs analysis to unmet healthcare/clinical needs and draft a preliminary user needs specification. Apply ideation strategies to brainstorm possible healthcare solutions. and where it would meet gaps in the patient/user journey Construct a product development lifecycle roadmap, with corresponding TRL classification Define and prepare prototyping plan and early risk assessment.	Analyse and articulate key design requirement specifications Assess technology go design and develop functional proof-of-concept prototypes, and determine what tests are required to de-risk the project Collaborates with different internal stakeholders (e.g., engineers and scientists) to define product requirements, develop prototype and validate results	Establish and execution of product development through the full design thinking process, from identifying unmet needs to testing and validation Respond and manage potential product development risks, develop a mitigation plan and manage risks Conduct design failure mode and effect analysis to design and develop innovation, including against competitive landscape relating to IP, regulatory, business models, usability and cost Apply key technological trends (e.g., AI, SAMD, 3-D printing) to the development of the innovative HMT product	Translate research into commercialization for complex systems, incorporating logistics and business needs such as design for pilot manufacturing and agile product development Confident to appraise required QMS standards and to conduct verification and validation process for safety and efficacy Review and assess appropriate key technologies to develop new products and capabilities (e.g., programming, designing cloud architecture) Justify the maximal commercial potential based on product development process, market needs and business landscape

continue

Source: L.E.K. interviews, research and analysis

APPENDIX FIG 1

Detailed proficiency description of each innovation skill & competency

	Basic	Intermediate	Advanced	Expert
Business Planning	Construct and execute basic customer and market survey for concept or product validation and to articulate key value proposition Prepare a preliminary market analysis (top-down and bottom up) Apply basic presentation and pitching proficiency Apply basic business, financial and accounting concepts and is able to create a preliminary business model canvas Has an overview of fundraising and investment landscape (i.e., public and private funding sources and options)	Analyze market positioning by conducting in-depth market landscaping (competitive landscape distribution channel, existing models) to develop a business plan with clear value proposition Examine and articulate key stakeholders along the value chain and the jobs to be done Demonstrates confidence in defending and pitching the business, networking and basic negotiation skill to initiate investment and partnership discussions	Confidently develops and executes business plan Formulate financial model with appropriate inputs Devise and refine pitches to pitch effectively to investors and partners Demonstrates strong negotiation skills in investment and partnership discussions; able to propose strategic partnerships, with establishment of appropriate types of partnership contracts Devise a partnership strategy and plan for various stages of a product's lifecycle	Review and refine business strategies, i.e., new sales and marketing opportunities, and perform pricing analysis and financial modelling Justify valuation, deal planning and structuring plans Demonstrates a wide network and strong ability to secure and maintain strategic partnerships and collaborations, with deep understanding of the implications and trade-offs of contractual terms and clauses
Clinical trial (CT) planning	Apply basics of clinical trial planning: overview, pros and cons of study designs (e.g., RCT), clinical trial ethics guidelines (e.g., HBRA/IRB), timeline of different clinical trial stages, basic statistics concept, and implication of clinical endpoints used Understands the role of CROs and can execute best practices in CRO management	Analyze different types of clinical trial strategies to meet clinical trial objectives Breakdown and succinctly address clinical trial ethics application steps and requirements, plan costing and resources for a clinical trial Designs SOP/guideline for conducting study, oversight, documenting data, adverse event reporting, and ensuring GCP compliance. Has the ability to interpret statistical clinical trial results and conduct interim analysis (if needed) Establishes, tracks and manages grant fund usage and performance against set indicators	Formulate overall clinical trial strategy and objectives, with high level roadmap Refine clinical trial patient inclusion/exclusion criteria to achieve trial objectives, and develop strategies for ensuring appropriate clinical trial enrollment Confidently executes clinical trials and related processes, including recruitment, data collection and event reporting Establish and manage suitable CROs as needed	Develop and justify comprehensive clinical trial strategy with detailed roadmap, including appropriate design, endpoints, data requirements Confidently appraise and assess primary and secondary endpoints based on clinical trial design, available comparative trial resources and understanding of the innovative solutions' v alue proposition Coordinate and manage complex, multi-centered CT trials, as well as perform and communicate statistical analyses and implications Experienced in negotiating CRO contract and risks management

