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Journey of science teacher education in Singapore: past, present and future

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Abstract

Singapore students boast stellar performance at international benchmarking studies such as PISA and TIMSS. One of the major contributors to the consistently good performance in mathematics and science is the quality of our science teacher education in Singapore. Through a consistent, systematic and continuous system, there is a seamless transition of pre-service teacher education to continuing professional development of science teachers in Singapore. This pathway of science teacher education is important as it enables science teachers to be kept abreast of changing educational innovations. Quality of science teachers is ensured from the first step of recruitment. Prospective teachers undergo a stringent selection process before they are admitted to the National Institute of Education for their pre-service education. Factors such as strong governmental support, resource availability, high quality professional development opportunities that are responsive to changes in educational landscape, and presence of a structure to allow planning and tracking of professional development trajectory ensures quality professional development. As such, science teacher education in Singapore is a compact model that is responsive yet stable, flexible yet structured, bespoke yet inclusive, varied yet focused, and specialized yet accessible. This paper will discuss science teacher education and professional development in the light of the larger Singaporean education landscape. It will also present challenges and way ahead for science teacher education and professional development in Singapore.

Keywords: Singapore, National science curriculum, Technical knowledge, Knowledge based economy, Survival driven education

Introduction

In this paper, I present the state of science teacher education in Singapore and suggest the way forward to make science teacher education future-ready. I first present the unique social context of Singapore and discuss science teacher education in the light of general education policies and educational mindsets in Singapore.

Singapore is a small island state in South East Asia that gained independence in 1965. Prior to independence, Singapore was under British rule from 144 years before we became part of Malaysia for two years. While Malay is the national language for Singapore, English is the lingua franca in schools and government departments. The use of English language is important to unify the different races of people who live in Singapore. The four key races making up Singapore are the Chinese (74.3%), Malays (13.4%), Indians (9.1%) and others, including Eurasians (3.2%) (Ministry of Health, Singapore, 2017). The use of a common English language allowed for the development of respect and understanding among the different cultures in Singapore and this enabled the development of a unique Singapore identity.

With a small land area of 719.2 km^2, land scarce Singapore has few natural resources, such as oil, minerals, and even water resources. The lack of land for agriculture and other forms of farming means that Singapore has to depend on food and water that is imported to Singapore from other countries. The lack of land and natural resources resulted in the country developing an economy based on knowledge since this depends on the only resource that the country has – human resource. Education in Singapore is hence a highly prized and valued enterprise since human resources are the only "natural" resource that Singapore has. As such, there is strong government support and generous funding for education and educational research in the country. With a population of 5.612 million people (Department of Population Statistics, Singapore, 2017), the emphasis placed on development of human resources is evident from the national budget on education. The national budget on education stands at SGD 12.9 billion in 2017 (Ministry of Finance, 2017). This amount is 3% of the national budget and is only second after that of defense. On the average, Singaporeans spend 10.7 years in school (Department of Population Statistics, Singapore, 2017). With the focus on education as a means for economic progress (and social mobility), it is no surprise that teacher's role in the society is one of great importance. Teachers are valued by the society as playing an important role to nurture responsible and useful citizens for the country.

There are currently about 33,378 teachers (with 23,774 being females) in Singapore in 2016 (Ministry of Education, Singapore, 2017). Out of these 33,378 teachers, 30,008 are graduate teachers and the rest are non-graduate teachers. The deployment of graduates in the teaching service is a deliberate one to ensure that only the best of each cohort of students are chosen to become teachers. The Ministry of Education (MOE) is the central body that is responsible for all matters related to education in Singapore. They are the direct employer of all primary, secondary and junior college teachers in Singapore. All teachers teaching in government schools in Singapore have to go the National Institute of Education, Singapore (NIE) to be certified to teach. Prospective teachers undergo a series of stringent selection processes including interviews and tests by the Ministry of Education (MOE) before they are selected. Upon selection, these students will be hired directly by the Ministry of Education and will be paid a salary when they undergo their pre-service teacher education at the NIE.

The NIE offers a range of pre-service teacher education programs to cater to the different entry points for prospective teachers. For individuals who have already had their university degrees, they will be enrolled in the 16-month Post-graduate Diploma in Education (PGDE) program. For fresh school leavers with their GCE 'A' levels or International Baccalaureate (IB) qualifications, they will be enrolled in a 4-year Bachelor of Arts (Ed) or Bachelor of Science (Ed) program. Upon completion of their studies, these prospective teachers will be posted to schools across Singapore by the MOE. They will have to serve a service bond of between three to four years.

