Chapter 13
Science Teacher Education in Singapore: Developing Twenty-First-Century Readiness

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Abstract To ensure the quality of pre-service science teacher education, the National Institute of Education in Singapore continuously review the programmes offered to students who aspire to become a teacher. There are two key teacher education programmes to cater to interested students with different backgrounds – the 16-month Post-Graduate Diploma in Education (PGDE) and the 4-year Bachelor of Science (Education) programme. Both programmes are built on the key principles of Teacher Education for twenty-first-century framework of V^3SK (values, skills, and knowledge). The three values fundamental to pre-service teacher education in general are (1) learner-centred values, (2) teacher identity, and (3) service to the profession and community. These values are deliberately worked into all programmes to enable the development of pre-service teachers into teachers who are ready for twenty-first-century classrooms. This chapter delves into the details of how the PGDE and the undergraduate programme prepare future-ready science teachers to teach science in schools. Besides presenting the structure of the teacher preparation programmes, we use personal narratives to present the lived experiences of pre-service teachers enrolled in the programmes to bring to life the programmes. We end the chapter with four recommendations for pre-service science teacher education in the years ahead.

Keywords Values-based education · Pre-service teachers · Professional knowledge of teachers

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13.1 Introduction

Science and mathematics education in Singapore is reputed to be crème de la crème based on the consistent excellent performance by grades 10 and 14 students in international comparative studies such as Programme for International Student Assessment (PISA) and Trends in International Mathematics and Science Studies (TIMSS). The achievements in mathematics and science among Singaporean students is due largely to a comprehensive educational ecosystem characterised by a clearly articulate national curriculum in science and mathematics, availability of teaching resources and infrastructure, and high-quality teachers. The affordances of successful science learning environment were highlighted by Oshima as early as 1920 in Japan. Oshima (1920) proposed three fundamentals for successful science teaching: (1) adequate facilities, (2) a thorough system of regulations and orders, and (3) well-educated teachers. He argued that in the absence of teachers who are enthusiastic and knowledgeable, the benefits of quality resources and an established system cannot be realised. Among others, teachers need to have sufficient knowledge regarding nature of science as well as scientific principles. In short, teachers need to consider science teaching from the perspective of both science content and pedagogy. More recently, Osborne, Simon, and Collins (2003) continued to emphasise the central role of teachers in science education by stating that the quality of the teacher is the major determinant of student engagement with science.

The top five economies for TIMSS 2016 science scores for 10-year-olds are Singapore, the South Korea, Japan, the Russian Federation, and Hong Kong SAR and for 14-year-olds are Singapore, Japan, Chinese Taipei, the Republic of Korea, and Slovenia (Matin, Mullise, Foy, & Hooper, 2016). Three economies, Singapore, South Korea, and Japan, have performed well for both 10-and 14-year old categories. In the next section, we examine the performance of Singaporean students in TIMSS as compared to Japan and South Korea to better understand the context in which Singapore science teachers operate.

Japan, South Korea, and Singapore are Asian economies that place an emphasis on the value of education. Science and mathematics education enjoy high status in these nations. Table 13.1 shows a comparison of science instruction time between Japan, South Korea, and Singapore.

With respect to homework, 52% of Singaporean students spent between 45 min and 3 h on science homework compared to 15% for Japan and 8% from Korea in the same duration range. Internationally, 28% of students spent between 45 min and 3 h

Table 13.1 Comparison of science instruction time between Japan, South Korea, and Singapore

	Science instruction time per year (hours)	
Economies	10-year-olds	14-year-olds
Japan	91	131
South Korea	76	94
Singapore	85	106
International average	76	144

on science homework (Matin et al., 2016). "The higher percentage of homework time and the higher instruction time on science in Singapore mean that Singaporean teachers have more room for designing meaningful classroom learning experiences, setting relevant homework, and giving appropriate feedback to students to help them learn science. These aspects are emphasized in pre-service teacher education in Singapore."