continue

Source: L.E.K. interviews, research and analysis

APPENDIX FIG 1

Detailed proficiency description of each innovation skill & competency

	Basic	Intermediate	Advanced	Expert
Regulatory	Conduct preliminary research to determine regulatory class of a healthcare product as medical device, drug, combination or IVD. To be familiarised with registration approval requirements of relevant authorities in SG (or at least 1 country), and apply these to implications on CT and product design	Understands the required regulatory and quality requirements, i.e., guidance documents, standards for different kinds of innovation projects; Able to design and carry out necessary tests and documentation. Adapt CT plans and product development to meet regulatory requirements and gather required documentations to submit application	Respond to regulatory landscape in at least 2 - 3 key relevant markets (US/EU/CN/AU), to determine key stakeholders in each regulatory landscape I.e., Authorities, notification bodies, consultants, certification bodies Aware of the basics to developing a regulatory strategy for product development and identifying optimal submission strategy	Leverages advanced technical knowledge to develop a comprehensive regulatory strategy for product development and optimal submission strategy, even in complex regulatory environment (i.e., ASEAN). Review and defend product development plan to meet all design control and design documentation requirements for dossier submission Assess business impact in context of a given regulatory strategy and can negotiate with authorities and perform other interventions to secure approval from local and global regulatory bodies
Market access	Apply understanding of healthcare value chain to elucidate identify the key stakeholders and factors influencing commercial viability of a product in target market (e.g., reimbursement infrastructures, key decision makers) and/or adoption into healthcare system Apply principles of coding, coverage and payment. Articulate value proposition in relation to initial pricing and business model	Evaluate and analyse pricing and reimbursement schemes and healthcare economics across key target markets Examine key channels in key target markets (e.g., public hospitals and clinics via tender and group procurement, private hospitals via private healthcare insurance and private procurement) Prepare a preliminary health technology assessment for quick compare and contrast to identify key target markets and value proposition to enter Derive initial pricing model and test deployment with select KOL users	Develop market access/healthcare adoption plan for new innovative products and services to navigate market landscapes Organise different stakeholder perspectives, and develop evidence to fit key markets and initiate negotiations with relevant stakeholders Establish channel strategy and drive innovation adoption with understanding of key channels Formulate key inputs to health economics models Develop pricing models and execute pricing strategy	Experience across the healthcare value chain in a market, with the ability to navigate complex market/healthcare system landscape and negotiate with different stakeholders to drive innovation adoption Confidently utilise appropriate channels to drive innovation adoption, and adapt to changes in channels as product, service or channel dynamics evolve Develop health economics models with careful clinical trial (equivalent metrics) and user surveys to engage with key stakeholders Derive a comprehensive pricing strategy and stakeholder engagement plan in preparation to seek reimbursement from existing/new codes