As a small country, Singapore has the privilege of a central education system and that is one of the key reasons for high fidelity of educational innovations across the country. The MOE has the responsibility to set the direction for education for the country and other organisations such as the Academy of Singapore Teachers (AST), NIE and the Singapore Science Centre will work closely with the MOE to support changes in educational initiatives. The MOE, NIE and schools have a close tripartite relationship whereby the NIE work with MOE and schools to ensure that professional development is well taken care of in schools with the support and funding from the MOE. As NIE is the sole teacher preparation institution in the country, this close working relationship with MOE is fundamental to ensure success of our educational system.

To raise the professionalism of teachers in Singapore and to empower them to make evidence informed decisions in their own practices, the MOE encourages teachers to participate in professional learning communities (PLCs) and to be engaged in some form of professional inquiry. Although there are no specific science education journals in Singapore (the population base in Singapore is too small), science teachers typically work with researchers from NIE to present at conferences as well as to publish in general education journals. Examples of general education journals by NIE include *Asia Pacific Journal of Education*, *Pedagogies – An international journal*, and *Learning: Research and Practice*.

Students in Singapore schools go through six years of primary education, four or five years of secondary education and two or three years of pre-university education before heading to the university. About 29% of the population are university graduates (Department of Population Statistics, Singapore, 2017). Students take a national placement examination at the end of six years in primary school. This examination is often perceived as an important examination as students are tracked based on their performance at this examination. Students are tracked to either a four-year (express) secondary education or for learners who need a little more time, they will be tracked to a five-year (normal academic) secondary education. There is also a group of learners who are deemed more suitable to pursue a more vocational route in their education and hence are tracked to a five-year (normal technical) secondary education.

All students in primary school will learn science starting from grade three. In secondary schools, students will do general science at grades seven and eight. They will have a choice if they wanted to pursue science at higher grade levels. In the last couple of years, Singapore students have shown consistently above average performance at international benchmarking studies such as Trends in Mathematics and Science Studies (TIMSS) (Martin et al., 2016) and Programme for International Students Assessment (PISA) (Organization for Economic Co-operation and Development (OECD), 2016). This good performance is a result of consistent and sound science and mathematics curriculum and high quality of teachers through the years. As such, the MOE and NIE have consistently placed emphasis on quality teacher professional development opportunities for all in-service teachers.

I have just described the Singapore society and her state of education today. The current state of Singapore education is shaped by events that happened in the past. In the next few sections, I describe the historical events in Singapore that contributed specifically to science education and science teacher education.

Historical overview of science teacher education in Singapore

"… as we could not compete on size, we need to leverage on science and technology to amplify our strengths and extend our reach." (Ng, 2010, pp.1–2).

The quotation above by Dr. Ng Eng Hen,[1] the Minister for Education at that time highlighted the importance of science and technology in Singapore. In his speech, he described science and research as a "buttress for economic growth" (Ng, 2010, p. 1). As the development of human capital is closely linked to the progress of the Singapore society, the demands of the country shape education policies and practices. Consequently, the emphasis on developing the manpower and talent for science and technology to support the Singapore economy begins in schools. Science teachers hence, play an important part in supporting science and technology education in the country. In a highly informative piece detailing the five decades of science education in Singapore since its independence in 1965, Poon (2014) discussed the development of science education that aligned to the key phases of growth of the Singapore society – survival-driven phase (1959–1978), efficiency-driven phase (1979–1996) and ability-driven phase (1997–2011). It was observed that educational changes occur in tandem with changes in the country's economic and societal landscape. For example, in the survival-driven phase, Singapore had just attained independence and faced rapid population growth coupled with high unemployment. There was thus a push to build our economy rapidly through industrialization (Goh & Gopinathan, 2008). Further, set against this backdrop was a growing student population[2] in the 1970s resulting in a need for massive recruitment of teachers (Gopinathan et al., 2008). Science at that time was taught in vernacular language (such as Hokkien, Malay, Tamil, and Mandarin) alongside English. Based on the 1963 report by the Commission of Inquiry into Education in Singapore, the dominant mode of science instruction was verbal dictation of notes by teachers. This was not surprising considering the fact that accessibility to science laboratory for learning was limited and with the massive recruitment of teachers, few primary school teachers have science background and there was also a lack of specialized training for science teachers at that time.