Unlike Japan and South Korea where there are many universities offering teacher education, Singapore has only one teacher education institution. The National Institute of Education (NIE) at the Nanyang Technological University is the sole teacher education to support all pre-service teacher education. The benefit of this monopoly is that Singapore does not have to grapple with issues such as differing teacher quality across different teacher education institutions, a phenomenon termed "professionalism and academism" (Isozaki, 2018, p. 4), or an oversupply of teachers (Im, Yoon, & Cha, 2016). However, similar to pre-service science teacher programmes in Japan and South Korea, Singapore has different ways of preparing primary and secondary science teachers. Primary science teachers are generalists, while secondary science teachers are trained as specialists within the sub-disciplinary of either biology, chemistry, or physics. Unlike Korea where the government controls the qualifications of teachers by regulating the coursework (Im et al., 2016), at the NIE, faculty have the agency to design the curriculum.

13.2 Pre-service Science Teacher Education at the NIE

There are two main ways to become a science teacher in Singapore – through a 4-year Bachelor of Science (Education) [BSc(Ed)] programme or a 16-month Post-Graduate Diploma in Education (PGDE) programme. The BSc(Ed) programme caters to pre-service teachers who have completed their GCE "A" levels or a polytechnic diploma. The PGDE caters to pre-service teachers who are science graduates. 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, pre-service teachers under the PGDE scheme are hired directly by the Ministry of Education and will be paid a salary when they undergo their pre-service teacher education at the NIE. Upon completion of pre-service teacher programmes at the NIE, teachers generally have to fulfil a service bond of between 3 and 4 years.

Shulman (1987) categorised seven areas of teacher knowledge as: (1) content knowledge, (2) general pedagogical knowledge, (3) curriculum knowledge, (4) pedagogical content knowledge (PCK), (5) knowledge of learners and their characteristics, (6) knowledge of educational contexts, and (7) knowledge of educational ends. These seven areas of teacher knowledge are manifested in a different form as the new V^3SK framework (National Institute of Education, 2019) at the NIE. The new V^3SK model aims to prepare future-ready teachers for the twenty-first century. V^3 denotes the three core values, while S represents the skills and K is the knowledge. The three core values that the community in the NIE embrace are summarised in Table 13.2.

With these three values forming the core, there are skills and knowledge that pre-service teachers need to develop as listed in Table 13.3. (For a personal account of the development and implementation of the NIE's TE^{21} model and V^3SK framework, see Chap. 2.)

The implementation of the new V^3SK model takes the form of courses and special programmes for pre-service teachers. For pre-service science teachers in the 4-year programme, they have to fulfil 69 academic units (each academic unit is equivalent to 13 h of learning). Courses are divided into academic studies, educational studies, curriculum studies, subject knowledge, service learning, and practicum. Academic studies (AS) courses focus on the learning of content knowledge. In science, pre-service teachers attend lectures, conduct laboratory practicals, and engage in scientific research under the tutelage of faculty who are biologists, chemists, and physicist. Learning under practising scientists allows pre-service science teachers to be exposed to cutting-edge science and also to learn how scientific research is carried out. Weaved into the AS courses are curriculum studies (CS) courses that delve in pedagogies in science, pedagogical content knowledge, and nature and philosophy of science. The AS and CS courses are complementary to each other, and this alignment helps pre-service teachers better understand the professional and academic aspects of science teaching and learning. On top of AS and CS courses, all science teachers also take courses in educational studies (ES). These courses focus on learner characteristics as well as the social contexts of learning. Inclusive education, character and citizenship education, and managing learners are some areas that all pre-service teachers, regardless of disciplines, have to learn.

Table 13.2 Values in the NIE

Values	Description
Learner-centred values	Empathy
	Belief that all children can learn
	Commitment to nurturing the potential in each child
	Valuing of diversity
Teacher identity	Aims for high standards
	Enquiring nature
	Quest for learning
	Strive to improve
	Passion
	Adaptive and resilient
	Ethnical
	Professionalism
Service to the profession and community	Collaborative learning and practice
	Building apprenticeship and mentorship
	Social responsibility and engagement
	Stewardship

Table 13.3 Skills and knowledge of pre-service teacher education in Singapore

Skills	Reflective skills and thinking disposition
	Pedagogical skills
	People management skills
	Administrative and management skills
	Communicative skills
	Facilitative skills
	Technological skills
	Innovation and entrepreneurship skills
	Social and emotional intelligence
Knowledge	Self
	Pupil
	Community
	Subject content
	Pedagogy
	Educational foundation and policies
	Curriculum
	Multicultural literacy
	Global awareness and environmental awareness