continue

Source: L.E.K. interviews, research and analysis

APPENDIX FIG 1

Detailed proficiency description of each innovation skill & competency

	Basic	Intermediate	Advanced	Expert
Intellectual property	Explain basic IP anatomy, types of IPs, IP regulations, IP lifecycle, costing and types of IP instruments available (e.g., patent, software, knowhow/trade secret, copyright, trademark) Apply principles of patentability and freedom to operate. Prepare a preliminary prior art search to evaluate healthcare innovation idea to inform feasibility	Define the inventive concept and analyze its positioning to determine its strength and weaknesses to develop a good competitive IP advantage and filing strategy (i.e., patent vs knowhow) Possesses a practical understanding of IP regulations and the implication of different IP clauses in agreement Navigate different IP clauses in agreements relating to research collaboration, licensing, fundraising etc.	Confidently develop IP commercialization strategy Deep understanding of IP regulations and implications, leverage knowledge to work with patent attorney to draft and file single or multiple IP applications Formulate offensive and defensive IP claims Establish costs associated to maintaining IP and patent family	Leverages specialised knowledge to develop IP commercialization strategies, respond to patent written opinions, office actions, infringements and invalidity, in tandem with patent attorneys Is confident in developing a sound IP strategy for portfolio management in relation to maintaining costs and commercial advantage. Stays abreast of global technology trends and developments and can analyze prior art to I) evaluate patentability and potential infringement of an IP (freedom to operate) ii) determine licensing opportunities and iii) to appraise new product development
Operational planning	Explain the operational aspects and financial aspects required for a health and medtech company to function, including processes (e.g., procurement), people (e.g., key staff needed, key stakeholders to engage), resources (e.g., lab and office infrastructure, supply chain management, warehousing and distribution) and budget (e.g., operating expenses and COGS) Apply basic quality management standards to ensure adherence to ISO standards in the early product development stages	Breakdown the components of a functional operational plan with financial considerations, identifying key processes, people, resources and budget needed, and execute the operation plan Direct and control operations, production, purchasing, supply chain management, warehousing and distribution to ensure customers are supplied with products/service at right time Apply individual quality management standards and utilization across product development stages	Develop, execute and refine a functional operational plan. Formulate a basic hiring strategy, and how to optimise talent in company Develop and control operational budgets to promote profitability as possible In-depth analysis of the applicable quality management standards and broad overview of different aspects involved in establishing a QMS system across business functions (design process, production control and surveillance) up to the later product development cycle (i.e., manufacturing)	Review and assess all operational aspects of a health and medtech company, able to easily adapt operational plans to changes in market conditions Adapt hiring strategy to optimise talent recruitment, development and retainment Justify, manage and defend operational processes and resources efficiently, and implement process improvements to reduce redundancy and cost Review areas to optimise operational budget based on strong financial understanding, including management of labor costs, COGS infrastructure and other costs Establish and further optimise internal quality management system that complies with current standards and ensures manufacturing quality

Source: L.E.K. interviews, research and analysis

APPENDIX FIG 2

Competency by 4 proficiency levels, and corresponding core and optional knowledge & ability

Innovation Skill & Competency	Knowledge & Ability	Proficiency Level			
		Basic	Intermediate	Advanced	Expert
Project Management	Project initiation and planning	Core	Core	Core	Core
	Project resource planning and budgeting	Core	Core	Core	Core
	Stakeholder identification, communication and management	Core	Core	Core	Core
	Understanding of QMS (ISO standards and quality requirements) relevant for health and medtech products and services	Optional	Core	Core	Core
	Project indicator tracking and reporting	Optional	Core	Core	Core
	Full product development lifecycle management	Optional	Optional	Core	Core
	Project risk management	Optional	Optional	Core	Core
	Multiple project management	Optional	Optional	Optional	Core
	Contingency plan development (for project milestones and funding)	Optional	Optional	Optional	Core

Source: L.E.K. interviews, research and analysis

APPENDIX FIG 2

Competency by 4 proficiency levels, and corresponding core and optional knowledge & ability