By 1973, the predecessor of the National Institute of Education (NIE), the Institute of Education (IE) was formed and specialized training of science teacher became possible (Steward, 2010). Gradually, in 1978, the Goh Keng Swee[3] Report was published and significantly influenced the efficiency-driven phase (1979–1996) of education change in Singapore. During the early parts of the efficiency-driven phase, education wastage was a cause for concern as the school drop-out rates were high, particularly from non-English speaking students. One likely reason could be that education policies during this period were shaped by societal pressures such as need to produce workers with technical knowledge for the economy rather than the educational needs of students. To reduce education wastage and to take the needs of students into consideration, ability tracking with differentiated curriculum was introduced during this period to allow for different pace of learning. During that time, the focus of the science curriculum was on developing inquiring minds and science process skills. It was also noted that at that time, only about 15% of the 7000 science teachers had a science degree, and some primary science teachers were deployed to teach science even though they were not trained to do so. The Ministry of Education hence needed to grapple with the competencies of teachers to deliver the science content accurately. Science was largely taught in a didactic manner with little evidence to indicate that student-directed inquiry took place (Singham, 1987). As such, the Curriculum Development Institute of Singapore (CDIS) was set up in the June 1980 to produce teaching resources as such textbooks and educational videos in an attempt to teacher-proof the curriculum. Additionally, to further enhance science teachers' competencies in terms of content knowledge and pedagogical skills, the science teachers' association worked with IE to provide teacher professional development on weekends and after school hours. These efforts laid important foundations for science education and science teacher education in Singapore.

As Singapore progressed, so did her education system. The country entered the ability-driven phase (1997–2011) with a focus on *Teach Less, Learn More*. The ability driven phase was characterized by a focus on teaching each child to maximize his/her potential. As science is one of the key pillars of economic growth for Singapore, innovations are encouraged and in order to help students learn science in a critical and creative manner, science as a form of inquiry formed the core of the science curriculum from 2008. Science teachers had to reinvent themselves to ensure that students learn the content of science through questioning, exploring and evaluating evidence rather than merely memorizing what was written in textbooks. This period also saw the close collaboration between the Ministry of Education and the National Institute of Education, Singapore working very closely to improve the quality of pre-service science teacher education as well as continuing professional development for teachers.

Current state of science teacher education in Singapore

To become a teacher in Singapore schools, an individual needs to have undergone teacher education training at the NIE. The NIE has expertise to develop teachers in all disciplines of study, including sciences. Science teacher education is conceptualized as a continuum from the education of pre-service teachers to the continuing professional development of in-service science teachers. Currently, prospective science teachers aiming to teach in secondary schools will be assigned two teaching subjects for specialization. For prospective teachers who are going to teach in primary schools, science can be one of their two specializations.

There are two main routes for pre-service teachers at the National Institute of Education, Singapore. The first is the Post-Graduate Diploma in Education (PGDE) which is a 16-month program for prospective graduate teachers who already have had a first degree. The second type of program is the four-year Bachelor of Science (Education) (BSc(Ed)) which is targeted at prospective teachers who are non-graduates. The students enrolled in the BSc(Ed) program are typically students who are younger

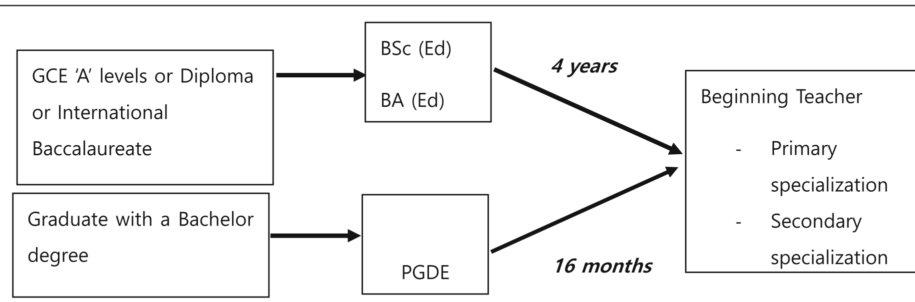

Fig. 1 Pathways to becoming a teacher

as they tend to be fresh school leavers who have just completed their GCE "A" levels,[4] their diplomas or their International Baccalaureate (IB) programs (Fig. 1).