Besides the theoretical aspects pedagogies, pre-service teachers in the BSc(Ed) programme also have the opportunity to learn from the classroom. In fact, the theory and practice nexus is an important feature in teacher education in Singapore. In year 1, pre-service teachers have a school experience where they attend school for 1 week to observe how science is taught in schools. Progressively, from the second to fourth year of study, pre-service teachers would attend a 3-week teaching assistantship, a 5-week teaching practice, and finally a 10-week teaching practice. These practicum experiences allow pre-service teachers to put into practice the content knowledge, pedagogical content knowledge, and knowledge about learners into practice – this is knowledge-in-practice as described by Cochran-Smith and Lytle (2001).

The PGDE programme is a shorter programme compared to the BSc (Ed) programme but is equally rigorous. As the pre-service teachers enrolled in this programme are science graduates, the programme does not cover academic content knowledge. The pre-service teachers are expected to have sound content mastery. For teaching practice, the PGDE programme has 4-week teaching assistantship and a 10-week practicum.

13.3 Becoming a Science Teacher in Singapore

In this section, we present personal narratives from two pre-service science teachers (Xinying and Dominic) enrolled in the BSc(Ed) programme, and both of them are under the Teaching Scholars Programme (TSP). At this point of writing, Xinying has just completed her programme and graduated with honours (high distinction), while Dominic is in his final year of study. We have chosen to illustrate how the NIE science teacher preparation programme is experienced by pre-service teachers using personal narratives because stories told by people reveal how individuals make sense of the world, and when stories are presented, it also helps others understand the existence of different interpretations of social life (Clandinin & Connelly, 2000). As Nicole Grimes (2013) wrote in her personal narrative of her identity as a Caribbean female teaching science in school, she justified her choice of using narratives by arguing that "the stories we craft describe our perceptions and our experiences, and in themselves are highly significant, as when examined closely, they provide us with information about our human culture" (p. 334).

Xinying My BSc(Ed) programme is a 4-year direct honours programme, whereby I will graduate to teach in chemistry and biology a secondary school. The courses in our programme can be classified into four main categories – (1) Academic Subjects (AS), whereby we study the content of our relevant subjects at a university level so that we are equipped with the necessary content mastery; (2) Curriculum Studies (CS), whereby we acquire pedagogical content knowledge so that we know how to teach our subject, (3) Education Studies (ES), where we learn about the key concepts and principles of education that supports our pedagogy in classrooms, and (4) Academic Discourse Skills, which equips us with the necessary language and communication skills for teaching. On top of that, we have industry internship (BUILD) and practicum stints for exposure to hone our crafts as educators. We also have two research opportunities – one in education and the other in our subject content.

Our AS courses allow me to be equipped with in-depth scientific knowledge so that I can have the necessary content mastery to deliver my subject to my students. The defining milestone of my journey through AS courses would be the Academic Exercise (AE), otherwise known as the Final Year Project, whereby I had to undertake a 9 month long research project on chemistry. I was involved with anti-cancer research, thus it covers both my subject disciplines – chemistry and biology. The learning curve was steep as there were many new skills I had to acquire. However, the experience was invaluable because it trained me to think like a scientist as I was exposed to an authentic way of doing science in a research lab. I had to design and modify procedures to suit my experiments and laboratory equipment, which inculcated in me critical thinking and problem-solving skills. It also taught me how to troubleshoot problems first hand (before I had to consult my professors for help) and think about why scientists do things in a certain way. This is useful as a twenty-first century science teacher, it is imperative that I teach my students how to do science and to expose them to a more authentic way of doing science. This experience also trained my resilience and the ability to cope with disappointments, as there were many failures along the way. Perseverance is an important quality to have as I step into my role as a teacher, since making mistakes are to be expected, and I would need to be able to take mistakes in my stride and improve from there.