Innovation Skill & Competency	Knowledge & Ability	Proficiency Level			
		Basic	Intermediate	Advanced	Expert
Product Development	Identifying unmet clinical needs & development of needs statement (Design thinking)	Core	Core	Core	Core
	Ideation & brainstorming (Design thinking)	Core	Core	Core	Core
	Concept screening (Design thinking)	Core	Core	Core	Core
	Understanding product development lifecycle and TRL classification	Core	Core	Core	Core
	Technology Assessment & developing product prototyping plan with early risk assessment (Design thinking)	Core	Core	Core	Core
	Design controls of QMS (ensuring design and process adheres to specific ISO requirements)	Optional	Core	Core	Core
	Key safety standards	Optional	Core	Core	Core
	Prototyping, defining product requirements specifications (Design thinking)	Optional	Core	Core	Core
	Testing and validation (Design thinking	Optional	Core	Core	Core
	Usability engineering for MedTech/HealthTech products and services	Optional	Optional	Core	Core
	Design failure mode and effect analysis	Optional	Optional	Core	Core
	Risk assessment & management	Optional	Optional	Core	Core
	Product portfolio strategy (setting goals for portfolio and new products, and defining development roadmap)	Optional	Optional	Optional	Core
	Key trends (e.g., AI, ML, SaMD, 3-D printing)	Optional	Optional	Optional	Core
	Design engineering (translating prototypes to more refined, standardised products, including robustness and reliability engineering)	Optional	Optional	Optional	Optional
	Design for manufacturing (optimizing the product design for the manufacturing process)	Optional	Optional	Optional	Optional

For last 2 abilities, only expect specific subject matter experts in a company (e.g., engineers with several years' of working experience) to have these highly specific technical competencies

Source: L.E.K. interviews, research and analysis

APPENDIX FIG 2

Competency by 4 proficiency levels, and corresponding core and optional knowledge & ability

Innovation Skill & Competency	Knowledge & Ability	Proficiency Level			
		Basic	Intermediate	Advanced	Expert
Business Planning	Business principles (accounting, finance, law)	Core	Core	Core	Core
	Business communication	Core	Core	Core	Core
	Pitching to investors and partners	Core	Core	Core	Core
	Market landscaping (identify key customers, competitors, distribution channel, business models)	Core	Core	Core	Core
	Business model development	Optional	Core	Core	Core
	Funding sources, fundraising and budgeting	Optional	Core	Core	Core
	Identification of potential partners for various stages of a product's lifecycle	Optional	Core	Core	Core
	Financial analysis and modeling	Optional	Core	Core	Core
	Drafting business agreement	Optional	Optional	Optional	Core
	Valuation and deal structuring	Optional	Optional	Optional	Core
	Business, sales and marketing strategy development	Optional	Optional	Optional	Core

Source: L.E.K. interviews, research and analysis

APPENDIX FIG 2

Competency by 4 proficiency levels, and corresponding core and optional knowledge & ability

Innovation Skill & Competency	Knowledge & Ability	Proficiency Level			
		Basic	Intermediate	Advanced	Expert
Clinical Trial Planning	Introduction to purpose, concept and design of CT (principles, stages, timeline, endpoints)	Core	Core	Core	Core
	Basic statistical concepts and methods	Core	Core	Core	Core
	Ethics in clinical research	Core	Core	Core	Core
	Introduction to CRO and best practices in CRO management	Core	Core	Core	Core
	Scientific literature appraisal	Core	Core	Core	Core
	Introduction to grant application (steps involved, requirements, costing and budgeting for resources)	Core	Core	Core	Core
	Development of clinical trial strategy (inclusion/exclusion criteria, enrolment, design)	Optional	Core	Core	Core
	Interpretation of statistical outcomes and analysis	Optional	Core	Core	Core
	Designing a clinical study protocol	Optional	Core	Core	Core
	Drafting a grant application	Optional	Optional	Core	Core
	Clinical trials management (e.g., sample recruitment, data collection and event reporting)	Optional	Optional	Core	Core
	Good Clinical Practice	Optional	Optional	Core	Core
	Statistical analysis	Optional	Optional	Optional	Core
	Designing and coordinating complex, multi-centered clinical trials	Optional	Optional	Optional	Core
	CRO contract negotiation and risk management	Optional	Optional	Optional	Core

Source: L.E.K. interviews, research and analysis

APPENDIX FIG 2

Competency by 4 proficiency levels, and corresponding core and optional knowledge & ability