One of the key features of both the pre-service programs is the courses in curriculum studies. Curriculum studies are essentially methods courses aiming to help the pre-service teachers learn how to teach. Learning how to teach is an important aspect of pre-service teacher education since what to teach is defined by the science syllabus set by the Ministry of Education, when to teach is determined by the schemes of work designed by teaching teams within each school, who to teach is assigned to the teacher by the school and where is teach is allocated to the teacher by the school resource teams. As such, I argue that the locus of greatest agency for a pre-service teacher is to learn to innovate in how they can teach their students such that they achieve the intended learning outcomes. While there are variations in emphasis among the teaching teams for biology, chemistry and physics curriculum studies courses, the key ideas of assessment, nature of science, science laboratory work, conceptual understanding and key strategies (such as questioning, scientific argumentation, flip classrooms etc.) in the different sub-disciplines are addressed. Further, to prepare the pre-service teachers to go into real classroom for teaching practice, a microteaching component is also included in all the curriculum courses. Pre-service teachers in the PGDE program has one 4-week observation in school and a 10-week practicum in schools at the end of their course. Pre-service teachers in the degree program has a 1-week observation in schools in year 2, a 5-week practicum in year 3 and a 10-week final practicum in year 4. Practicum allocations are determined by the placement unit of the MOE based on requests made by schools. During their school practicum, pre-service teachers are mentored by a senior teacher in school as well as a supervisor from NIE. In this partnership, the pre-service teacher, their school mentor and the NIE supervisor develop a better understanding of the teaching and learning process of a teacher and also of students in learning science in school.

The key assumption for the PGDE program is that the pre-service science teachers possess current and adequate subject matter (be it knowledge in biology, physics or chemistry) mastery since the pre-requisite for admission into the program is a first degree in the relevant field. As such, specific content of physics, chemistry and biology are *not* included in the program. While this assumption is largely valid based on the fact that degree awarding universities teach their students content sufficiently, there are instances where this assumption breaks down. Let me illustrate an instance where this assumption fails. Based on my experience as a science education scholar for the past 10 years and who taught in high school biology for another 10 years, I witnessed a case of a pre-service teacher who was trained to teach biology in school as he obtained a BSc in biology in the early 90s. After his graduation, he worked as an event organizer for 10 years. In the 10 years that he was an event organizer, he had limited exposure to biology. When he enrolled in the PGDE program and was assigned to be a biology teacher based on his educational qualifications, he had great difficulty in keeping his content knowledge up-to-date. In fact, during one of the lessons, when the class was discussing how to teach students to use the micropipette and the safety precautions related to using the micropipette, he was anxious and indicated that he personally had never used the micropipette before in his undergraduate days. He was uncertain how he could possibly teach his own students how to use the various equipment (such as the machine for polymerase chain reaction (PCR)). This student was eventually counselled and advised to sign up for additional science content upgrading courses whereby he will learn the latest science content at university level again. This incident highlighted an emerging trend of the shortened shelf life of scientific knowledge in the era of knowledge explosion. Scientific knowledge is constantly changing and updated. As such, science teachers education need also to equip pre-service science teachers with the means to keep themselves current with changing content knowledge without being overwhelmed by them. This posed a challenge to science teacher education programs as NIE tries to ensure that science teachers know the foundational knowledge of the discipline and yet remain current to the changes in scientific knowledge.

Another assumption for the PGDE program is that a pre-service teacher who has obtained a BSc can teach related scientific discipline in a high school. For example, it is assumed that pre-service teacher who specialized in molecular biology at the undergraduate level will be able to teach ecology at secondary school level since these are all the topics in the biology curriculum. Or a pre-service teacher with an engineering degree and able to teach physics in a high school. While this may be generally true, some pre-service teachers experience tensions in teaching subject matter knowledge that they are not proficient. Although content upgrading courses are available for pre-service teachers, the number and range of courses offered is not able to keep up with the varied and different demands of pre-service teachers who entered the program. There is also currently few research carried out in Singapore to better understand how much content knowledge is required for science teachers to be proficient in their teaching. While it seemed important to understand this aspect of science teacher education, few studies are in the pipeline to examine this issue due to the complexities related to data collection in this type of research. One possible way that the MOE is working on to overcome this issue of low confidence with subject matter knowledge is to have formal peer mentoring structures whereby pre-service teachers with different specialization backgrounds are put together in learning communities. It is hoped that this will encourage a culture of peer learning to level up subject matter knowledge.

The two issues related with the PGDE program for pre-service science teachers have less effect on the BSc(Ed) program. This is because the pre-service teachers in this program learn subject matter knowledge throughout the four years. The curriculum studies courses are taught from year 2 to year 4 of the program. The key issue faced by the pre-service teachers in the BSc program, however, is that they have to grapple with learning both the subject matter knowledge as well as how to teach the subject matter knowledge concurrently. Given that the pre-service teachers enrolled in this program are also generally younger[5] and less mature, some of them find it demanding to handle the two concurrently.

