Chapter 5
Science Education Research and Practice in Malaysia

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Abstract Science education is often seen as the vehicle for Malaysia to become a developed country based on science and technology. As a result, Malaysia has made the policy of producing 60 % of its critical mass of educated people, both at school and university, in the science and technology discipline. However, we have yet to reach the target because of the decline of interest in science among students. Various strategies and policies have been formulated and adapted to arrest the situation. This chapter begins by looking at the historical and social contexts that have driven developments in science education in Malaysia. With this context, it brings forth the research that has been embarked on looking at the issues, problems and effectiveness of the practices in science classrooms. This chapter also looks critically at the usefulness of research in informing practice including the barriers hampering the bridging of the gap between research and practice. To conclude, possible and future trends of research in science education are recommended.

5.1 Introduction

Malaysia, like any other developed countries, realises that the driving force of one's economy is largely on the innovation and commercialisation of scientific knowledge. Thus, it is not surprising to see Malaysia's strong emphasis on learning science in schools and universities, so as to have the critical mass in the field of science and technology. Science subjects are taught early in Malaysian education system. In the 1960s and 1970s, science as a subject was introduced from Year 1 in the primary level. In the 1980s, science was not taught as a core subject, but students still learnt science in the subject called 'Man and Environment' where science was one of the integrated elements. In the mid-1980s, science as a subject was reintroduced again and has since been taught in the primary education level starting from Year 3.

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Science continues to be offered as a core subject for all students at the lower secondary level (age 13–15 years old). Particular emphasis is given on the acquisition of scientific knowledge, mastery of scientific and thinking skills, and inculcation of moral values concurring with the premise that man is entrusted with the responsibility of managing the world and its resources wisely. In order to understand the current status of science education in Malaysia and suggest future directions in science, a historic review of the development of science education is presented next in this chapter.

5.2 Science Education in Malaysia

Science teaching had a humble beginning in Malaysia in 1937. Strong recommendations were made for the introduction of science in the curriculum in all English secondary schools for boys and girls. However, Malaysia was unable to do so because there was lack of adequate equipment and qualified science teachers available. A special education committee was then appointed in 1939 by the Government of the Straits Settlement and the Federated Malay States to formulate the aims of science education and draw up a science syllabus. This committee unanimously advocated that every young mind, whether boys or girls, should be led to appreciate the wide field of interest opened up by the study of science and should be trained to understand and apply the methods of scientific reasoning and investigation.

The Commission of Higher Education in Malaya in 1939 also recommended that general science should be taught in secondary schools. This school science course was to be planned as a self-contained whole, designed as preparation for life in a scientific age rather than as a mere preparation for examination or for a scientific career (since only a very small proportion of secondary pupils continued with the study of science after the School Certificate stage). The commission also recognised that the education needs of those following scientific or technical careers should not be allowed to overshadow the needs of the others who would form the ordinary educated citizens of the future.

After the Second World War, a four-year course in general science was to become an integral part of the curricula of all secondary schools. The syllabus followed contemporary patterns in Britain. A Post-School Certificate course in science was not then available, but a course of higher studies in science was taught at Raffles College, Singapore.

5.3 Post-independence Science Education

After Malaysia's Independence in 1957, science education was given a special place in the educational policy. It was seen as the area of the curriculum most likely to provide a stimulus to economic growth through increases in the supply of scientific and technical manpower on which development would depend. Another broad purpose of teaching and learning science was that it is seen as a cultural and educational discipline. In other words, a firm basis in science subjects is not only for research but also for development.

The five-year Malaysia Plans since then all have stressed the commitments to expand and improve the quality of science education. The government knows that the real, long-term solution lies in raising the quality of teaching and learning science, in its efforts to develop a progressive society committed to science and technology. This can be seen from its commitment in modernising the curriculum.

5.4 Curriculum Reform in Science

In the early 1960s, science was still offered in primary and lower secondary schools as a general science course. The pressure of nationalistic fervour to become a strong nation through the development of science and technology encouraged leaders to focus curriculum reform on science subjects. It was planned to develop in line with government goals for socio-economic development. In 1966, Malaysia started to update and reform the science curriculum, beginning with the lower secondary level. A decision to adopt existing new curricula from other countries had to be taken because of the shortage of local expertise and educational resources.

It was decided to base the revisions of the science curriculum on British models, for three reasons: first, the structure and organisation of the Malaysian education system reflected its colonial origin, whereas pedagogical traditions resembled those in the UK, and many science teachers and decision-makers had received at least some part of their training in Britain; second, initial assistance in terms of expertise in initial training and implementation was promised by the British Government if its curriculum was adopted; and third, the prestige of the British advisers working in Malaysia played a sizable role. In this light, the Scottish Science Project was adopted to provide a basis for integrated science for the lower secondary school science curriculum. The philosophy behind this curriculum was to enable children to learn science better through developing their interest and observation in what they were learning.

5.5 Integrated Science Course

Primary work in adopting the Scottish Science Project materials was conducted from 1968 through 1971. January 1969 saw 20 Malaysian schools begin teaching the first year of a Scottish-based Integrated Science Programme; in 1970, fifty more schools joined the programme, followed by 100 more in 1971. Because of large class sizes in Malaysia (40 plus students per class) as compared with the Scottish situation (20 per class), and anticipated difficulties in training and securing equipment, the two-year Scottish curriculum was extended to three years of study in Malaysia. Integrated science combined work in physics, chemistry and biology under broad topical headings. As a follow-up, Nuffield ‘O’-level curriculum in the separate sciences was also adopted for the upper secondary level.

The new science courses have a list of specific learning–teaching goals. For example, for the Nuffield-based pure physics course, they were as follows:

- Learning for the future: to provide pupils with the necessary background so that they may pursue further studies in physics and be users of physics.
- Understanding physics: pupils should acquire a basic understanding of the primary concepts of physics.
- Understanding how scientists think: pupils should be introduced to the process of scientific inquiry.
- Learning how to handle ideas in physics and communicate them: pupils should learn the language of physics.
- Learning with enjoyment and interest: teaching must convey the idea that learning physics is more than just for passing examination.
- Awareness of the social significance of science: pupils must be made aware of the influence of physics on their society and environment.

Adherence to these aims would modify both the format and style of science teaching in Malaysia. In emulating British instructional models, it was hoped that a general strategy of learning through guided discovery would replace the traditional system of authoritarian lectures.

5.6 Modern Physics, Chemistry and Biology Course

In moving towards the adoption of a Nuffield science curriculum, a detailed schedule of activities was planned and a six-year period of development allowed for the following:

1968 Practical in-service courses were held for 120 teachers in physics, chemistry and biology. This familiarisation work was conducted by British instructors.

1969 Practical in-service courses were held for 60 teachers and education officials by visiting British instructors.
Thirty teachers combined efforts in writing sessions to produce Form IV Teachers’ Guides and Students’ Workbooks.

1970 British instructors again conducted practical in-service courses serving 90 teachers and officials.
Twenty-eight teachers continued the writing efforts of the previous year to produce Form IV materials.

1971 One hundred and twenty teachers received in-service training on the Form IV course of study. These teachers represented the three disciplines: physics, chemistry and biology.

The trial edition of the Form IV Teachers' Guides and Students' Workbooks was published.
Writing sessions begun to produce Form V Teachers' Guides and Students' Workbooks.

1972 Materials were tested in 30 pilot schools.
Practical in-service training was provided for 200 Form IV and V teachers.
Trial versions of Form V materials were completed and published.
Final versions of Form IV books were revised and published.

1973 Sixty more pilot schools were added to the teaching scheme.
In-service training for 200 teachers was conducted by local personnel.
Revision and publication of final version of Form V books took place.

All schools in Malaysia were required the new modern science, physics, chemistry and biology curriculum. All students taking the courses have been provided with the necessary textbooks; schools have obtained some additional laboratory equipment needed for the new experimental situations; and students were to carry out more hand-on activities. Thus, the logistics of implementing the reforms proceeded smoothly.

The national curriculum is regularly being required to ensure the relevance and quality of science education. In the 1980s, the Education Ministry decided to implement the recommendations made by the Cabinet Education Committee regarding the need to provide basic and general education at primary and secondary school levels. With the aim to provide basic education which encourages pupils to acquire full mastery of the basic skills (while providing opportunities to develop their talent, interests, and creativity), it was decided not to offer science as a separate subject at the primary level. Science forms part of an integrated subject and is offered in year four as discussed later. The new primary school curriculum was implemented nation-wide in 1983.

The secondary school science curriculum would also have to be modified to meet the current needs and as continuation of the effect made in the primary level. The Ministry of Education is in the process of developing a new secondary school curriculum in line with the recommendations made by the Cabinet Education Committee (1979) (MOE 1979).

5.7 Science in the Primary Curriculum

In 1979, a Cabinet Committee of Malaysia was formed to look into the implementation of the National Education Policy. Its report stated, among other things, '*… the content of the primary school curriculum is too heavy for children between the ages of six and twelve. Some pupils are not able to follow it, resulting in their mastery of only a few skills'* (para 193: p 100). In addition, it was found that '*the curriculum has been formulated separately according to subjects and there is little* *integration between the subjects in the curriculum*' (para 194: p 100). The Cabinet Committee recommended that:

> The Ministry of Education takes certain steps to ensure that education at the primary school level be in the form of basic education, with emphasis on the learning of the 3R's, that is Reading, Writing and Arithmetic. (para 196: p. 101)

Based on this recommendation and findings from other studies, a new primary school curriculum, which is in line with the recommendation in the Cabinet Committee Report, has been developed.

5.8 The Aims of the New Primary School Curriculum (NPSC)

The rationale of the NPSC is that the primary school should provide basic education. The aims of the primary school curriculum focus on ensuring that the overall development of pupils takes place. Overall development includes intellectual, spiritual, physical and emotional development as well as the development of talent and the fostering of moral, aesthetic and social values.

This curriculum ensures that every pupil acquires the necessary skills, knowledge, values and attitudes. Specifically, the NPSC aims to enable pupils to:

- Master Bahasa Malaysia (the National Language of Malaysia), in line with its status as the national and official language of the country;
- Master the basic language skills, that is, to converse, read and write in the medium of instruction of the school (the three media of instruction are Bahasa Malaysia, Chinese and Tamil);
- Acquire a strong foundation in mathematical skills;
- Acquire learning skills;
- Understand, read, write and converse in English;
- Develop desirable attitudes and behaviour based on human and spiritual values accepted by society as embodied in the Rukun Negara (Malaysian ideology) and to make these basis of daily life;
- Acquire knowledge and understanding of, an interest in, and sensitivity towards man and his environment;
- Interact socially, respect the rights and capabilities of others and possess the spirit of cooperation and tolerance;
- Develop their talents, leadership qualities and self-confidence;
- Show interest, understanding and appreciation in cultural and recreational activities within the context of the national culture and participate in these activities.

5.9 Structure of NPSC

The NPSC (see Table 5.1) is planned to enable pupils to acquire skills in three basic areas—in the area of communication, the area of man and his environment and the area of individual self-development—appropriate to the needs, interests, talents and mental abilities as well as the readiness of the pupils.

The area of man and his environment consists of two components: the humanities and environment component, and the spirituality, values and attitudes component. The humanities and environment component is integrated with the basic skills component at an early stage. Later, when the basic skills have become fairly established, the former is taught separately. The spirituality, values and attitudes component consists of Islamic Religious Education and moral education. These subjects are given special attention as they are crucial to the development of attitude, character and personality.

In 1982, the Ministry of Education of Malaysia launched its NPSC for its limited implementation stage in 305 schools. It was planned that the NPSC takes on the six-year primary education on a year-to-year basis. This meant that the NPSC in 1982 was only for the first-year (Year 1) children, and in the following year, the NPSC was carried on to the second year (Year 2) and onwards year-by-year in the same schools. Meanwhile in each following year, the NPSC went into its full implementation whereby Year 1 was launched in 1983 to all the approximately 6500 primary schools in Malaysia, as shown in Table 5.2.

The NPSC's structure is divided into two phases: Phase I for the first three years and Phase II for the later three years of the primary school education. In Phase I, teaching and learning emphasises the basics in reading, writing and computation.

Table 5.1 The new primary school curriculum

Area	Component	Subject	
		Phase I	Phase II
Communication	Basic skills	Language of instruction Bahasa Malaysia English language Mathematics	Language of instruction Bahasa Malaysia English language Mathematics
Man and his environment	Spiritual values and attitudes	Islamic religious Education for muslim pupils	Islamic religious Education for Muslim pupils
		Moral education for pupils of other religions	Moral education for pupils of other religions
Individual self-development	Humanities and environment Cultural and recreational	Music Art education Physical education	Man and his environment Music Art education Physical education

Source Kementerian Pelajaran Malaysia (1983), Kurikulum Baru Sekolah Rendah—Matlamat, Rasional, Bidang Pelajaran dan Strategi Pengajaran dan Pembelajaran (The new primary school curriculum—Aims, rationale, areas of study and teaching and learning strategies), p. 26

Table 5.2 Implementation of new primary school curriculum

Year	Limited implementation (305 schools)	Full implementation
1982	Year 1	–
1983	Year 2	Year 1
1984	Year 3	Year 2
1985	Year 4	Year 3
1986	Year 5	Year 4
1987	Year 6	Year 5
1988	–	Year 6

Elements in the humanities and environment and the cultural and recreational components are used in the teaching and learning of the basic skills. Apart from that, Muslim pupils study Islamic religious education, while pupils of other religions will attend moral education classes. For the whole duration of Phase II, teaching and learning will continue to reinforce the mastery of the basic skills. In this phase, the acquisition of knowledge and the utilisation of language for thinking and communication are emphasised. In addition, the utilisation of mathematical skills and knowledge to solve problems, to think logically and to understand societal issues, are emphasised together with manipulative skills and business practice. Opportunities are also provided for pupils to express themselves through music, drawing and writing, as well as to understand and use various means of acquiring knowledge.

5.10 Science Education in Primary Schools

In Malaysia, children start their formal education at the age of six, and the primary education extends for six years. Before the introduction of the NPSC in 1982, Malaysian primary school children learned science introduced as part of the subject called man and the environment, and this subject is only introduced at the 4th year of the primary education where basic science topics such as energy, water, air, light, shapes, structure, size, weight and volume are introduced to the students through this subject. The main aim of this subject is to develop an understanding of the interaction of man and his surroundings.

5.11 New Integrated Secondary Science School Curriculum

The Ministry of Education Malaysia then embarked on developing a new secondary school curriculum to replace the ‘modern’ physics curriculum that is more responsive and relevant to the country’s needs. The new curriculum aims to provide general education, as recommended by the Cabinet Education Committee which focusses on the following:

- The overall and balanced development of the individual and
- Orientation of the individual to society.

The entire school curriculum in all subjects from Forms 1–5 (Grades 6–11) has been reviewed, and appropriate changes are made. These changes include the following:

- The integration of the intellectual, spiritual, emotional and physical aspects in the curriculum design.
- The internalisation and practice of the spiritual, moral and citizenship values.
- The acquisition of the essential and basic skills and knowledge. There are profound changes with curriculum design, strategies and techniques of teaching and preparation for the materials and resources for learning of lifelong education.
- The focus is on providing a general education and preparation for lifelong education. The development and implementation of the new secondary curriculum in physics inevitably offer a challenge. The new curriculum was first implemented in 1989.

5.12 Realising 60:40 Policy

Since 1967, Malaysia has set the 60:40 policies for the purpose of ensuring the pool of students taking up science at school and university levels. Various efforts and strategies are planned by Ministry of Education to realise the 60:40 policy. One strategy is the streaming policy.

Prior to 1983, based on the students' performance on the PMR (lower secondary assessment) examination taken at the end of lower secondary school years, students were streamed into science, technical and non-science (arts) tracks at the upper secondary levels. Often, those who are qualified to do science were forced to do science regardless of their interest. In this science track, science was taught as separate subjects (biology, chemistry and physics) to students. Similarly, for those in technical tracks, they were taught science as separate subjects. Students in the non-science track, however, still continued to take science as one common subject.

This streaming policy was later seen to be rigid in that students were not given choice in deciding their future. Since 1983, students have been given more choices at the upper secondary level through the offering of various electives groups such as 'science electives', 'Quranic electives' and 'economic electives'. For those students who are interested in pursuing science and technology as their career can opt for the science electives (biology, chemistry, physics and additional science) in addition to the core science subject. Science is now offered as a common subject to all regardless of what track of studies the students are involved. Science as a common subject to all is in line with the view of providing science for all and a way to promote scientific literacy. With the current practice of 'open system', science education system aims to promote science for all and at the same time providing tracks for those pursuing studies that aim at becoming scientists and technologists.

Another strategy is to provide technical tracks in day schools in addition to building more technical boarding schools. The numbers of boarding (residential) schools that provide 100 % classes for learning science are also increased. Excellent students graduating from these fully residential science schools as well as from the day schools are offered scholarships to study abroad at the tertiary level in the science disciplines. MOE also realises the role of science and mathematics teachers in encouraging students to opt for science stream courses; thus, these teachers, including counselling teachers, are given seminars on the importance of science and information on science-related careers (Buang et al. 2010).

Science education is also supported by other governmental and non-governmental agencies in Malaysia (Syed Zin 2002). The Ministry of Science, Technology and Innovation (MOSTI) plays a crucial role in leading informal and non-formal science education. There are many agencies under MOSTI that operates to execute this aim. For instance, schools organised field trips to National Science Center and National Planetarium, agencies that are established under MOSTI. Non-governmental organizations, such as World Wide Fund for Nature, have actively provided support to the Ministry of Education (MOE) to conduct various co-curricular activities pertaining to environmental science. The Ministry of Education also realises that it has a lead role but this is not sufficient to popularise science; therefore, it emphasises that informal and non-formal learning of science can be the main contributors in the effort of increasing science literacy and interest of people in science and technology. Beginning in 2012, MOE has expanded the involvements of external agencies to support the informal learning of science (MOE 2012).

5.13 Current Status of Science Education

Despite the concerted and systematic efforts in enhancing the participation in science studies as well as fostering positive attitudes towards science and technology, the percentage of students enrolling in science stream at the upper secondary level is still below the targeted 60:40 science to arts ratio. Figure 5.1 depicts the trend of enrolment for students following the science and arts classes for the period between 1981 and 2009. The highest percentage of enrolment students doing science was 31.2 %, and it declined to 29.3 % in 2009.

A similar trend of enrolment is reflected at the tertiary level (see Tables 5.3 and 5.4). Again, between 1995 and 2005, the science enrolments at tertiary level

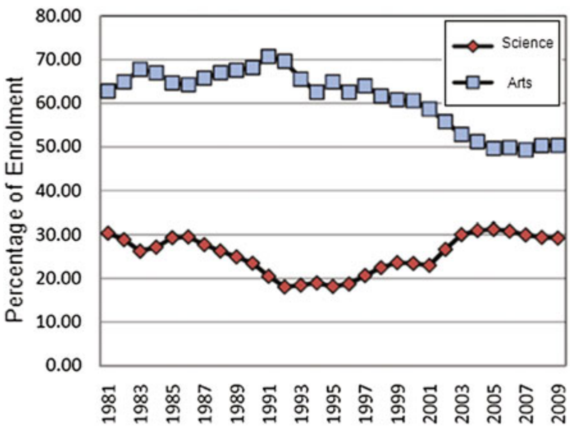

Fig. 5.1 Percentage of enrolment 16 and 17 years old according to science and arts classes between 1981 and 2009. *Source* Adapted from Abu et al. (2011). With permission from Mohd Salleh Abu: Kompilasi dan Review ke atas Penyelidikan Pendidikan Berkaitan Sains dan Matematik di Malaysia, p. 3, Mohd Salleh Abu, Mohammad Bilal Ali, Fatin Aliah Phang Abudllah dan Salmzia Salleh

Table 5.3 Enrolment of first degree courses from local public institutions 1995–2005

Courses	1995	2000	2005
Arts[a]	44886 (59.3 %)	81914 (48.0 %)	103846 (42.5 %)
Science[b]	18171 (24.0 %)	49575 (29.0 %)	71897 (29.4 %)
Technical[c]	12652 (16.7 %)	39305 (23.0 %)	68784 (28.1 %)

Note a Arts includes humanities, economics, business and law
b Science includes medicine and dentistry, agriculture and pure sciences
c Technical includes engineering, architecture and town planning and survey and others
Source Adapted from Awang (2004). With permission from Halimah Awang: Human capital and technology development in Malaysia. International Education Journal, 5(2), p. 241

showed only marginal increase from 24 to 29.4 %, that is far below the target of 60 % enrolment in science- and technology-related courses (see Table 5.3). Thus, Malaysia is in a dire need to create a critical mass of scientific and technical manpower to ensure that its economic growth is sustained and propelled in this era of knowledge- and innovation-based economy.

Reasons for the falling recruitment and interests in science and technological (S&T) studies and careers are many. One of the most cited reasons is the perceived view that school science is unexciting and abstract. Such perception is due to the learning experiences that students undergo including (a) examination-oriented teaching which led to teaching being mainly geared towards passing the national public examinations, (b) the ineffective teaching of abstract topics which resulted in failure to come up with right conception that results frustration to students and (c) lack of practical and experiment activities thus affecting students‘ interest in and their ability to engage in scientific inquiry (Buang et al. 2010; Phang et al. 2012). Similar reasons are also found among students from other developed countries.

Table 5.4 Student enrolment in public higher institution 2011–2012

Discipline	Year	Total
Education	2011	17824
	2012	19883
Arts and humanities	2011	15547
	2012	16218
Social science, business and law	2011	66432
	2012	67317
Science, mathematics and computer	2011	26075
	2012	27151
Engineering, manufacturing and construction	2011	35635
	2012	39331
Agriculture and veterinary	2011	4713
	2012	4099
Medicine	2011	8193
	2012	8893
Services	2011	6139
	2012	5874
Total	2011	180558
	2012	188766

Source http://www.mohe.gov.my/web_statistik/Indikator_PT-2011-2012.pdf

In a review of research in science and mathematics education in Malaysia, Abu et al. (2011) found that a high percentage of students showed interest in and positive attitudes towards science and mathematics. Results from the ROSE study also showed that the attitudes and interests of Malaysian secondary students towards S&T-related issues and topics were mostly very positive and ranked among the top few nations participating in the study (Schreiner and Sjoberg 2004). However, students still tend not to choose science-related courses at upper secondary and tertiary levels. Factors contributing to that are (a) students' perception that a 'special ability' is needed in learning science; hence, only certain people are able to learn science (Talib et al. 2009); (b) bleak career prospects associated with it; and (c) lack of parental support in pursuing science-related careers (MOE 2012).

The perception of science as a difficult subject—to learn and to excel in—has swayed those able and qualified students to do science to opt for arts-based courses at upper secondary level. As Talib et al. (2009) and Abu et al. (2011) indicated, part of the reason is due to the claim that art-based subjects (such as economics, accounting and Quranic studies) are supposedly 'relatively easier' to learn compared to science-based subjects. Opportunities gaining entry into university is wide since one is likely to get good results by taking arts-based subjects. Lack of knowledge and awareness of careers opportunities in science also hinders students from pursuing science at tertiary level.

The practice of ‘open system’ in the Malaysian education system at the upper secondary level has facilitated able students to pursue the arts-based courses; prior to 1983, these students would be ‘automatically’ streamed into the science tracks. The open system in education coupled with the misconception about learning science has further exacerbated the low enrolment in the sciences as compared to that in the arts stream at higher secondary level to be less than the expected 60:40 per cent ratio.

Low enrolment in science is also critical among the students from rural schools. These students fare poorly compared to their urban counterparts in terms of (a) their performance in national examination level in the PMR examination (Abu et al., 2011), (b) lack the motivation to further their studies to the extent the rate of dropouts is high in rural areas (Halim 2004) and (c) ineffective teaching strategies which do not meet their learning and ability needs (Meerah et al. 2010). Low participation in science among the rural students suggests that equal opportunities in learning science is not met and thus obstructs the promotion of science for all, which is one of the main tenets of science education in every science curriculum change and reform in Malaysia.

The results of TIMSS assessment are also an indication of Malaysian science education system, with reference to the other countries. In general, Malaysia performs slightly above the mean average indicating the quality of the science education is good. However, based on the TIMSS reports in 1999, 2003 and 2007, the performance of Malaysian students was found to decline; particularly, Malaysia had lower average achievement in 2007 (20th ranking in mathematics) than in 2003 (ranked 10th) and in 1999, despite an improvement from 1999 to 2003.

One of the factors associated with the declining trend especially from 2003 to 2007 is due to the language of instruction (Zain 2010). The TIMSS 2007 report indicated that countries with large proportions of students from homes where the language of the test (and consequently the language of instruction) is not often spoken had lower average science achievement than those who spoke it more often. In the case of Malaysia, this report indicated that the policy of teaching science and mathematics in English (PPSMI), introduced in 2003, might be the reason for this decline.

In a multicultural society like Malaysia, students speak in their mother tongue at home which would be Malay, varieties of Chinese’s dialect or Tamil. The decision to switch the medium of instruction from Malay to English as the medium of instruction in science and mathematics was that the English is the language of scientific and technological knowledge; and thus, mastery of English in the field would ensure effective acquisition of the scientific and mathematics knowledge that is rapidly developed and widely disseminated in English. The implementation of the policy is supported by significant investments in training to improve the English proficiency of teachers as well as through the provision of instructional in materials such as courseware, textbooks, activity books and ICT facilities including computer laboratories, notebooks and LCD projectors.

Despite the systematic and strategic efforts in implementing the PPSMI policy that leads to significant curricular changes, there was much debate among parents, society, politicians and academicians on this policy. The debate revolves around among others (a) the status of Bahasa Melayu as the national language; (b) the readiness and capabilities of teachers teaching mathematics and science in English; and (c) effectiveness of the policy in enhancing science and mathematics learning. Major studies revealed that students in rural school often lag behind their counterparts in urban schools in terms of achievement in science, found that the gap is further widened with the introduction of teaching science and mathematics in English (Ong and Tan 2008; Hudson 2009; Na and Mostafa 2009) and showed that teachers are supportive of the policy, but they are struggling to implement it. Teachers need to deliver the subject matter in the form that can be understood by learners in a language which is either a second or third language to the majority of Malaysian learners.

The successful implementation of the policy also depends on teachers' own linguistic capabilities. Zain (2010) argued that based on 'one of the findings from UNESCO indicated that learning takes place effectively when the medium of instruction is in the mother tongue during the early years of schooling' (*Language Diversity in Multicultural Europe, Comparative Perspective on Immigrant Minority Languages at Home and at School* at www.unesco.org/most/discuss.htm). These pieces of evidence along with the various contentions around the policy led to this policy being abolished in 2012 and consequently replaced with the *To Uphold Bahasa Malaysia and To Strengthen English Language (*MBMMBI) policy. The MBMMBI policy involves the use of Bahasa Melayu as the medium of instruction in all National Schools and the use of the respective mother tongues in all national-typed schools for mathematics and science. At the same time, English language is enhanced through the improvement of methods of teaching English.

5.14 Future Directions

The state of school science education indicated earlier is due to many factors among which are curriculum, quality of teaching, assessment and quality of teachers. Thus, suggestions for future directions would be to improve in all aspects.

5.14.1 Science Curriculum

It is clear that the utmost aim of science education in Malaysia is to enable the country to have the manpower required in the science and technological field. The development of an updated and relevant science curriculum is ongoing. Currently, in the Malaysia Education Blueprint 2012–2025, the education system is giving emphasis on (a) strengthening critical thinking and character building; (b) cultivating creativity, innovation and entrepreneurship; and c) strengthening communication, resilience and self-confidence competencies. As a result, the 1987 New

Primary Science Curriculum and the New Integrated Secondary Science Curriculum are being revised. In the transformed curriculum, cultivating creativity and innovative thinking are being emphasised in the design subject (MOE 2013). Integrating engineering element such as design thinking and problem-solving in the curriculum presents opportunities for students to acquire skills such as problem-solving, creativity and innovation.

Similar initiatives are also implemented in the USA, and it has been shown that through engineering design thinking and activities, students are able to develop higher order thinking skills, problem-solving skills, skills for working collaboratively and increase interest in learning science (Macalalag and Jurado 2011; Becker and Park 2011; Stohlman et al. 2012). This initiative is known as science, technology, engineering and mathematics (STEM) education. STEM education has gained prominence in Malaysia since 2012; in 2014, the Ministry of Education developed a STEM education conceptual framework, and this framework encompasses all levels of education from preschool to tertiary level. The framework outlines the goals of STEM education in Malaysia, the outcome expected of the students, the role of the practitioner and the relevant modality to achieve the goals.

Another derivative of STEM is the integration of entrepreneurship discipline with the teaching of science (Buang et al. 2010). The concept of integrating elements of entrepreneurship with design thinking based on scientific knowledge is conceptualised as ‘entrepreneurial science thinking’. Studies have shown that through the inculcation of entrepreneurial science thinking, students were able to use scientific knowledge to plan technology-based products that can be commercialised (Armstrong and Tomes 2000; Menzies 2010). Buang et al. (2010) created curriculum materials based on the entrepreneurial science thinking concept and found that students were motivated and saw the relevance of learning science after being exposed to the entrepreneurial science thinking activities. Students in Buang et al.’s study also mentioned that they would like to be scientists in the future, and some of them were able to see that career in science goes beyond being a scientist. Buang et al. believed that entrepreneurial science thinking-based curricula can fulfil the needs of Malaysia to develop manpower that is innovative and able to turn scientific discoveries into commercialised products as well as increase participation of students in science and technology disciplines.

5.14.2 Quality of Teaching

Quality of teaching is also a factor that determines students’ interest in science and attainment levels. Research has shown (e.g., Osborne 2007) that inquiry-based methods are science teaching pedagogies that contribute more to increase student interest in science compared to didactic and deductive method that is still widely practised (Abu et al. 2011).

One way to encourage teachers to use innovative teaching methods that are often based on research drawn upon theories of education are to provide curriculum materials. However, science teachers lack the time and have difficulty in translating research evidence-based teaching into their practices. Ratcliffe et al. (2006) and de Jong (2005) suggested that science teachers will consider and adopt the research evidence-based teaching in their practices when facilitated through the provision of curriculum materials. Chances of teachers using and accepting as well as the success of the curriculum materials to be effective will increase, when teachers and researchers collaboratively develop the materials.

The newly released Malaysian Education Blueprint 2013–2025 also stresses developing students' higher order thinking skills. Thus, teachers and curriculum developers are directed to foster higher order thinking skills (HOTs) with the hope to understand and improve the dynamics of teaching and learning process including science teaching and learning. Consequently, the International Baccalaureate Middle Years Programme (IB-MYP) was deemed to be the way to change the teaching and learning approach in the national secondary schools with the purpose of developing students' thinking and innovative skills. As a pilot project, IB-MYP will be implemented in selected 10 national schools and projected to train a total of 800 teachers. Like any MOE projects emanated from specific policy, the impact of the programme is researched and serves as an input to further policy-making. In this instance, policy drives research, and in turn, research provides feedback to policy-making.

Science teachers should also adopt alternative pedagogies when teaching students from rural areas and those in the interior, where the schools lack the facilities such as laboratory and educational resources compared to their urban counterparts, so that the implementation of a centralised science curriculum as in Malaysia is felt by all. In Meerah et al. (2010) study on teachers teaching marginalised children using alternative pedagogies such as toys, the students' environment and games had managed to improve their interest in science; and the science teachers were facilitated to adopt the alternative teaching strategies through a collaborative action research.

5.14.3 Quality of Assessment

As indicated by Osborne (2007), there is still a lack of assessment in science education that engages students in higher order thinking such as constructing arguments, evaluating and interpreting data and asking questions. Similar situations also exist in Malaysia where the focus of assessment is still on content or cognitive skills related. Malaysia's performance in PISA is an indicator of the nature of assessment that focuses on low thinking skills. Malaysia ranked third in the bottom third of 74 participating countries in PISA 2009 and 2012.

Malaysia is currently moving towards implementing school-based assessment that would allow more opportunities in assessing for learning skills such as problem-solving or creative thinking. This innovation is still in the pilot stage since various issues need to be addressed in any curricular changes, namely the teachers' competency, as well as students' and parents' acceptance of the improvement.

Research also needs to be done on how to assess problem-solving or creative thinking. In the context of science education, school-based assessment related to assessing science process skills was introduced in 1995. The goals of evaluation of science laboratory skills, also known as PEKA, are commendable, but in a way similar to the implementation of the policy of teaching science and mathematics in English, teachers are unable to implement PEKA effectively.

Abu et al. (2011) found that science teachers lack the understanding of the concept of PEKA, that is developing students' proficiency in science process skills through a series of experimental work that students have carried out. Instead, teachers tend to evaluate their students with the aim of giving good grades at the end of the assessment. In other words, science teachers tend to perform summative rather than formative assessment for a process-based activity such as experiments. Yong and Sam (2008) asserted that there is yet available assessment frameworks for teachers to be used as a guide in executing school-based assessment. Hence, there is an urgent need to develop an assessment framework that is usable, valid and reliable. Thus, future directions would involve more research on how to raise the concern level of the teachers to curricular changes.

5.14.4 Quality of Science Teachers

Curriculum change is a continuous process, and there is a need for in-service and professional development courses for teachers in order for them to adapt to the changes as well as updating their content knowledge and the pedagogical and curriculum skills and knowledge. Professional development needs to be done constantly as Osborne (2007) highlighted changing teacher pedagogy cannot be done through on–off courses. Other than attending courses, ongoing professional development could be achieved through constant change of ideas, discussion and on ways to improve or adopt innovative teaching methods. Such teaching and learning collaborations, where teachers who are familiar with the realities of teaching are interacting together, are able to collaboratively improve teaching and learning.

The head of science department at the school has an important role in facilitating such collaboration; and these heads of department themselves also need professional development so that they can play a more effective role in the professional growth of their science colleagues. In addition, research evidence should also be integrated in the standards of science teachers; thus, this would ensure the adoption of innovative teaching based on research.

Besides these courses, teachers are also encouraged to further their studies. Some of them may receive scholarships to continue their postgraduate education to further improve their knowledge and skills in education fields. The expansion in postgraduate education has been tremendously brought about because of the increase in capacity of providing more opportunities to pursue higher education locally with the opening of more universities to concentrate only on postgraduate research education programmes while reducing the intake of undergraduate students.

Postgraduate programmes prepare students to acquire research skills and embark on research. Most research in Malaysia is from these graduate students, of course with their supervisors or their lecturers. There has been a flux of research work. This is also true in the field of science education, where students and their supervisor carry more research work than their lecturers on their own. However as argued by Ayob (2008), the impact of such research is lacking since the focus of the research conducted by postgraduate students is personally oriented. What is needed is more of longitudinal studies whereby the impact will be more meaningful.

Continuous professional development of science teachers could also be achieved through constant reflection on one's practice systematically. This self-reflection disposition is especially helpful and important for student teachers who are able to see how theory informs their practice, particularly during their teaching practice. An experience gained by a student teacher conducting action research on her own practice allowed her to realise the importance of teaching for understanding and the importance of research in teaching as a novice in research. Through action research, student teachers are able to develop reliable situational knowledge (Halim et al. 2014a) that promotes professional development.

In Malaysia, science teachers are encouraged to improve their teaching and their students' learning through conducting action research by themselves, either individually or collaboratively with other teachers or outside experts, by working in their own classroom. Teachers are also encouraged to present or share their research findings with others. The Ministry of Education even holds the national competition as well as offering recognition for the best action research award. It is hoped that such a systemic effort would encourage research culture on the part of the teachers in order to improve science teaching and learning in schools. This practice needs to be extended to all science teachers, and research could be done to see the impact of conducting action research on one's professional development growth.

5.14.5 Science Teacher Educators

Quality science student teacher depends on the quality of science teacher education programmes. If we are to prepare a high-quality science programme, we need to have quality teacher educator workforce. So far in Malaysia, there is no standard of science teacher educators. Having such a standard will ensure that science teacher educators have the capabilities to design and implement teacher education programmes, institutes and workshops. A tentative framework of the standard proposed by (Lederman et al. 1997) includes that science teacher educators, among others, have a strong science knowledge base and understand science pedagogy, curriculum, instruction and assessment, and research capabilities. Abell et al. (2009) suggested an additional standard that is knowledge for teaching preservice teachers. Research on validating these standards in the Malaysian context and its effect on the quality of science teachers should be a research agenda.

5.14.6 Research-Based Policy

Malaysia continuously reviews educational policies with the aim to constantly improve the quality of science education. Often, policy development and changes related to education have been based on emulating best practices. These best practices are drawn, normally, from outside of Malaysia such as Lesson Study (Japan), I-Think Programme (UK) and International Baccalaureate (IB) curricula. Often, these best practices are implemented as pilot projects.

Development of policies and monitoring of the execution of policies are now, however, increasingly based on research commissioned by the ministry. A task force has been set up in the ministry—Education Performance and Delivery Unit (PADU), and its role is to monitor and ensure success of the national blueprint. Policy research is often conducted in two ways by (a) foreign educational consultants and (b) local educational consultants namely the local academics. In both situations, ministry officials are involved as collaborators, and the research is supervised by the related departments in MOE.

Recent review of Malaysian education policy was led by UNESCO (2012). Pilot projects such as implementation of IB curricula in the Malaysian context was researched on and done collaboratively with foreign and local educational consultants. An example of local academics involved solely in policy research is the reviewing the 60:40 policy that is currently ongoing. Preliminary findings show that there is a gap between the understanding of the needs of the policy and the practice at the grass root level. Preliminary findings also indicate that the realisation of 60:40 needs to be looked in a holistic manner since the realisation of the policy is dependent on gamut of factors such as quality of science teachers, quality of science teaching and learning, careers in science and technology, and parents involvement.

While it is acknowledged that an independent review or research by foreign consultants has its benefits, nevertheless, they will be not be able to understand fully the culture and context of the educational system and practices. More participatory collaboration between local academics and policy-makers as well as practitioners should be encouraged. Ongoing formative evaluation should be carried out on the effectiveness of pilot projects so that the projects are adapted to the local context before nation-wide application. Drawing on outcomes from local research to inform policy should be enhanced. A national clearing house on educational research should be institutionalised, thus could benefit the research outcomes and inform the policy-makers in which the findings are grounded in the local context and understanding.

5.15 Gap Between Research and Practice

Malaysia believes in the influence of teachers on student's achievement, thus always maintains the need to improve teachers' quality. However, studies have failed to identify which teachers' characteristic is a strongly determinant of school achievements (Idris 2012). It has, nevertheless, been shown that teaching of effective teachers—namely how they behave when they were in the classroom—has impact on their students' achievement (MOE 2013; Idris 2012).

Research (Halim et al. 2014b; Stigmar 2010) has also shown that effective teachers are those who are able to communicate effectively, think critically and plan systematically. The researchers further suggested that effective teachers are those who acquire research skills and have the ability to accommodate needs of diverse abilities. In science education, knowledge of students' preconceptions and misconceptions is the knowledge base derived from research, and this knowledge base along with other types of knowledge base (Darling Hammond et al. 2005; Shulman 1987) is available for teachers to understand and value which needs to be adapted to within educators' specific contexts (Kreber 2002). One way to effectively influence the use of research in practice is by getting teachers to involve in action research.

In the Malaysian context, even though action research among teachers has been propagated since 1994 and it is still ongoing, the heavily centralised education system appears to be the main barrier to its effectiveness. The education system, centrally controlled, made it unnecessary for teacher to explore the use of research in their teaching. Instead, teachers will seek for directions and advice from the top; and the top-down approach seems to work well in this centralised system. The technical model of teacher competency, that is, one that is assumed to develop competencies through direct application of innovations without problems, appears to be strong in the Malaysian education system.

Thus far, no incentives for teachers who conduct research or completed their further studies were given. The action research culture programme, even though is ongoing with national awards being set up, has also been on a decline, to foster teachers to carry out research in order to improve students learning. Nevertheless, incentives are provided for teachers to do collaborative research with their university counterparts. Focus on teachers' quality improvement has been on development of teachers competencies in research.

In this highly centralised system, teachers have always concentrated on teaching students to perform very well at the end of the year external examination which has been used as a measure for accounting school performances. Since the performance in the examinations is what counts, parents have always pressured the schools and teachers to teach to the examination curriculum. Thus, teacher as a researcher is not considered as an important ideal that Malaysia schoolteachers have (Idris 2012).

Perhaps the use of research findings by teachers would be a culture when teachers seek for higher education. As shown earlier in this chapter, the Ministry of Education has propagated the need for teachers to seek for further education, and incentives are being planned to be given on completion of their student teaching education. There are also new changes being implemented such as the teaching of higher order thinking and lifelong learning concepts for teachers, and this would see new light on the use of research in teaching and learning. However, thus far, studies on teachers' quality according to the perception of higher education administrators and other stakeholders do not accord the research elements to the teachers.

5.16 Conclusion

The objectives of science education are to provide the majority of the students, as citizens in the twenty-first century, a firm foundation in science and at the same time to achieve the target number of students needed in the S&T workforce. In meeting both goals, science education in Malaysia has undergone various curricula and policy changes. These changes are still ongoing for the goals are not fully met as well as the need to keep in place to the ever-evolving knowledge in the improvement of science education.

Besides the development of an updated and relevant science curriculum, its delivery and implementation should always be enhanced and a concern to policy-makers and practitioners. Science education research has to some extent managed to influence the practice, and experience has shown that graduate students tend to appreciate and continue to think critically of their practice in light of theories and research findings. Efforts to improve teaching through research on one's own practice, sharing practices and employing research-based knowledge have been also institutionalised.

Nevertheless, the centrality of the Malaysian education system has impeded to some extent the mindset and practice of science teachers to use research evidence in their work. Schools are given the autonomy to determine teaching approaches and strategies. The curriculum specifications for science, however, do provide suggested teaching and learning activities to help teachers plan and implement more effective teaching and learning sessions. Even though the curriculum specifications for science serve as a guide, it is quite common for teachers to follow it religiously. The foundation to overcome, such mindset and practice that are bound by directive orders from the central, has being laid through the expansion of postgraduate studies, thus may be able to reduce the gap between science education and practice. In the meantime, continual improvement of science education in Malaysia through research at higher institutions and working collaboratively with teachers and the MOE, especially the development of curriculum materials and conducting longitudinal studies, should be the priority in science education research.

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