Innovation Skill & Competency	Knowledge & Ability	Proficiency Level			
		Basic	Intermediate	Advanced	Expert
Regulatory	Definition and classification of medical devices/diagnostics	Core	Core	Core	Core
	SG health product regulatory requirement (standards, guidelines, stakeholders)	Core	Core	Core	Core
	Regulations for clinical trials	Core	Core	Core	Core
	Navigating registration pathway and submission requirements (steps, timelines, requirements)	Optional	Core	Core	Core
	APAC/US/EU medical device product regulatory and quality requirements (in relevant target markets)	Optional	Optional	Core	Core
	Developing regulatory strategy (e.g., optimal submission strategy, assess business impact)	Optional	Optional	Optional	Core
	Designing product development plan to meet all design control and design documentation requirements for dossier submission	Optional	Optional	Optional	Core
	Regulations for health product manufacturing and supply chain	Optional	Optional	Optional	Core
	Post-market surveillance and risk management	Optional	Optional	Optional	Core
	Regulatory overview of emerging trends and technology (e.g., digital health, wearable)	Optional	Optional	Optional	Core

Source: L.E.K. interviews, research and analysis

APPENDIX FIG 2

Competency by 4 proficiency levels, and corresponding core and optional knowledge & ability

Innovation Skill & Competency	Knowledge & Ability	Proficiency Level			
		Basic	Intermediate	Advanced	Expert
Market Access	General introduction to healthcare value chain and identification of key stakeholders (e.g., reimbursement infrastructure, decision makers)	Core	Core	Core	Core
	Introduction to basic reimbursement concepts and health technology assessment	Core	Core	Core	Core
	APAC/US/EU healthcare pricing, reimbursement and healthcare economics landscape (based on relevant target market)	Optional	Core	Core	Core
	APAC/US/EU understanding of key channels (e.g., public hospitals and clinics via tender and group procurement, private hospitals via private healthcare insurance and private procurement) in relevant markets	Optional	Core	Core	Core
	Understanding stakeholder perspectives for reimbursement approval (evidence requirements and negotiation channels)	Optional	Optional	Core	Core
	Development of health economics model	Optional	Optional	Optional	Core
	Developing market access strategy to drive product adoption (e.g., innovative pricing)	Optional	Optional	Optional	Core

Source: L.E.K. interviews, research and analysis

APPENDIX FIG 2

Competency by 4 proficiency levels, and corresponding core and optional knowledge & ability

Innovation Skill & Competency	Knowledge & Ability	Proficiency Level			
		Basic	Intermediate	Advanced	Expert
Intellectual Property	Intellectual property fundamentals (basic regulations, types of instruments, IP lifecycle, IP anatomy) and costing basics	Core	Core	Core	Core
	Evaluating IP intelligence (analyzing prior art)	Core	Core	Core	Core
	Patent portfolio management and cost monitoring	Core	Core	Core	Core
	Defining and analyzing patentability of inventive concept	Optional	Core	Core	Core
	Development of basic IP strategy with competitive advantage and filing strategy	Optional	Core	Core	Core
	Drafting and filing IP applications and agreements, including collaboration and licensing	Optional	Core	Core	Core
	Crafting offensive and defensive IP claims	Optional	Optional	Core	Core
	Understanding costs associated to maintaining IP and patent family	Optional	Optional	Core	Core
	Developing advanced IP strategy (portfolio management, maintaining costs and commercial advantage)	Optional	Optional	Optional	Core
	Handling legal actions	Optional	Optional	Optional	Core
	Understanding of global trends and development to inform changes in IP strategy	Optional	Optional	Optional	Core

Source: L.E.K. interviews, research and analysis

APPENDIX FIG 2

Competency by 4 proficiency levels, and corresponding core and optional knowledge & ability