Besides the development of pre-service science teachers to teach in secondary schools, the PGDE and the BSc (Ed) program also train primary school teachers. As many of the pre-service teachers teaching primary science do not have a background in science, science educators and school administrators grapple with the problem of weak subject matter knowledge. Teachers' self-efficacy and competencies in science is a problem that our science teacher education program need give more pay attention. Due to the limited duration of the pre-service science teachers program, we tackle the issue of limited science subject matter among our primary school teachers through science teacher professional development when they are actually teaching science in schools. Kim et al. (2011) demonstrated both similarities as well as differences in perception of science as a form of inquiry between in-service and pre-service elementary science teachers in Singapore. For instance, while both pre-service as well as in-service science teachers show general preference to guided inquiry, pre-service teachers are less concerned about having a conducive environment for the inquiry while in-service teachers weighed having a conducive environment as very important. These results from researches are used to inform and shape the offerings of science teacher professional development. For instance, in designing inquiry courses for in-service teachers, science educators here would include a component on the role of science learning environment to foster science as inquiry and discuss how these conducive environment can be sustained.

Based on the seamless model of science teacher education in Singapore, after the initial pre-service teacher education, science teachers are involved in continuing in-service teacher professional development. The model for teacher professional development and pre-service teacher education is said to be seamless for two reasons – a) there is continued funding from MOE for teachers to come back to NIE to learn, and b) professional development courses are design such that they build on the existing knowledge base that pre-service teachers have learnt in their teacher preparation courses. Science teacher professional development plays a very important role ensuring currency and innovation of science teachers in Singapore. The professional development courses and programs offered to science teachers are designed in consultations with the Ministry of Education to ensure that the courses meet the needs of science teachers. The close partnership between MOE and NIE ensures relevance of professional development opportunities for the teachers. Typically, MOE will work with schools to conduct a needs analysis of areas that teachers need for their professional development. They will then present the list of needs to NIE to request for NIE to mount the courses. NIE will also present MOE with a list of courses that NIE faculty think is important and relevant for teachers and request for MOE endorsement to fund teachers to attend the courses. Eventually, after considerations of priority and funding availability, a final list of courses consisting of suggestions by MOE and NIE will be drafted as professional development offering for each year. As NIE is part of the Nanyang Technological University, Singapore (NTU), teachers can be awarded certificates for the courses that they complete.

The courses offered to science teachers include those that help to improve and increase the subject matter knowledge of teachers. For example, courses such as “Topics in biological sciences for primary science teaching” aimed at increasing the knowledge in biology of primary school science teachers. These courses are ongoing since there will always be teachers who need to update their subject matter knowledge. There are also courses that aimed at helping teachers cope with a change of curricular focus. For example, when there is a new area or focus on a new topic, courses such as “Teaching the revised H1[6] chemistry extension topics – nanomaterials and polymers” will be conducted to help teachers learn the new content. The duration of these courses are typically between three hours to about 36 h. This large range of courses is to cater to the differing needs of teachers, some of whom are unable to commit to professional development of longer duration due to responsibilities at the work place. Unlike pre-service teacher education that is compulsory, engagement in professional is voluntary, not considered as work duty for the teachers and there are usually no monetary rewards attached to attending professional development. Teachers teaching in government schools however, are usually sponsored by MOE to attend these courses that run in the afternoons. Each year, about 11,000 teachers attend professional development courses offered by NIE. Private school teachers are not entitled to sponsorship by the MOE but the teachers can self-fund to attend courses at NIE.

The conditions for science teachers professional development appears extremely conducive for science teachers to engage in continuous learning – sponsored course fees, and responsive and relevant courses. However, one of the key challenges that we face with teacher professional development courses is one of low attendance. This is due to reasons such as demands of time for the various activities that teachers are involved in at school, the sense of responsibility that teachers have to be present with their students everyday and the inability to see a direct and immediate impact of learning from courses into their practice (Tan et al., 2015; Chang et al., 2014). While there are currently no concrete evidence of the percentages of teachers who attend professional development voluntarily, schools, MOE, and NIE are currently working out structures and ways to enable and encourage teachers to be more forthcoming.

In this section, I described the structure of the two key programs (PGDE and BSc (Ed)) that supplies Singapore with primary and secondary science teachers. The existing structure has generally worked well for the past 10 years despite the some of the challenges described. To complement pre-service teacher education, science teacher professional development programs and courses are also instituted to support continuous learning. The conditions and tensions in science teacher professional development were also presented. In the next section, I discuss some future directions for science teacher education in Singapore to develop future-ready science teachers.

Future direction for science teacher education in Singapore

Teaching, and in this case, science teaching, is nestled within a complex ecosystem of people, policies, systems, social practices and social norms (Tan et al., 2015). Science teachers hence need to look beyond examination concerns (Kim et al., 2011) of the larger societal landscape in their innovation for better and more effective teaching and learning. In this section, I look ahead into science teacher education in Singapore by looking back into the past and positioning myself in the present. Given the excellent performance by Singapore students in science and mathematics at PISA and TIMSS, it is logical to claim that our science teachers have played an important part in teaching our students well. By deduction, our science teacher education programs and structures must have worked well. Singapore science education and science teacher education could perhaps just cruise along this pathway of success. So, what are some of the challenges ahead for the Singapore science teacher education and what innovations should science teacher education in Singapore aim for?

Just-in-case learning versus just-in-time learning

The current model of science teacher education in Singapore is shaped largely by the belief that we need to front-load pre-service as well as in-service teachers with all the knowledge and skills that they will need as a teacher throughout their entire teaching careers. This front-loading typically takes place during the pre-service teacher education programs, either in four years or 16 months. It is likened to a mindset of excesses – learn everything as you never know when you will need the knowledge and skills. This *just-in-case* way of thinking guided the design of many existing science teacher education programs in Singapore. As a result, our programs and courses are crowded and packed with the latest knowledge of science presented alongside the basic and classical science. Consequently, this leaves teachers with little time to engage in in-depth reflection to assimilate the new information they have learnt with their own knowledge. As reported by Korthagen et al., 2006in their reflection of the fundamental principles guiding teacher education programs and practice across three different university contexts in Canada, Australia and the Netherlands, one of the key principles of learning to teach requires a shift in focus by teacher education programs from the curriculum to the learners. As such, in order to be more effective, it is needful for the existing science education programs to reconsider the focus on the curriculum to examine how we can position the learners at the core of our curriculum design. Instead of starting with the content that needs to be taught, more attention can be paid to the existing knowledge of pre-service and in-service teachers and design flexible curriculum to meet the diverse needs knowledge gaps of teachers. Shifting from *just-in-case learning* to *just-in-time learning* will avail more time for reflective learning.

As we move further along into the twenty-first century, to cater to *just-in-time learning*, we should perhaps revisit the idea competency-based teacher education model (Arends et al., 1971) where science teachers can choose to enroll in courses where they perceive a personal need. To actualize competency-based teacher education, we need to first breakdown the skill sets and knowledge required by science teachers into smaller outcomes so as to facilitate evaluation of levels of attainment. For example, the knowledge and skills that a primary school science teacher is likely to need (MOE, 2014) is reflected in Table 1. Beginner level deals with basics in the subject matter knowledge, while the intermediate level will require some demonstration of application of the subject matter knowledge to solve some problems. At the expert level, the learners will be able to critique and suggest new ideas in the respective subject matter knowledge.

Diagnostic tasks and test items targeted at specific competencies and knowledge can be designed to enable teachers to accurately evaluate their personal levels of attainment for the various competencies. Science teachers can identify their strengths and areas of need for professional development. Similarly, science educators can also better apportion their time to offer courses that are teachers' areas of need. Moving towards a more *just-in-time* way of learning, as compared with *just-in-case* learning could help teachers make more immediate connection of what they have learnt to their practice and hence the relevance and impact of application could be better traced. Further, spending time only on learning knowledge and skills that the teachers need helps to free up time for more in-depth thinking and planning. In-depth reflection will also help to enrich the individual professional portfolio that all pre-service teachers in Singapore currently maintain.

Harnessing the power of technology

As with all modern and progressive cities and societies, Singapore as a nation aspires to be a Smart nation (Smart Nation and Digital Government Office, 2017). The

Table 1 An example of knowledge and skills required of a science teacher teaching lower primary science

	Level of attainment		
	Beginner	Intermediate	Expert
Subject Matter Knowledge (MOE, 2014, p.12)			
Diversity of living things and non-living things (General characteristics and classification)			
Diversity of materials			
Cycles in plants and animals			
Cycles in matter and water			
Plant parts and function			
Digestive system			
Magnets			
Light and heat as a form of energy			
Science Process Skills (MOE, 2014, p.12)			
Observing			
Using simple apparatus and equipment			
Predicting			
Generating possibilities			
Formulating hypothesis			
Management Skills (MOE, 2014, p.12)			
Managing group work			
Managing seat work			
Planning for hands-on activities			
Managing online learning			
Professional Competencies (MOE, 2014, p.12)			
Lesson planning			
Setting valid assessment items			
Formative assessment practices			
Commenting on students written work			
Devising meaningful homework for learning			
Designing meaningful online learning materials			

intentions of a smart nation is to enable better living and to facilitate the building of stronger communities. The government of Singapore has identified five key domains to leverage technology – transport, home and environment, business productivity, health and enabled aging, and finally public sector services. While education was not listed as one of the key domains, it is imperative that education should also harness the power of technology since the students who are attending school are digitally-abled and progressive and they would expect classrooms to work the same way as their homes, and the society as a whole.

Science teacher education can also harness the power of technology to help to overcome the problem of the lack of time for teachers to attend professional development. Digitizing courses and programs and making them available online will enable teachers, both pre-service teacher education as well as teacher professional development to learn at their own time, pace and at anytime of the day. In this way, accessibility to learning is not confined to the location where the teacher is but is able to allow learning anytime and anywhere. In the current state, our pre-service science teachers have already been exposed to technology-enabled learning and they have indicated positive attitude towards the use of computers due to the availability and accessibility (Teo, 2008). In our attempts to harness technology in science teacher education and professional development, it is important that we take into account the readiness of every teacher, particularly in-service teachers. Lin et al. (2013), in their study of 222 pre-service and in-service science teachers, showed that female science teachers indicated higher self-confidence in their pedagogical knowledge but have lower self-confidence in technological knowledge when compared to males. Compounding that, female in-service science teachers' perceptions of technological knowledge, technological pedagogical knowledge, technological content knowledge and synthesized knowledge of technology, pedagogy and content significantly and negatively correlate with their age. As such, as NIE forged ahead to harness the power of technology in science teacher education and development, there is a greater urgency to expose and increase their technological efficacy earlier.

Besides learning online, technology is also an enabler for the formation of learning communities among teachers. This is one aspect of science teacher education that has great potential for growth. Teachers can learn from one another and at the same time contribute their ideas to help others improve. As early as 2008, Hogan and Gopinathan (2008) has advocated the building of teacher professional learning communities as a next step towards bridging the gap between intended education policies and practice in Singapore. They argued that professional learning communities position teachers as active learners and typically ground learning in teachers' professional practices and research on effective practices. With technology, teachers across different schools (although Singapore is a very small country, and meeting face to face is not an issue, locating a common time slot for meeting still proved to be challenging) can share ideas and materials in a digital space. The community can include a science educator who can also serve as a resource for new ideas. To fully harness the power of technology to improve science teacher education, more can also be done to improve the designs of online learning.

Integrated STEM education

In recent times, there seemed to be renewed interest among science educators for Science, Technology, Engineering and Mathematics (STEM) education, some in its purest integrated form. There is certainly value in introducing STEM way of thinking and problem solving in schools, particularly in Singapore since the principles of STEM is aligned with developing twenty-first century skills such as critical and creative thinking, communication, problem solving etc. (Anaiadou and Claro, 2009). After all, real-life authentic problems does not exist just as a biological problem or a chemical problem. Real-life problem identification and solutions require knowledge and skills from the disciplines of science, technology, engineering and mathematics. As such, to make learning more authentic to students in schools, STEM principles and problems can be used. If STEM is to be implemented, it appears that science teachers are expected to take the lead. This posed a problem in Singapore as classes are organized around subjects and typically, each subject is taught by different teachers. Science teachers are trained only to teach science while mathematics teachers are trained to teach mathematics. The proficiency and comfort levels of a biology teacher to engage in engineering design and technology could be highly limited. This presents a challenge for science teacher education should integrated STEM be implemented in schools. Science teacher education could potentially be redesign to offer STEM as a subject in science teacher education. Subject matter knowledge of engineering design, problem identification and problem solving can be explicitly taught. Science teachers will also learn the difference between science, technology, engineering and mathematics. STEM task designs, strategies to actualize STEM in schools and organization of teaching teams for STEM can also be included in the programs. In this way, science teachers tasked to teach STEM in schools will have the confidence and knowledge to engage in STEM teaching.

At present, there is no special science education programs that specifically prepares pre-service teachers to teach in STEM schools. Even as I argue for an integrated STEM education program to prepare science teachers, I am also well aware of the challenges that this will pose in the current educational landscape in Singapore. Teo and Ke (2014) cautioned that even though specialized STEM teacher preparation programs are needed, they are also mindful that such specialized programs may actually limit Singapore science teachers' horizontal transition into mainstream schools and their abilities to understand the needs of diverse learners. This situation is perhaps more acute to Singapore since students in specialized STEM school are usually high progress learners and teachers teaching these students may not be well prepared to teach more mixed ability students in mainstream schools. Similarly, Tan and Leong (2014) also discussed the tensions and dilemmas of mapping STEM innovations in schools to the assessment requirements of the national science curriculum. The lure of teaching to the test to ensure that students perform well on tests is always tempting teachers away from innovative STEM instructions. As such, I argue that designing a specialized program to prepare STEM teachers would allow these various tensions and challenges to be discussed to generate greater awareness and also generate possible solutions. This will certainly enable science teacher education to be more future-ready.

In this section, I discussed three key directions which science teacher education in Singapore can embrace in the future – (1) just-in-time learning, (2) technology enabled learning, and (3) integrated STEM education. These three directions are identified based on current trends and challenges of science teacher education in Singapore currently. It is hoped that these initiatives will propel science teacher education into a future where learning is borderless, timeless and flexible. As with the journey of science teacher through the last 52 years have shown, the social and political landscape plays a central role in shaping education policies that eventually shape science teacher education. This was particularly evident in the early years of Singapore's journey as described in the preceding sections. There is little indication that this trend will change in the near future. As we look ahead, we can expect science teacher education to continue to evolve to meet the needs of the nation of Singapore. At the National Institute of Education, Singapore, we continue to be responsive to the needs of science teachers by offering relevant and meaningful courses, working collaboratively on educational research projects and concurrently also play the role of thought-leaders in educating pre-service and in-service teachers about the latest effective trends in science education. To fulfil this role, science education research plays a crucial role for NIE. Evidence informed programs and practices are the cornerstone of science teacher program planning and decision-making. Research such as using wearable technologies, neurosciences and effective pedagogies for early childhood and low tracked learners have been strongly encouraged, judging from the themes of recent grants calls by various organisations in Singapore. It is hoped that through these research, more insights can be gained about effective science teaching and learning and that these insights will in turn enhance science teacher education.

Challenges ahead

I discussed the challenges faced by science teacher education and science teacher professional development in Singapore and have discussed the way forward to overcome the challenges related to science teacher education and forging ahead with a future-ready teacher education program. However, it is important to note that the macro context of the Singapore society also presents some challenges for the future-ready programs for science teacher education. The slow population growth in Singapore is a major challenge for the country as a whole and the education sector is not spared as well. With fewer babies born each year, schools are merging (Isnin, 2017) and hence, the need for teachers have also decreased. With a smaller enrolment of teachers, the role of NIE has to be re-examined and a stronger focus needs to be placed on in-service teacher education to continue to improve the quality of teachers in Singapore. Unless these macro level issues are taken care of, there will be limited funds approved for innovations in teacher education programs.

Endnotes

[1]Ng is the last name of the Education Minister. It is a convention in Singapore to put the last name first. Dr. Ng was the Minister of Education from 2008 to 2011.

[2]In 1966, there were about two births per woman in Singapore. This results in the implementation of the "Stop at Two" policy in 1966 (Source: Population trends, various years. Singapore Department of Statistics. Ministry of Community Development, Youth and Sports)

[3]Dr. Goh Keng Swee was the Minister of Education in Singapore from 1979 to 1984. He was also the second deputy Prime Minister of Singapore from 1973 to 1984. He published the Goh report that significantly shaped and impacted education in Singapore. Streaming or tracking of students started with this report that aimed to move education in Singapore from fair to great.

[4]Singapore adopts the British examination of GCE 'O' and 'A' level as the country was previously a British colony.

[5]The students enrolled in the BSc programs are usually fresh school leavers. The average age for females are 19 years old while the males are 21 years old. The males are older in the cohort as they have to serve two years of mandatory military service.

[6]Subjects at the GCE 'A' level examination can be offered at three levels, namely, H1 (Higher 1), H2 (Higher 2) or H3 (Higher 3). H2 level is the level of study at A levels while reading subjects at H1 level means a reduced curriculum when compared to H2 level. Reading the subject at H3 level requires the student to learn more than the requirement at A levels.

Availability of data and materials
Not applicable.

Author's contributions
The author conceptualized and wrote this paper.

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Competing interests
I declare that I have read through the areas of competing interest, both financially and non-financially and declare that I do not have any competing interest.

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