In preparation for my poster presentation, I was required to condense my research project into a poster. When I was presenting my poster to my examiners and other audience, it also honed my scientific communication skills as I had to present my project in a detailed but clear manner to cater to a wide variety of audience. This trained me to deliver my content in a concise but clear manner, which is important for teaching. Through doing AE, I got to be under the mentorship of two supervisors, who role modelled what good mentors are like. They probed me into thinking in the right direction without divulging too much, and were there to troubleshoot when needed. Most importantly, they had high expectations of me, but were also encouraging when I kept failing. The care and concern that they have shown me how good mentors are not only skilful in guidance, but they also care about the wellbeing of their mentees. As I may be required to mentor students for science research projects in my job, my supervisors modelled how I can guide my students without spoon-feeding too much and how to impart scientific skills to my students.

Complementing the AS courses, the CS courses equip us with the pedagogical content knowledge to prepare us to teach our subjects. I would highlight two particular CS courses, one for each CS – chemistry and biology. My first chemistry CS course, *Curriculum and Pedagogy in Chemistry,* exposed me to the intricacies and difficulties of teaching chemistry. I learnt that chemistry teaching and learning is difficult due to the three level of representations in chemistry – macroscopic (observable and tangible phenomenon), submicroscopic (molecules, atoms, ions, protons, electrons etc.), and symbolic level (chemical equations, formulae, structures). By having an understanding of the three levels of representation, I am better able to deliver my lessons since I made a conscious effort to position my explanations at specific level of representation. I will also teach students the different representations and how to integrate and transit between the multiple representations. Through this course, I was first exposed to the basics of lesson planning – introduction, lesson development and conclusion. I also learnt that in a good lesson, there should always be evaluation measures put in place to assess student understanding before moving on with the rest of the lesson. I also learnt various pedagogical tools I can use in my chemistry lessons – analogies, concept mapping, using magnets and models as visuals to represent submicroscopic particles, as well as using discrepant events and demonstrations to engage students. I will keep in mind the various pedagogical tools so that I can vary my instructional methods in my future lessons and select the most appropriate tool to enhance my explanation of concepts.

Another memorable CS course was the course on *Assessment in Biology.* This course helps me to have an understanding of formative and summative assessment. For summative assessment, we learnt about how we can use Table of Specifications to set papers, and also how when setting multiple choice questions and structured questions, we need to ensure validity (questions assess specific learning objectives) and reliability (questions are clear and precise) of our questions. For MCQs, we need to have strong distractors so that our MCQs can serve our purpose for assessment. This course has made me aware that during the setting of MCQs, I must think through the rationale for each distractor carefully. Strong distractors must be convincing, and they can be common student mistakes, which I should take note of when I take my own classes in the future. For formative assessment, I learnt various tools such as using concept cartoons, Think-Pair-Share to get students to discuss scientific conceptions and misconceptions and using Making Thinking Visible (MTV) routines such as See-Think-Wonder and Predict-Observe-Explain. I also learnt how I can quickly get a sensing of students understanding by using Fast Cards, mini whiteboards or Plickers to check their understanding. I foresee that I will be using such tools in my science classes in the future so that I can not only check understanding, but also vary the assessment tools I use so that I can make science learning fun for my students while ensuring that they understand the concepts that I am teaching them.

Besides content research for AE, I also had to undertake an education research project for a year under the Undergraduate Research on Campus (URECA) programme. For my project, I had to develop a multi-tier web-based multiple choice question diagnostic instrument to diagnose alternative conceptions in chemical bonding. It was through reading the literature on common difficulties faced by students that I had a better understanding of why students find chemistry difficult. Through insightful discussions with my supervisor, I also gained more insights into how chemical bonding can be taught in a different way which may prevent the development of some alternative conceptions that are common among students. The project also allowed me to explore my own conceptions about the topic and also discuss these conceptions with my supervisor to see whether they are scientifically sound, allowing me to adjust my mental models of the various types of bonding, enhancing my mastery of my subject content. This is useful as chemical bonding is a difficult topic for students to grasp but it is an important topic which students need to master as it forms the fundamentals to learn other concepts in chemistry.

One of the highlights in my journey to become a teacher was the four practicum stints that are staggered throughout our four years at NIE. After we have completed each year in NIE, we were posted to schools for a practicum stint during our summer break (with the exception of our final practicum in year 4). The practicum programme is structured such that they are of increasing length (two, five, five and ten weeks) so as to gradually build up our competencies as a teacher under the guidance of our Cooperating Teachers (CTs), who will mentor us throughout the entire duration of the practicum stint. Our CTs are senior members of staff in the school that we are attached. After the end of our first year, we were attached to a primary and secondary school for one week each. While the experience was short, it allowed me to see the differences between primary and secondary school teachings. At the end of year 2, I was blessed with the opportunity to go for International Practicum in Denmark, whereby I was attached to a school in Copenhagen for five weeks. It was then that I got to experience a different education landscape from Singapore. The defining differences would be how the curriculum is more flexible as compared to Singapore's, the teacher-student barrier was less prominent and the greater level of autonomy given to students to participate in decision making of how they want to learn.

I felt that the last two practicums (Teaching Practice 1 and 2) were the most fulfilling, albeit challenging, because it was then when I really got a first-hand experience of teaching in a Singapore school. For both practicum stints, we had to observe for a week and teach for the remaining weeks of practicum. NIE can equip us with examples of pedagogies that we can use in our teaching, but the real learning took place on the ground during TP1 as we are dealing with real students. For TP1, I taught Express classes for both pure chemistry and biology, and also a Sec 1 N(T)[1] class. It was then I was exposed to a spectrum of different students. I remembered feeling challenged and rather overwhelmed at the start because I am teaching real students now, with different learning needs and backgrounds whom I need to handle. Further, I was dealing with quite an abstract topic for pure chemistry – mole concept, which I do not feel prepared to teach. I remembered feeling discouraged after my first chemistry lesson with my Secondary 3 class as I did not give adequate scaffolding to my students and threw them into the deep waters of solving mole concept problems. I was rather thankful that my CT taught me how to do the damage control and the scaffolding for mole concept afterwards, so I could salvage the damage in the next lesson. This experience taught me how scaffolding is important, and also how to scaffold concepts for mole concept. I also learnt how to break down complex mole concept problems for my students by teaching them how to focus on what the question was asking and crossing out irrelevant information that is distracting. It also taught me how for topics that require doing practice problems such as mole concept, we need to take our students through a few examples to let them get the hang of doing these problems first before letting them practise on their own.

The second and final Teaching Practicum presented another set of challenges. Although I was already relatively well acquainted with the school (since it was the same school that I did my TP1 in), I felt challenged to cater to different learning needs of my students as well. I taught a class of high progress learners for both chemistry and biology, and another class of low progress learners for combined chemistry as they were N(A) students doing combined science for Subject-Based Banding (SBB). For the high progress learners, there was a need to stretch them and I often felt that my content mastery was challenged because there were times that they would pose questions on concepts that I had not thought about. Thus, it pushed me to clarify my concepts and mental models by consulting my CTs and school answer schemes so that I am prepared to handle questions that my students posed to me. In contrast, I felt the difference when it came to my SBB class, because concepts that I could briefly touch on for my other class had to be slowed down and scaffolded. It was the need to differentiate instruction – deciding on which practice examples to use, how much to handhold and how much to stretch my students that was difficult for me. Although I would say that I am still struggling to find the right balance, my chemistry CT gave me room to explore which examples to use and also gave feedback on which examples were good, which could be improved and suggestions on how to improve. It was the in-class practice and the feedback from my CTs on how I can improve that helped me developed as a trainee teacher.

[1] Singapore has a tracking system where students are streamed in Express stream (4 years of secondary education), Normal (Academic) (5 years of secondary education), or Normal (Technical) [N(T)] (5 years of secondary education that is more vocational based). This tracking system will replaced with SSB (subject-based banding) in 2024. SSB is a practice to allow students to take classes at various levels of difficulty based on their strengths.

Through the last two practicum stints, I learnt how to deal with failure in the classroom, as I often think that I was short-changing my students every time I make a mistake in class. As a result, I was quite hard on myself when I made mistakes, but I am slowly learning to accept that mistakes are part of the process and that they are to be expected (although I am still working on that). Most importantly, after making mistakes, I need to move on and improve by reflecting on my mistakes, thinking of what had gone wrong and what I can do to rectify the mistakes while consulting with my CTs or other more experienced teachers for advice. Hence, I would say that practicum has imbued a reflective thought process in me, whereby after each lesson, I would quickly do a self-reflection of how the lesson went, what I could have improved and how I would have done the lesson differently if given another chance. I feel that this is very important for the 21st century teacher, as we must constantly reflect to learn and improve our craft so as to adapt to the changing profiles of our students.

After my first year of university, I got to embark on a six-week internship at Science Centre Singapore. During my internship, my duties included explaining exhibits to visitors, conducting the Tesla Coil show, helping out in workshops and be involved in planning demonstrations for future shows etc. Science Centre has exposed me to a fun way of teaching science – I learnt interesting demonstrations such as creating elephant toothpaste (which can be used when I teach catalysts in my science lessons), doing chromatography on canvas bags and how colour changes of the universal indicator can be used to interest and engage students. Explaining concepts to different groups of visitors also honed my science communication skills, as I had to cater to different profiles and age groups of visitors. Doing the Tesla Coil show honed my public speaking and communication skills while building my confidence to speak in front of a large crowd. I learnt how to deal with difficult visitors as well – a group of visitors wanted us to conduct one of our shows in a language other than English, and we had to stand our ground and explain that our shows are strictly conducted in English only. When dealing with difficult people, it is important to appear professional (and not appear flustered or frustrated) and objective in explaining our rationale for doing things. This skill is important when I enter the workplace – I would need to deal with multiple stakeholders in education, of which some parties may be difficult to deal with, and I need to be clear of the rationale of why I do things and be able to communicate my rationale well.

Dominic The Teaching Scholars' Programme (TSP) was established in 2014. Under this programme, scholars pursue a four-year Bachelor's degree course in Science or in Arts (BSc or BA) while having unique opportunities for personal development. Throughout the four years, I was exposed to a plethora of rigorous content modules aimed at helping me acquire content mastery in biology and chemistry. These modules are taught by faculty members with deep experience in the discipline. This, facilitated by small class sizes, provides the opportunity for my peers and I to engage in deep discussion with the faculty members, allowing us to engage in the epistemic practices of science more intimately. Beyond that, we are also exposed to various pedagogical courses that give scholars a basic understanding of educational theory and pedagogical content knowledge to prepare them for teaching.

The TSP offered several opportunities that are unique as they are not offered to other student teachers from the Post-Graduate Diploma in Education (PGDE) track, who enter teacher preparation after having completed their undergraduate degree from other universities. One of these unique programme is the Building University Interns for Leadership (BUILD) module which allows TSP scholars to engage in a short internship stint in an organisation that may not necessarily be related to education. Organisations range from Ministry of Education offices to non-profit organisations such as homes for the disadvantaged to even science laboratories. This internship is a valuable experience as it broadens my perspective in terms of observing organisation practices in different industries while learning how to work in a different environment. Another unique module is the Virtue and Leadership module. In this module, lessons are centred around reflecting and understanding the personal values and beliefs held by each scholar. We go on to connect these values with leadership practices that we can and will eventually carry into the classroom and staffroom.

Practicum is an essential component of any teacher preparation course. TSP scholars would have four rounds of practicum, with the level of responsibility increasing with each year of study. In the second year of study, I had an opportunity to engage in an International Practicum (IP). Instead of a practicum in a school in Singapore, I got to observe lessons and understand school cultures in different countries. The IP is a useful opportunity for me to understand the education systems of other countries and gain insights on how differences in socio-cultural environment influence educational policies and teaching strategies.

Yet another unique feature of the TSP programme is that each TSP scholar is attached to a faculty member who is an expert in the scholar's first teaching subject. This faculty member is known as an academic advisor. This arrangement helps to create a special relationship between my academic advisor and myself. I receive guidance that is not normally seen in other university courses and this guidance supports my development in various ways depending on the topics discussed between my academic advisor and I. Aside from that, I am also offered opportunities to attend seminars and conversations with in-service practitioners such as those preparing to be school leaders in the Management and Leadership (MLS) course.

While reflecting on my teacher education journey to date, I noted there were two main things that have helped me to understand the competencies required of a science educator. The first thing that came to mind was the idea of dialogicality. When I first learnt this word as part of a compulsory multicultural studies course, I felt it aptly described a large part of the TSP programme. My cohort is very small (and hence class sizes for various courses are also be small) in comparison to other university courses. The small class size, coupled with the academic advisor-student relationship, created a very special space that allows for numerous conversations between student and faculty members to take place. These conversations were not inhibited by any awkwardness or superficiality, which augmented the quality of conversation. The course instructors that I encountered embraced the value of conversations, engaging us in discussion ranging from the sciences to educational studies. Indeed, the quality of learning I experienced is richer and allowed access into the inner workings of the disciplines. These conversations had allowed me to appreciate not just the concepts, but the values and attitudes of the faculty members and peers had also shaped my own values as well. Through these dialogic processes, such as conversing with faculty members and peers, I gleaned the power of conversations. In the twenty-first century classroom, students should be treated as unique individuals and a dialogic approach readily places the student as distinctive and valued individual. The numerous conversations that were made possible within this programme allowed me to understand the power of communication and how it could be used to reach students and hopefully empower them in their learning.

Another quality that I felt was heavily emphasised was the role as a teacher researcher. Classrooms evolve and student profiles change regularly. The teaching environment changes rapidly. Teachers would need to know how to engage in obtaining new information and evaluating that information against our teaching needs. This is where the value of research comes in. I felt very fortunate to engage in not only one but two educational research projects so far. The process of research is very valuable because it trained me to learn how to source for new information and practice making judgements on whether the findings of a particular piece of research is useful. This is a key competency for science educators to acquire (especially since the discipline itself calls for this ability to exercise judgement on validity!).

Perhaps the next part may not be generalizable for every preservice teacher in TSP, but the research component in the programme has transformed my understanding of science education and appreciate the nuances it possesses. It is no longer a simple case of discovering misconceptions and addressing those misconceptions. Now, I realised that it is also a matter of what educators should do to engage students in science in a more authentic manner. It became a question for me, of how we can develop ways to demonstrate the processes of justifying and legitimising knowledge claims to the students as a role model. In summary, there was a greater realisation of the challenges that science educators face. In a way, I felt my horizons have broadened tremendously and I am thankful that this expansion in perspective-taking as it certainly would prepare me for the rapidly changing classroom environment.

Finally, I think one thing that could be changed in such teacher preparation programme is how the fundamentals of lesson planning are being taught to student teachers. I recalled it was extremely difficult for me to appreciate the differences between the concepts of specific instructional objectives, learning outcomes and behavioural objectives. While examplars were consistently shown to facilitate understanding, it felt that the art of lesson planning was sidelined. Understandably, the limited number of hours in each module would mean certain things need to be prioritised. However, lesson planning is a basic skill that should have received more attention early in the programme. By learning how to construct such learning objectives properly, it would increase the chances of student teachers being able to know whether their lessons are sufficiently feasible and thoughtful to be implemented.

Another thing that perhaps not all would agree with me is the chance to engage in deeper discussion with the theoretical aspects of science education. The basics of teaching and how to conduct science lessons are crucial. However, I believe discussing the theoretical aspects of learning science is very important. By knowing the concepts of epistemic practice or the disciplinary practices in science, it would immediately elevate one's understanding of their role as a science educator. Learning these concepts do help to clarify the rationale of using certain strategies as well as constructing more powerful questions to push the students' thinking further.

13.4 Discussion

Examining the experiences of Xinying and Dominic highlighted several important elements in twenty-first-century pre-service science teacher education. Firstly, the central role of practicum experiences in schools in developing pre-service teachers' ability to think and respond to changes in classrooms. The practicum experiences allow pre-service teachers to test the ideas they learn in university courses and determine if they actually work. This knowledge-in-practice (Cochran-Smith & Lytle, 2001) also allows pre-service teacher to reflect on their strengths and weaknesses and hence serves as a way for them to "fill the gap" in their growth. Both Dominic and Xinying mentioned how the four practicum experiences where impactful in helping them develop their teaching skills.

Secondly, science pre-service teacher education can offer opportunities for research, both in academic domain and education domain. Science education literature has shown that laboratory internship attachment is a powerful instructional approach to engage students in authentic science (Barab & Hay, 2001; Charney et al., 2007). The learning experiences of both Xinying and Dominic also highlighted that it was through engagement in research projects that they develop the needful twenty-first century competencies of problem-solving, negotiation, creativity, collaboration, and communication (Partnership for 21st Century, 2016). These are skills that are oftentimes difficult to infuse into lectures in the university. As such, creating opportunities or spaces through engagement in research projects allows pre-service science teachers to develop both discipline conceptual understanding, appreciation of epistemic practices, and a chance to sharpen their twenty-first century competencies.

Thirdly, both Xinying and Dominic place importance on mentorship in their pre-service experiences. Both of them had good academic mentors at the university and also cooperating teachers in schools. Both of them benefitted from positive role modelling as well as a close and safe mentor-mentee relationship. The structure of a mentor-mentee relationship can be likened to an apprenticeship model in learning, where the apprentice learns in close proximity under the wings of a master. The expert-novice partnership allows for craft and nuances of teaching to be passed on with greater fidelity as compared with mass lectures.

Finally, for pre-service science teacher education in the twenty-first century to be successful, there needs to be a supportive multiparty ecosystem. As evident from the description of Xinying and Dominic, their experiences involved not just the NIE but required the support of schools, the Ministry of Education, public and private organisations, collaborations with universities internationally, and the local community. Establishing close working partnerships with various organisations, pre-service science teachers can benefit from rich perspectives that are relevant to growing science teachers that are available in different organisations. After all, as the famous Africa proverb goes, "it takes a village to raise a child" – developing a successful science teacher requires the involvement and partnership of many.

References

Barab, S. A., & Hay, K. E. (2001). Doing science at the elbows of experts: Issues related to the science apprenticeship camp. *Journal of Research in Science Teaching, 38*(1), 70–102.

Charney, J., Hmelo-Silver, C. E., Sofer, W., Neigeborn, L., Coletta, S., & Nemeroff, M. (2007). Cognitive apprenticeship in science through immersion in laboratory practices. *International Journal of Science Education, 29*(2), 195–213.

Clandinin, D. J., & Connelly, F. M. (2000). *Narrative inquiry: Experience and story in qualitative research*. San Francisco: Jossey-Bass.

Cochran-Smith, M., & Lytle, S. (2001). Beyond certainty: Taking an inquiry stance on practice. In A. Lieberman & L. Miller (Eds.), *Teachers caught in the action: Professional development that matters* (The series on school reform) (pp. 45–58). New York: Teachers College Press.

Grimes, N. K. (2013). The nanny in the schoolhouse: The role of femme-Caribbean identity in attaining success in urban science classrooms. *Cultural Studies of Science Education, 8*, 333–353. https://doi.org/10.1007/s11422-012-9476-1.

Im, S., Yoon, H.-G., & Cha, J. (2016). Pre-service science teacher education system in South Korea: Prospects and challenges. *Eurasia Journal of Mathematics, Science & Technology Education, 12*(7), 1863–1880.

Isozaki, T. (2018). Science teacher education in Japan: Past, present, and future. *Asia-Pacific Science Education, 4*(10), 1–14.

Matin, M. O., Mullise, I. V. S., Foy, P., & Hooper, M. (2016). *TIMSS 2015 International results in science.* Retrieved on 20 June 2019 from Boston College, TIMSS & PIRLS International Study Centre website: http://timssandpiris.bc.edu/timss2015/international-results/

National Institute of Education. (2019). The new V^{3}SK model. Singapore: National Institute of Education. Retrieved on 21 June 2019 from https://www.nie.edu.sg/docs/default-source/td_practicum/te21%2D%2D-v3sk.pdf

Oshima, C. (1920). *Rika-kyoujyu no genre (The principles of science teaching*) [In Japanese]. Tokyo, Japan: Dobunkan. Cited in Isozaki, T. (2018). Science teacher education in Japan: Past, present, and future. *Asia-Pacific Science Education, 4*(10), 1–14.

Osborne, J., Simon, S., & Collins, S. (2003). Attitudes towards science: A review of the literature and its implications. *International Journal of Science Education, 25*(9), 1049–1079.

Partnership for 21st Century Learning. (2016). Framework for 21st century learning. Retrived on 29 June 2019 from http://www.p21.org/our-work/p21-framwork

Shulman, L. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review, 57*(1), 1–22.