Innovation Skill & Competency	Knowledge & Ability	Proficiency Level			
		Basic	Intermediate	Advanced	Expert
Operational Planning	Introduction to day-to-day operations for a Med/HealthTech company (processes, people, resources and budget)	Core	Core	Core	Core
	Basic QMS standards for a health and medtech company	Core	Core	Core	Core
	Developing a functional operational plan (identifying key processes, people, resources and budget needed)	Optional	Core	Core	Core
	Introduction to hiring and talent strategy for Med/HealthTech company	Optional	Core	Core	Core
	Supply chain management (including procurement, production, warehousing and distribution)	Optional	Core	Core	Core
	Developing and controlling operational budget	Optional	Optional	Core	Core
	Implement QMS system across the business	Optional	Optional	Core	Core
	Risk management and contingency planning for operations	Optional	Optional	Optional	Core
	Developing hiring strategy	Optional	Optional	Optional	Core
	Optimizing operational budget (management of labor costs, COGS infrastructure and other costs)	Optional	Optional	Optional	Core
	Optimizing QMS and implementing process improvements	Optional	Optional	Optional	Core

Source: L.E.K. interviews, research and analysis

APPENDIX FIG 3

Stakeholders interviewed and surveyed

Interviews (N = 46)

Innovation stakeholder	Geography	N
Healthcare providers (incl. medical schools, healthcare clusters)	Singapore	9
Engineers	Singapore	1
Scientists	Singapore	3
Incubators/accelerators	Singapore	3
Start-ups	Singapore	8
	China/APAC	3
	US/Europe	2
SMEs (50-250 employees)	Singapore	2
	China/APAC	1
MNCs (>250 employees)	Singapore/APAC	5
Regulators		2
Total		**41**

Global Med/ HealthTech innovation training providers	Geography	N
	US, EU, APAC, Singapore	5

Survey (N = 90)

Innovation stakeholder	Geography	N
Clinician/doctor	Singapore	8
Allied health professional	Singapore	8
Institute of Higher Learning (IHL) professors and lecturers	Singapore	8
	China/APAC	2
	US/Europe	2
Engineers	Singapore/APAC	10
Scientists	Singapore	10
	China/APAC	2
	US/Europe	2
Start-up entrepreneurs	Singapore	10
	China/APAC	2
	US/Europe	2
Commercialization manager	Singapore	8
Business development manager	Singapore/APAC	13
Regulators	Singapore	3
Total		**90**

References

[1] National Research Foundation "RIE2025 Plan" (2020) https://www.nrf.gov.sg/rie2025-plan Last Accessed: 24 Nov 2021.

[2] EDB "Singapore dazzles as a world leader in medical manufacturing" (2018) https://www.edb.gov.sg/en/business-insights/insights/singapore-dazzles-as-a-world-leader-in-medical-manufacturing.html Last Accessed: 10 Jan 2022.

[3] National Research Foundation "Human Health & Potential" (2020) https://www.nrf.gov.sg/rie2025-plan/human-health-and-potential Last Accessed: 24 November 2021.

[4] Teo, C.L., et al. "COVID-19 awareness, knowledge and perception towards digital health in an urban multi-ethnic Asian population." Scientific Reports 11 (1) (2021): 10795.

[5] Douglas Hannah. "One Way to Build More Resilient Medical Supply Chains in the U.S." Harvard Business Review (2021).

[6] Tan Bao Zhen and Sheng Yee Zher. "The Adult Learners' Perception of Online Learning." Institute for Adult Learning Singapore (2021).

[7] National Institutes of Health "Testimony on Driving Innovation through Federal Investments before the Senate Committee" (2014) https://www.nih.gov/about-nih/who-we-are/nih-director/driving-innovation-through-federal-investments Last Accessed: 10 Jan 2022

[8] SkillsFuture Singapore Technical Skills and Competencies for the Skills Framework (SFw) for Healthcare https://www.skillsfuture.gov.sg/skills-framework/hc Last Accessed: 10 Jan 2022.

[9] Kirkpatrick Partners "The Kirkpatrick Model." https://www.kirkpatrickpartners.com/the-kirkpatrick-model/ Last Accessed: 10 Jan 2022

[10] Denend, Lyn et al. "Are We Making a Difference? A Case Study of Assessment in Innovation Training." The Bridge Vol. 31, No. 4, (2021): 43-50

Supported by: