



MINISTRY OF HIGHER EDUCATION

STEM EDUCATION IN MALAYSIA

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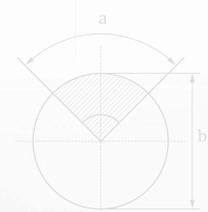
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STEM EDUCATION IN MALAYSIA

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Foreword



Alhamdulillah, praise be to Allah for his grace and mercy for the opportunity to say a few words regarding the publication of this book. In light of continuous global competition and the technology breakthroughs in science, technology and engineering progress, it is imperative for the Malaysian higher education system to produce holistic, innovative, entrepreneurial and balanced graduates through the Malaysia Education Blueprint 2015-2025 (Higher Education).

STEM education is important in preparing students for the global challenges. Most advanced countries focus on STEM because it embraces every aspect of life as well as contributes to the nation's future economic progress. The country needs talents who are equipped with STEM knowledge and skills in order to maintain our nation's global competitiveness. For such purpose, various initiatives have been introduced by the Ministry of Higher Education namely the Integrated Cumulative Grade Point Average (iCGPA), 2U2I work based learning Programme, Malaysia MOOCs (Massive Open Online Courses), CEO@Faculty Programme, Accreditation of Prior Experiential Learning (APEL) and many more.

The awareness of the importance of STEM has promoted great changes in the national education system. In ensuring that the education system is at par with global needs, many transitions were made in the process of introducing STEM at the school level. Experts have predicted that the Fourth Industrial Revolution (4IR) will be driven by development in science, technology and engineering advances particularly biotechnology, artificial intelligence, robotics, the Internet of Things and other innovative technologies. The 4IR will introduce new practices which will fundamentally alter the way we live, work and relate to one another. Thus, the Malaysian higher education system needs to adapt to the challenges and critical needs of the 4IR. The Higher Education 4.0 framework will guide the higher education institutions in preparing STEM talents for the country in embracing the challenges of 4IR.

Thank you.

DATIN PADUKA IR. DR. SITI HAMISAH TAPSIR

Director General of Higher Education

Department of Higher Education

Ministry of Higher Education

Preface

Knowledge of science and technology is essential for Malaysia to attain a scientifically driven economy and become a developed nation by 2020. Science, Technology, Engineering and Mathematics or STEM, is a transdisciplinary approach in exposing students to think more logically and holistically as well as equip them with 21st century skills and attributes.

With the advent of the Fourth Industrial Revolution (4IR), Malaysia needs to develop future-proof graduates who are prepared to cope with the demands of the 4IR. Emerging technologies such as Artificial Intelligence and Internet of Things are growing at an exponential rate never before experienced by any of the industrial revolutions. It is essential that our talents be equipped with the knowledge on disruptive technologies and innovation and trained to become critical, creative and innovative thinkers with humanistic competencies. In other words, we need to nurture our future generation with curiosity and inquisitive minds along with the humanistic values in fronting the challenges of the 4IR. Thus, with STEM education on the rise, we will be able to assist our future generation to appreciate and develop their passions towards STEM from young. This will result in future-proof talents who are globally skillful and marketable in STEM education.

STEM education provides our children a comprehensive view of the world around them and equips them with science and math-based problem-solving skills critically needed as adults. These children will face various challenges in the future and STEM knowledge and competencies will assist them in solving those problems along the way. Collaborations and support system from the quadruple helix ecosystem i.e. institutions, industry, community and academia will definitely help to materialise this endeavour. It is our aspiration that such concerted effort will increase STEM literacy for Malaysian students who will ultimately pursue advanced degrees and careers in STEM-related fields.

CHAPTER ONE

**CURRENT STATUS AND TRENDS OF SCIENCE,
TECHNOLOGY, ENGINEERING
AND MATHEMATICS (STEM)**

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ABSTRACT

As a significant approach in the field of modern pedagogy, STEM (Science, Technology, Engineering and Mathematics education), is widely considered as a crucial factor that drives economic growth, create new jobs and solve environmental and global problems. Due to its importance, nations across the world firmly insist on engaging every student to the high quality of STEM education in such way that they can be innovators, researchers or leaders who have the ability to think critically and contribute to developing the world. In this chapter, we briefly shed some light on the state, policies, strategies and initiatives of STEM education in the USA, Europe, Singapore and Malaysia. The review reflects that the situations of STEM education differ from one country to other. For instance, it seems STEM education in the USA is affected by the racial, ethnical, cultural, linguistic, socioeconomic, gender, and geographic aspects due to the wide diversity of the society. It is also elicited that there is an inadequate amount of teachers skilled in STEM subjects. In the European countries, reports indicated that the number of students who are interested in pursuing a career in the field of STEM is low. However, the review reveals that Singapore has emerged as top STEM educated country. With regard to the state of STEM education in Malaysia, the review reflects that it still faces some issues such as insufficient localised STEM learning materials and weak interest of students in continuing STEM related studies at secondary and tertiary levels.

From educators' perspectives, the STEM education should be more learner-centred, and the teachers should be equipped with the full academic and professional requirements that can help contribute to genuine and typical pedagogical models. Finally, this chapter concluded with some remarks that aimed at enhancing STEM education.

1. INTRODUCTION

With the emergence of the third millennium, countries across the world have been competitively focusing on improving the new educational approach known as STEM (Science, Technology, Engineering and Mathematics) which is driven by environment and economy challenges. This practical approach is not only intended to prescribe a set of activities or practices, but it is rather meant to start an extended dialogue in regards to opportunities for innovation and encouraging research and development. Academics have opined that this approach can build a stronger base that can be successful in various contexts and, thus, can serve diverse learners and motivate more actions towards achieving transformative changes. Several countries, such as USA, UK and the Scandinavian countries, advances in STEM have long been central to the nations' ability to develop cleaner and more efficient domestic energy sources, manufacture smarter and better products, improve health care, safeguard national security, preserve the environment and, more importantly, grow the economy.

However, several indications point toward that current educational pathways are not significantly leading to a sufficiently large as well as well-trained STEM workforce to achieve this ambitious goal. Several developed countries view that their education system should base on the culture of STEM enhancing students in its disciplines and equip to excel in STEM. Science and mathematics have transformed the world in almost every way imaginable. In the same way, technological and engineered innovations have 'flattened' the world socially, politically and economically. A new citizenry and workforce of problem-solvers, innovators and inventors who are self-reliant and able to think logically are one of the critical foundations that drive innovative capacity in a state [1].

2. STEM IN THE UNITED STATES OF AMERICA (USA)

It is a well-known fact that the USA has grown as a global leader in several disciplines based largely on the efforts of her scientists, investors and engineers [2]. Gradually, STEM education has emerged as a new discipline and, hence, the need for STEM has been increasing day by day in the current complex world in general and in the USA in particular [3]. Maintaining America's historical pre-eminence in STEM fields involves a comprehensive and intensive effort to guarantee that the STEM workforce is equipped with the training and skills required to excel in these areas [4].

It has been estimated that American companies may need around 1.6 million STEM-skilled employees in the next five years [6]. Consequently, it has become clear that STEM workforce plays a vital role in the stability in addition to the sustained growth of the U.S. economy besides being a critical component for the U.S. to win the future [5].

2.1 State of STEM Education

The performance of STEM education in the USA has been affected by several factors including racial and ethnic, linguistic, cultural, socioeconomic, gender, disability, and geographic lines. Several reports and studies revealed that the USA has been trailing several countries in STEM education [7]. According to the National Assessment of Educational Progress (NAEP) seven results, only 13 percent and 19 percent of Black and Hispanic students, respectively, have scored at above proficiency in eighth-grade mathematics constituting a proportion of less than 43 percent of White students and 61 percent of Asian students. Additionally, NAEP data reflected that other underrepresented groups perform below their White and Asian peer groups. Likewise, in eighth-grade science, 45 percent and 46 percent of White and Asian students, respectively, perform at or above proficiency, compared with 20 percent or less of racial and ethnic minorities. With regard to gender, despite the gaps narrowing in mathematics between girls and boys, the performance trends over time remain reflecting higher percentages of males than females scoring at or above proficiency in the last ten years. In science, the gender gaps have largely persisted as static from 2009-2011 [6].

Also, there is an insufficient number of teachers who are skilled in STEM subjects, and at the same time, the number of American students who have superior skill in STEM fields is much to be desired [2].

2.2 Policies and strategies

Currently, policies and practices that document reasonable access to the best STEM teaching and learning are not well known. Therefore, states, districts, and schools struggle to provide all students with the STEM experiences required for the 21st century, irrespective of college and career aspirations [6]. Hence, it is evident that policy makers should make STEM education as a top priority to guarantee that all students in the country received a justifiable quality STEM learning opportunities. This should also include providing capable teachers to ensure that all students have the chance to study and be inspired by science, technology, engineering, and math and have the opportunity to reach their full potential [2]

2.2.1 Committee on STEM Education (CoSTEM)

The Federal STEM education investment for 2017 to support STEM education for all students were priorities into three major areas. These are 1) improving STEM teaching and supporting active learning; 2) expanding access to rigorous STEM courses and 3) addressing bias and expanding opportunities for underrepresented students in STEM [8]. To implement these priorities, a Committee on STEM Education (CoSTEM) of the National Science Technology Council, which is comprised of 14 agencies, was given the task of formulating a cohesive national strategy to improve STEM education [6].

With the backing of federal funds, the national strategy that was designed sought to improve STEM instruction aiming at preparing 100k excellent new K-12 STEM teachers by 2020 and support the existing STEM teacher workforce. Also, the strategy aim at increasing and sustaining youth and public engagement in STEM to support a 50 percent increase in the number of U.S. young people who have an authentic STEM experience each year before completing high school. The plan also includes enhancing STEM experience of undergraduate students aiming at graduating one million additional students with degrees in STEM fields over the next ten years. Furthermore, CoSTEM

will also oversee efforts to better serving groups historically under-represented in STEM areas to increase the number of students from groups that have been underrepresented in STEM fields and graduate with STEM degrees in the next ten years and improve women's participation in areas of STEM where they are significantly underrepresented. Lastly, CoSTEM was responsible for designing graduate education for tomorrow's STEM workforce to provide graduate-trained STEM professionals with basic and applied research expertise, options to acquire specialised skills in areas of national importance, mission-critical workforce needs for the CoSTEM agencies, and ancillary skills needed for success in a broad range of careers[6].

In addition, there were two coordination approaches to increase the success of STEM strategic plan. The first deals with building new models for leveraging assets and expertise. This would be implemented in priority areas at collaborating agencies to leverage their capabilities to ensure the most significant impact of Federal STEM education investments. The second focuses on building and using evidence-based approaches. This was achieved by conducting STEM education research and evaluation to build up evidence about promising practices and program effectiveness. The results would be made available to the relevant agencies and also shared with the public to improve the impact of the Federal STEM education investment [6].

2.3 STEM Education Initiatives

As a matter of fact, the policies of the USA focus on exploiting Federal investment to increase students' access and engagement in active, rigorous STEM-learning experiences. To accelerate progress in achieving this ultimate goal, meaningful efforts to inspire and recognise young inventors, discoverers, and makers need to be undertaken by the government [8].

2.3.1 Examples of STEM programs

Educate to Innovate (EtI)

'Educate to Innovate (EtI)' initiative was launched by the USA President, Obama, in 2009. The main part of EtI is to develop public-private partnerships to enhance interest and engagement in STEM, mostly in the form of out of school activities. The EtI have elaborate science-related television programming

based learning. The Sesame Street and Discovery Communications channels agreed to include STEM content based program. Additionally, Etl formalised National Lab Day and the annual White House Science Fair, in an effort to bring STEM to the national forefront for all students including those capable of research projects [9].

Change the Equation (CTEq)

The initiative ‘Change the Equation’ (CTEq) which is a non-profit organisation established to manage and increase the efforts of corporations toward enhancing STEM achievement and persistence. It connects to business and education to ensure that all students are receiving highquality STEM education by making schools, communities and states work together to adopt and implement excellent STEM policies and programs.

Possibly the most significant piece of Etl is (CTEq) that includes many of the largest science and technology-related companies in the US, including Google, Intel, Boeing, Microsoft, Exxon Mobil and others. While it seems that CTEq is just gathering steam, the idea of coordinating the efforts of industry toward improving STEM. Additionally, CTEq’s members are actively engaged in: 1) elevating STEM literacy by advocating evidence-based state policies and practices that are known to produce STEM-literate high school graduates; 2) supporting rigorous and high standards for what students should master at each grade level to ensure student success; and 3) increasing their return on investment by supporting evidence-based high-quality STEM learning programs [10].

Race to the Top

President Obama initiative ‘Race to the Top’ was considered as a historic moment in American education. The initiative was aimed to help the states to do systematic reform to improve teaching and learning in schools. ‘Race to the Top’ introduced important change in the American education system, mostly in improving standards and to bring policies and structures in line with the goal of college and career readiness. The program has initiated states nationwide to follow higher standards, improve teacher effectiveness, use data effectively in the classroom, and adopt new strategies to help struggling schools.

More recently, ‘Race to the Top’ initiative has channeled over US\$4 billion to 19 states that have established robust plans that address the four key areas of K-12 education reform as described below. These states serve 22 million students and employ 1.5 million teachers in 42,000 schools, representing 45 percent of all K-12 students and 42 percent of all low-income students nationwide. The four key areas of reform included: 1) Development of rigorous standards and better assessments; 2) Adoption of better data systems to provide schools, teachers, and parents with information about student progress; 3) Support for teachers and school leaders to become more effective; and 4) Increased emphasis and resources for the rigorous interventions needed to turn around the lowest-performing schools.

What makes this initiative more effective is that it focussed on competitions. For instance, in 2012, the Obama Administration launched a ‘Race to the Top’ competition at the school district level known as ‘Race to the Top’ - District. The budget of this program reached \$400 million in 2012 in schools to establish new models to personalise learning for students, so that they can engage their interests and take responsibility for their success. Reports showed that the ‘Race to the Top’ - District competition encouraged transformative change within schools, targeted toward leveraging, enhancing, and improving classroom practices and resources [11].

Mathematics and Science Partnerships

This program advocates higher education (IHEs), local education agencies (LEAs), and elementary and secondary schools to join programs that help to enhance the content knowledge of teachers and the performance of students in the areas of mathematics and science. These programs are planned to:

- 1) Improving and upgrading the status and stature of mathematics and science teaching by encouraging IHEs to improve mathematics and science teacher education; 2) Focusing on the education of mathematics and science teachers as a career-long process; 3) Bring mathematics and science teachers together with scientists, mathematicians, and engineers to improve their teaching skills; and 4) Provide summer institutes and ongoing professional development for teachers to improve their knowledge and teaching skills. [12]

Also, another program called ‘Teacher Quality Partnership’ (TQP) Grant Program aims to increase student achievement by enhancing the quality of new as well as current teachers by a collaborative effort among IHEs including schools/colleges of education, high-need school districts (local educational agencies (LEAs), and high-need early childhood education (ECE) programs[13].

Teachers for a Competitive Tomorrow

As could be seen from all the initiatives mentioned above, it is obvious the teachers are the corner stone of the STEM programs. Therefore, the purpose of the Teachers for a Competitive Tomorrow (TCT) initiative is to first develop and implement programs to provide integrated courses of study in STEM that lead to a baccalaureate degree in science, technology, engineering, mathematics with concurrent teacher certification. Secondly, the TCT aims at developing and implementing two- or three-year part-time master’s degree programs in science, technology, engineering, mathematics for teachers to enhance the teachers’ content knowledge besides the required pedagogical skills. Last, but not least, the program promotes on developing initiatives for professionals in STEM that lead to a master’s degree in teaching that results in teacher certification [14]

3. EUROPE

3.1 State of STEM Education in Europe

Interest in STEM education in the European countries has been on the increase since two decades ago [15]. European countries view that high-quality STEM education is essential for them to be able to compete globally, to sustain the knowledge-based economy and to embrace the digital age. However, there are some difficulties that need to be addressed. For example, recent evidence illuminates that in both mathematics and science, there is an underachievement of 15-yr-old who are still above the ET 2020 benchmark of 15%. Also, the majority of countries across Europe continue to face a low number of students who are interested in pursuing a career in the field of STEM [16]. Meanwhile, there is a need for one million additional researchers to keep Europe growing by 2020 [15]. In addition, there is also a low percentage of girls choosing the field of STEM [17].

According to EU-STEM coalition, there is a need for the workforce to be equipped with ICT skills while STEM graduates need to have core competencies like solving and communication skills which are required in modern business environments. Although the number of people who choose to study STEM subjects in higher education continues to increase, however, the patterns are not the same across the Union. The STEM subjects persist as ‘challenging’ where a major number of STEM graduates preferred to work in other areas than STEM after graduation [18]. In addition, there are challenges regarding teachers. For instance, several reports showed that there is a shortage of teachers especially for the subjects of physics and mathematics in many European countries. There are four reasons behind this problem. The first is related to the age where there is a big gap of age between students and teachers. The second is related to technology where STEM developments in industry and research move rapidly. The third problem deals with training where most of STEM teachers require ongoing professional training. Lastly, the fourth obstacle is the acute shortage of candidates to become STEM teachers [17].

3.2 Policies and Strategies

3.2.1 Education and Training 2020 (ET2020)

‘Education and Training 2020’ (ET2020) is a forum aims at exchanges of mutual learning, best practices, gathering and dissemination of information providing proofs of what works, as well as supporting policy reforms. In 2009, ET 2020 set four common EU objectives to address challenges in the systems of training and education by 2020. The first goal was on how to make lifelong learning. The second objective addresses ways of improving the quality and efficiency of education and training. The third objective aims at promoting equity, social cohesion, and active citizenship. The last aim focuses on enhancing innovation and creativity, including entrepreneurship, at all levels of training and education.

Based on the objectives above, several benchmarks for 2020 were established for a European education. The first decision was to increase the number of students who should participate in their early childhood education reaching 95%, at least. On the other hand, fewer than 15% of 15-year-olds should be under-skilled in reading, science and mathematics and the rate of early leavers from training and education aged 18-24 is supposed to be below 10%. Additionally, at least 40% of people aged 30-34 should have finalised some

form of higher education and at least 15% of adults are supposed to participate in lifelong learning. Most importantly, a proportion of at least 20% of higher education graduates and 6% of 18-34 year-olds with an initial vocational qualification should have spent some time training or studying abroad. The last benchmark was to ensure that at least 82% of recent EU graduates (20 to 34 year olds) should have found employment no more than three years after leaving education [19].

3.2.2 Objectives and Recommendations

The European Union has framed several objectives and recommendations towards science education and STEM. Specifically, six high-level objectives of the Framework for Science Education for Responsible Citizenship have been identified. The first objective is that science education should be a necessary component of a learning continuum for educational processes, from pre-school to active engaged citizenship. The second objective is to make science education focuses on competencies with a special emphasis on learning through science and, then, shifting from STEM to STEAM through linking science with other subjects and disciplines (In STEAM - A includes ALL other disciplines). Hence, all levels should comprehend the significance of science education as a means of acquiring key competencies to simplify the transition from “education to employability” (E2E) by learning about science through other disciplines and learning about other disciplines through the subject of science. The third objective focuses on the quality of teaching through induction during both pre-service preparation and in-service professional development to improve both the depth and quality of learning outcomes. In this way, several processes should be taken to continually improve teaching quality, with more focus on teacher competencies and disciplinary knowledge. Besides, efforts should be undertaken to attract more highly motivated and qualified people to become teachers and to boost the prestige and status of the profession where appropriate methodologies should be established for teaching research ethics as well as raising the awareness of research integrity.

Consequently, the fourth objective focuses on the collaboration between formal, non-formal and informal educational providers, enterprise and civil society. This partnership should be developed to ensure relevant and meaningful engagement of all societal actors and their relation with science and, thus, increase uptake of science studies and science-based careers to improve employability and competitiveness. The reason beyond that is to promote real

partnerships between teachers, students, researchers, innovators, professionals in the enterprise including other stakeholders in science-related fields, to work on challenges and innovations of real-life, including associated social, ethical and economic trends. The fifth objective was to promote responsible research and innovation (RRI) and enhance public understanding of scientific findings as well as the capabilities to explain their benefits and consequences. Based on this perspective, the link between researchers, scientists, science educators and the media should be strengthened to ensure more effective public communication, in such a way that makes the consequences and underlying issues understandable by stakeholders. This makes them directly and actively involved in innovation projects and scientific research. Finally, the sixth objective was to put more emphases on connecting science education strategies and innovation, at local, regional, national, european and international levels, taking into account societal needs and global progress where science education should benefit from the international experiences and guidelines. In other words, sharing knowledge about STEM should be actively pursued with international partners recognising solutions for global societal challenges that face humankind [15].

3.2.3 EU STEM Coalition

The EU STEM Coalition consists of Netherlands, Denmark, Estonia and Belgium. It was launched on the 2nd of October 2015 and gets the support of several European organisations such as CSR Europe, FEANI and Ecsite. According to the brochure of the EU STEM Coalition [18], there is a need for several actions to be taken to develop the STEM education in the Europe Union. The first action is to find out how to increase children’s interest in mathematics and science at school. Additionally, it is necessary to ensure that the STEM subjects in higher education equip students with a comprehensive range of competencies, including important transversal skills such as flexibility, creativity and an entrepreneurial mindset. Moreover, the STEM Coalition is responsible for building beneficial alliances between educators, employers, government and other partners to reach a common understanding of the required skills.

Consequently, to meet the need of economic welfare and innovation, several EU members state articulated national strategy depending on national STEM platforms called ‘triple helix’ which bases on the close cooperation between the ‘triple helix’ of government, business and education. In this way, the EU STEM

Coalition aims at addressing the need for innovation, growth and jobs, and to boost economic competitiveness with the help of technological innovation, by finding out a momentum for the implementation and development of national STEM strategies in the state of EU member [18].

3.3 STEM Education Initiatives

Several initiatives have been introduced throughout the European States regarding the STEM approach. Most of these initiatives have overall strategies to develop science education initiatives to encourage STEM studies. For instance, there were more than one thousand initiatives in Germany in 2001 and 470 initiatives in the UK in 2004. Generally, it is estimated that between three-thousand and five-thousand initiatives have been introduced in Europe [17].

3.3.1 Initiatives to encourage STEM studies

According to *Kearney* (2015) [16], to encourage younger generations to pursue STEM studies and professional careers, numerous policy approaches have been identified. These approaches include 1) Development of effective and attractive STEM teaching methods and curricular; 2) Enhancement of training for teachers and professional development; and 3) Guiding younger generations towards STEM careers through initiatives that tackle the social perception of STEM professions, career guidance including information on the labour market [16].

3.3.2 Cooperation with employers

There was also a significant number of STEM efforts initiated by the EU that focused on the collaboration among employers. The reason behind this is to encourage students to follow STEM careers, which increasingly tends to develop further cooperation between companies and schools. Mainly, these initiatives recommend strengthening the relationship between educators and students in schools, professionals of STEM in the workplace and to guide students towards STEM. This can be organised through visits from university students or STEM professionals to schools or by teachers and students to places of work. Hence, implementation of recent education reforms in EU have been executed by strengthening links between the labour market sphere and education through involving social partners and companies in curricula

improvement in several countries as an approach to ensure that the provision of professionals is in line with the various economic needs. On the other hand, marketing campaigns were not ignored by many initiatives to attract young people to appropriate educational paths [20].

3.3.2 inGenious

inGenious is one of the largest and most strategic projects in science education which is funded by the European Commission. The aims of *inGenious* are to increase young Europeans' interest in STEM education and careers, addressing the lack of interest in STEM subjects and future skills gaps as serious challenges. As such the innovative practices for engaging the course of STEM teaching are important for the *inGenious* programs. Key goals of the program are to enhance pupils' interest in STEM subjects and careers through providing teachers, school counselors and career advisers with required resources and ideas. The course consists of eight modules, which develop a learning path through the analysis of the reasons behind pupils' disaffection for STEM to the experimentations and development with innovative practices to overcome such difficulties.

The eight modules include 1) Increasing student's engagement to study STEM; 2) Original teaching practices in the STEM classroom; 3) Innovative STEM teaching using STEM resources from across Europe; 4) Discovering virtual and remote labs and how to use them in the classroom; 5) Exploring STEM in the real world through virtual visits to research centers; 6) Helping students to understand what STEM jobs are as career counselling; 7) Meeting real life STEM professionals; and 8) Dealing with stereotypes. Some of the *inGenious* major achievements are the Network of 340 *inGenious* teachers, a network of over 40 partners and associate partners ready to help schools and teachers, extended network of over 1500 *inGenious* teachers, collection of 158 school-industry collaboration practices, teachers and students evaluation of 34 school-industry practices [15].

4. SINGAPORE

4.1 State of STEM Education in Singapore

Singapore has the honour to be the top STEM educated country in the world. It has scored the highest ranking in all subject areas in the Programme for International Student Assessment (PISA 2015). Singapore is roughly 18 score points ahead (equivalent to half a year of schooling)–of the next highest-scoring country on the PISA science test, eight score points ahead of the next highest-scoring country in reading, and 16 points ahead of the next highest-scoring country in math. Additionally, the country also dominates the Trends in Mathematics and Science Study TIMSS 2015 math and science rankings at the fourth and eighth-grade levels. Singapore is considered an all-star when it comes to the performance of its students on international tests, regardless of the types of questions being used or the age or grade level being tested. At the same time, many people feel that there are limited lessons for other countries to learn from Singapore given the country's small size and unique features that do not necessarily translate well to other education systems, particularly those in developing countries [21].

4.2 Policies and Strategies

The Singapore's education system, policies and practices in the last 50 years grew through three steps in parallel with the rapid socioeconomic changes taking place both at local and global educational landscape. The first is characterised as 'Survival-driven' (phase 1960-1970). In which Singapore has developed her own education system where many schools were established, numerous teachers were recruited and trained, and a large number of students were enrolled in the newly established schools. The second phase is described as 'Efficiency-driven' (1970-1990). In this phase, the government aimed to ensure that students continued their education as requirement for all jobs within the country. A high educational standard was put in place by the government to reduce the number of students' dropout. This was achieved by centralising the curriculum and standardising textbooks and practices for schools. Measures were used to ensure that teachers followed centrally instructed curriculum and teaching practices. The graduate students rates rose by the end of the 1980s and more changes happened in the late 1980s where the Ministry began to think on how education can be used for the needs brought by a knowledge-

based economy through establishing independent and autonomous schools. By the mid-1990s, there was a need to reorganise the entire education system as to stay responsive to the knowledge-based economy, and it had to be customised to meet the needs of schools. Fundamentally, the purpose of schools were to educate individuals to think, change and respond to the needs dictated by the knowledge-based economy [22].

The third phase is described as 'ability-driven paradigm.' In this stage, the 'Thinking Schools, Learning Nation' (TSLN) initiative was put in place from 1997 onwards. The aim was to change the education system by developing a culture of deep thinking and learning. Three key principles guided TSLN: Firstly, strong measures were taken to raise the quality of teachers. This was accomplished through the review of remuneration for teachers and also by stronger professional development initiatives through teachers' networks. Secondly, TSLN gave school leaders more autonomy. Thirdly, the establishment of school inspectorate system with the introduction of School Excellence Model (SEM). This was to enable schools to flourish as the SEM was a model that laid the responsibility and ownership for improvement on the shoulder of the schools itself. In order to galvanise the autonomy movement and SEM, the cluster system was introduced by the Singapore government. Schools were organised into communities and mentored by superintendents. Clustering enabled schools to reflect on their practices and created platforms for schools to learn professionally from each other [22].

In 2005, a new initiative was introduced called 'Teach Less, Learn More' (TLLM). It was a continuation of TSLN, but it focused more on classroom pedagogy and getting teachers to reflect on how they are teaching, and what they are teaching to improve students' learning within an open sharing culture. Additionally, teachers began to look more deeply into their work as to innovate teaching and learning. On the other hand, the ownership belonged to teachers and schools, with school leaders providing them with the necessary support to improve their pedagogy and engagement with the students. At the systemic level, Ministry of Education (MOE) had to be flexible enough to relinquish control and facilitate ownership by supporting schools in this journey. The fundamental purpose of these reforms was to strengthen the professional practices of the entire teaching profession, by strengthening leadership, curriculum instruction and teachers' pedagogical practices [22].

Based on the initiatives mentioned above, all Singapore schools are now striving for excellence and trying to improve accordingly. Teachers are also striving for greater professionalism. The next phase could be a continuation of both the TSLN and TLLM initiatives. Currently, the education system aims to foster stronger values-driven professionalism in the teaching community based on strong teacher identity, shared professional ethos and learner-centeredness [22].

4.3 Singapore Education-Characteristics, Program, initiatives

Ministry of Education- Singapore (MOE) aimed to give each child a broad and deep foundation for a lifelong journey of learning and to provide additional support for those who need it.

4.3.1 Curriculum 2015

The Curriculum 2015 (“C2015”) Committee was established to review the curriculum, assessment and pedagogy of Singapore schools. The evaluation and appraisal of the Singapore education system by C2015 was accomplished by engaging with many stakeholders such as educators, parents and industry employers. The committee has established some principles on what to learn and how to learn and has vision on Strong Fundamentals, Future Learning as listed in the following Table [23].

| | |
|--------------------------------------|--|
| Strong fundamentals. | High standards of knowledge, skills and values are maintained, especially in key areas such as languages, mathematics, science, humanities and physical well-being. |
| Future orientation. | The curriculum is reviewed on a regular basis and incorporates future learnings for students to live and work as fully-functioning adults. |
| Broad-based and holistic curriculum. | Students access learning in the cognitive, moral, social, moral, physical and aesthetics domains. |
| Finer customisation of learning. | Curriculum, pedagogy and assessment are customised according to students’ profiles, interests, abilities and talents so that they can maximise their individual potential. |

Challenging and enjoyable learning.

Learning is a positive and fulfilling experience for all students as they learn in and outside the classroom. There is high expectation for all and strong teacher-student relationships. The curriculum stretches capable students and scaffolds less able students to enable them to experience success.

4.3.2 Masterplan3 (2009-2014)

Masterplan initiatives were revealed in 2009, aiming at achieving several goals to enhance learning. The first objective was to equip Singaporean students with the critical competencies and dispositions to succeed in a knowledge economy. ICT is among the scale that could help improve many of these competencies. The second goal was to tailor learning experiences according to the way that each student learns best. In other words, it improves the teacher ability to detect on what had happened in student learning for better outcomes. The third objective is to encourage students to go deeper and advance in their learning. For those who can and want to go further in any subject, ICT is a powerful adjunct for learning. For instance, technology allows scientific concepts like atomic structures or protein structures to be better understood using 3-Dimensional representation, as compared to traditional 2-Dimensional representation. The use of tools such as data loggers can help automate laborious operations such as data collection and graph plotting, thus freeing up time for more important data analysis and design of experiments. Finally, the fourth objective was to learn anytime, anywhere. In this way, the use of ICT allows such mobility and flexibility in learning, freeing it from the physical confine of classrooms and the rigidity of structured curriculum time.

According to Masterplan3 the above mentioned objectives can be achieved by integrating ICT during planning and design of lessons plans by focusing on improving the capabilities and skill sets of teachers. The best practice and successful innovations need to be shared across schools and further building up infrastructure to maximise the potential of ICT [23].

4.3.3 STEM INC

In February 2014, Science Centre Singapore had set up its new STEM INC unit, which developed and implemented the Science, Technology, Engineering, and Math Applied Learning Programs (STEM ALP). The program aimed to help pupils with age ranged from 13 to 15 to use what they learned in STEM subjects to solve real-world problem. STEM INC aims to give students a strong sense of ownership in their learning while helping them see the relevance of STEM to their future career options.

Hence, the name “STEM INC” represents two major notions. The first is that students are incorporating STEM knowledge into the real-world problem-solving. The second indicates that students should look at STEM as an enterprise through which they can create wealth or future for themselves [24].

5. MALAYSIA

5.1 Current State of STEM

Malaysia has considered STEM education as an important factor in building nation and the economy starting from the 1970s. Since then, numerous efforts have been carried out to improve STEM education status. However, there are some issues that related STEM education in Malaysia such as shortage of localised STEM learning materials and the weak interest of students to continue in STEM related studies at secondary and tertiary levels. Other issues were related to non-option teachers teaching STEM subjects, inappropriate STEM teaching and learning strategies, as well as suitable assessment procedures which inspire further STEM learning, are the significant factors that need to be considered as to create an effective and yet meaningful STEM learning experiences in Malaysia [25].

All international indicators showed that for Malaysia to become a developed nation, she needs to strengthen her STEM education. For instance, Malaysia's performance in TIMSS from 1999 to 2011 showed that students' performance is not promising. The results of PISA (2009) showed that Malaysia ranked in the bottom third of 74 participating countries, below the international level and the average of OECD (Organisation for Economic Co-operation and

Development). These findings revealed that there is an urgent need for a strong intervention as to achieve the targeted number of STEM related graduates and to enhance future students achievement.

According to the assessment of MOE education blueprint, the STEM education in Malaysia has been affected by several factors. The first of these factors is the limited awareness about STEM where there is a perception amongst students and parents that STEM subjects are harder than Arts subjects. In other words, there is a general lack of awareness among students and parents of the value of STEM learning and its relevance to everyday life. The second factor is the current STEM curriculum places greater emphasis on content at the expense of practical aspects and does not sufficiently emphasise its relevance to everyday life. The third factor is related to the inconsistent quality of teaching and learning where the approaches are teacher-centred, and students lack sufficient opportunities to be critical, creative and innovative. Moreover, several teachers also lack the requisite knowledge in Science and Mathematics subjects. The last factor refers to a limited and outdated infrastructure where 20% of schools have Science labs that are damaged and no longer functional, and some schools also lack modern equipment and facilities [26].

5.2 Policies and strategies

In 1967, Higher Education Planning Committee reports recommended that the range of students in Science/Technical stream compared to that in art stream is to be at the proportion of 60:40, or what is called now 60:40 policy [27]. The Malaysian's Ministry of Education started to implement this policy in 1970. This strategy put the benchmark for scientists, engineers, doctors and highly skilled technicians needed to participate in the nation building. However, to date, Malaysia has not yet achieved the targeted ratio of 60:40 [28]. Subsequent policy, national science and technology policy, was announced by the Malaysian government in 1987. This policy articulated the framework of science and technology and development in Malaysia and aimed to boost the scientific inventions and improve infrastructure in science, education and related area [29].

In 1991, Vision 2020 was established. The aim was to move Malaysia to the industrialised developed countries. One of the goals was for the country to progress into a scientific and progressive society. The investment in science and innovation is one of the strategies identified towards developing the country [30].

Consequently, a Malaysian Education Blueprint (2013-2025) was developed. The Blueprint was a concerted effort by education experts from UNESCO, World Bank, OECD, and six local universities with input from principals, teachers, parents, students, and other members of the public from every state in Malaysia. The aim is to prepare Malaysia's children for the needs of the 21st century and increase public and parental expectations of education policy. To achieve a quality education of an international standard, strengthening the quality of STEM education has been suggested. The Ministry aimed to ensure that it prepares students with the skills required to meet the challenges of the world that is being transformed by the applications of science, technology, engineering and Mathematics (STEM). Also, the blueprint will lay the foundations at the school level towards ensuring that Malaysia has a sufficient number of qualified STEM graduates to fulfil the employment needs of the industries that fuel its economy. Measures undertaken will include several factors. The first deals with raising student interest through new learning approaches and an enhanced curriculum: incorporating higher-order thinking skills, increasing use of practical teaching tools and making the content relevant to everyday life. The second focuses on teachers, aiming at sharpening skills and abilities of teachers: training teachers in primary and secondary schools to teach the revised curriculum. Last, but not least, the third focuses on building public and students' awareness: increasing parents and students' STEM awareness through national campaigns.

The Malaysia education blueprints have drawn the road map for strengthening the delivery of STEM across the education system in three waves, as illustrated in the following table [26].

Wave 1 (2013 - 2015): strengthening the Foundations

- Raising student outcomes and interest through new learning approaches and an enhanced curriculum
- Sharpening skills and abilities of teachers
- Building public and student awareness
- Encourage upper secondary students to enrol in the Science stream.

Wave 2 (2016 - 2020): Building on the foundations

- roll-out of the KSSM (Secondary Schools Curriculum Standard) and revised KSSR curriculum (Primary Schools Curriculum Standard)
- Ministry will begin participating in the Grade 4 TIMSS assessment encourage the development of inter-school learning communities to enable teachers to share their experiences in teaching the new curriculum the Ministry will upgrade existing Science equipment and facilities in schools
- The Ministry will extend its STEM awareness programmes to primary school students and their parents.
- The Ministry intends to adopt an informal approach to strengthening interest in STEM education
- The Ministry will also encourage teachers and students to take greater advantage of informal learning centres

Wave 3 (2021 - 2025): innovating to the next level

- Ministry will evaluate the success of all initiatives from the first two waves and develop a roadmap for the future.
- It will introduce fresh initiatives and programmes as required.

5.3 STEM Education Initiatives

5.3.1 Blended Learning Open Source for Science or Mathematics Studies (BLOSSOMS)/ National Blue Ocean Strategy (NBOS) on STEM education/21st Century Learning

Universities and other academic institutions have also initiated efforts to improve the STEM education approach in Malaysia. For example, the collaboration between Ministry of Education, Universiti Teknologi Malaysia and Massachusetts Institute of Technology supported the idea of STEM learning through video library. The videos give lessons in science and mathematics and are freely available online. Around ten video lessons on various Science and Mathematics topics were proposed by the group. This type of learning offers teaching and learning in an active, creative and critical way. Another effort was to build Modular Science Laboratory. In 2015, the National Blue Ocean Strategy - Program Inisiatif Libat Sama (Collaborative Initiative Program) (NBOS-PILS) commenced its pilot project at Sekolah Agama Menengah Tinggi Sultan Hisamuddin, Klang to build a Modular Science Lab. This program offers significant acceleration towards the provision of hands-on STEM learning at a lower cost and a shorter period. The 21st Century Learning Programme aimed to develop thinking and problem-solving skills through dynamic classroom environment. To date, a total of 1,249 primary schools and 665 secondary schools have implemented the programme. The impact, progress and expansion of the programme are monitored by State Education Department (JPN) in the respective states [31].

5.3.4 EduWebTV

The establishment of an e-learning video library for students is another effort by MOE to facilitate teaching and learning in STEM. These short videos focus on explaining specific topics and cover multiple subjects, including the critical subjects of Bahasa Malaysia, English language, Science and Mathematics. The Mini One is to enhance the quality of this library by having Schools Inspectorate and Quality Assurance or Jemaah Nazir dan Jaminan Kualiti (JNJK) curate all submissions to ensure that they are of high quality, and drawing on other websites that offer comparable e-learning content (for example, the Khan Academy or Learn zillion videos for mathematics and science). The Ministry also aimed to map these videos to the curriculum to make it easier for students to search for contents [26].

6. STEM FROM EDUCATION PERSPECTIVE

Based on the above overview, an important question that might arise is ‘What is STEM in the eyes of educationists?’ In other words, what is the status of STEM from the pedagogical perspectives? In this subsection, this issue is briefly highlighted. Most of the educational research devoted on STEM revealed that this significant approach persists as unaffordable luxury. To explain further, educationists in different parts of the world see STEM education as an interesting conundrum. They view it as the typical approach that can be followed to reach the ultimate goals in a shorter time with a higher level of professionalism. However, this unabridged ambition needs unique efforts. To achieve satisfactory STEM education, the whole pedagogical approaches all over the globe should focus on a wide-ranging approach to recognise a standardised STEM education. To realise such a dream in a real educational context, learners should be the main focus, where activities in class should be more learner-centred. As students are the ultimate target of the various educational processes, they should be exposed to STEM education at a very early stage. On the other hand, teachers should be equipped with the whole academic and professional requirements that can help contribute to a true and typical pedagogical models of outstanding and well-rounded methods of STEM teaching.

Several STEM education researchers, such as Md. Mokter Hossain et al. (2012) [32], Kennedy et al. (2014) [33] and Muhammad Abd Hadi Bunyamin et al. (2016) [34], insisted that STEM curriculum should play a vital role in STEM education. Additionally, at all school levels, STEM curriculum should be technology-driven, where both teachers and learners should be technologically literate. In short, STEM education dilemma needs interdisciplinary efforts to achieve success.

7. CONCLUDING REMARKS

In summary, the pedagogical approach, STEM, is a vision which is being addressed as a necessary educational technique that can lead nations to an innovative future. In other words, STEM should be dealt as a saviour of the generation education since it inspires and stimulates beneficial professional actions among various stakeholders. The following are some of the major conclusion drawn from the above discussion:

1. There should be an adequate number of teachers who are professionally skilled in STEM subjects enabling them to teach students who have superior skills in STEM. To achieve this purpose, there should be a continuous development programs for professionals in STEM that lead to a qualified and certified teachers in STEM.
2. As in the case of Europe alliance, STEM should be firmly interrelated to private companies and labour market so that students can be positively motivated as STEM can work as a bridge for their future.
3. It is important to encourage students to pursue STEM careers, which increasingly tends to develop further cooperation between companies and schools. Moreover, STEM should be accompanied with learning autonomy.
4. It is highly recommended for schools to form a cluster system where schools can be organised into communities and supervised by superintendents. The process of clustering enables schools to widen their practices and, thus, new and broad platforms can be created for schools to learn from each other professionally.
5. To encourage ubiquitous teaching and learning of STEM, relevant authorities should develop ICT infrastructure which is compatible with both mobility and flexibility that constitutes the core of the learning processes. In other words, ICT can be the vehicle that will free learning from traditional and classical classrooms and at the same time saving both money and time for schools.
6. Educationalists and policy makers should think of a distinctive approach that can lead to a standardised STEM, that is understandable by all stakeholders in general and learners in particular according to educational contexts. The approach should emphasise on the curriculum content and avoid biasness with regard to gender, age and culture.

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CHAPTER TWO

STEM EDUCATION: ISSUES AND WAY FORWARD

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ABSTRACT

Science, technology, engineering and mathematics (STEM) workforce is a key component in the creative and knowledge-based economy which is driven by innovation. This in turn is a key ingredient for creating new business clusters and jobs. In addition, STEM competencies are important both in the STEM and beyond STEM occupations. Thus, the emphasis on promoting STEM education is escalating locally and globally. However, the discussion for STEM education varies across contexts and stakeholders. While, diversity of ideas lead to enrichment it can also be a hindrance to the advancement of STEM education. It is the aim of this chapter to highlight issues related to STEM education in the literature namely on a) definition of STEM education, b) approaches to STEM integration, and c) resources supporting STEM education. The chapter also provides evidence and personal views on how Malaysia has responded to the issues. This chapter then proposes possible policy implications and strategies in promoting and enhancing effective STEM education in Malaysia.

1. INTRODUCTION

Science, technology, engineering, and mathematics (STEM) are the foundation of the modern world. As early as the 70s, Malaysia has given priority in science education or commonly known as Science and Technology (S&T) education which includes mathematics and technical based education at both school and tertiary levels. S&T education plays a utilitarian purpose namely providing a country like Malaysia with three kinds of intellectual capital: (1) scientists and engineers who will continue research and development as the core to the economic growth of a country, (2) technologically proficient workers who are capable of dealing with the demands of a science-based, high-technology workforce, and (3) scientifically literate voters and citizens who make intelligent decisions about public policy and who understand the world around them (Reeve, 2015).

The above aims of science education are still echoed in the current objectives of the STEM initiative in Malaysia at the school level - "is to produce students who have knowledge, skills and values in the STEM fields in order to increase the number of experts, which is expected to spur the country's economic development" (pg. 10. CDC 2016). As to remain globally competitive, Malaysia needs pool of workers of all races, men and women, excelling in science and engineering and considering careers in STEM. The National Council for Scientific Research and Development estimates that Malaysia will need 493,830 scientists and engineers by year 2020 (MOE, 2013). At the current scenario, the Ministry of Science, Technology and Innovation (MOSTI) (2012) estimates that there will be a shortfall of 236,000 professional in STEM related fields. The importance of a society that is literate in STEM is specially relevant to the sustainability of a society (economically, socially and environmentally) in this rapidly changing world and economy (Halim 2013).

The current situation shows that the quantity and quality of human capital related to STEM is in need of attention. In terms of quantity, students' enrolment in the science stream (pure science subjects) decreased to as low as 29 percent (Jatarajah et al. 2014). The lack of students' participation in STEM is further exacerbated when students who have done well in high school tend not to graduate with degrees in science and engineering (Dodson, 2013). In 2011, only 45 percent of students graduated were from the science stream, including technical and vocational programs. There was an increased of approximately 15 percent secondary school students who met the requirement to study Science after Lower Secondary National School Assessment (PMR), but chose not to do so (Osman and Saat, 2014).

In terms of quality, according to Martin et al. (2012) based on the TIMSS 2011 performance, a total of 18 percent of Malaysian children has limited prerequisite knowledge and skills in science classrooms, meanwhile, 55 percent of them had limited prior knowledge in science. Many students are not graduating from high school with the knowledge and capacities required to pursue STEM careers or understand STEM related issues in the workforce or their roles as informed citizens. This raises concerns about the education system's ability to produce sufficient STEM graduates and literates for the society well-being.

The workforce of the 21st century must have science and mathematics skills, creativity, fluency in information and communication technologies and the ability to solve complex problems including social issue. The target of STEM education is to encourage students to pursue STEM careers in order to meet the growing need for trained professionals in these areas (Dodson, 2013).

2. WHAT IS STEM EDUCATION?

According to Dugger (2010) and Reeve (2015) a basic definition of each of the STEM areas is as follows, Science is a study of the natural world; Technology is modifying the natural world to meet the needs and wants of society; Engineering is using math and science to create technology and Mathematics: a language of numbers, patterns, and relationships that tie science, technology, and engineering together.

However, there are many definitions and interpretations of STEM education and no clear consensus on its meaning as observed by Bybee (2013):

'When STEM first appeared in education contexts, it caught the attention of several groups. Botanical scientists ...thought educators had finally realised the importance of a main part of the plants. Technologists and engineers were excited because they thought it referred to a part of a watch... political conservatives were worried... they thought it was a new education emphasis supporting stem cell research' (pg. 1-2)

In Malaysia, the concept of STEM education at the basic education (primary and secondary levels) has three strands- STEM field, STEM stream and STEM approach (CDC 2016):

- i) STEM as a field covers traditional disciplines such as Medicine, Engineering, Food Technology, Physics, Chemistry, Biology, Mathematics and Statistics, as well as the more specialised disciplines such as Astrophysics, Biochemistry and Genetic Engineering.
- ii) STEM Stream refers to enrolling of students in upper secondary school to a stream of their choice and inclination. Thus, the Ministry of Education has outlined the STEM stream as six packages a) Pure Science Package (e.g. Physics, Chemistry, Biology, Mathematics, Additional Mathematics), b) Pure Science and Professional Elective Subjects (S&T) Package (e.g. Technical Communication Graphic, Computer science), c) Pure Science and Religious Study Package (e.g. Islamic Syariah Education and Arabic Language), d) Science and Additional Science Package (e.g. additional science, additional mathematics and any electives of the students choice), e) Science and Additional Mathematics Package (e.g. additional mathematics and any electives of students choice) and f) Science & MPEI (Science) Package (e.g. Basic Sustainability and Sport Science). For an overview of subjects offered in each package, please refer to Appendix for sample packages in CDC (2016).
- iii) STEM approach refers to a pedagogical strategy that emphasises application of knowledge, skills and values from the disciplines of Science, Technology, Engineering and Mathematics, in an integrated manner to help students solve problems encountered in the real world. The element of engineering and technology is integrated in the approach as students are encouraged to critically and creatively solve the related STEM problems.

Based on the conceptions and experiences, STEM education is usually referred to science or mathematics subject. In this case, STEM education refers to a stand-alone STEM course (for example physics or calculus) or a program of study that includes a variety of courses from the STEM areas (CDC 2016 ; Reeve 2015). It is seldom that STEM being referred to technology or engineering. The term technology also has varied meanings as some refer it to ICT based and others refer it to the technological product or artifact itself (e.g. chip board, hand phone, car). As for engineering discipline, engineering design thinking is the focus of STEM education either as a curricular approach or as a means to develop technology that require meaningful learning and as an application of mathematics and science concepts through project based and inquiry based teaching and learning.

Although there is no clear consensus on the meaning of STEM education, the varied meaning suggests that the desired educational aims and namely developing human capacity building for STEM workforce and STEM literate society for Malaysia appear to be an ongoing continuous process. Evidence from the current achievement and progress as well as the rapid advance in science and technological, warrants for such an educational aim. Enhancing the interest in stand-alone subjects such as physics, is still needed and important, despite addressing the issue as early as the 70s. At the same time the need to view STEM education as an integration of various disciplines should be promoted and emphasised since tackling solutions today's complex problems reflect the need of an interdisciplinary based solution- thus often known in the literature as STEM integration education.

Therefore, concept of STEM education in Malaysia as viewed by many to fall along a continuum from comprising one stand- alone subject to a more integrated subject. In terms of approaches to STEM teaching and learning, it should also fall along a continuum from an effective meaningful lecture approach to project based, problem based and inquiry approaches. Currently STEM education is being promoted through the formal system of education. At the same time, various stakeholders (e.g. NGOs, Industries, and Universities) are also promoting STEM education through various informal STEM programs. The informal STEM learning provides an effective venue for STEM integrated education.

3. APPROACHES TO STEM INTEGRATION

The current debate on STEM education is towards advocating for STEM integration (English 2017). The argument for STEM integration is that school subjects have long being taught in isolation but the nature of work and solutions for STEM related challenges need multidisciplinary, interdisciplinary or transdisciplinary approach. Tsupros ,Kohler & Hallinen. (2009) provide an often quoted definition of STEM education that is:

“an interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons as students apply science, technology, engineering, and mathematics in contexts that make connections between school, community, work, and the global enterprise, enabling the development of STEM literacy and with it the ability to compete in the new economy.”
(Tsupros et al., 2009)

Therefore, STEM integration education offers meaningful learning to students whereby students are able to see how concepts and skills from various disciplines are being used to solve real-world problems. These real world problems are often introduced as a learning context at the beginning of a lesson as compared to the traditional way where solving hypothetical problems or everyday problems that are of not of their interest is often dealt with at the end of a STEM lesson. However, STEM integration education also faces many challenges and critics.

As argued by English (2017), the challenge for STEM educators is ‘*how to effectively integrate the disciplines and at the same time ensuring the integrity of each*’ (pg. 3). In addition, science teachers are traditionally trained to specialise in teaching a particular subject, e.g. chemistry. At the same time, science teachers also claimed that integration, namely science and mathematics, have already being done in their current practice. The following lists some definitions of STEM integration approach with some examples of STEM integration lessons in the related literature for further understanding of the integration concept and make STEM integrated education a possibility.

Examples of STEM integration

There are three main integration approaches in the literature: multidisciplinary, interdisciplinary and transdisciplinary (Drake 1991; Vasquez, Sneider, Comer 2013). Vasquez, Sneider and Comer (2013) have succinctly provided a description of each type of integration:

- a) Multidisciplinary- students learn concepts and skills separately in each discipline, but in reference to a common theme. For example, the common theme is Solar system. Activities from various subjects or disciplines that can contribute to the theme can be drawn in. Figure 1 shows an example of multidisciplinary approach adapted from Vasquez, Sneider and Comer (2013). Such an approach helps students to connect ideas across subjects in an engaging context.

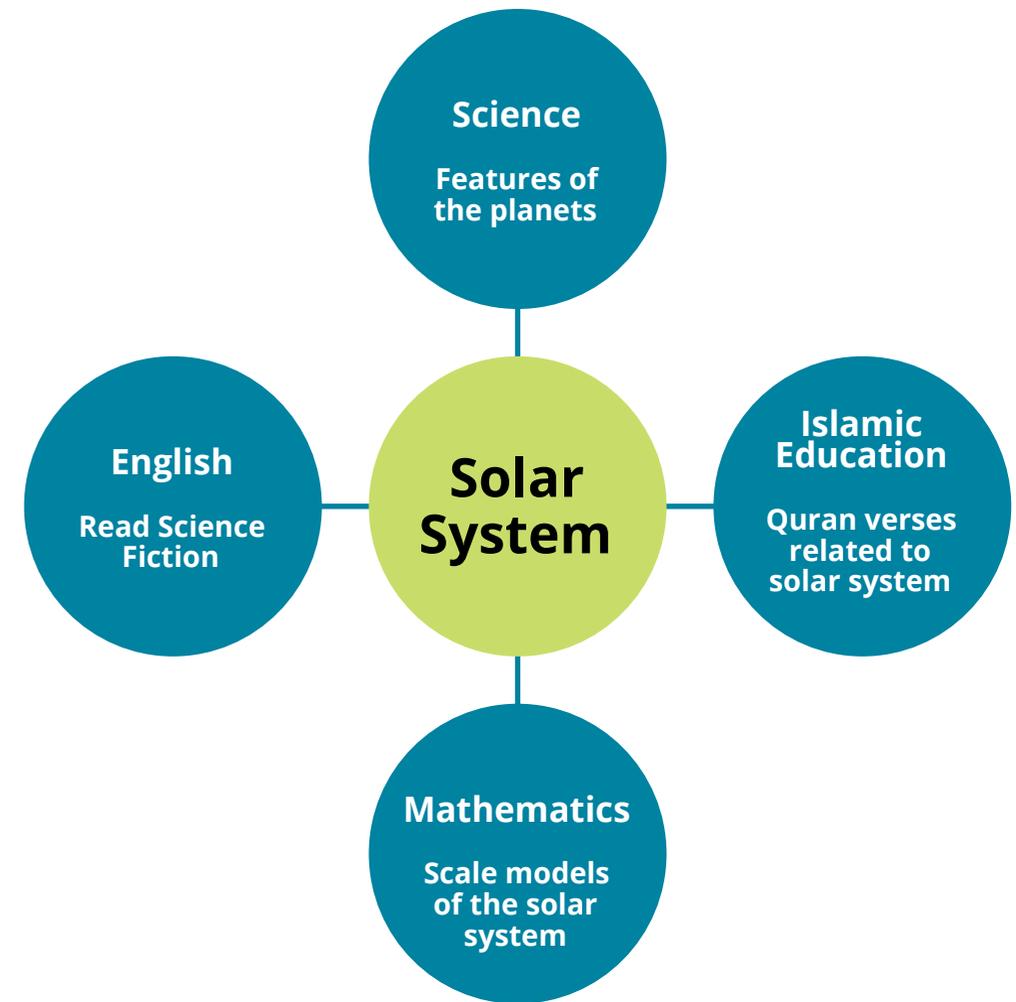


Figure 1: A multidisciplinary approach

- b) **Interdisciplinary**- this approach draws a key concept or skill that is important for all students to learn; and the same concept or skill is common or embedded in two or more subjects. Another view of interdisciplinary is that teaching and learning is organised around application of skills and concepts from different subjects. Thus, students' learning of the concept or skill is meaningful and enriching when they are able to see the connection of the disciplines that they might learnt separately. Based on Vasquez, Sneider and Comer (2013) example of Solar system again, the interdisciplinary approach can be explained as in Table 1.

Table 1: The interdisciplinary approach

| Example 1 | | |
|--|---|--|
| Common concepts to both disciplines | | |
| Science | Size and Distance Scale | Mathematics |
| Investigate how planets in the Solar system e.g. Sun and Earth are the same and different? | | Use understanding of ratio to estimate size and distance of Sun from Earth |
| Example 2 | | |
| Engineering | Solar system | Technology |
| Design a telescope | How can telescopes be used to study the features of Moon and Jupiter? | Ideas or inventions of previous telescopes |

Note: Interdisciplinary approach can involve more than two disciplines.

- c) **Transdisciplinary** approach- the teaching and learning is student-centred and grounded in the real world application of content- not based on any subject matter. In this approach, the real world problems are not well defined and there is no one correct answer. Thus, students are to apply their knowledge and skills and in doing so are able to develop their 21st century skills such as team work, creative thinking and problem solving abilities. Examples of transdisciplinary approach are a) the topic of global warming- students are

expected to relate the solution of global warming through social, political, economy and environmental perspectives, or b) how would a meteorologist forecast a weather on planet X?

Drake (1991) as well as Vasquez, Sneider and Comer (2013) argue that none of these integration approaches is better than the other. These approaches vary in terms of level of integration and it can be used from the primary to graduate school. The types of integration used would depend on the needs and contexts of the teaching and learning situation. For STEM integrated education, the transdisciplinary approach is the most relevant.

Together, Stohlmann, Roehrig and Moore (2014) and English (2017) explicitly highlight the role of engineering in the acronym of STEM- where the concept 'E' is generally overlook in the discussion of STEM education. Engineering is a natural connector for integrating STEM disciplines in the classroom given the need for engineering design solutions to use mathematical and scientific ideas (NRC 2011). The integrated approach uses engineering design (includes thinking processes: ask, imagine, plan, create and improve) as a means to develop technologies that require meaningful learning and an application of mathematics and/or science through project-based, problem-based and inquiry-based.

Stohlmann, Roehrig and Moore (2014) provided examples of SEM connections for various learning contexts that suggest the need of engineering design principles in the learning activities (see Table 2). Table 2 also provides learning contexts that not necessarily involved any of the SEM disciplines.

Table 2: Subject matter connections for various learning context

| Context | Science | Engineering | Mathematics |
|--|---|----------------------------|--|
| Design a solar car that moves the furthest and in a straight line. | Fleming's left hand rules, Friction force, normal force, external force | Engineering design process | Illuminating angle Ratio |
| Determine if a gold crown is real or fake | Mass, Volume and Density | - | Slope and analysis of graphs |
| Design a kite | - | Engineering design process | Scale drawings Concepts of parallelograms |

Source: Adapted from Stohlmann, Roehrig and Moore (2014) pg. 20

English (2017) has then provided a comprehensive STEM integration matrix that takes into account the role of content (primary, supporting or absent) and role of context (disciplinary contexts and background contexts (e.g. societal or historical issues)). This matrix can act as a tool to guide on how to analyse, categorise and create the content and context of integrated STEM activities (see Table 3). This table also allows the variations of STEM education that are and can be introduced such as STEAM where the A word refers to Arts.

Table 3: Sample of STEM integration matrix

| Content | Science | Technology | Engineering | Mathematics | (Arts) |
|----------------------|----------|---------------|--------------|-----------------|--------|
| Primary Supporting | x | | x | x | |
| Context Disciplinary | | x | x | | |
| Background | Personal | Societal x | Occupational | Historical x | Other |

Source: English (2017) pg.4

There are many variations of STEM and the notable one is STEAM as an approach to target students who are interested in arts to be involved in STEM education. As argued by English (2017), the importance of arts to technology and engineering cannot be underestimated. We have witnessed magnificent bridges in the world where engineers also consider the aesthetics part of it so that the structure will fit well in their surroundings.

Technological innovations such as IPAD is said to be a product of marrying art and science (English, 2017). Another explanation to such a technological innovation could be also explained from the perspective of entrepreneurial thinking or orientation of the technological creator(s). Buang et al. (2009) have suggested integration of science and entrepreneurial thinking as an alternative solution to address the development of techno-entrepreneurs who in turn are able to contribute to the creative economy that Malaysia espouses. Such an integration has been coined as Entrepreneurial science thinking (EnScit) or STEEM- where E stands for entrepreneurial.

Another initiative is STEMind- STEM education that is based on *tauhidic* (Rahim et al. (2014). STEMind is an integration of *Aqli* and *Naqli* knowledge in the context of STEM so as to produce Ulul Albab (those deeply rooted in knowledge). Students are exposed to teaching and learning experiences with excerpts from Al-Qur'an as essences in self-development and self-reflection. Students are developed to be self-consciousness as *khalifah* and eventually to be a member of the *ummah* who are both creators and literate with technological advancements inspired from nature (alam).

While STEM integrated education has been advocated widely, but the concern to whether STEM integration can lead to learning the content and processes of the core disciplinary content is questionable. As argued by English (2017), STEM integrated is ideal at the end of various units of disciplinary studies. Other than concern for the integrity of each discipline to be maintained, the implementation level of STEM integrated is still an issue. Some of the other factors delimiting the total integration at the school level are that teachers are trained only in one discipline and the inherent organisation difficulties within schools for team teaching and planning for a STEM integrated curriculum.

Nevertheless, Banks and Barlex (2014) have provided practical suggestions on how science or individual discipline can benefit in the light of learning it in STEM integrated way. While at the same time, maintain the learning the content and process of that particular discipline. It is realised through a subject called Design and Technology.

The following is an excerpt of teaching science in the light of STEM by Banks and Barlex (2014):

Teaching buoyancy: Primary pupils would have been taught the concept of density and calculation of different materials. It could be taught either in the science or mathematics class. Then pupils can be challenged their understanding “Why ships made of steel and iron can float?” Their learning can then be extended to the design and technology class namely to create small scale boats. (Adapted from pg. 55-56)

Such a teaching scenario does exist in the Malaysian science classrooms especially in the learning of the concepts and process. What is needed and more important is to encourage and enhance the planning of lessons collaboratively and in so are able to identify individual content and process that could fit each other. Therefore, students are able to have a coherent framework of the disciplines and thus meaningful learning can occur.

In light of the discussion of STEM integration, it is clear that to teach STEM totally as an integrated fashion is still debatable. What is more important is that to use the integration approach where appropriate and students need to be given a chance to experience STEM integrated education. STEM integration offers students one of the best opportunities to experience learning in a real world situation, rather than to learn bits and pieces and then to have to assimilate them at a later time (Tsupros, Kohler & Hallinen, 2009).

3.1 Resources supporting STEM education

Based on the complex and challenging notion of STEM education, it is imperative that all stakeholders are involved in developing and promoting STEM education. One way to accomplish this, as argued by Basham, Israel and Maynard (2010) is to view STEM education through an ecological model. In a STEM learning ecosystem, the child is at the centre of the model and they are either directly influenced by people closed to them (e.g. family and friends) and indirectly by their environment and culture. Figure 2 demonstrates the interactions of various people and settings in a child's education.

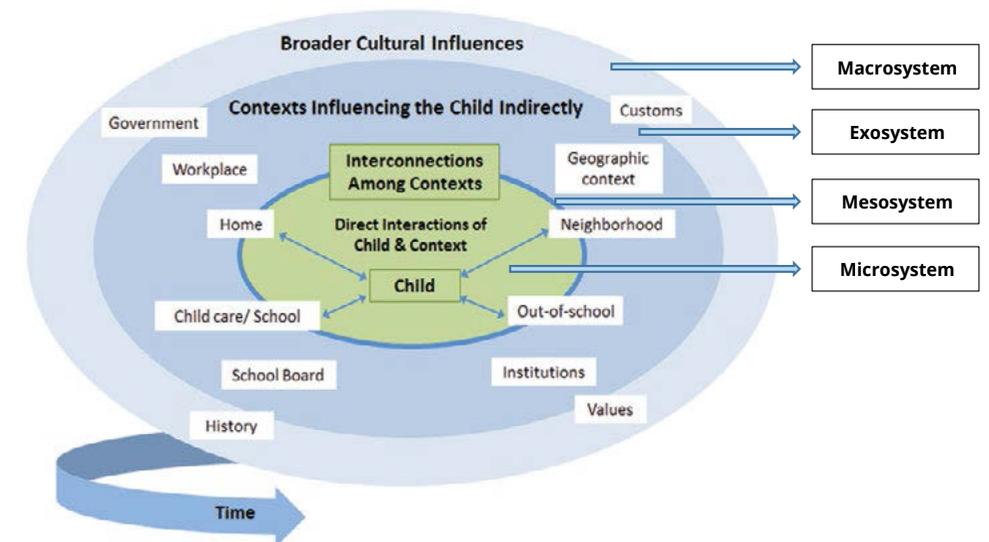


Figure 2: STEM learning ecosystem

Source: Adapted from NRC (2015) pg. 6

Direct interaction with the child include home and out of school activity. The quality of interaction between people (e.g. parents) and settings/ systems (e.g. school) also affect the quality of the child STEM educational experience. Distant layers from the child influence him/her indirectly. The time factor indicates that learning is a dynamic process.

Malaysia through various initiatives either individually or as an institution (governmental or non-governmental organisations) are beginning to play their role in promoting STEM education as illustrated in the STEM learning ecosystem. A caveat is in order here as it is acknowledged there are existence of various STEM education initiatives in Malaysia. However, it is not possible to highlight all the initiatives in such a limited space. Nevertheless, examples of programs to clarify the concept of STEM learning ecosystem are provided. At the:

- a) **Macrosystem-** the government, for example, has set various policies to address, promote and develop STEM agenda. In 2010, Global Science Advisory Council (GSIAC) chaired by the Malaysian Prime Minister himself has pledged Malaysia's commitment to promote and develop STEM education. Since then MOE and MOHE have actively formulated STEM concepts and strategic plan regarding STEM initiatives.
- b) **Exosystem-** public and private institutions of higher education, for example, are working collaboratively with teachers and schools in supporting STEM learning to the students through outreach programs. Among the programs are School@UKM program (including BITARA STEM, Crystal, Prismatic and PermataPintar Summer STEM program) and UPSI Celik STEM Minda.

The Malaysian National STEM Movement (a conglomerate of universities, industries, MOE and NGOs- currently headed by DVC Research UPSI) has intensively encourage the involvement of various organisations e.g. private and public higher institutions, state governments, MOE and industries (e.g. Media and Petrosains) to create partnerships and networking to conduct STEM colloquiums and activities such as Mentor Mentee programs (Universities and schools) in various part of the countries. STEM education is also being promoted in shopping malls as a mean to promote STEM to parents as well.

- c) **Mesosystem-** represents the links between the systems that influence the student (e.g. connection between the school and home). Efforts to involve parents in child's education have been advocated in the Malaysian Education Blueprint (2013-2025) through the concept of SARANA. What is needed is to extend and include in SARANA the role of home to support STEM learning. It requires the school to work collaboratively with parents and vice versa. Similarly, teachers can also work collaboratively with informal science learning settings to create environment that support STEM learning and experiences. Association of Science, Technology and Innovation (ASTI), for example, has been focusing on encouraging students in Tamil schools to be interested in STEM.
- d) **Microsystem-** at this level, the systems that have direct influence on the child are homes, schools, out of school and neighbourhood. Halim et al. (2017) in a small scale research indicated that parents' who showed positive values towards science will provide psychological and monetary support to their children. Community or neighbourhood could provide youth programs and parks that promote STEM learning. An example is STEM cafe in Penang - where hobbyists and enthusiasts provide STEM experiences in the forms of workshops.

The STEM learning ecosystem and eventually the programs and activities provided are as a result of collaborative efforts between organisations. In particular, the collaborative effort between disciplines (e.g. different faculties in the universities) is important to provide the STEM experiences especially when it is offered as STEM integrated education.

4. WAY FORWARD

As Malaysia continues its attempts to develop STEM workforce and STEM literate societies but has to also specifically address the issues and challenges facing STEM education as described earlier. The focus of future directions of the Malaysian STEM education would involve policy implications and strategic planning both at the macro and micro level.

At the macro level, future strategies should involve:

- i) Examine the construct of STEM and STEM education since a construct is a product of time and circumstances, at an interval of every 3 or 5 years. For example Korea has always focused on the STEAM approach. Would Malaysia consider STEMind rather than only STEM i.e. STEMind which is based on Tauhidic might align well with the philosophy of education in Malaysia? Or STEM education that enforces entrepreneurial orientation? Does the current STEM education encompass the underrepresented community such as disable students and minority students?
- ii) Develop a systemic approach to educational policy that aligns with the STEM learning ecosystem. Such an approach would ensure students have access to learning experiences that respond to students' interest in formal and informal settings.
- iii) Continuous analysis of the trend and workforce of STEM and related STEM occupations and beyond. Such a database can inform the future of educational planning.
- iv) The existing partnership and networking among educators, business leaders, industries, and communities can be further enhanced when bureaucracy between organisations is lessened. There is a need to reduce the bureaucracy gap between organisations. Support in terms of policy and resources to partnerships that offers STEM education programs is important so that STEM activities can be sustained towards meaningful impact.
- v) Resources for quality STEM education are important. According to Darling-Hammond in Basham, Israel and Maynard (2010) the level of funding in areas such as school resources have been shown to influence quality of education.

Funding is necessary among others for research in STEM education, transform physical infrastructure to meet STEM education instruction, and to provide effective STEM professional development program.

At the micro level, the strategies would involve developing (i) quality STEM curriculum, (ii) quality STEM teachers through continuous professional development, (iii) quality STEM teacher educator workforce in universities and teacher training institutions and (iv) quality informal STEM activities through collaboration with STEM's related agencies.

- i) So far, MOE has provided provisions for STEM education in the current school curricula. Hence, it is also imperative that the assessment system is to be aligned with the curricula objectives in promoting STEM education. Formative and summative assessments of the curricula in meeting the objectives of STEM education are also be part of the future directions in efforts to advance STEM education.
- ii) Quality STEM education depends on quality STEM teachers. Research (Nugent et al. 2015; Schreiner and Sjøberg 2005) has shown that teachers are the most influential factor in promoting students' interest and self-efficacy in STEM. The focus of professionalism should:
 - a) begin with addressing the mind-set, self- efficacy, attitudes and also beliefs on the integrated STEM instruction of teachers. Even though addressing the mind set of teachers regarding STEM education is already part of the MOE strategic plans, one however, should keep in mind that bringing the intended mind set of STEM would require a continuous effort. Often it is heard that cascading method of professionalism does not reach to the grass root and through on-off courses. Thus, a collaborative professional development program within the school system (through professional learning community approach) and between school and related institutions should be supported and encouraged.
 - b) involve teachers to adopt more STEM-centred pedagogy such as project-based, problem-based, inquiry-based, or design-based tasks to engage students in addressing complex contexts that reflect real-world situations. Nature of professional development program should provide participants with experience in conducting the integrated STEM instruction through combination of "hands on" and small group discussion as these approaches

of professional development program have been proven to increase teachers skill and affective variables related to integrated STEM teaching (Mohd Shahali et al. 2015).

- c) realised the difficulties of curriculum integration namely to what extent a teacher must be responsible for (has expertise in) multiple STEM content areas. Most undergraduate teacher education programs did not expose students to integrated STEM teaching and learning, and do not include engineering concepts or engineering design practices into their curriculum. Hence teacher training programs need to address STEM education in their pre service and post graduate programs.
- iii) Quality STEM student teacher depends on the quality of STEM teacher education programs. If we are to prepare a high quality STEM programs we need to have a quality teacher educator workforce. So far in Malaysia there is no standard of STEM teacher educators. Having such standard will ensure STEM teacher educators have the capabilities to design and implement teacher education programs, institutes and workshops. A tentative framework of the standard proposed by (Lederman et al. 1997, p. 233) includes science teacher educators among others have a strong science knowledge base; understand science pedagogy, curriculum, instruction and assessment; and research capabilities. This framework could be altered to suit the need of STEM teachers' standard in Malaysia. Research on validating these standards in the Malaysian context and its effect on the quality of STEM teachers could be done.
- iv) To support the STEM education in the formal setting, more informal learning programs for students should be conducted. Informal learning experience can make significant contribution in providing appropriate learning opportunities to diverse learners and in motivating them to learn science both within and outside of school (Hofstein & Rosenfeld 1996). Collaboration and partnerships among various agencies are encouraged to deliver after-school learning programs that promote students' interest towards STEM subjects and career.

STEM education and STEM discipline research

A particular policy implication that is worth mentioning separately is providing provisions and grants to research on the impact of STEM education such as on students' learning of content, interest towards STEM careers, best practices of STEM programs, STEM teaching and learning resources, longitudinal study on STEM education, also performance on international assessments. Such research based evidence is important for future planning and thus policy makers are able to make informed decisions on the future of STEM education.

A clearing house that posits outcome of research on STEM education and STEM teaching and learning resources would facilitate teachers to provide effective STEM education. Latest research on STEM disciplines can also includes teaching and learning resources for students and teachers to use in classrooms or just to satisfy their own curiosity. As suggested by Bansham, Israel and Maynard (2010) access to research on STEM disciplines is a form of an early access to the content of higher institutions of their interest.

5. CONCLUSION

Success in the 21st century and beyond is the creation of wealth and sustainable well-being of a society that depends on the ideas and skills of the nation. The STEM competencies which include the 21st century skills become more crucial with the imminent wave of the fourth industrial revolution especially when automation comes into the scene. As the world becomes increasing technological, the value of the nation's asset will be determined to some extent by the quality of the country's STEM education. Malaysia has begun to respond to the changes well and effectively. Nevertheless, Malaysia still needs to keep in pace with the ever evolving knowledge in the improvement of STEM education. With concerted effort from all stakeholders as well as clear policies and directions, Malaysia will always be able to meet all the challenges and beyond.

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CHAPTER THREE

MRSM ULUL ALBAB AND STEM EDUCATION - WHAT IS THE FUTURE?

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Abstract

Ulul Albab is an educational programme of integration between the existing programmes in MARA Junior Science College (MRSM) with the religious school programme inclusive of Tahfiz Al-Quran. The programme is designed to produce professional experts, entrepreneurs and technocrats that are well versed in the field of religion-based Al-Quran and *Sunnah* known as the Ulul Albab generation. The integration of the Sciences and religiosity is in line with STEM education. The Malaysian Education Blueprint mentioned on the initiative of developing an Ulul Albab generation that is well versed in science and technology, pairing with a solid faith and strong religious commitment. The effort in creating an Ulul Albab generation befits the nation's future leaders. This chapter presents an overview of the stakeholders' perspective on the expectation of the Ulul Albab programme in MRSM Kota Putra, Besut Terengganu in the pursuit of achieving students' academic excellence. A qualitative methodology in the form of semi-structured interviews was conducted with four MARA stakeholders and students from MRSM Kota Putra who has gone through one cycle of the Ulul Albab program. The findings from this study indicated stakeholders' aspiration for this programme to produce academically excellent students with highly creative and critical thinking skills. It is in line with STEM education, where students in the Science stream should be creative, innovative and have the critical ability to problem-solving. The expectation of having a balanced life in the existing world that we live on and the life hereafter should be embedded in the students themselves. These were explicitly

expressed by the stakeholders as well as the students. Therefore, integrating STEM elements in the Ulul Albab curriculum will enhance the students' knowledge in science and deepen their religiosity and realising the objective of producing an Ulul Albab generation.

Keywords: Ulul Albab generation, Stem education, integration, balanced individual, MRSM (MARA Junior Science College)

1. INTRODUCTION

The Ulul Albab programme was initially mooted and inspired by the then MARA chairman, YB Dato' Seri Idris Jusoh as an attempt to integrate Islamic education into all curriculum programmes in schools. This is an educational programme of integration between the existing programmes in MARA Junior Science College (MRSM) with the elements of religious school programme inclusive of the learning in the Tahfiz al-Quran. MRSM Ulul Albab education programme is designed to produce professional experts, entrepreneurs and technocrats that are well versed in the field of religion-based al-Quran and *Sunnah* known as the Ulul Albab generation. Since MRSM follows a pure science-based curriculum, it is then appropriate to see how well the science subjects are integrated with religiosity and spirituality. This chapter presents an assessment of the program based on a qualitative study undertaken by the authors.

2. OBJECTIVE

The main objective of this programme is to develop an Ulul Albab generation who are not only knowledgeable and skilled in many areas but also possess good qualities as a human being; namely devoted, noble, responsible and committed to religion, nation and the society. MRSM Kota Putra, Besut, Terengganu was selected as the pioneer school for the programme, and currently, it is also implemented in three other MRSMs which are MRSM Kepala Batas, MRSM Gemencheh, MRSM Sg Besar and the most recent is MRSM Semporna which has also been identified as an Ulul Albab MRSM. The government will be allocating RM600 million to open up four more MRSM Ulul Albab in the near future (Harian Metro, 2017). This goes on to show that MRSM Ulul Albab will be the driving force behind the nation's development of the future Ulul Albab generation.

3. DEFINITIONS OF ULUL ALBAB

What is Ulul Albab? The followings are some of the descriptions of Ulul Albab from the Al-Quran and Islamic Scholars.

3.1 The Al-Quran

In general, the word "Ulul Albab" is attributed to a group of individuals who possess the characteristics of Ulul Albab as mentioned in the al-Quran. The word Ulul Albab is mentioned 16 times in the Al-Quran. It can be found in several chapters/surah including Al baqarah:269, Ali Imran: 7, Ar ra'du :19, Ibrahim:52, Al zumar :9,18, Shad : 29, surat Al baqarah :179,197,al maidah :100, al thalaq :10, surah Ali imran :190, Yusuf :111, Shad :43, al Zumar :21, al mu'min :54. The term Ulul Albab in the Quran demonstrated values, greatness and importance to Muslims and humanity at large. According to the Quranic translation from the Religious Department of Indonesia, the term Ulul Albab is defined as "men of understanding" and "men of wisdom". A muslim scholar, Mohd Asri Zainul Abidin was quoted from his article titled "Be an Ulul Albab and not the Owner of a Weak Mind" ("Jadilah Ulul Albab, Bukan Pemilik Fikiran Lembab") states that Ulul Alba are those who possess wisdom and a mature understanding that allow them to make accurate judgments. This was supported by Abdullah (2006) who states that Ulul Albab are those who are wise and possess knowledge in the field of *fardhu ain* (the obligatory by each individual) and *fardhu kifayah* (the obligatory of the communities). Meanwhile, according to Danial Zainal Abidin (2007) the term Ulul Albab portrays individuals who think deeply and are able to put all things in the right perspectives. In addition, these individuals live out the concept of remembrance and thoughts by chanting and glorifying Allah through observation of God's creation (Sabri, 2009).

3.2 Al-Marbawi

Meanwhile, Al-Marbawi Dictionary states that Ulul Albab is originally derived from two words which are Ulu and Al-Albab. Ulu means "those who have", while Al-Albab is a plural form of the word "lubb", which stands for "the essence of something", "with content", "pure mind" and "the heart". It is a combination of intelligent mind and subtlety in character.

Philosophers raise other various definitions related to Ulul Albab based on their point of views. Idris (2006) as cited in Wan Mariana & Mohd Shafiee (2012), defined Ulul Albab as individuals with strong foundation of al-Quran, extensive and diverse knowledge as well as able to think and observe events of God's creation through their eyes and with their sharp mind, they will learn from it. Meanwhile, Shahran (2006) asserted that Ulul Albab as a group of people who are given privileged by Allah s.w.t, in which those who are given wisdom and knowledge. Osman (2006) highlighted that Ulul Albab are encyclopedic scholars, who are the most important individuals who spread the spirit of Islam and mold Islamic civilisation based on their ability to master various fields of knowledge (as cited in Wan Mariana & Mohd Shafiee, 2012).

Ultimately, they will discover the truth that could save them in the world and hereafter. This requires them to develop a mature mind that can distinguish between right and wrong, between good and bad, between what is beneficial and what is futile as deemed by Allah, Glory be to Him, the Exalted (s.w.t) as Ulul Albab individuals. This is stated in surah *al-Zumar*:

“Therefore, reveal to My servants. (They are) those who make a great effort to listen to the words (which conveyed) and they follow the words; those are the people who have been given guidance by Allah and they are Ulul Albab”.

3.3 Sabri (2009)

In his book entitled '*Generasi Ulul Albab Segunung Harapan Seteguh Gagasan*', Sabri (2009) had listed several perspectives regarding the definitions of Ulul Albab from various Islamic scholars' perspectives. One of them is the Mohd Asri Zainul Abidin who has defined Ulul Albab as those who possess wisdom and a mature understanding that allows them to make accurate judgments. His notion is supported by Abdullah (2006) who states that Ulul Albab are those who are wise and possess knowledge in the field of *fardhu ain* and *fardhu kifayah*. The individuals that live out the concept of remembrance and thoughts by chanting and glorifying Allah s.w.t through observation of God's creation (Sabri, 2009).

3.4 Danial Zainal Abidin (2007)

Meanwhile, according to Danial Zainal Abidin (2007) the term Ulul Albab portrays individuals who think deeply and are able to put all things in the right perspectives. From the definitions above, the concept of Ulul Albab serves as an important paradigm in every action based on deep mastery of knowledge which can be applied in any circumstances and challenges faced by Muslim communities and the world in general. Therefore, there is a need to integrate the concept of Ulul Albab in the Malaysian education system to produce ideal human being.

All these definitions have shown the importance of an Ulul Albab generation that possesses religiosity and spirituality as well as with a sound knowledge in science and technology. Thus, MRSM or MARA Junior Science College, which uses a pure science-based curriculum needs to transform and makes necessary changes in the existing curriculum to realise the objective set by their stakeholders. STEM education comes in at a right time for MRSM to accomplish the goals.

4. THE MRSM ULUL ALBAB PROGRAMME

The MRSM Ulul Albab programme was designed based on three main components namely *Quranic*, *Encyclopedic*, and *Ijtihadik*. Figure 1 illustrates the whole concept of Ulul Albab programme. In this model, the three most important elements of the programme serve as the basis of Ulul Albab curriculum.

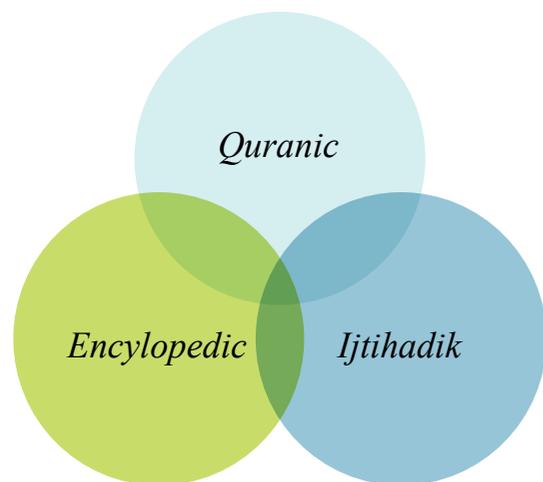


Figure 1: Ulul Albab Model

4.1 *Quranic*

Quranic component focuses on two aspects which are acquiring skills in (i) memorisation (*hafazan*) and (ii) Arabic language. Students in this programme are required to memorise 30 *juz'* or parts of the Quran and understand the concept of reading, remembering, understanding, thinking, practising and disseminating. The target is for students to memorise the 30 *juz'* of Quran over a period of 3 years.

4.2 *Encyclopedic*

The purpose of Quran education is to instil love, understanding, and appreciation of the Quran as the divine revelations from Allah s.w.t (Rosadah et al., 2006; Wan Mariana & Mohd Shafiee, 2012). Apart from producing al-Quran generation, Ulul Albab programme also seeks to develop an encyclopedic generation.

According to Idris (2008), encyclopedic generations are those who acquire various disciplines (multidisciplinary) and various types of languages (multilingual) as well as highly skilled and may become the key source of reference for the community. In the pursuit of materialising encyclopedic generation, students are required to learn other languages such as Japanese and Mandarin.

In addition, students are also expected to master soft skills and academic subjects through the MRSM Soft skills and Academic Skills programme that is implemented in MRSM. Besides, it is also hoped that students will master the principles of skills through Basic Form 1 Skills programme, which was introduced in 2010 with the intention of developing students who are highly competent in the field of cognitive and kinesthetic skills as well as possess noble morals (Mohd Shahril & Sidek, 2013). The Basic Skills which were introduced comprised of Language, Scientific skills, Mathematical, and Performing Arts skills which are required for the students to enhance their learning processes in the science stream as well as in the religious study.

Apart from that, in the era of globalisation, technology in general and the Information & Communication Technology (ICT) in particular has become one of the significant tools in enhancing teaching and learning process. Therefore, students need to be equipped with the most recent ICT resources and multimedia facilities to assist in their learning process.

4.3 *Ijtihadik*

Idris (2008) asserted that *ijtihadik* education could be defined as an educational process that is able to produce intellectuals and Muslim scientists who are creative, innovative and are willing to try new things and generate new ideas for the betterment of humanity. In addition, *ijtihadik* generations are able to think and make a correct judgment and capable in solving crisis faced by the society. With the intention of producing *ijtihadik* generations, students are required to take part in extra co-curricular activities in order to enhance the character, intellect and physical development of students. Additionally, the Ulul Albab programme is also integrating three main extracurricular activities; horseback riding, swimming, and archery.

5. INTEGRATION OF ULUL ALBAB CURRICULUM IN STEM EDUCATION

STEM refers to the areas of science, technology, engineering, and mathematics. STEM was initiated as a way to promote education in these related areas as to prepare students with the skills required to meet the current demands and challenges of the world.

5.1 National Science and Technology Enrolment Policy of 60:40 (1970)

Malaysia has put much emphasis on Science and Technology education as a focus in developing the country towards accomplishing a developed nation status ever since 1970 with the implementation of the first National Science and Technology Enrolment Policy of 60:40. The policy stipulated that 60 percent of students' enrolment would be in science stream and another 40 percent would be in arts (Curriculum Development Division, 2016). This policy was implemented with the primary purpose to increase the number of students in the field of Science and Technology to produce more scientists, engineers, mathematicians, physicians, doctors and highly skilled technicians for nation building. This is also in line with the objectives of the MRSM education system.

5.2 Vision 2020

In 1991, Vision 2020 was introduced by the former Prime Minister of Malaysia, Tun Dr Mahathir Mohamad, where it outlined the nine strategic challenges for Malaysia to be a fully developed nation by 2020. One of the challenges specified in the Vision 2020 is to establish a scientific and progressive society, a society that is innovative and forward-looking, one that is not only a consumer of technology but also a contributor to the scientific and technological civilisation of the future.

In addition, to move a step closer to achieving the goal, the Ministry of Education has acknowledged the importance of STEM as mentioned in the Malaysia Education Blueprint (2013-2015), whereby measures will be taken to ensure that Malaysia has a sufficient number of qualified STEM graduates to fulfill the needs and demands of the industries in order to make Malaysia a high-income nation. These measures include raising students' interest towards

STEM through new and innovative learning approaches, sharpening skills and abilities of teachers through training and building public and students' awareness through national campaigns.

5.3 The National Philosophy of Education (NPE)

The National Philosophy of Education (NPE) which was initiated in 1987 serves as the most significant document that funnels and influences the path and purpose of education in Malaysia. The establishment of NPE is perceived as an effort "to bring the separate, ad hoc and implicit purposes into a clear statement of national educational policy" (Ahmad, 1991; Mohd. Said, 1991 as cited in Habsah et al., 2009).

The NPE serves as a focal point for knowledge acquisition, teaching and learning continuously from the beginning of the educational process. Education in Malaysia is regarded as a continuous process throughout life that lays a foundation for learning from childhood to old age and is not limited to one particular area or discipline but rather interconnected with each other and described as integrated or "cross-curricular" (Mohd Najib et al., 2011). The NPE which was enthused by the Mecca Conference in 1977 had historically developed from a long and challenging process of nation building in the country since 1957 as outlined as below:

"Education in Malaysia is an ongoing effort towards further developing the potential of individuals in a holistic and integrated manner, in order to produce individuals who are intellectually, spiritually, emotionally and physically, balanced and harmoniously, based on a firm belief in and devotion to God. Such an effort is designed to produce Malaysian citizens who are knowledgeable and competent, who possess high moral standards and who are responsible and capable of achieving a high level of personal well-being to contribute to the betterment of the nation, family and society."

(Curriculum Development Centre, 1990)

Based on the NPE, it is clear that the National Curriculum places great emphasis on developing a holistic and balanced individual. Education in Malaysia provides opportunities for each individual to maximise their potentials and equip learners with essential skills, knowledge, values, attitudes, interests and talents to face challenges in this rapidly globalising world.

Education empowers people to be able to contribute to their society and thus, ensuring sustainable human and economic development and social cohesion among the nations at large. The primary reason for schooling is for students to widen and deepen their knowledge across various disciplines and subjects and skills based on the following aspects; social skills, intellectual skills, physical skills, spiritual skills, aesthetic values, moral values, and information and communication technologies (ICT) skills (National Report Malaysia).

Habsah et al., (2009) indicated that education in Malaysia in perspective should demonstrate the ideals of the Malaysian NPE which emphasises on the “humanisations of education” (Cabinet Report, 1979). Therefore, every components of the education system should concentrate on developing individuals who are knowledgeable and competent and possess a strong belief and devotion to God as explicitly declared in NPE.

The fundamental nature of NPE is to develop the potential of Malaysian citizens in a holistic and integrated manner with intellectually, spiritually, emotionally and physically balanced. To translate this philosophy into the teaching and learning process in the classroom, each subject matter in the national curriculum needs to formulate their goals and objectives that reflect the philosophy. Indeed, the NPE intends to develop the potential of individuals in a holistic and integrated manner so as to produce individuals who are intellectually, spiritually, emotionally and physically balanced and harmonious.

This is in accordance with the first principle of the Pillars of the Country or the Rukun Negara which is a “Belief in God” (Habsah et al., 2009). In addition, education in Islam focuses on “human civilisation” (Sideq, 2006), in which to produce individuals who are not only well-educated and competent but also possess knowledge that preserves a man from errors of judgment. In Islam, education is viewed as an instrument by which people can be trained in the Islamic ways of life. The goal of education is to produce human beings who abide the Islamic teachings. The fundamental philosophy underlying the Islamic education is based on the concept of holistic education which comprises the aspects of intellectual, spiritual, emotional and physical.

Therefore, in order to uphold the ideals of Islamic and holistic education as indicated in the NPE curriculum, there should be an integration of Ulul Albab curriculum into the STEM education in order to produce intellectuals,

professional experts, and technocrats that are not only knowledgeable and competent but also skilled in the field of religion based on the Quran and *Sunnah*.

5.4 Integration Efforts

The integrated education of Ulul Albab into STEM will add significant value in the birth of Muslim community who will be creative as well as critical thinkers and at the same time are well versed in Quran as well as portraying and practising the values of Islam. Ghazali (1989) asserts that an integrated knowledge is vital in developing a holistic and well-balanced human being. Ghazali further emphasised that the development of mental, physical, emotional, ethical and aesthetical aspects are difficult to attain without an integration between Islamic curriculum and modern secular system. Islam regards all types of knowledge as complementary and congruent in the sense that “empirical, sensory, and intellectual knowledge” have never been separated from the divine knowledge in Al-Quran. Hence, the disintegration from Islamic education will lead to ‘compartmentalisation of knowledge’ that is contradicting to the Islamic beliefs (Solehah & Rahimah, 2008). Narongraksakhet (1995) also stresses the importance of integrated curriculum of Islamic educational system and secular education as Islamic education is not a mere teaching and reading of Quran, Hadith, and Fiqh and Islamic knowledge, but also includes a wide-ranging of branches of knowledge.

6. EVALUATION OF THE ULUL ALBAB PROGRAMME IN MRSM KOTA PUTRA

An evaluation of the implementation of the Ulul Albab curriculum in MRSM Kota Putra was conducted to evaluate the success of Ulul Albab curriculum in producing excellent students with respectable character, based on values and virtues of Islam. A qualitative research design through semi-structured interviews was conducted to gather in-depth findings. Several students, teachers and MRSM stakeholders were identified as the respondents for the study to answer these research questions;

- i) What is the stakeholders' expectation towards students academic achievement?
- ii) What is the stakeholders' expectation towards the students' character (sahsiah)?

The findings of the study are listed below:

Findings No 1

The study carried out by Umi Kalthom, et al. (2014) found a positive correlation between Quran recitation and students' academic achievement, in which students who demonstrated outstanding performance in Quran recitation performed better academically.

Findings No 2

The study also found that the spiritual elements comprise in the Ulul Albab curriculum provided significant influences towards students' character building. Positive changes among the students can be seen through various aspects such as performing prayers five times a day, more concern for their aurat (intimate parts), respecting each other, and so on. Teachers and wardens who were interviewed also agreed that there is a significant difference between students in Ulul Albab programme and those who are not in the programme.

Findings No 3

Students who are in the programme possess better character and personality as compared to those who did not go through the programme. These results are in line with a previous study conducted by Sarina Sulaiman (2012) who found that

the number of disciplinary cases in MRSM Kota Putra was low, and it shows that Quran recitation and memorisation influence positive personal development.

Findings No 4

From the interview session, students firmly believed that the Quran memorisation activity had changed their lives for the better. They believed that Quran memorisation in Ulul Albab programme had helped them to become individuals who are idealistic in noble values, with good morals and characters.

Findings No 5

It is also found that the students aspire to continue the Quran recitation and memorisation even after graduation. Majority of the students expressed their concern and worried that there would be no continuation of the Ulul Albab elements when they enter into the tertiary education programme. Therefore, this illustrates that there is a growing need to integrate the Ulul Albab module into the secular education system.

Findings No 6

The study found that academic excellence and producing creative and critical thinkers among students is the dominant expectation of Ulul Albab programme in Kota Putra. This is proven by the statement of stakeholder 1:

“We wanted the best for MRSM. He (the student) is excellent in the academic aspect.”

Academic excellence theme can also be interpreted through several statements that led to the outstanding academic performance. This is supported by the testimonial of stakeholder 4:

“Encyclopedic means the ability to acquire several areas of knowledge. Multi-disciplinary and multilingual...”

Stakeholder 2 also provided indicators of academic excellence through his statement:

“Science and technology are already in our system in MRSM to produce excellent Bumiputera students in the area of science and technology, that’s the basic.”

This goes on to show that the stakeholders hoped that through the Ulul Albab programme, MRSM would be able to produce students who are excellent in academics as well as competent in the field of Science and Technology.

Apart from that, Ulul Albab programme also aims to produce students who can think creatively and critically. This was stated by stakeholder 4:

“We want our students to be creative and innovative. So it has to be a thinking program”

He also emphasises the concept of Ijtihadik when discussing the expectations of MARA stakeholders in developing creative and critical thinking students. This is evidenced by the following statement:

“Ijtihadik. Able to give opinion and solving problems. More towards brain-based. How they use the brain!!”

From the above statements, MARA stakeholders are hoping through the Ulul Albab programme, MRSM students will be creative and critical thinkers. The students are then able to apply the knowledge and experience with innovative ideas. This is pertinent in this day and age of the 21st Century learning. Science education is already part and parcel of the MRSM system (Maktab Rendah Sains MARA). Therefore, the integration of STEM education is ongoing, but it needs to be enhanced to produce an Ulul Albab generation with a firm hold on STEM education.

7. ACCEPTANCE OF ULUL ALBAB IN STEM EDUCATION

As discussed earlier, STEM education is part of the curriculum implemented in the MRSM system. Since the students are selected, they are ready to accept the integration of Ulul Albab and the STEM component to be merged in the curriculum. During the interview sessions with the students, one of the respondents queried why teachers do not include the Quranic aspects into the standard sciences curriculum. For example, in the learning of subjects like Chemistry, Biology and Physics (Umi Kalthom et al., 2014). They queried why Islamic scholars are not cited in the core science curriculum. Names like Ibnu Khaldun, Al Khawarizmi and other Muslim scholars in the field of science are not revealed in the science and mathematics subjects. This is a good indication that these groups of selected students are ready for Islamic components to be incorporated into the sciences subjects.

The integration of Islamic education and secular education has long been discussed by scholars from Universiti Kebangsaan Malaysia in the year 1984 (Nik Azimah, 2007). STEM education appears to be separated where there is no continuation of STEM knowledge and the concept of *tawhid* (Faszly et al., 2014). This is the opposite of Islamic teachings as Islam views knowledge as something sacred because all knowledge is the manifestation of God to man (Azizi et al., 2011). Due to this issue, a group of STEMind researchers (STEM Islamic and Da’wah) from Universiti Kebangsaan Malaysia (UKM) has developed a module known as the Ulul Albab Empowerment Module (*Modul Pemerkasaan Ulul Albab*) with the goal to produce an Ulul Albab generation. The module will be able to continue the efforts of integrating scientific and Islamic knowledge in STEM education.

The Ulul Albab Empowerment Module has been established to integrate STEM education with Islamic concept, based on *tawhid* - the integration of *Aqli* and *Naqli* knowledge. The objective of this STEMind module is to create STEM education that is more holistic and exciting to the students, particularly at a secondary school level. This module involves the integration of teaching and learning of STEM education with *Tauhidik* Science to be delivered to students especially in Tahfiz School, MRSM Ulul Albab and Tahfiz Science. It is hoped that this module will be able to produce scientific-minded students who will always associate with God’s greatness as the Creator. In other words, recreating the Islamic scientists, as we once had achieved during the glory of Islamic Civilisation of the past.

The establishment of Pioneer Schools in Integrated Islamic Education systems in Brunei has shown that not only Malaysia but Brunei is also aware of the importance of integration of Islamic knowledge with STEM education and has decided to promote and provide comprehensive education path for their future generations as well (Maimun et al., 2015). This education system promotes the idea that education should contain both Islamic and worldly knowledge and that both pieces of knowledge should not be detached from one another.

The decision made by Brunei Darussalam in realising the concept of an Integrated Education is deemed wise, despite significant challenges and should be followed and implemented in Malaysia as well. It is justifiable as Malaysia is an Islamic country with Islam as the official religion of the federation and majority of the population are Muslims, to adopt Islam in its education system which strives to produce holistic and well-rounded citizens for the betterment of the future world.

8. CONCLUSION

Even though students have been exposed to STEM subjects all these years, there have not been many research done on the subject (Considine, 2013). However, it is universally accepted that STEM education is important for the future of a country (Carter, 2013; Harkness, 2012; Youn et al., 2013). The nation that is equipped with knowledge on STEM will lead to having a dynamic work force with reference to innovation and changes that will progressively contribute to the development of a country in the 21st century. The knowledge on STEM education that is added with the elements of religion, spirituality and the roles of Islamic scholars will further enhance the students as a whole. They questioned as to why names of these famous Islamic scholars were not mentioned in the academic sciences subjects. This clearly shows that the students are more than ready for the required changes. The change will have to begin somewhere, and it has to start with STEM education and the integration of religiosity and spirituality.

It is clearly shown that STEM education is the key to the future of a nation and when added with religiosity, a holistic generation will be created to lead the country. Therefore, it is essential for the integration of STEM education with elements of Islamic Ulul Albab education characteristics. Even though there were teething problems in implementing the programme at MRSM, the students were able to cope and excelled academically. This will be a promising beginning for these students to acquire the attributes of an Ulul Albab generation towards their quest to become professional in their respective endeavour. Subsequently enhancing the STEM education is for the betterment for the future of the nation.

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CHAPTER FOUR

A COMMUNITY INITIATIVE TO PROMOTE INTEREST IN SCIENCE, TECHNOLOGY, ENGINEERING AND MATHEMATIC (STEM) AMONG MALAYSIAN SCHOOL CHILDREN

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Abstract

This is a report on the science, technology, engineering and mathematic (STEM) enhancement programmes conducted in Malaysia under the Kuala Lumpur Engineering Science Fair (KLESF) initiative. Five major programmes under KLESF will be covered in this report, namely KLESF: The Fair, KLESF Mentor Development Programme (KMD), KLESF Mentorship Programme (KMP), KLESF STEM Educator Enhancement Programme (KSEEP) and KLESF STEM Workshop (KSW). Objectives, implementation and impacts of these programmes will be presented and discussed. Based on the outcomes of these programmes it shows that STEM education at primary and secondary levels should not be confined to schools, teachers and parents but involving more stakeholders including industry, non-governmental organisations (NGOs), universities, professionals, volunteers, etc. The KLESF initiative has proven that such community based and multi-stakeholders approach is feasible and effective in enhancing the interest of children in STEM subjects through more diverse ways of experiencing and learning especially the hands-on approach.

1. INTRODUCTION

Teaching and learning of STEM by children in the schools has been very much of bookwork-based in Malaysia. However, it has been found that inquiry based and hands-on learning is significantly important. Such approach can improve effectiveness of learning as students be able to identify and study phenomena or problems that arise from their surroundings and then followed by conducting a survey and analyse possible explanations or solutions before concluding or implementing the solutions. Such approach of STEM learning has been reported in many studies done in the past [1][2][3][4].

Bookwork-based teaching of science and mathematics in Malaysian schools could have been one of the factors causing the learning of the subjects by students to be less effective. Difficulty in understanding the concepts of the subjects has resulted in school children not interested in them. It is true that globally, the interest in STEM subjects among school children has declined over the years. In Malaysia, we have seen the same decline especially in the past few years. To address the problem, various initiatives have been taken by the government which primarily focus on curriculum, schools, teachers and students. But, these are not adequate enough if other stakeholders are not involved. In recent years, it has be observed that more and more initiatives have been undertaken by the community and non-governmental organisations (NGOs) to address the problems in Malaysia. One of such initiative is the Kuala Lumpur Engineering Science Fair (KLESF) which is reported here.

2. BACKGROUND AND OBJECTIVE OF KLESF

The Kuala Lumpur Engineering Science Fair (KLESF) started in 2013 when five founding organisations came together to explore ways to address a major challenge faced in Malaysia: the declining interest in STEM among school students in Malaysia. The five organisations are

1. ASEAN Academy of Engineering and Technology (AAET),
2. Malaysian Industry-Government Group for High Technology (MIGHT),
3. Universiti Tunku Abdul Rahman (UTAR),
4. Institution of Engineers Malaysia (IEM) and
5. National Science Centre (Pusat Sains Negara [PSN])

The main objective of KLESF is to enhance the interest in STEM among school children in Malaysia by engaging all stakeholders in its programmes and activities that emphasise on hands-on, experiential exposure, learning and skill development for students and teachers which complement the STEM curriculum in the schools. Detailed objectives are as follows.

1. To enhance school students' interest in science, technology, engineering and mathematics (STEM).
2. To enhance the awareness of the public on the roles and importance of STEM in socio-economic well-being and sustainable development.
3. To enhance the awareness and participation of business and industry in promoting learning and career development in areas related to STEM among school students and community.
4. To provide networking for schools, educators, industries, public and private sector to share information and experiences on projects, extra-curriculum and good practices in science and mathematics education in schools.

KLESF is also part of the “Science to Action (S2A)” initiative launched by the Prime Minister on 1 November 2013 with the objective to enable Malaysia to sustain its growth beyond 2020 through utilisation of science and technology.

3. OVERVIEW OF KLESF'S PROGRAMMES

In order to achieve its objectives KLESF has planned and implemented various programmes with roles and achievable objectives for various stakeholders as listed in Table 1.

| Stakeholders | Roles / Objectives |
|---------------------------|---|
| Children | <p><u>Roles</u></p> <ul style="list-style-type: none"> Participation in KLESF programmes and activities <p><u>Objectives</u></p> <ul style="list-style-type: none"> Enhanced interest in STEM Better understanding of STEM and its importance for future career development |
| Parents | <p><u>Roles</u></p> <ul style="list-style-type: none"> Participation of children in KLESF programmes and activities Support to KLESF's fund raising effort <p><u>Objectives</u></p> <ul style="list-style-type: none"> Enhanced children's interest in STEM Enhanced awareness and understanding of the importance of STEM in future career development of children |
| Schools / Teachers | <p><u>Roles</u></p> <ul style="list-style-type: none"> Participation in KLESF programmes and activities by students and teachers Facilitation for KLESF volunteers to conduct programmes and activities in schools Promotion of STEM among students in collaboration with KLESF <p><u>Objectives</u></p> <ul style="list-style-type: none"> Enhanced students' interest in STEM Enhanced knowledge and skills in STEM for more effective teaching of the subjects in schools |

| Stakeholders | Roles / Objectives |
|-------------------|---|
| Volunteers | <p><u>Roles</u></p> <ul style="list-style-type: none"> Participation in KLESF programmes and activities as facilitators and mentors <p><u>Objectives</u></p> <ul style="list-style-type: none"> Better understanding of education process in schools |
| Government | <p><u>Roles</u></p> <ul style="list-style-type: none"> Approval and endorsement of KLESF programmes and activities Facilitation and encouragement for schools' and agencies' participation in KLESF programmes and activities Support to KLESF's fund raising effort <p><u>Objectives</u></p> <ul style="list-style-type: none"> Enhanced students' interest in STEM and thus higher proportion of students taking STEM subjects / programmes Strengthening of the effort of engaging community more extensively in school education as per current education policy |
| Industry | <p><u>Roles</u></p> <ul style="list-style-type: none"> Participation in KLESF programmes and activities Support to KLESF's fund raising effort <p><u>Objectives</u></p> <ul style="list-style-type: none"> More and better trained STEM workforce Enhanced achievement of corporate social responsibility |
| NGOs | <p><u>Roles</u></p> <ul style="list-style-type: none"> Participation in KLESF programmes and activities Support to KLESF's fund raising effort <p><u>Objectives</u></p> <ul style="list-style-type: none"> Enhanced impact of community programmes Enhanced collaborative link and network with other stakeholders |

Table 1

Thus far, in order to achieve its objectives KLESF has set up and implemented various programmes as listed in Table 2.

| Programmes | Descriptions |
|--|--|
| KLESF: The Fair | An annual fair that gathers relevant STEM content providers to provide hands-on and other activities for school children. |
| KLESF Mentor Development Programme (KMD) | A programme to train teachers / volunteers to be mentors for school children on STEM experiments and projects. |
| KLESF Mentorship Programme (KMP) | A programme to arrange for volunteers to go to schools to mentor children on STEM experiments and projects. |
| KLESF STEM Educator Enhancement Programme (KSEEP) | A programme to provide opportunities for teachers to learn effective approaches, methodology and good practices in STEM education. |
| KLESF STEM Workshop (KSW) | A programme that organises hands-on workshops at certain locations for nearby children and parents. |

Table 2

4. KLESF: THE FAIR

Fairs have been found to be effective in promoting STEM interest and awareness worldwide. There have been STEM related fairs organised annually in various countries. Examples of such fairs are The Intel International Science and Engineering Fair (Intel ISEF) [5], The Google Science Fair [6] and The Beijing Science and Technology Week [7].

It was felt that a fair that provides opportunities for school children to experience STEM hands-on and other activities is necessary in Malaysia. To achieve that the five founding organisations (AAET, MIGHT, UTAR, IEM and PSN) came together to form the KLESF in 2013 and conducted the inaugural KLESF: The Fair 2014 on 25 to 27 April 2014 at the National Science Centre of Malaysia. The 2014 fair marked the beginning of the KLESF as a community based initiative to promote interest in STEM among school children in Malaysia.

4.1 Industry's Involvement

KLESF was set up with the concept of openness and inclusiveness in terms of participation by stakeholders. It emphasises on the participations of multiple stakeholders especially those in the industry. Exhibitors are required to provide relevant STEM hands-on activities to visitors. This is indeed something new to the industry players as they are not supposed to exhibit products in the usual commercial way but required to come up with STEM content and activities suitable for school children. Such content can be related to their businesses but they should avoid direct promoting or selling of their products at the fair. This poses challenges to the fair organiser in convincing companies to take part and there were many companies which were not familiar with such concept but eventually be able to adapt and changed accordingly. The number of industry exhibitors in the fair has increased from 20 companies in 2014 to 50 companies in 2016.

4.2 Universities' Involvement

Other major exhibitors in the fair are the universities. Malaysian universities have been encouraged to run various community programmes and activities by the Ministry of Higher Education. Many of them have set up and carried out STEM related programmes for schools. Such effort has intensified in recent years as universities experience declining percentage of new students applying for STEM courses. It is felt that STEM programmes for schools can help to increase interest of school children taking up STEM subjects in schools and eventually pursuing STEM courses in the universities. The number of universities taking part in the fair rose from 5 in 2014 to more than 16 in 2016. UTAR being one of the co-organisers of KLESF has contributed more than 30% of the STEM content participation of the fair by universities.

4.3 Science of Magic

A new approach taken by the organiser to promote interest in STEM among young children is by incorporating science into programmes or activities that are entertaining and fun. One effective way is to introduce science in magic performances. Science of Magic is a carefully planned magic performances that has been implemented at the fair since 2014. The magicians provide explanation of the scientific principles applied in some of the magic tricks performed. These approaches have been proven to be popular and effective in promoting STEM interest especially among young children.

4.4 STEM and Career

Besides children it is important to create and enhance the awareness of parents and teachers of the relevance of STEM studies for future career development of children. One effective way of achieving this is by having industry players to demonstrate how science and technology are being applied in their businesses. This is not just only enabling the children understand the science and technology that are driving the various industry activities but also assist parents and teachers to understand the importance of STEM knowledge and skills in human resource requirements of industry. To make the effort by the industry players more coherent, the organiser has set up thematic zones at the exhibition space of the fair. Since 2015 a thematic zone based on information communication technology (ICT) has been set up to gather companies in ICT to exhibit and demonstrate how technology drives the business sector. This is also an exemplary partnership among industry, government (Malaysia Communication and Multimedia Commission [MCMC]) and NGO (the KLESF organiser). Such effort will be strengthened and extended to other industry sector in future.

4.5 NGOs' Participation

In recent years we have seen more NGOs being formed to promote STEM interest among the youth. Many of them have derived their own community programmes that may be known only to limited public members. The fair serves as an effective platform for such NGOs to exhibit, demonstrate and publicise their programmes and contents. We have seen such involvement of NGOs increasing from less than 5 in 2014 to 15 in 2016.

4.6 Participation in KLESF: The Fair and Perception of Public

The organiser has been systematically tracking the overall participation in the "KLESF: The Fair" since its inception. Over the years, various indicators clearly have shown that the participation of schools, children, parents, teachers, industry and public has increased overtime. One important indicator is the total number of visitors recorded in each of the yearly fair. We have seen the number increased from about 20,000 in 2014 to 28,000 in 2015 and 54,000 in 2016. Table 3 shows more details of all stakeholders' participation in the fair for the past three years.

| Participation in KLESF: The Fair | 2014 | 2015 | 2016 |
|---------------------------------------|---------------|---------------|---------------|
| No of schools | 150 | 200 | 382 |
| No of companies | 20 | 32 | 50 |
| No of NGOs | 4 | 15 | 16 |
| No of universities | 5 | 18 | 24 |
| No of volunteers | 1,000 | 1,500 | 2,000 |
| No of government agencies | 2 | 2 | 9 |
| No of participating foreign countries | - | 3 | 4 |
| Total no of visitors | 19,690 | 27,647 | 54,267 |

Table 3

Perceptions of students and parents have also been assessed and found to be very much positive. For example, survey has shown 80% and 73% of primary and secondary students respectively rated “KLESF: The Fair 2015” as good or excellent. It has also been found that 65% and 62% of primary and secondary students respectively indicated that their interest in STEM increased after visiting the “KLESF: The Fair 2015”.

Figure 1 and Figure 2 illustrate children participating in the hands-on activities of “KLESF: The Fair” accompanied by their parents. Figure 3 shows university students conducting hands-on activities for a group of children in the fair. Figure 4 shows the magician engaging secondary school students in one of the Science of Magic performances during the fair. Figure 5 illustrate a stage performance in which a DIY robot was demonstrated by an exhibitor of the fair. Figure 6 shows an activity in ICT put up by a company during the fair.



Figure 1



Figure 2



Figure 3



Figure 4



Figure 5



Figure 6

5. STEM DESIGN COMPETITION AND KLESF CHALLENGE

One important component of STEM interest promotion is the design competition. There are various design competitions that have been set up for school children by government and community organisations. However, most of these competitions have limited coverage in terms of types of school and geographical area. There is no competition that is practically open to all nationwide and comprehensively covers most areas of STEM. It was felt that it is necessary for KLESF to make efforts to address the gap. In conjunction of “KLESF: The Fair”, a competition has been set up and organised since 2015. The competition, known as “KLESF Challenge”, is open to all Malaysian school children and overseas participants. The objective of the organiser is to develop “KLESF Challenge” towards becoming an established national and international STEM designed competition. It is also hoped that it will serve as platform to identify and select project teams to represent Malaysia in international STEM competitions.

Besides “KLESF Challenge”, the fair organiser has also been working closely with other parties that organise design competitions with more specific scope and coverage. Some of these competitions have been held in conjunction with the fair. For example, the “Young Innovate competition” in 2015 and 2016 and the “Robotic Challenge 2016”. There are more of such competitions to be held in conjunction with the “KLESF: The Fair in the future”.

Figure 7 and Figure 8 show some of the student projects participated in KLESF Challenge.



Figure 7



Figure 8

6. KLESF MENTOR DEVELOPMENT PROGRAMME (KMD)

In order to have more volunteers who are able to guide and mentor school children effectively on hands-on STEM experiments and projects, there is a need to have good training programmes that can be offered to people who are interested. KLESF has started such trainings under its KMD programme with the target focused on university students and school teachers. KMD runs together with the KLESF Mentorship Programme (KMP) which will be properly planned and deliberated. Numerous training tracks in biology, chemistry, physics, electronics and robotics have been designed and conducted under the KMD programme since 2014. Some successes especially among university students have been achieved thus far.

However, the organiser faced some problem in the running of the training for teachers. Most of the teachers trained did not initiate any STEM projects in their schools after the training or did not respond to follow-up inquiries by the organiser. As a result, the training for school teachers was suspended in 2016. This was a setback that the organiser is still looking for a possible solution.

Table 4 shows the numbers of teachers and university students that KLESF has trained under its KMD programme.

| KMD target group - no of mentors trained | 2014 | 2015 | 2016 |
|--|------|------|------|
| Teachers | 69 | 131 | - |
| University students | 28 | - | 158 |

Table 4

Figure 9 and Figure 10 show the volunteer trained in biology and chemistry tracks respectively in KMD programme.



Figure 9



Figure 10

7. KLESF MENTORSHIP PROGRAMME (KMP)

It is widely known that school children do not get sufficient exposure to hands-on experience in science and mathematics learning in schools due to various reasons. This is assumed to be one of the major factors causing children to be less interested in the subjects. KMP aims to address the issue by providing more STEM hands-on experience to school children that complement the existing school science and mathematics curriculum. It is hoped that children will be more interested in science and mathematics with such hands-on experience. However, manpower is a major concern if such initiative is to be implemented with a wider coverage. One possible way is to utilise the manpower of university students who are attached to different universities nationwide. If some of the university students can be trained to be STEM mentors and make arrangement to visit the nearby schools to conduct hands-on activities and mentor school children on STEM projects then the initiative is more feasible and sustainable. KLESF does not aim to carry out the programme nationwide all by itself. The organiser only intend to initiate such programme, known as KMP, and set up a working model that can serve as a reference for all other universities to emulate if they do not have one but intend to set up. Thus, a pilot run was started in UTAR in 2014.

In the KMP programme conducted by UTAR, university undergraduate students are encouraged to take up STEM community service as part of their 2-credit hour compulsory co-curriculum subject. Through KLESF the university students are trained on STEM hands-on in certain areas such as biology, chemistry, physics, electronics, robotics, etc. for about two weeks under the KMD programme. They are then arranged to go to the assigned secondary schools to conduct hands-on and mentor lower secondary students on STEM projects for about 10 weeks with 2 to 3 hours per session per week under the KMP programme. Most schools welcome such initiative. In fact, the organiser has received requests from schools more than what it can provide. It is the intention of KLESF to share such experience and the working model set up in UTAR with other interested universities so that more schools and children can benefit as more universities undertake similar initiative. Table 5 shows the statistics of KMP during its implementation period thus far.

| KMP - no of participants | 2014 | 2015 | 2016 |
|--------------------------|------|------|------|
| Schools | 7 | - | 9 |
| School students | 265 | - | 574 |
| University students | 28 | - | 158 |

Table 5

Figure 11 and Figure 12 show lower secondary school students doing experiments and projects under the guidance of university students and staff.



Figure 11



Figure 12

8. KLESF STEM EDUCATOR ENHANCEMENT PROGRAMME (KSEEP)

Although there is a lack of success with teachers on the KMD programme discussed earlier KLESF is still committed to assist teachers to be more effective in teaching science and mathematics in schools. Teachers are the people our children possibly have the longest learning contact time with and thus it is important that they are effective in their teachings. Efforts have to be made to ensure that it happens. KLESF through KSEEP attempts to achieve it by organising an annual symposium called Symposium on Science Education (SoSE). The symposium is set to achieve the following objectives:

- To share innovative and effective teaching methods in STEM education.
- To create awareness of the current innovative teaching methods and how to embed innovation in the teaching and learning of STEM education.
- To provide networking opportunities for STEM educators from various schools, colleges and universities.

Since its inception the symposium has benefited teachers and educators. The numbers of teachers and educator benefited from this programme are 225 in 2014, 200 in 2015 and 268 in 2016.

Figure 13 and Figure 14 show sharing sessions of SoSE in which teachers and educators discuss and share experiences and effective approaches in teaching science and mathematics.



Figure 13



Figure 14

9. KLESF STEM WORKSHOP (KSW)

We have realised that “KLESF: The Fair” has limited coverage in terms of geographical area. It’s major benefits *are those* people who are in or near the central region of West Malaysia. There are many areas of Malaysia in which the population cannot access the fair easily. Thus, it is felt necessary that some of these areas be offered some of the content of the fair. The organiser has conducted numerous mini KLESF workshops in various rural or sub-urban areas in Malaysia under the KSW programme.

Such workshops are usually carried out in selected schools at which children from surrounding areas can visit and participate in the activities. Such events are normally held over weekends and involved several content providers like universities, NGOs and relevant government organisations. Thus far, KLESF has organised STEM mini workshops in Teluk Intan and Sungai Besar. More districts or towns will be covered in the future.

One of the feedback that we have gathered from the parents who have visited “KLESF: The Fair” is that the hands-on activities should be organised more often for children, if possible on a regular basis. Realising the need, KLESF started organising mini workshops which are organised regularly on weekends at UTAR campus.

Such workshops are run for 2 to 3 hours per session in the weekends. A session is typically conducted by 3 to 4 volunteer mentors for a group of up to 25 children. The children are normally accompanied by parents who are encouraged to be also involved in the activities.

Table 6 lists the number of participants of the mini workshops organised by KLESF since 2014.

| KSW - no of participants | 2014 | 2015 | 2016 |
|--------------------------|------|------|-------|
| Children | 400 | 400 | 1,551 |
| Parents | - | - | 131 |

Table 6

Figure 15 and Figure 16 show children participating hands-on activities of the mini workshops under the KSW programme accompanied by parents.



Figure 15



Figure 16

10. CONCLUSION

KLESF it is still very much a work in progress and there is still a lot that it can learn from others and thus improve. However, in its short history KLESF has proven to be a successful community initiative which has managed to attract and involve various stakeholders in coherent and integrated programmes to promote interest of school children in STEM studies and career. It can also serve as a model for other interested parties with similar objectives to emulate in other parts of Malaysia or the world.

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CHAPTER FIVE

INCULCATING THE ENTHUSIASM IN MATHEMATICAL SCIENCES THROUGH MALAYSIAN MATHEMATICAL SCIENCES SOCIETY (PERSAMA)

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ABSTRACT

Persatuan Sains Matematik Malaysia (PERSAMA) is a non-governmental organization that aspires to be the platform that fosters collaboration among Malaysian mathematical scientists. The main objective of PERSAMA is to place mathematical sciences and its body of knowledge to an upper level of various aspects. PERSAMA, thus initiates a number of activities in order to increase its visibility among the public and subsequently raise public awareness and acknowledge mathematical sciences researchers. The annual activities of PERSAMA are Symposium Kebangsaan Sains Matematik (SKSM), National Mathematical Olimpiad (OMK), International Mathematical Olimpiad (IMO), PERSAMA Annual Award and publications of the Bulletin of the Malaysian Mathematical Sciences Society (Buletin PERSAMA). Other activities include Mathematics camp, Matemadesa and Discovery Mathematics (Menemui Matematik). These activities are significant to inspire and reinforce interests of the community in the mathematical sciences body of knowledge. PERSAMA will continuously play an important role to inculcate the enthusiasm in mathematical sciences in line with advances in STEM education.

1. INTRODUCTION

Persatuan Sains Matematik Malaysia (PERSAMA) was founded in 1970. PERSAMA aspires to be the platform that fosters collaboration among Malaysian mathematical scientists with the objective to enhance mathematics education in Malaysia. PERSAMA aims to place mathematical sciences and its body of knowledge to an upper level of articulation, sophistication, exploration, knowledge association and recruitment. Starting with only 42 members at its inception, PERSAMA now has more than 1000 members, which include members of mathematical sciences and school mathematics teachers. PERSAMA too has more than 600 institution memberships especially from the public/private schools and colleges.

One of PERSAMA's goal is to increase its visibility among the public. Various activities are initiated to promote mathematical sciences among Malaysians in terms of research, education and its applications. These activities are activated heeding the following objectives: to effect improvements in the teaching of mathematics, to provide means of communication between students, teachers and others interested in mathematics, to foster an interest in the study and pursuit of mathematics and its applications, to take such measures as may be expedient to advance the views of the Society on any question affecting the study and teaching mathematics.

There is a need to raise public awareness and acknowledge mathematical sciences researchers in the mass media and to present the relevancy of the field to other disciplines. This is somehow related to the nation's pride and civilisations inculcating knowledge and enthusiasm of mathematics and sciences in Malaysia. The current trend shows a declining number of students who are interested in taking mathematics and sciences in school (I. Z. Arfudi 2016; O.C. 2016). Thus, PERSAMA has made an attempt to mitigate this daunting trend by organising various activities which align with PERSAMA's objectives, mission and visions. In addition, mutual understanding of the usage and applications of mathematics in the Malaysian culture should be broadcasted. Among activities initiated and managed include: Mathematics camp, Matemadesa, Simposium Kebangsaan Sains Matematik (SKSM), National Mathematical Olimpiad (OMK), International Mathematical Olimpiad (IMO), PERSAMA Annual Award and publications of the Bulletin of the Malaysian Mathematical Sciences Society (Buletin PERSAMA) and Discovery Mathematics (Menemui Matematik). These activities realised the needs of the Malaysian public of diverse cultures and ages. Certainly, there are more that can be done.

2. ISSUES IN STEM

PERSAMA has different categories of membership; a fellow is nominated by the council, majority of the ordinary and life time members are academic staff of universities and colleges with a number of high school teachers and interested math community, student members consist of undergraduate and graduate students, and institutional members mostly comprised of high schools. Teaching and learning mathematics is the bread and butter of most PERSAMA members. Helping educators and students on how best to teach and to learn is an integral mission of PERSAMA. It devotes huge amount of fund and energy via its various activities in providing insightful perspective to the mathematical sciences community as a whole.

For many academicians, teaching and research alone will not earn them the tenure and promotion they're seeking. The current phrase of "Continued Scholarly Growth" or "Scholarly Engagement" requires an academic to be involved in development of experimental programs, deliver and present research papers at national and regional meetings of professional societies, hold offices in professional organisations, participate as panels in meetings of professional organisations, and editorships of professional journals. PERSAMA is a place to become involved in so many of these activities.

STEM is a heterogeneous cluster of subjects (may include health professions, agriculture, computing, medicine, environment-related fields, depending on the country); issues are not necessarily the same for each discipline. There is a lack of international standardised data, especially for the upper secondary level STEM fields of study. There exist inconsistency of the decreasing trend of student's interest and participation in STEM disciplines; the more developed and industrialised is the country, the more its progress in education. Issues of gender disparities and imbalances; limited participation of specific groups such as the indigenous people, in STEM study and occupations; stereotypes and well-rooted beliefs that STEM disciplines are hard and only for the talented; that mathematics is only for the few are commonly well-known. STEM education alone is not sufficient to enable and support innovation. Knowledge (content) becomes rapidly obsolete and outdated; at the same time, the level of detail within each discipline has become unmanageable: defining the 'basics' is challenging. Innovation increasingly requires collaborative and interdisciplinary knowledge (and in a globalised world, this involves intercultural understanding and collaboration). Integrated and

interdisciplinary approaches to STEM disciplines can be problematic (teachers insufficiently prepared, strong traditional disciplinary boundaries, low status of integrated learning areas compared to single subjects). There are tensions between early and late specialisation and streaming; between early differentiation into several disciplines and integration into broad learning areas; and between traditional pedagogical approaches and competency-based approaches.

Economic growth in the 21st century will be driven by the nation's ability to both generate ideas and translate them into innovative products and services. Improving high school graduation rates and ensuring that all students are ready for universities or colleges and the workforce is vital to compete in the global economy. State leaders increasingly view science, technology, engineering, and mathematics (STEM) achievement as a critical component of success in higher education, career and life. STEM education is linked to the nation's future prosperity, but we are failing to prepare students with the basic building blocks they need to be successful in postsecondary and workforce pathways.

Science and mathematics are taught as discrete subjects unconnected to other coursework. Students are not often exposed to the connections between the work they are doing currently in math and science and postsecondary fields of study and STEM occupations. Most of what students learn about the real-world connections to math and science is relegated to the field trip to a museum or planetarium. Yet these students rely on technology every day in smart phones, computers, and televisions without understanding the underlying connections to math and science. Helping students to see the connections between math and science and future career opportunities is a critical aim of the STEM pipeline. Students typically form notions of their career path in secondary school. Without the right information, fully capable students may bypass STEM study because they could not foresee the applications of STEM knowledge. Motivating interest in math and science requires improved teaching strategies in the classroom and opportunities outside the classroom to demonstrate linkages between math and science, real-world applications, and future careers. Teachers and other school staff will need help in making students see these linkages.

However, in many cases, the higher education system and research universities fails to see the connection between academic outputs and the needs of the marketplace. Policymakers contend that more attention must be paid to the job demands of the regional economy. Programs and degree outputs must be better matched to the job market to sustain economic growth. This is particularly important with regard to STEM education, where supplies of STEM teachers are tight and global competition is strong.

As the nation's mathematical sciences society, PERSAMA thrives to play an active role to elevate the urgency to advance STEM education. Activities such as mathematics camp, mathematical sciences conference and mathematics competition are organised to instill and reinforce interests of the community in the mathematical sciences body of knowledge, with the pursuit to make meaningful changes across education systems that align with the workforce expectations which will ultimately aid economic growth.

3. MATHEMATICS CAMP

Mathematics Camp is a continuous activity for the educators to increase student's interest and confidence in mathematics. Mathematics Camp involved a structured activity with the purpose of increasing students' ability in solving problems and analytical skills while fostering their passion through mathematics. The main activity in Mathematics Camp emphasises on mathematics games where students can appreciate the applications of mathematics in the real world. Through mathematics games, students are able to identify that mathematics is closely related to everyday life and nature. Additionally, the structured activity also provides a fun opportunity to build softskills essentially teamwork and confidence building.

Generally, Mathematics Camp program constitutes of eight activities. Among the activities are Ice Breaking, "Senamatik" (Mathematics Physical Exercises), Motivational Talks, Mathematics Recreational, "Burumatik" (Mathematics Treasure Hunt), Mathematics Project and Mathematics Logic and Reasoning. These eight activities include elements of physical, emotional, spiritual and intellectual. Some of the activities require students performing sketch, quatrain, rhyming, chanting west, sports with some mathematical element.

Annually in April, School of Mathematical Sciences, Universiti Sains Malaysia and PERSAMA in collaboration with Sekolah Kebangsaan Bertam Indah, Pulau Pinang will organise Mathematics Camp called “I Love Math Camp”. For instance, in 2016 more than 200 students involved, they came from 23 primary schools from Pulau Pinang, Kedah, Kelantan, Perak, Pahang and Kuala Lumpur. I Love Math Camp is a one day camp adapting the concept of *Clash of Clan* to attract and increase the competitive spirit among the students through activities which involve the mathematics element.

In the *Clash of Clan* there will be six to ten booths. Each booth will have an activity such as puzzle, game and hands-on math activities. The students are divided into groups and each group will undergo the activity in each booth within the specified time allocated. The leader of the group with the assistance of a facilitator will choose different group member for each activity at the booth. Based on their performance the group will obtain some coins at each booth. After each group has completed the activity and collected the coins from each booth, they then discuss with their facilitator to decide on the number of cannonballs and fortress to be purchased. Next, all the groups move to the battle ground for second stage activity.

In the second stage, each group will assign a few members to be the attacker and defender. The attacker is a person that will throw the cannonballs towards the opponent’s fortress while defender is the person that will guard the fortress. The battle is concluded when a group runs out of cannonballs and the winner is chosen based on the group with the highest number of fortress saved. Thus, prior determination of the winner’s rounds of battle will be conducted depending on the number of groups. In short, the students had an enjoyable moment and importantly the program achieved its objective.



Figure 1. Photos During the I Love Math Camp at Sekolah Kebangsaan Bertam Indah, Pulau Pinang

4. SIMPOSIUM KEBANGSAAN SAINS MATEMATIK (SKSM)

Simposium Kebangsaan Sains Matematik or commonly known as SKSM is one of PERSAMA efforts and initiative to strengthen and expand mathematical research in Malaysia. Through this symposium, researchers and students from around the country gather together to discuss and exchange ideas while presenting their recent research studies at this symposium. It is also a platform to attract and flourish the interest of students and researchers in the field of writing and research.

Each year, SKSM will be co-organised by PERSAMA and a chosen Public University (UA) as a host. For example, Simposium Kebangsaan Sains Matematik Ke-16 (SKSM16) was organised by Kolej Universiti Sains dan Teknologi Malaysia or KUSTEM (now known as Universiti Malaysia Terengganu (UMT)) was held at Renaissance Hotel, Kota Baharu, Kelantan on 4 June 2008. While Simposium Kebangsaan Sains Matematik Ke-17 was organised by Universiti Putra Malaysia at Mahkota Hotel, Melaka. In the year 2010, Simposium Kebangsaan Sains Matematik Ke-18 was held at The Zon Regency Hotel, Johor Bahru. Next, Simposium Kebangsaan Sains Matematik Ke-20 was held on 18 December 2012 at Palm Garden Hotel Putrajaya hosted by Universiti Kebangsaan Malaysia (UKM). On 6 November 2013, Simposium Kebangsaan Sains Matematik Ke-21 was organised by Universiti Sains Malaysia (USM) at The Gurney Resort Hotel & Residences, Pulau Pinang. It is then followed by Simposium Kebangsaan Sains Matematik ke-22 on 24 November 2014 at Hotel Grand Blue Wave, Shah Alam hosted by Universiti Malaya (UM). As for year 2015, Simposium Kebangsaan Sains Matematik Ke-23 was held on 24-26 November at Universiti Teknologi Malaysia (UTM) by UTM. And for year 2016, UMT once again hosted Simposium Kebangsaan Sains Matematik Ke-24 from 27-29 September at Primula Beach Hotel, Kuala Terengganu, Terengganu.

Simposium Kebangsaan Sains Matematik (SKSM) is a very important yearly event because it is the gathering platform for experts in various fields of mathematics around Malaysia to discuss and exchange ideas as well as to collaborate in research. It has also become a useful medium for students and researchers to broaden their knowledge in their respective fields. Inserted in the SKSM program is the grand PERSAMA Awards. Figure 2 presents some of the players who have participated in the symposium.



Figure 2. Participants Simposium Kebangsaan Sains Matematik

5. NATIONAL MATHEMATICAL OLIMPIAD (OMK)

National Mathematics Olympiad (OMK) is a national mathematics competition organised by the Malaysian Mathematical Sciences Society (PERSAMA). OMK is the most prestigious academic competition in Malaysia, where the best students from around the country compete to solve the challenging mathematics problems. In 2014, more than 8,500 students from across the country participated in the OMK. The following year in 2015 showed an increase of participants in OMK which consist of 8,600 students. In year 2016, there were 5,500 students who participated in this competition. Students who achieve outstanding results in OMK will be shortlisted to represent Malaysia to the International Mathematical Olympiad (IMO).

OMK was held in Malaysia since 1971, founded by a number of mathematicians from University of Malaya. At first, OMK was opened only to students in Form 6 and the OMK questions consisted of only objective questions.

In the mid-1990s, OMK question's format had been changed to the subjective questions / problems solving which are questions that require written answers either in presenting the work towards a solution or evidence. In 2007, OMK format was changed again to the format that is being used now. In addition, beginning in 2008 the participation and registration of OMK have been made online through the official website of PERSAMA which is <http://www.persama.org.my> PERSAMA. Meanwhile, any related informations about OMK can be found from PERSAMA website and OMK facebook (https://www.facebook.com/groups/133669493325088/?ref=br_rs Olimpiad Matematik Kebangsaan (OMK), Malaysia).

OMK participation is open to all secondary schools and pre-university in Malaysia. However, entries must be in the form of a team of four. Typically, each school or pre-university will send their best students in mathematics for OMK. There are three categories, namely, Bongsu (Form 1 and 2), Muda (Form 3 and 4), and Sulong (Form 5 and 6 or equivalent). Each school can send as many teams in each category. Each team will be charged a participation fee. Schools who are interested in joining OMK should register online at the PERSAMA website.

OMK is a handwritten competition, as is commonly used in school examinations. Students are not allowed to discuss and use reference materials during the competition. Students are given a duration of 2 hours 30 minutes to answer all questions in two parts. Part A contains 6 questions, and Part B consists of 3 questions. For Part A, students need only to write the final answer in the space provided, without the need to write a complete solution. For Part B, students must write a complete solution showing the working steps or evidence, not just the final answer. Questions can be answered in Bahasa Malaysia or English. Each question is worth 2 marks for Part A and 6 marks for Part B with the full marks being 30 marks.

Students are only allowed to use pen or pencil and the geometry sets (compass, protractor, ruler) during the competition. Students are not allowed to use any form of aid to calculate such as calculators, cell phones, abacus, and laptops.

Prof. Dr. Arsmah Ibrahim has been the OMK coordinator from the years 1998 to 2003. The following years, i.e. 2004 to 2009, OMK coordinator position was held by Prof. Dr. Roslinda Nazar from Universiti Kebangsaan Malaysia, while in 2010 OMK coordinator is Assoc. Prof. Dr. Khairil Anuar Arshad from Universiti Teknologi Malaysia. Dr. Nor Muhainiah Mohd Ali, also from Universiti Teknologi Malaysia, took over as OMK coordinator starting in 2011 and held the post until 2016. For this year, i.e 2017, Assoc. Prof. Dr Abdul Fatah Wahab takes over as OMK coordinator and the competition will be held on 29th July 2017. Figure 4, 5 and 6 show OMK competition which was conducted in 2016.



Figure 4. OMK Competition at UTM Johor Bahru for 2016



Figure 5. Registration of OMK Participants and The Participants Waiting to Enter Competition Halls



Figure 6. OMK Participants Answering OMK Questions

6. INTERNATIONAL MATHEMATICAL OLIMPIAD (IMO)

International Mathematical Olympiad (IMO) is a prestigious mathematical competition for high school students. It was started back in 1959, and took part by only 7 countries mainly from Eastern Europe. At present, more than 100 countries from 5 continents are regularly participating in the competition. The main aim of the competition is to support the development of the problem solving skill among school children. IMO is a self-governing autonomous body and has its own Advisory Board that monitors the smooth running of the event and to ensure the questions in the competition are of highest quality.

In this competition, students will sit for two consecutive days examination with each examination duration of 4 hours 30 minutes. Each examination consist of three questions of different level of difficulty. The questions cover four main topics in mathematics which are algebra, geometry, number theory and combinatoric. A correct answer to each question will be awarded with 7 points that makes a perfect score of 42 points if the participant could answer all of the questions correctly.

Malaysia began to send students to the competition since 1995 which is considered as a co-curriculum project under the Ministry of Higher Education. PERSAMA has assisted in providing training to students who represent the country in the IMO competition for many years. PERSAMA plays an important role in tapping the talents in mathematics among students at the national level and giving the appropriate exposure that leads to a well prepared participants for the competition. PERSAMA is committed to realising the Government's aspirations to develop high order thinking and mathematical problem solving skills among the younger generation. This initiative has resulted to a very fruitful outcomes.

Performance of the Malaysian team shows a commendable increase. For the first ten years of involvement in the IMO, Malaysia's position is at the bottom of the list of countries participating in the IMO obtaining a position between 60 to 70. This stage can be catagorised as a learning phase for Malaysia. Malaysia then began to rise. Starting from the year 2005, Malaysia's position elevated from 75th place with a minimal total score of only 15 to the 23rd position among competing countries with a score of 129. The Malaysian team achieved points beyond three figures (i.e. more than 100) for the first time in 2012. The maximum points that can be obtained is 252. However Malaysia's achievement was slightly dropped in 2015 and 2016.

To win a medal at the IMO is indeed a rewarding and fulfilling achievement. Only with effective and strategic training plans will produce medallists among Malaysian participants. For the record, Malaysia won two bronze medals for the first time in 2000. The first silver medal for Malaysia was in 2008 while the first gold medal was in 2011. Up to the year 2014, Malaysia has successfully won 3 gold, 9 silver, 19 bronze medals and 27 honorable mentions. The year 2014 was the best year for the Malaysian team with 2 Gold, 1 silver, 1 bronze and 2 honorable mention with accumulated point of 129. The summary of the Malaysian achievement can be obtained from the official website of IMO at https://www.imo-official.org/country_team_r.aspx?code=MAS.

The success of the Malaysian team does not come easily. An effective action plan and a well structured training management implemented by PERSAMA have elevated some moderate trainee in the camp to excellent participants. Based on experience and discussions with other countries that conduct IMO training, PERSAMA had strategised a more intensive training with sound modules to ensure students get extensive exposure to the competition style materials of IMO. In addition, PERSAMA has also included a stress management module in the training as to ensure the team is always motivated and focused during the training and in the competition.

Student selection process to represent Malaysia in the IMO competition is also restructured. The first filter for selection is at the national level competition known as the National Olympiad Competition (OMK) organised by PERSAMA where high achiever students are identified and selected for the next stage of qualification assessment. A total of 60 students will be selected to follow the one-day expository seminar on IMO that normally held in November and followed by a series of IMO training camp in December and January. Students' achievements are monitored in the workshops and only the best 20 will be selected to attend the next workshop with an opportunity to sit in an international competition held in March. Students who attended the workshop in March had the opportunity to sit for an international competition of Asia Pacific Mathematical Olympiad (APMO). Based on the performance of the students at the APMO, the best 12 will be selected to undergo the following training camp. Another screening will be held in April through mathematics competition known as the Tournament of Town. This competition is based in Russia. The best 6 students will be finalised to represent the country to the IMO, they are usually selected based on the overall performance throughout the training activities.

Starting in June 2014, the management of the IMO training is assumed by PERMATA. Nevertheless, PERSAMA is still collaborating with the Ministry in providing training and guidance to students who enroll in the IMO training. With an effective training schedule and modules, it is not impossible for Malaysia to sit among the 10 best countries in the IMO as what have been achieved by other ASEAN countries such as Singapore (2011-2014), Thailand (2008-2012) and Vietnam.

7. PERSAMA AWARDS

PERSAMA plays an important role in boasting mathematical talent among students of all ranks, be it at the national level and also at the international level. It is the responsibility of PERSAMA to anchor the government needs to bring out more goodness in mathematical sciences among the young generations. For that reason, PERSAMA Award was established. It was initiated in 1997 and was first awarded in 1998. The objective of the PERSAMA Award is to promote the outstanding scientific work in Malaysia, especially in the field of mathematical sciences. The first three years, PERSAMA Award was sponsored by Sime Darby (1998-2000), followed by Syarikat Telekom Malaysia (2001-2002), Ministry of Higher Education (2010 - 2011) and Nationwide Express (2010 - 2012). During the period from 1998 to 2002, the International Mathematical Olympiad (IMO) medalist and the National Mathematical Olympiad (OMK) winners were celebrated at the PERSAMA Award ceremony. In those days, PERSAMA Award includes: Best SPM Student Award (in Mathematics), PERSAMA Felo Award, Book Award (Original & Translation), Doctor of Philosophy Thesis Award, Master Thesis Award, Manuscript Award of local journals. After 2002, the ceremony of PERSAMA Award was held in conjunction with the National Symposium on Mathematical Sciences (SKSM). PERSAMA Award has received participation from Public Universities, Publisher from Public Universities and Schools. The category of the awards after 2002 include:

1. Anugerah Felo PERSAMA
2. Anugerah Buku (Karya Asli)
3. Anugerah Buku (Karya Terjemahan)
4. Anugerah Tesis Doktor Falsafah
5. Anugerah Tesis Sarjana
6. Anugerah Makalah Ilmiah Dalam Jurnal Kebangsaan
7. Anugerah Rekacipta Matematik
8. Anugerah Rencana Popular

8. CONCLUSIONS

The Malaysian Mathematical Sciences Society (PERSAMA) serves as the body that nurture cooperation among Malaysian mathematical scientists, the government, industries, and the public to incalcut enthusiasm in mathematical sciences education. PERSAMA has initiated numerous activities within its capabilities such as the Mathematics Camp, National Mathematical Olympiad (OMK) and Simposium Kebangsaan Sains Matematik (SKSM). These activities are garnered to draw attention of the community on the importance of mathematics in everyday living and the significance to improve and strengthen mathematics education. It is vital for PERSAMA to organise activities which attract the young generations for they are the nation's future human capital that will drive Malaysia towards becoming a developed nation.

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CHAPTER SIX

MALAYSIAN STUDENTS PARTICIPATION AT THE INTERNATIONAL PHYSICS OLYMPIAD

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Abstract

Malaysian students' participation in the International Physics Olympiad (IPhO) since 2002 is discussed in this chapter. The challenges and the achievements of the students are elaborated and illustrated in great detail. Suggestions for improvement of the physics curriculum were drawn up as to assist in the preparation for students to participate in the future Olympiads. It is the aspiration of the Malaysia Education Department that the selected students will be more competitive and striving to the improvement of the overall standings in IPhO.

1. INTRODUCTION

Science subjects such as Physics, Chemistry, Biology and Mathematics are the most basic and important subjects in science, technology, engineering and mathematics (STEM) education. A strong foundation in these subjects is required to produce excellent scientists, engineers, technologist, medical personnel and other related professionals.

The International Physics Olympiad (IPhO) is one of the premier Olympiads today. It is an annual international physics competition involving students from the pre-university level. The first IPhO was held in Warsaw, Poland in 1967 and Malaysia first participation in IPhO was in 2002. More than 80 countries with 400 top students participated in this annual competition. The statutes of IPhO among others states that:

“in recognition of the growing significance of physics in all fields of science and technology, and in the general education of young people, and with the aim of enhancing the development of international contacts in the field of school education in physics, an annual physics competition has been organized for secondary school students. The competition is called the International Physics Olympiad and is a competition between individuals”

Malaysia started to compete in IPhO during the 33rd competition 2002 in Bali, Indonesia. The students were selected from junior colleges, matriculation colleges and sixth formers students from schools throughout the country. Malaysia also competed in the Asian Physics Olympiad from 2001 to 2005. One of the objectives of sending participants to this competition is to give our top physics students a chance to compete with the best of the world.

Experience by other participating countries in IPhO has been reported (Čáp & Mucha 2011; Campbell & Walberg 2011; Petersen & Wulff 2017; Polma & Kříž 2017). In this chapter the Malaysian experience competing in IPhO from 2002 to the present are discussed.

2. ABOUT IPHO

Each country can send up to five students and two team leaders to the competition. The students must be less than 20 years old on the 30th of June of the competition year. The students are selected from schools and pre-university colleges. University's Students are not eligible to enter the competition.

The IPhO usually runs for about ten days in July of each year. Upon arrival the students and leaders at the IPhO, they will be grouped at the different IPhO venues. The five students will be ushered and guided by another student from the host country and will have to spend two days completing in the exams, one day for theoretical exam and another day for practical exam. Other days are filled with academic activities and sightseeings. The leaders representing their countries will discuss the problems and solutions as prepared by the host country.

The IPhO competition consists of two parts. In Part I students are given three theoretical questions (30 points) and in Part II they are to answer one or two experimental questions (20 points). Parts I and II are given on separate days and the students are allocated five hours for each part. The questions are based on IPhO syllabus (Appendix 1) as available on IPhO website (IPhO 2017).

The questions in standard “English Language” are prepared in advance by the host country and presented to the IPhO board member, which is made up of the team leaders from all participating countries. The questions are carefully vetted and modified to the satisfaction of the board members. Team leaders must be proficient in physics and English. Answers and marking scheme are also discussed and agreed upon by the board. After that, the leaders are given the opportunity to translate the questions into their own languages. The leaders of the Malaysian team will still translate the questions into Bahasa Malaysia, although almost all of the students are proficient in English. The Bahasa Malaysia version is made available to help them to understand more of the questions. Therefore our students are given two sets of questions, namely questions in the primary form (English) and also the questions that are translated into Bahasa Malaysia. The students can write their answers in any language of their choice.

Marking of the answer scripts is done by ‘double marking’, the team leaders are given a copy of the students answer script to be marked. Official graders, normally from the host country will also mark the answer scripts. This is followed by a

moderation of the marks between the leaders of each country with the official graders before the final marks for each student are agreed upon. This process can be very complicated and requires commitments, expertise and diplomacy on both sides. Marks are given for individual student and a perfect score is 50. According to the IPhO statute the distribution of medals is as follows:

- Gold Medal (6% of the top participants)
- Gold + Silver (18% of top participant)
- Gold + Silver + Bronze (36% of the top participants)
- Gold + Silver + Bronze + Honorable Mention (HM) (60% the top participants)

3. SELECTION PROCESS, TRAINING AND ACHIEVEMENTS

The process of selecting students will always begin early of each year. The state education department nominates one or two students to represent the state. Students from the private schools and MARA colleges are also invited to attend the first training camp. In the first camp about 50 students are invited and at the end of the camp, a test will be given from which about 25 students are selected for the second camp. The students will be asked theoretical and experimental questions in these camps. After completion of several training camps, the final five students are selected to represent Malaysia. The photos of the Malaysian team to the 2005, 2011 and 2016 IPhO are shown below.

The achievement of the Malaysian team from 2002 to 2016 is given in Appendix

2 (MyIPhO 2017). The medal tally is given in Table 1. The number of medals is as follows: 1 gold, 1 silver, 6 bronze and 24 honorable mentions.

Table 1. Medals and awards at International Physics Olympiad 2002- 2016

| IPhO | Gold | Silver | Bronze | Honourable Mention |
|--------------|----------|----------|----------|--------------------|
| 2016 | - | - | 1 | - |
| 2015 | - | - | - | 1 |
| 2014 | - | - | - | 2 |
| 2013 | - | - | 1 | 1 |
| 2012 | - | - | - | 3 |
| 2011 | 1* | - | - | 1 |
| 2010 | - | - | 1 | 1 |
| 2008 | - | 1 | - | 1 |
| 2007 | - | - | 1 | 3 |
| 2006 | - | - | 1 | 2 |
| 2005 | - | - | 1 | 2 |
| 2004 | - | - | - | 4 |
| 2002 | - | - | - | 3 |
| Total | 1 | 1 | 6 | 24 |

* With Special Prize from the European Physics Society

The Malaysia team to 2011 IPhO, Bangkok, Thailand



Chew Kok Wei from Chung Ling High School, Penang made history when he won Malaysia's first gold medal in the 42nd IPhO (July 2011 Bangkok). He also won the Special Prize from European Physics Society for the "Most Balanced Score in Theory and Experiment".

4. IMPACT AND BENEFITS

Participation in the International Physics Olympiad allows our students to enjoy problem solving, gauge their knowledge with challenging and stimulating questions, solve some real-world problem in Physics, gain experience on open-ended and novel physics questions and develop the skills required for admission to the top universities

Our students can measure their skills against the best students from other countries through the competition. The success in winning medals gives our students the confidence to compete internationally. In addition, this competition gives our students the opportunity to interact and exchange experiences with students from other countries.

Typically Nobel Prize winners are invited to give lectures and our students gained new knowledge through a series of world-class scientific lectures. The team leaders and officials experience a sense of belonging for working twenty-four hours without a break as a cohesive team during the competition.

Most of our students who represented the country in IPhO went on to study physics, engineering and other fields at many prestigious universities throughout the world including the Ivy League. Most went on to obtain MSc and PhD in their respective fields. A Facebook account (Physics Olympiad - Malaysia) keeps all the Olympians and future Olympians together.

5. CHALLENGES

Generally IPhO competition is more on challenging individual student's ability to solve physics questions of the highest standard and does not involve team effort. Thus each student sent to IPhO should be independent and must have the will, determination and mental resilience to compete. Coaching individual student to achieve a high level abilities in both the theoretical and practical aspects is a challenge because each of them has their own strengths and weaknesses. Thus it would require a relatively long time and a very effective training strategy to train the selected students.

The nature of the questions in the Physics Olympiad is likened to “Problem Solving”. The existing secondary school syllabus may not be able to prepare our students with these skills because the current syllabus emphasised on a different level of physics. Furthermore, students are not exposed to using advance instrument such as digital multimeters, oscilloscopes and others, which are not readily available in a typical physics laboratory in our schools.

The IPhO syllabus shown in Appendix 1 indicates that the level and breadth of physics knowledge expected of a pre-university level at the international level is much higher than the STPM or matriculation level. Thus, our physics syllabus should be periodically benchmarked against the international level. This will ensure our STEM education is at par with those considered the best in the world.

6. CONCLUSION

Intensive efforts and training should be given to our students because they have the potential to achieve greater success. Each student sent to the IPhO competition should be independent and have the will, determination and mental resilience. However coaching individual students to achieve a high level is deemed as a real challenge. We are blessed with trainers and coaches who are very committed and highly knowledgeable in the physics. For further improvement, it requires more provision in financial support, expertise and commitment from all parties. Appropriate incentives such as the chance to go to university of their choice should be given to students who represent the country and won medals in this competition.

Malaysia must institute a more systematic program to train students in the lower secondary level. Good level of physics, chemistry, biology and mathematics among students will increase the country’s competitiveness in the fields of science, engineering, technology and medicine. Students of high capability when exposed to global competition such as IPhO will have a high intellectual level that is useful for us to be a developed country. This would also help Malaysia as a hub for higher education in this region.

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Appendix 1

IPhO Syllabus

1. INTRODUCTION

1.1 Purpose of this syllabus

This syllabus lists topics which may be used for the IPhO. Guidance about the level of each topic within the syllabus is to be found from past IPhO questions.

1.2 Character of the problems

Problems should focus on testing creativity and understanding of physics rather than testing mathematical virtuosity or speed of working. The proportion of marks allocated for mathematical manipulations should be kept small. In the case of mathematically challenging tasks, alternative approximate solutions should receive partial credit. Problem texts should be concise; the theoretical and the experimental examination texts should each contain fewer than 12000 characters (including white spaces, but excluding cover sheets and answer sheets).

1.3 Exceptions

Questions may contain concepts and phenomena not mentioned in the Syllabus providing that sufficient information is given in the problem text so that students without previous knowledge of these topics would not be at a noticeable disadvantage. Such new concepts must be closely related to the topics included in the syllabus. Such new concepts should be explained in terms of topics in the Syllabus.

1.4 Units

Numerical values are to be given using SI units, or units officially accepted for use with the SI. It is assumed that the contestants are familiar with the phenomena, concepts, and methods listed below, and are able to apply their knowledge creatively.

2. THEORETICAL SKILLS

2.1 General

The ability to make appropriate approximations, while modelling real life problems. Recognition of and ability to exploit symmetry in problems.

2.1 Mechanics

2.2.1 Kinematics

Velocity and acceleration of a point particle as the derivatives of its displacement vector. Linear speed; centripetal and tangential acceleration. Motion of a point particle with a constant acceleration. Addition of velocities and angular velocities; addition of accelerations without the Coriolis term; recognition of the cases when the Coriolis acceleration is zero. Motion of a rigid body as a rotation around an instantaneous center of rotation; velocities and accelerations of the material points of rigid rotating bodies.

2.2.2 Statics

Finding the center of mass of a system via summation or via integration. Equilibrium conditions: force balance (vectorially or in terms of projections), and torque balance (only for one-and two-dimensional geometry). Normal force, tension force, static and kinetic friction force; Hooke's law, stress, strain, and Young modulus. Stable and unstable equilibria.

2.2.3 Dynamics

Newton's second law (in vector form and via projections (components)); kinetic energy for translational and rotational motions. Potential energy for simple force fields (also as a line integral of the force field). Momentum, angular momentum, energy and their conservation laws. Mechanical work and power; dissipation due to friction. Inertial and non-inertial frames of reference: inertial force, centrifugal force, potential energy in a rotating frame. Moment of inertia for simple bodies (ring, disk, sphere, hollow sphere, rod), parallel axis theorem; finding a moment of inertia via integration.

2.2.4 Celestial mechanics

Law of gravity, gravitational potential, Kepler's laws (no derivation needed for first and third law). Energy of a point mass on an elliptical orbit.

2.2.5 Hydrodynamics

Pressure, buoyancy, continuity law. The Bernoulli equation. Surface tension and the associated energy, capillary pressure.

2.3 Electromagnetic fields

2.3.1 Basic concepts

Concepts of charge and current; charge conservation and Kirchhoff's current law. Coulomb force; electrostatic field as a potential field; Kirchhoff's voltage law. Magnetic B -field; Lorentz force; Ampère's force; Biot-Savart law and B -field on the axis of a circular current loop and for simple symmetric systems like straight wire, circular loop and long solenoid.

2.3.2 Integral forms of Maxwell's equations

Gauss' law (for E - and B -fields); Ampère's law; Faraday's law; using these laws for the calculation of fields when the integrand is almost piece-wise constant. Boundary conditions for the electric field (or electrostatic potential) at the surface of conductors and at infinity; concept of grounded conductors. Superposition principle for electric and magnetic fields.

2.3.3 Interaction of matter with electric and magnetic fields

Resistivity and conductivity; differential form of Ohm's law. Dielectric and magnetic permeability; relative permittivity and permeability of electric and magnetic materials; energy density of electric and magnetic fields; ferromagnetic materials; hysteresis and dissipation; eddy currents; Lenz's law. Charges in magnetic field: helicoidal motion, cyclotron frequency, drift in crossed E - and B -fields. Energy of a magnetic dipole in a magnetic field; dipole moment of a current loop.

2.3.4 Circuits

Linear resistors and Ohm's law; Joule's law; work done by an electromotive force; ideal and non-ideal batteries, constant current sources, ammeters, voltmeters and ohmmeters. Nonlinear elements of given V - I characteristic. Capacitors and capacitance (also for a single electrode with respect to infinity); self-induction and inductance; energy of capacitors and inductors; mutual inductance; time constants for RL and RC circuits. AC circuits: complex amplitude; impedance of resistors, inductors, capacitors, and combination circuits; phasor diagrams; current and voltage resonance; active power.

2.4 Oscillations and waves

2.4.1 Single oscillator

Harmonic oscillations: equation of motion, frequency, angular frequency and period. Physical pendulum and its reduced length. Behavior near unstable equilibria. Exponential decay of damped oscillations; resonance of sinusoidally forced oscillators: amplitude and phase shift of steady state oscillations. Free oscillations of LC -circuits; mechanic-electrical analogy; positive feedback as a source of instability; generation of sine waves by feed back in a LC -resonator.

2.4.2 Waves

Propagation of harmonic waves: phase as a linear function of space and time; wave length, wave vector, phase and group velocities; exponential decay for waves propagating in dissipative media; transverse and longitudinal waves; the classical Doppler effect. Waves in inhomogeneous media: Fermat's principle, Snell's law. Sound waves: speed as a function of pressure (Young's or bulk modulus) and density, Mach cone. Energy carried by waves: proportionality to the square of the amplitude, continuity of the energy flux.

2.4.3 Interference and diffraction

Superposition of waves: coherence, beats, standing waves, Huygens' Principle interference due to thin films (conditions for intensity minima and maxima only). Diffraction from one and two slits, diffraction grating, Bragg reflection.

2.4.4 Interaction of electromagnetic waves with matter

Dependence of electric permittivity on frequency (qualitatively); refractive index; dispersion and dissipation of electromagnetic waves in transparent and opaque materials. Linear polarization ; Brewster angle; polarizers; Malus' law.

2.4.5 Geometrical optics and photometry

Approximation of geometrical optics: rays and optical images; a partial shadow and full shadow. Thin lens approximation; construction of images created by ideal thin lenses; thin lens equation luminous flux and its continuity; illuminance; luminous intensity.

2.4.6 Optical devices

Telescopes and microscopes: magnification and resolving power; diffraction grating and its resolving power; interferometers.

2.5 Relativity

Principle of relativity and Lorentz transformations for the time and spatial coordinate, and for the energy and momentum; mass-energy equivalence; invariance of the space time interval and of the rest mass. Addition of parallel velocities; time dilation; length contraction; relativity of simultaneity; energy and momentum of photons and relativistic Doppler effect; relativistic equation of motion; conservation of energy and momentum for elastic and non-elastic interaction of particles.

2.6 Quantum Physics

2.6.1 Probability waves

Particles as waves: relationship between the frequency and energy, and between the wave vector and momentum. Energy levels of hydrogen-like atoms (circular orbits only) and of parabolic potentials; quantization of angular momentum. Uncertainty principle for the conjugate pairs of time and energy, and of coordinate and momentum (as a theorem, and as a tool for estimates).

2.6.2 Structure of matter

Emission and absorption spectra for hydrogen-like atoms (for other atoms — qualitatively), and for molecules due to molecular oscillations; spectral width and lifetime of excited states. Pauli exclusion principle for Fermi particles. Particles (knowledge of charge and spin): electrons, electron neutrinos, protons, neutrons, photons; Compton scattering. Protons and neutrons as compound particles. Atomic nuclei, energy levels of nuclei (qualitatively); alpha-, beta- and gamma-decays; fission, fusion and neutron capture; mass defect; half-life and exponential decay. Photoelectric effect.

2.7 Thermodynamics and statistical physics

2.7.1 Classical thermodynamics

Concepts of thermal equilibrium and reversible processes; internal energy, work and heat; Kelvin's temperature scale; entropy; open, closed, isolated systems; first and second laws of thermodynamics. Kinetic theory of ideal gases: Avogadro number, Boltzmann factor and gas constant; translational motion of molecules and pressure; ideal gas law; translational, rotational and oscillatory degrees of freedom; equipartition theorem; internal energy of ideal gases; root-mean-square speed of molecules. Isothermal, isobaric,

isochoric, and adiabatic processes; specific heat for isobaric and isochoric processes; forward and reverse Carnot cycle on ideal gas and its efficiency; efficiency of non-ideal heat engines.

2.7.2 Heat transfer and phase transitions

Phase transitions (boiling, evaporation, melting, sublimation) and latent heat; saturated vapor pressure, relative humidity; boiling; Dalton's law; concept of heat conductivity; continuity of heat flux.

2.7.3 Statistical physics

Planck's law (explained qualitatively, does not need to be remembered), Wien's displacement law; the Stefan-Boltzmann law.

3. EXPERIMENTAL SKILLS

3.1 Introduction

The theoretical knowledge required for carrying out the experiments must be covered by Section 2 of this Syllabus. The experimental problems should contain at least some tasks for which the experimental procedure (setup, the list of all the quantities subject to direct measurements, and formulae to be used for calculations) is not described in full detail. The experimental problems may contain implicit theoretical tasks (deriving formulae necessary for calculations); there should be no explicit theoretical tasks unless these tasks test the understanding of the operation principles of the given experimental setup or of the physics of the phenomena to be studied, and do not involve long mathematical calculations. The expected number of direct measurements and the volume of numerical calculations should not be so large as to consume a major part of the allotted time: the exam should test experimental creativity, rather than the speed with which the students can perform technical tasks. The students should have the following skills.

3.2 Safety

Knowing standard safety rules in laboratory work. Nevertheless, if the experimental set-up contains any safety hazards, the appropriate warnings should be included in the text of the problem. Experiments with major safety hazards should be avoided.

3.3 Measurement techniques and apparatus

Being familiar with the most common experimental techniques for measuring physical quantities mentioned in the theoretical part. Knowing commonly used simple laboratory instruments and digital and analog versions of simple devices, such as calipers, the Vernier scale, stop watches, thermometers, multimeters (including ohmmeters and AC/DC voltmeters and ammeters), potentiometers, diodes, transistors, lenses, prisms, optical stands, calorimeters, and so on. Sophisticated practical equipment likely to be unfamiliar to the students should not dominate a problem. In the case of moderately sophisticated equipment (such as oscilloscopes, counters, rate meters, signal and function generators, photo gates, etc), instructions must be given to the students.

3.4 Accuracy

Being aware that instruments may affect the outcome of experiments. Being familiar with basic techniques for increasing experimental accuracy (e.g. measuring many periods instead of a single one, minimizing the influence of noise, etc.). Knowing that if a functional dependence of a physical quantity is to be determined, the density of taken data points should correspond to the local characteristic scale of that functional dependence. Expressing the final results and experimental uncertainties with a reasonable number of significant digits, and rounding off correctly.

3.5 Experimental uncertainty analysis

Identification of dominant error sources, and reasonable estimation of the magnitudes of the experimental uncertainties of direct measurements (using rules from documentation, if provided). Distinguishing between random and systematic errors; being able to estimate and reduce the former via repeated measurements. Finding absolute and relative uncertainties of a quantity determined as a function of measured quantities using any reasonable method (such as linear approximation, addition by modulus or Pythagorean addition).

3.6 Data analysis

Transformation of a dependence to a linear form by appropriate choice of variables and fitting a straight line to experimental points. Finding the linear regression parameters (gradient, intercept and uncertainty estimate) either graphically, or using the statistical functions of a calculator (either method acceptable). Selecting optimal scales for graphs and plotting data points with error bars.

4. MATHEMATICS

4.1 Algebra

Simplification of formulae by factorization and expansion. Solving linear systems of equations. Solving equations and systems of equations leading to quadratic and biquadratic equations; selection of physically meaningful solutions. Summation of arithmetic and geometric series.

4.2 Functions

Basic properties of trigonometric, inverse-trigonometric, exponential and logarithmic functions and polynomials. This includes formulae regarding trigonometric functions of a sum of angles. Solving simple equations involving trigonometric, inverse-trigonometric, logarithmic and exponential functions.

4.3 Geometry and stereometry

Degrees and radians as alternative measures of angles. Equality of alternate interior and exterior angles, equality of corresponding angles. Recognition of similar triangles. Areas of triangles, trapezoids, circles and ellipses; surface areas of spheres, cylinders and cones; volumes of spheres, cones, cylinders and prisms. Sine and cosine rules, property of inscribed and central angles, Thales' theorem. Medians and centroid of a triangle. Students are expected to be familiar with the properties of conic sections including circles, ellipses, parabolae and hyperbolae.

4.4 Vectors

Basic properties of vectorial sums, dot and cross products. Double cross product and scalar triple product. Geometrical interpretation of a time derivative of a vector quantity.

4.5 Complex numbers

Summation, multiplication and division of complex numbers; separation of real and imaginary parts. Conversion between algebraic, trigonometric, and exponential representations of a complex number. Complex roots of quadratic equations and their physical interpretation.

4.6 Statistics

Calculation of probabilities as the ratio of the number of objects or event occurrence frequencies. Calculation of mean values, standard deviations, and standard deviation of group means.

4.7 Calculus

Finding derivatives of elementary functions, their sums, products, quotients, and nested functions. Integration as the inverse procedure to differentiation. Finding definite and indefinite integrals in simple cases: elementary functions, sums of functions, and using the substitution rule for a linearly dependent argument. Making definite integrals dimensionless by substitution. Geometric interpretation of derivatives and integrals. Finding constants of integration using initial conditions. Concept of gradient vectors (partial derivative formalism is not needed).

4.8 Approximate and numerical methods

Using linear and polynomial approximations based on Taylor series. Linearization of equations and expressions. Perturbation method: calculation of corrections based on unperturbed solutions. Numerical integration using the trapezoidal rule or adding rectangles.

Appendix 2

List of Malaysian students in IPhO and medals

2016 - Zurich Switzerland (47th IPhO 10-17 July 2016)

| | | |
|-----------------|--|--------------|
| Lee Ming Yi | SMK Tinggi, Bukit Mertajam, Pulau Pinang | Bronze Medal |
| Ang Wei Sze | Asasi Pintar UKM Bangi, Selangor | |
| Toong Khong Ang | Permata Pintar UKM Bangi, Selangor | |
| Luqman Hakim | Kolej MARA Banting, Selangor | |
| Moh Ling Siang | SMK Marudi, Sarawak | |

2015 - Mumbai, India (46th IPhO 5-12 July 2015)

| | | |
|--------------------|--|-------------------|
| Chan Jer Yong | SMJK Chung Ling, Pulau Pinang | Honorable Mention |
| Farish Mohd Ismail | Kolej MARA Banting, Selangor | |
| Lee Ming Yi | SMK Tinggi, Bukit Mertajam, Pulau Pinang | |
| Leong Khee Ing | SMK Green Road, Kuching, Sarawak | |
| Ong Yi Jie | SMJK Yok Bin, Melaka | |

2014 - Astana, Kazakhstan (45th IPhO 13-21 July 2014)

| | | |
|----------------------------|-------------------------|-------------------|
| Ahmad Samhan Mohamed Aslam | Kolej MARA Banting | Honorable Mention |
| Boay Zhen Jie | SMK Tinggi Klang | Honorable Mention |
| Chong Pooi Seong | SMK(L) Methodist | |
| Poh Wai Chang | SMK Tinggi, Melaka | |
| Saw Chiang Ping | SMJK Chung Ling, Penang | |

| 2013 - Copenhagen, Denmark (44 th IPhO 7-15 July 2013) | | |
|---|-------------------------|-------------------|
| Yeoh Chin Vern | SMJKC Katolik, Selangor | Bronze Medal |
| Poh Wai Chang | SMK Tinggi, Melaka | Honorable Mention |
| Man Chee Seng | SMJK Sam Tet, Ipoh | |
| Muhammad Asyraf Hafizuddin | Kolej MARA Banting | |

| 2012 - Tartu, Tallinn, Estonia (43 rd IPhO) | | |
|--|---------------------------------|-------------------|
| Koay Hui Wen | SMJKC Perempuan Cina, P. Pinang | Honorable Mention |
| Ooi ChunN Yeang | SMJKC Chung Ling, P. Pinang | Honorable Mention |
| Yeoh Chin Vern | SMJKC Katolik, Selangor | Honorable Mention |
| Lee Yuan Zhe | SMK ST. Paul, Seremban | |
| Imran Arifin | Kolej MARA Banting | |

| 2011 - Bangkok, Thailand (42 nd IPhO) | | |
|--|--------------------------------------|--|
| Chew Kok Wei | Chung Ling, High School Pulau Pinang | Gold Medal & European Phys. Soc. Prize (The Most Balanced Score) |
| Khaw Kok Liang | SMJK Chung Hwa Confucian | Honorable Mention |

| 2010 - Zagreb, Croatia (41 st IPhO) | | |
|--|-----------------------------------|-------------------|
| Chew Kok Wei | Chung Ling High School, P. Pinang | Bronze Medal |
| Mohamad Kamil Idris | Kolej MARA Banting | Honorable Mention |

| 2008 - Hanoi, Vietnam (39 th IPhO) | | |
|---|-------------------------------|-------------------|
| Ng Xin Zhao | Malacca High School | Silver Medal |
| Phan Chow Fu | SM Tinggi Klang | Honorable Mention |
| Muhd. Khairul Azri b. Zulkipli | Kolej MARA Banting | |
| Saw Siong Keat | SMJK Chung Ling, Pulau Pinang | |
| Kee Wee Siong | SMK Tinggi Klang, Selangor | |

| 2007 - Isfahan, Iran (38 th IPhO) | | |
|--|-----------------------|-------------------|
| Khoo Kent Loong | SMJK Sam Tet, Ipoh | Bronze Medal |
| Cavan Chiam Choon Hao | St Xavier Inst., P.P. | Honorable Mention |
| Ng Xin Zhao | SMK Tinggi Melaka | Honorable Mention |
| Mohd Farhan Mohd Jafri | Kolej MARA Banting | Honorable Mention |
| Abdul Muhaimin Izham | Kolej MARA Banting | |

| 2006 - Singapore (37 th IPhO) | | |
|--|-----------------------|-------------------|
| Low Ching Hua | SMJK Yu Hua, Kajang | Bronze Medal |
| Goh Boon Chong | Chung Ling HS, Penang | Honorable Mention |
| Khoo Kent Loong | SMJK Sam Tet, Ipoh | Honorable Mention |
| Faiz Rashdi b Muhammad | Kolej MARA Banting | |
| Mohd Safwan B Ahmad Nazri | Kolej MARA Banting | |

2005 - Salamanca, Spain (36th IPhO)

| | | |
|------------------|--------------------------------|-------------------|
| Lim Chun Pin | Chung Ling HS, Penang | Bronze Medal |
| Ho Teck Hsien | Sek Men St Francis, Melaka | Honorable Mention |
| Ooi Chin Hong | Chung Ling HS, Penang | Honorable Mention |
| Nur Aizaan Anwar | Kolej MARA Banting | |
| Chew Chia Leng | Chung Ling High School, Penang | |

2004 - Pohang, Korea (35th IPhO)

| | | |
|---------------------------|--------------------|-------------------|
| Mohd Nasri Kasuan | Kolej MARA Banting | Honorable Mention |
| Lee Tuan Cheong | Sek. Men Kepong | Honorable Mention |
| Chee Hang Seng | Sek Tinggi Melaka | Honorable Mention |
| Yeo Hock Chai | Sek Tinggi Melaka | Honorable Mention |
| Nik Mohamed Mohaz Mohamed | Kolej MARA Banting | |

2002 - Bali, Indonesia (33rd IPhO)

| | | |
|------------------|----------------------------------|-------------------|
| Kwong Chang Chee | Chung Ling HS, Penang | Honorable Mention |
| Lim Chun Yee | Chung Ling HS, Penang | Honorable Mention |
| Ting Kee Yong | Sekolah Methodist Sibul, Sarawak | Honorable Mention |

CHAPTER SEVEN**STEM OUTREACH
BY MALAYSIAN YOUNG SCIENTISTS**

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ABSTRACT

This article describes the perspectives of Malaysian students in taking Science, Technology, Engineering and Mathematic (STEM) subjects for their future endeavours. The sharp decline of their enrolment number has triggered a due attention from all relevant parties, ranging from the ministries, universities and schools, private corporations, parents, professional bodies and non-governmental organisations (NGO), so that all could work meticulously towards a resolution of this problem. In this context, Malaysian young scientists, mainly university lecturers, students and members of Young Scientists Network- Academy of Sciences Malaysia (YSN-ASM), have taken a pragmatic action by engaging themselves in a wide variety of STEM outreach initiatives. All these hard works have been rewarded with many great supports and overwhelming response.

1. OVERVIEW

Over the last two decades, the enrolment number of students in the subjects of Science, Technology, Engineering and Mathematics (STEM) has declined tremendously, despite of the countless efforts and initiatives taken in this perspective. The current situation is in a particularly worrisome predicament as our beloved country is gearing towards knowledge-based economy, which requires throughput of talents in various science and technology driven areas, e.g. fabrication of functional materials for electronic and electrical applications, agricultural biotechnology for food production and export commodities, green and clean energy resources for sustainable development etc. This clearly indicates that some pragmatic actions are required in order to circumvent this serious issue or else, we will fail to achieve our goal of being a developed and high-income nation even for the next three decades. Thus, transforming our society into highly knowledgeable, skilled and practiced with strong background of Science education is inevitably the key success factor in this pursuit.

Considering the disproportionate growth of students taking arts stream compared to science stream, there is a strong need to promote interest in STEM among the young generation. Among the common reasons given by students that they find many topics in STEM are boring, difficult to understand and rather too ambiguous and constrained. Worse still, students who are not already planning to major in STEM often regard it as a waste of their time, a message unfortunately echoed by their parents or peers. It is therefore imperative to change the perception of public through proper communication that STEM is the game-changer in their current careers and future endeavours. In this context, there are certain benefits of organising science outreach at various levels as this provides a platform for the parents and children to experience themselves different engineering, maths, and science exhibits or experiments in a less formal way compared to those they have learned during school days.

This also plays a pivotal role in disseminating ideas on the importance of STEM to the public and indirectly could increase the public awareness and enhance the interest in science. On the other hand, the outreach activities provide hands-on training to the exhibitors, who may come from students, teachers or university lecturers, to speak confidently while articulating their ideas and research findings by a lucid way. It is always essential to organise exhibition and such kind of event allows all parties to interact and exchange their views pertaining to the subject of

interest with the talented ones or experts. In addition, a large-scale international exhibition also helps to establish linkage and networking for government agencies, private sectors, educators and schools for sharing information on extra-curriculum and practices in STEM at both school and university levels.

2. YOUNG SCIENTISTS NETWORK-ACADEMY OF SCIENCES (YSN-ASM)

Experience the fun of science is an important factor to be further explored in promoting STEM. Opportunity to have this worthwhile experience has been put to a test by a group of prominent Malaysian young scientists in escalating and nurturing STEM among school children. The Young Scientists Network (YSN) was established under the auspice of Academy of Sciences Malaysia (ASM) on December 12, 2012. The YSN-ASM members are below the age of 40 years and selected based on their distinguished career in scientific research and passion to contribute to the country. There are several STEM based activities handled by YSN-ASM in collaboration with many other academic entities. The uniqueness of those activities is the involvement of young scientists from various branches of science and able to become an icon of science to students. In addition, postgraduate students (Master and Doctor of Philosophy) are also involved in a wide variety of hands-on and sharing activities with teachers and students. The experience and skills of postgraduate students also play an important role in sharing and encouraging students' interest in science.

3. SCIENCE OUTREACH

Science Outreach program was planned to stimulate interest and awareness of students, teachers and parents in STEM through the engagement of hands-on and challenge-response activities at both school and international levels. Some of the objectives outlined in the program are

- i. to promote interest and awareness of science among students and the general public
- ii. to foster scientific thinking in problem solving
- iii. to inspire the younger generation to become future research leaders
- iv. to bridge the gap between young scientists and school students

Some of the activities were carried over to blend in the existing programmes in ASM, universities and ministries. Members of YSN-ASM also use these events and feedbacks from the participants in drafting a new module or planning an activity. This could bring the students closer to science, thus strengthening their awareness that STEM is very important in life and rewarding as well!. In order to achieve this, these activities need to be tailored-made and borderless, where activities should not only focused at school, but expanding to university research laboratories that are equipped with the state-of-art and sophisticated instruments. Note that advancement of knowledge requires meticulous effort of finding evidence-based data through research as to support all postulations before they could be accepted as facts. Meanwhile, the conducive learning ambience at university may inspire the younger generation to study hard so that they can enrol into their desired universities.

As recognition of highly active and proactive roles demonstrated by YSN-ASM, tremendous invitations have been received from different schools and agencies across Malaysia since 2014. However, the ever increasingly challenging situation has forced YSN-ASM to be more selective and cost-effective in all sort of outreach activities. In view of this, the Science Outreach team alienated the activities, which are spearheaded by the YSN-ASM experts, in accordance with the following arrangement: (i) Northern Zone is handled by USM team, (ii) Central Zone is covered by UPM and UKM teams, (iii) Southern Zone is managed by UTM team, (iv) Eastern Zone is led by a joint effort from UPM and UMT, (v) Both Sabah

and Sarawak are assigned to UPM and nearby universities. Nevertheless, a cross-boundary teamwork is possible when there are special needs of certain expertise and consultancy.

4. STUDY VISIT AND MOTIVATIONAL TALKS

In one of the past activities, the students and teachers from Sekolah Menengah Sains Raja Tun Azlan Shah, Taiping (SERATAS) enjoyed their study visit to the Faculty of Science and the Institute of Biosciences, Universiti Putra Malaysia (UPM). They were given an exposure to a multidisciplinary science event linking chemistry, physics and biology. Their valuable experience was built through the activity of DNA modelling, solid and protein crystallisation, fungi fermentation in bioreactors and production of chemicals by the reaction of a biocatalyst.

The visitors were allowed to assessing research equipment specifically for biophysical and physicochemical characterisation; these instruments are only available in modern research laboratory and worth millions of ringgit. Since the visit was part of the activities during Noble Laureate week, which was organised by ASM in collaboration with Galeri Petronas in Suria KLCC, the tournament was continued with a courtesy visit to the special exhibition of Nobel Prize and Faces of Science@Malaysia. They also attended a motivational talk at the Scientific Café with ASM Fellow, Tan Sri Dr. M. Jegathesan, an Olympian and renowned sports figure in Malaysia. The excitement was further escalated by a visit to the PETROSAINS.



Students were amazed by the hi-tech equipments (left) and during the Science Café presentation by ASM Fellow, Tan Sri Dr. M. Jegathesan (right).

As to foster a stronger relationship, an intensive two-day Back2school programme was conducted in SERATAS Taiping involving 12 YSN-ASM young scientists and 24 graduate students. A number of 240 students and 20 teachers from more than 10 boarding schools (including those from Johor, Terengganu and Perlis) and 10 secondary schools in the Larut Matang and Selama districts had participated in the first YSN Science Outreach in the Northern Zone. It is very important to note the significant role and commitment of the principals and the teachers to gather a huge number of students throughout Malaysia. The ‘adopted school’ concept was also initiated between SERATAS and the Faculty of Science, UPM, where various science activities may be developed between school and university. In this context, the alumni plays a significant role in establishing such relationship. This example can be exemplified and nurtured in order for it to grow and spread to other schools.

5. SCIENTIST IN THE CLASSROOM

Among the highlights of activities organised by YSN-ASM, the ‘Scientist in the Classroom’ programme has received a very warm response from the students. In this initiative, a young scientist will replace a teacher to teach a selected topic in the syllabus so that the instructor will infuse elements from the related research and specific applications. This alternative method could change the students’ perception that a relevant theory, which is often regarded as difficult and boring, to something easy and open access to technology, innovation and new career. For example, enzyme engineering, which is now widely used in industrial fields, could shed new insights into biotechnology, pharmaceutical and medical.

Lecture or talk session is designed to be minimal as the students may not be able to endure long hours session. A 40 minutes multidisciplinary or transdisciplinary or innovative talk, and followed by a 20 minutes questions and answers (Q&A) session, which is believed to be more suitable in this perspective. For example, an overview lecture on “Nanotechnology and Biotechnology” by young scientist could be an eye opener for the students to choose their interests and career in the future. These interactive sessions help the students to realise the importance of science and not just to memorise the facts to achieve good grades. The students are advised to know and understand the multidisciplinary and transdisciplinary science as it is one of the important elements of the impactful research that benefits our global community.



A banner showcasing the activities and Malaysian top young scientists (YSN members)

There is nothing better than learning from the actual self-experience. Interactive science activities were conducted in the teaching laboratories for 45 minutes in one session. Each student would have the opportunity to conduct his/her experiments in the laboratory or station covering Physics, Chemistry, Biology and Engineering. For instance, the biology laboratory covered two activities, namely the DNA characterisation of a variety of plant cells (biotechnology) and human anatomy (medical). The chemistry laboratory demonstrated carbon allotropes, molecular symmetry and structure, modelling and computational chemistry simulations. The Physics laboratory performed various substations of daily activities, which illustrates the physical phenomena such as friction, force and acceleration by using items from domestic and waste. The Engineering laboratory focused on the concepts of physics and mathematics in the fields of electricity, electronics and solar. Consequently, these interactions by experiments had enabled the young scientists to encourage and instil the students’ interest in science. From the frequently asked questions, these show that the students were eagerly desired to know more about the selection of science-related courses of the undergraduate and graduate studies. The graduate students would come into action by sharing their experiences and giving few tips to students who were looking for a field that fits their interests.

Awards and prizes were also available to all students, teachers and schools involved as souvenirs and appreciation. The session ended with young scientists and graduate students who were overwhelmed by the students for photo session and autograph. This episode was very important for the students as they can begin to see Science as a new capital in knowledge advancement and not just being too obsessed by the world of entertainment or sport as we often hear.

6. SCIENCE CARNIVAL / FESTIVAL

As YSN-ASM is increasingly known among schools, there are many invitations received from universities to join their science carnival and for the admission to the university. Foundation Center of Agriculture (ASPER) UPM has consistently invited YSN-ASM each year to join their Science Fair. With an estimated nearly 5 thousand visitors comprising of students, teachers and parents, the YSN-ASM scientists have influenced the parents, to the extent that is possible and to encourage their children to choose science at the university level. The exhibits in the form of kits and simple science also attracted parents to experience it with their children. Such disclosure is necessary so that students are not alone in choosing their majors or careers, but also the role of the parents in supporting their interests and decisions. YSN-ASM also helped many of their members' faculty to participate in science festival all around Malaysia. They are actively involved as mentors for interactive activities and demonstrations as well as to helping students to deal with questions of science and mathematics effectively. These opportunities serve to increase the visibility and footage of YSN-ASM through many other interesting activities such as the National Science Challenge (NSC), which receives more than fifteen thousands of entries every year.

7. PENANG INTERNATIONAL SCIENCE FESTIVAL

All efforts from YSN-ASM Science Outreach are well recognised especially the team has been invited to take part in the Penang International Science Fair Penang (PISF) since 2014. YSN-ASM is given several booths and a special interactive slot for the three-day event at the Penang International Sports Arena (PISA). This mega event has attracted more than 20,000 visitors including international participants. The main attraction of our activity is to demonstrate learning science by hand-on experiments. A wide variety of activities involving direct participation of youngsters were carried out in order to foster their interest in science and more importantly, these serve to give them a right perception to the 'fun' nature of science. More than 10 young scientists and 20 graduate students showed their commitment in the showcases pertaining to cryogenic effect, solid structure, symmetry, laser grafting, dyes colouring, DNA and brain model, microorganisms and many others. Meanwhile, the fundamental scientific concepts, e.g. magnetism, density, pH, surface tension, were also introduced through simple experiments by using commercially available products to relate their daily experience to the fun of

science. From the conducted surveys and positive feedbacks, the participants have dedicated their interests that learning science is definitely fun and interesting and not just as the oft-stated boring subject.



YSN members entertaining the crowds during Penang International Science Festival

In collaboration with Universiti Sains Malaysia and American Chemical Society (ACS) Malaysia chapter, YSN has taken part in organising a workshop themed as "The Science Wizard for Teeny Tiny Thingy" during Penang International Science Fair (PISF) 2016. This activity was aimed as to develop young minds by exposing them to STEM through a unique, stimulating and innovative experience. The systematic planning and implementation was also one of successful factors towards the promotion of science to the public, especially to instil the importance of science in the young generation.

8. DUTA SAINS AND CREATIVITY & SCIENCE 4U CARNIVAL

Several YSN-ASM members also engaged themselves in the Ministry of Science, Technology & Innovation (MOSTI) flagship programme "Duta Sains" which was initiated by ASM. This initiative was aimed to improve science literacy and awareness among communities, create a knowledgeable community that is equipped with skills and knowledge to create solutions of local problem. Four selected districts were Jerlun (Kedah - Northern Zone); Setiu (Terengganu - Eastern Zone); Tangga Batu (Melaka - Southern Zone) and Tuaran (Sabah). The highlight of the program was a science for community carnival in each district which were

warmly received by more than five thousand rural community folks. ASM and YSN-ASM were invited to set up a booth in conjunction with the Creativity and Science4U 2016 programme for the state of Sabah, in conjunction with the Duta Sains and 'Pesta Keamatan' for Tuaran District in Sabah.

Note that the main objective of this programme is to cultivate the interest of science, technology and innovation among schools students, universities/ college students, as well as the community. Many government and private agencies, were involved in setting up exhibition booths and organising various initiatives. YSN-ASM Science Outreach portion of the booth was themed as "Amazing World of Cells", which demonstrated infographics of good and cancerous cells by real cancer specimens and brain model. Meanwhile, the research works of the YSN-ASM members were highlighted so that they could advocate the importance of research to the public and to show facts that our Malaysian researchers had done numerous impactful research.

Due to the positive response from previous events, Science Outreach team has continued to working together with MOSTI and NSC for the Carnival of Creativity & Science Series in Johor. The team was led by mainly YSN members and UTM lecturers to show case interesting scientific experiments related to the effect of superconducting, variety of bacterial species and Math-Sudoku activity. This event aimed to nurture student's interest in science and enabled science learning by experiences beyond the normal official classroom. The activities were arranged in such a way to stimulate active learning, to activate the students' mind and to enrich their experiential learning through discovering of science in various hands-on experiments. Inevitably, the students could extend their learning process not only through the knowledge they gathered from the schools. These activities also conveyed a positive message to students in the perspective of learning science.

9. KUALA LUMPUR ENGINEERING SCIENCE FAIR

The YSN-ASM Science Outreach team has also participated in Kuala Lumpur Engineering Science Fair (KLESF) 2016, which is one of the most prestigious science fairs in Malaysia. This event is an initiative with various programmes and activities that aims to promote interest in STEM among primary and secondary school students. In this three-day event, thousands of students thronged the booth that was manned by YSN-ASM members and the facilitators recruited from the

Chemistry Club Students, Faculty of Science, and postgraduates of Faculty of Medicine and Health Sciences, Universiti Putra Malaysia.

The students were indulged with a wide spectrum of scientific experiments related to chemistry and biology including pH indicator using red-cabbage, fruits-powered battery, baking soda-volcano, human anatomy model, 3D brain puzzle etc. The response was overwhelming as many positive feedbacks were well-received from the parents and students in regards to the demonstrations and experiments.

10. TRENDS IN INTERNATIONAL MATHEMATICS AND SCIENCE STUDY

The involvement of YSN-ASM is not restricted to the laboratory activities or science exhibitions, but it also extends to a higher degree by providing assistance to the international assessment of mastery of science and mathematics among students. YSN-ASM young scientists show their meticulous effort in helping two schools to sit-in the tests conducted by the Trends in International Mathematics and Science Study (TIMSS). It is worthwhile highlighting that TIMSS, is a series of international assessments related to the students' knowledge of math and science around the world, conducted by the International Association for the Evaluation of Educational Achievement (IEA). Two schools, Sekolah Menengah Desa Serdang, Serdang and Sekolah Menengah Khir Johari, Bandar Baru Bangi were selected for this evaluation. Approximately 420 students were given tutorial and formative exercises by a group of facilitators from the UPM lecturers, YSN-ASM scientists and undergraduates of the Faculty of Science, UPM. The intensive workshops were held during weekends over a three months period from May to October in 2014. These involved interactive teaching and training of problem-solving, so that the students could tackle the science and mathematics questions effectively.

11. PROGRAMMES FOR UNDERPRIVILEGED GROUP AND INDIGENOUS PEOPLE

The disabled community has inspired us in different ways. Despite their disabilities, we were pleased to know that those with physical disabilities were able to experience science in a fun way like never before, as some mentioned that they had never being taught science or knew what science is. In view of this, the science outreach team is keen to instill science awareness within the community, which perhaps be marginalised or neglected sometimes. The Whizz Kids Science Workshop Series, a specially formulated programme by USM team, is dedicated for the less-fortunate children in handicap homes in Penang. This program aims to introduce the underprivileged children to the fascinating world of science and to inspire their passion in science. The event took place at the Eden Handicap Service Centre, Penang and has benefited the underprivileged children; especially the orphans, who are without substantial education or even to have the privilege to attend regular school. Through these educational talks and hands-on session, the children were greatly motivated and have learnt to communicate their scientific observations.

In recognition of the special needs of the students from indigenous community, YSN-ASM has jointly organised a programme themed “Transmission of Scientific Community” with the Students’ Association, Faculty of Science, Universiti Putra Malaysia. A three-day science camp was hosted at Sekolah Menengah Kebangsaan Muhibbah, Sungai Siput due to its huge number of Orang Asli students. Before going to the camp, the facilitators have done their homework on the need to understand the difficulties faced by this special student group, who are more passive and relatively weak in science literacy. Subsequently, the approach was altered in order to communicate effectively with them and this could reduce their defensiveness towards changes and shyness so that they could accept Science as an important tool for the betterment of their community.



Programme Transmission of Scientific Community with Orang Asli kids at SMK Muhibbah, Sungai Siput, Perak received a good media coverage for being different and attractive.

12. AFFILIATE PARTNERSHIPS

The YSN Science Outreach team also cooperates with other non-academic parties such as PETROSAINS. Several members have been invited to exhibit their research findings, deliver scientific talks or as science icons. For example, YSN-ASM members were involved in the exhibition of micro-organisms living systems under the thematic “The Nature’s Kingdom”, which has attracted many parents and kids.

13. CONCLUSION

Since the inception of YSN-ASM, the outreach activities have been undertaken by Malaysian young scientists as part of their commitments to uplifting the science interest among the Malaysian community. Their talents are more than just knowledge and skills in lecturing or carrying out research but these could also be extended to various interactive programmes, multidisciplinary events and community services. Note that changing the perception of the public and students towards learning STEM is an on-going important agenda and this requires our due attention and collective efforts from all relevant parties. It is definitely a difficult task that we need to face, to deal and to overcome through every single resource we have. In addition, we have to accept the facts that Malaysia is critically in need of talented scientists; in particular, knowledge is now recognised as the driver of economic growth and productivity that leads to new insights into technology, information and economic performance. With all the progresses seen thus far, these serve to indicate a positive sign that we are still residing on the right track towards our nation building in knowledge-based economy.

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Disclaimer: All the aforementioned outreach activities are of collective effort from YSN-ASM, and other concerned personnel, universities, agencies, companies and non-governmental organisation (NGO) bodies. The authors would also like to extend their sincere gratitude to the people who have contributed in this write-up or in any sort of assistance otherwise.

CHAPTER EIGHT

EMPOWERING STEM EDUCATION THROUGH UPM STEM

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Abstract

The Malaysian Prime Minister Najib Razak report in 2014 stated that Science, Technology, Engineering and Mathematics (STEM) education is not only to create economic opportunity for individuals, but it's to provide the fuel needed to power a science and technology driven economy in Malaysia¹. Nonetheless, the target ratio of 60:40 for the number of students enrolling for STEM and non-STEM fields has not been met regardless of the programs initiated. To improve these shortcomings, UPM STEM was initiated as efforts to create and increase students' awareness in these fields and reduce these gaps. This chapter deals with experiences on how to successfully implement a university STEM hands-on modules to achieve the goals of increasing STEM enrolment in the STEM fields.

1. THE INITIATIVES

It all started when the University Community Transformation Centre (UCTC) organised the ‘Basics of Extension’ course that has successfully opened the mind of lecturers to do voluntary work in the community via the transfer of knowledge. The questions that rose were ‘there are many public and private higher education institutions around here, but are we able to see the development of local communities in line with the number of universities?’ Of course, the answer is no. Hence, what is our contribution to the local community? Are we doing enough to build legacy of innovators and pioneers? Does it make us a bad scientist if we were conducting state-of-the-art research when the surrounding community did not benefit from it? If all the answers were no, it can be said that the situation is shocking. We, as academicians really have to do something to make sure that this is going to change. However, what are the benefits of transferring our expertise to the local community? How can we explain our research work in simple words to a farmer or a rubber tapper, or even a young school student? How can this be done effectively? The answer is definitely not using the scientific language normally found in academic manuscripts, but one that these groups can understand. Therefore, this is the biggest challenge; how to make sure that knowledge can be transferred to the target group?

Knowledge transfer is crucial with the increment of the number of students’ intake in pure science stream nationally. Many students feel that science, technology, engineering, mathematics (STEM)-related subjects are ‘killer subjects’ as well as their inability to apply science in real life. The anxiety about these learning experiences and the low level of academic confidence in science and mathematics subjects² were identified as the main factor causing many among students not to choose the science stream in higher secondary level. In addition, the teaching method, evaluation systems, demographic factors, and school management also contribute to the issues.

STEM-related subjects are the most useful branches of knowledge and play an important role in the development of a nation. In Malaysia, STEM has been an area of high interest since 2009³. In fact, this field is also regarded as an important area for “maintaining economic development, improving the quality of life and national security” as mentioned in the National Science Policy⁴. Therefore, various efforts have been made to enable STEM-related fields to be accepted and become an important part of this country’s society⁵. Unfortunately, after so many efforts being

made to achieve the above aim, the progress and success achieved in the STEM field in the country have yet to become something to be proud of. In fact, in many cases, many misunderstandings arise in this field. Students and parents themselves assume that the subject or subjects related to STEM are ‘difficult’. The Public Awareness of Science and Technology in 2004⁶ shows that 42.3% of Malaysians are of the opinion that science and math subjects are difficult subjects⁷. As a result, there is a deterioration in terms of achievement of students in schools and at the same time, the proliferation of STEM knowledge becomes very weak or may not happen immediately.

2. MISSION AND VISION TOWARDS A SUCCESSFUL STEM LEARNING

UPM has carried out many science outreach programs since 2003. However, since the beginning of STEM education globally, this outreach program has been rebranded as UPM STEM with the aim of creating awareness and increasing the number of students who choose the STEM stream through hands-on modules at various school levels by using materials that are readily available at a lower cost. Besides, the rebranding emphasises more on the STEM components towards the sustainability of STEM applications, in line with the needs and development of today’s education.

Our goal is to guide and provide expertise, leadership, support, and resources to the schools, communities, and educational institutions in the STEM field, while our mission is to become an expert in STEM education by applying attractive hands-on modules to students, educators, communities, and policy makers in the field of education to address global community challenges that require expertise of the STEM human capital. To achieve these, a number of initiatives were designed to produce STEM human capital and solve this global problem of the century through the integration of four essential STEM subjects. Teachers are an important asset in using the STEM approach in teaching and learning. This will encourage the continuous use of STEM skills in Malaysian education from pre-schoolers to career options. With this, future workforce can be prepared to meet the rapidly changing world dynamic requirements.

3. DO-IT-YOURSELF (DIY) MODULE DEVELOPMENT

The hands-on modules are developed along with the goals and targets in STEM education and the national syllabus by giving more emphasis on hands-on activities and incorporating elements of higher order thinking skills (HOTS). These modules encourage more engaging in learning and provide opportunities for students to easily understand a topic or concept. On the other hand, the activity in the module based on four components of STEM can be implemented using tools that are easily available to students so that they can relate the theories learned with applications in everyday life. The development of this low-cost module can also be used as a practical activity for students in schools.

4. VOLUNTEERS

University as a platform for a one-stop centre provides various services to communities across the country. Thus, the STEM programs also meet the goals of the Ministry of Higher Education in targeting one million students from public and private universities to participate in the UCTC program. This is because the program involves the faculty and students (as facilitators) in community-based transformation activities enabling the local communities to attend short-term courses as well as to access and the use of the intellectual and physical infrastructure of higher education institutions to promote entrepreneurial activity. In this way, higher education institutions can use their expertise to resolve the local community issues, open up dialogues among academics at various institutes.

These volunteer and facilitators are from faculty students who will have opportunities to inculcate critical and creative thinking in them, which is an important attribute for functional graduates. Thus, the UPM STEM program can also produce more credible facilitators in terms of effective teaching delivery and have high quality soft skills through participating in voluntarily programs. What is important is the empowerment of students' engagement from public universities participating in the knowledge transformation program to the community.

5. STEM DIALOGUES

The STEM dialogues is aimed at providing a platform for institutions engaging in STEM-related education and teaching, sharing of experiences and discussing their work, as well as networking between institutions with schools and external agencies. The main goal is to increase the interest and performance in STEM-related fields as early as pre-schoolers to career options.

The forum's discussion sessions provide opportunities for participants from various backgrounds (academicians, teachers, industry representatives, and the National Science Centre) to jointly reflect on the role of guidance in training and professional development of STEM education by developing and sharing ideas on how to implement the best STEM practices in Malaysia. This can be utilised by the community with collaboration and strong financial assistance from organisations and industries to run the event at the national level. Additionally, the interest in the STEM field in Malaysia can be enhanced with the help of social media that often act as the platform for various entertainment activities and television reality programs targeting youngsters.

The dialogues are an eye opener to the ever-changing multidisciplinary science subject, which affects everyone on a daily basis. The flow of money spent on education and STEM-related activities is not always a disadvantage as it will produce STEM's human capital that will contribute to society in the future.

6. THE UPM STEM EXPERIENCES

6.1 The First Move

The first step is targeted at students from low-income family backgrounds. Most of them live far in the vicinity of oil palm estates. The less fortunate students get out of the house to school as early as four in the morning and need to ride four different vehicles before reaching the school. They are also responsible in caring for other siblings after school in the afternoon.

There were two separate programs introduced to this focus group. The first is targeted at parents or guardians because they are the closest people who will influence the interest of the choice of students during the upper secondary while the second is the STEM transformation camp to the lower secondary students.

The parents and guardians who come from low-income families are more likely to focus more on working to ensure adequate family finances. As a result, they are less focused on their children's education. This has an impact on the education of their children where they are no longer interested in learning, resulting in the lowest performing position (i.e. in band 5 and 6) in school effectiveness. From the interviews conducted during the outreach program to the parents of the low educational qualifications, they were very much appreciated of the efforts taken to attract their children to the STEM field. In fact, they put very high hopes to see their children getting the highest education, thus providing a brighter future and better quality of life.

6.2 STEM Transformation Camp in Low-Band Schools

The STEM transformation camp chooses a majority of its students from low-income families background and whose parents are working in estates. The impact on the overall performance of the school is in the school effectiveness which drops and reaches the lowest band of 5 and 6. Therefore, the program aims to increase the interest and performance of the lower secondary students (forms 1 to 3) in STEM-related subjects. On the other hand, the long-term objective is to increase the number of students choosing the science stream when they enter higher secondary level.

The lower secondary school modules include Brainy Brains, Wonders of STEM, and Little Einstein's Explorace slots. In the science exploration activities for example, students were guided through the high-level thinking ability (HOTS) in solving different problems of components in each station. The knowledge learned at each station is in line with their daily lives. The wonder of STEM slot requires students to think of innovative ideas to build simple design and vehicle models using easily obtainable everyday materials.

6.3 STEM Educational Programme for Special Need Pupils (MBK)

The program involves engaging special children in exploring STEM through games. These MBK pupils are having various degree of learning disabilities, including autism, hyperactive disorder (ADHD), Down Syndrome, cerebral palsy, slow learner, epilepsy, and dyslexia. MBK pupils require a variety of fun and interesting activities that could attract their attention in order for them to learn like normal children. Hence, classroom learning is not the only medium recommended to educate these kids. Learning outside the classroom provides a good option to enhance understanding and give students the necessary experience and self-confidence. Additionally, this hands-on approach is an opportunity for these students with special needs to use sensory skills as to understand the science and mathematical concepts more easily and in a fun way. In addition to building self-confidence, the program is also expected to increase the interest in science and math subjects among primary school students as early as possible so that they can relate the facts learned at school with everyday applications at home.

The basic concepts of physical Sciences, Technology, Engineering and Mathematics components are applied in the activities in accordance with the science syllabus curriculum. Simply, a relaxed approach similar to their daily life is used like how to produce their own playdough that can be both conductors and insulators using Mathematics component and recipes and through the use of simple ingredients that can be easily found in the kitchen such as flour, sugar, salt, and cooking oil. All these can help to attract their attention to learn and apply the simple circuit designs (technology component). The examples of other activities were categorised as a range of games to magnetic and non-magnetic things. These special children were excited when they are able play racing cars attached with magnetic materials.

Among other activities that interest these MBK pupils were the challenge of designing structure and bridges using marshmallows and toothpicks, soda-powered rocket, and colourful rubber tube bracelets. The pupils were excited when they were able to produce their own bracelets that match the concept of density differences between oils and colourful water. The children were also very excited when they saw boats using recycled items like plastic bottles could move on its own, and they asked whether they could make it themselves.

Overall, the UPM STEM program for MBK pupils helps to bolster self-confidence among these children to explore into the field of science which is interesting, besides enabling others, especially academicians who are experts in various fields to monitor these children closely by understanding their needs and nature.

6.4 Instilling the Science Culture to an Ulul Albab Students by Forensic Modules

Various education approaches have been implemented in line with the focus set by the Education Ministry and demands of the society in Malaysia that emphasis should be given on education based on the Al-Quran, As-Sunnah as well as science and technology. All these are aimed at nothing but to produce more capable individuals and human capital in the fields of STEM. In realizing this need, the Ulul Albab program has been implemented in most national and private schools. This Quranic, encyclopaedic, and ijihadik concepts under this program will produce human capital who is not only able to understand and cultivate the Quran but also capable of solving problems by mastering various branches of STEM education. This module is based on the integration of STEM into the Ulul Albab program by linking STEM knowledge with the verses and passages of the Quran as well as stories during the days of the Anbiya.

The program aims to provide hands-on exposure and training to form four students in solving STEM-related activities. For form five students, this program is an added value to the existing STEM knowledge and reinforces the fundamentals that they have learned. The students were given the chance to witness the beauty of the STEM fields in their everyday life but also able to apply and solve various problems during the activity. In addition, the program inspired them to pursue their tertiary education in the institutions of higher learning as they were able to share the experiences of university undergraduate students who served as their facilitators during the mentee mentoring programme.

Students were not only explored and involved themselves in the variety of STEM activities that are designed to be fun and enjoying, but they could also be able to associate them with the contents of Al-Quran that they learn every day. For example, materials such as iron, magnetic materials, light, fire, and water and its properties are described clearly in details of the Quran. In fact,

signs of the creation of human beings are also expressed in the Quran and this phenomenon was realised through the hands-on activities in thereproductive system of cattles and humans. The students were very excited to be given the opportunity to perform surgeries on calves specially brought from UPM farms.

The forensic science activities were conducted with emergency situation slots put up by the facilitators. Interestingly in these slots, all students participated in various scenarios as in a crime scene simulation. Before starting the investigation, the students were given preliminary information about the evident materials and forensic anthropology techniques used to help identifying a person and determine if the crime has been committed. This forensic science module has helped the students to use scientific methods by collecting, evaluating, and testing evidence as to determine whether their hypotheses on the crime is right, thus will help them to identify the criminals through simulated incidences. Among other activities that caught their interests were a parachute designing challenge and water rockets which were made from recycled materials. The students were very excited to be able to produce and analyse a rocket model and parachute within their respective groups.

Besides serving as a back-up for other academic programmes and as pioneer for STEM-based programmes and research in the future, the ‘Seeding Science Culture’ also helps to bolster self-confidence of participating Form Four students and will inspire them to explore the “fun” field of Pure Science. Most importantly, those hafiz and hafizah will be able to understand STEM phenomenon besides having a better understanding of the Al-Quran.

7. RECOGNITION

In 2015, we were awarded the ‘High Impact Project’ Award from the UPM Industry and Community Appreciation Night (ICAN), UPM’s leading organisation supporting knowledge transfers programs. We were honoured to have received this award as it celebrates our efforts to make an impact in STEM education. The award was only possible because of the active approach we have undertaken to the investing in our community and the dedication and interest demonstrated by our team members cum volunteers.

8. CONCLUSION

In conclusion, the STEM Education various programs strived to raise awareness on the important role played by STEM education experts in Malaysia for a more competitive future economic prosperity. UPM STEM supports the strengthening of STEM-related programs for educators and students, as well as towards increasing the state investments in STEM education. We also support the funding of the enhancements for fundamental science research to inspire the current and future generations to pursue careers in the STEM fields.

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CHAPTER NINE

EMPOWERING HOTS THROUGH REAL LIFE AND HANDS-ON ACTIVITIES

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ABSTRACT

Despite being significant in daily life, physics in a primary education level that has been witnessing a decline in these past few years. Realising this concerning scenario, a science volunteers team named Putra Outreach Physics was established in the Faculty of Science, Universiti Putra Malaysia (UPM). This team adopts the concept of “physics camp” which consists of several segments with different learning approaches. In one of the approaches named Crime Science Investigation (CSI), students have the chance to perform simulated murder case investigation procedures including collecting and analysing evidence as well as interrogating suspects; utilising the principles of physics. While theories are very much needed and being taught extensively in classrooms, outdoor activity is an alternative approach that has its effectiveness. With that thought in mind, Running Physicists was introduced. Meanwhile, “Youreka!” is designed by the team to enhance students’ higher order thinking skills. This activity requires students to make full use of materials given to design and produce an innovative invention. Lastly, the routine of memorising facts is much more easier and efficient for students, by applying mnemonic and turning sentences into songs methods. Thus, a segment called My Melody Waves is included to encourage students to practise these methods. In short, Putra Outreach Physics is a project undertaken by Universiti Putra Malaysia to contribute to the development of physics among Malaysian school children which would lead to an increase in their academic performance.

1. PHYSICS OUTREACH: REACHING BEYOND CLASSROOM

Physics is one of the four fundamental science fields which require mathematics and it is the root to several applied science fields. Despite its significances in daily life towards humanity, physics in term of the academic sector has been witnessing a concerning decline in these past few years. Malaysia Education Certificate (SPM) results of 2016 showed a decrease in the number of students who obtained A+, A and A- for this subject compared to the previous years. This situation is not only worrisome to teachers and parents but also to the University community especially lecturers and students who are majoring in physics. Based on surveys and literature reviews conducted, several factors lead to the negative growth of national students' achievements in this subject. These factors identified are crucial in deciding on the necessary measures to overcome the problem.

Nowadays, students tend to memorise all the physics theories and formula without appreciating them towards everyday applications. Ineffective teaching and learning sessions add up to the situation with school students losing their interest in the subject due to the failure of relating physics theories to their respective applications. Other than that, the routineness of teaching and learning sessions that need to be endured by students every day is undoubtedly capable of draining out their mental and physical energy which leads to the loss of focus in class. Every day classes can be improved if they are integrated with outdoor activities which require students to use their physical along with physics knowledge learnt in class.

Based on simplified surveys carried out on students in several schools, the students considered physics as one of the hardest subjects since it requires them to comprehend two main cognitive components which are analysing and memory. Analysing component includes understanding questions and figures as well as choosing appropriate values and variables before proceeding with mathematical calculations. Memory component on the other hand includes memorising facts, applications and examples that are vastly elaborated in every topics. Analysing skill is relatively easy to be improved through repeated exercises but to possess an excellent memory needs a strategic and creative solution. This is to ensure the process of storing data into the mind becomes something fun and not tiring.

Realising this concerning scenario, a science volunteers team named Putra Outreach Physics was established in the Faculty of Science, Universiti Putra Malaysia (UPM). The team is led by Dr. Yap Wing Fen, a senior lecturer and more than 100 physics undergraduate students as members and their target is to solve the stated problems. Until today, more than a thousand students from more than ten schools across the nation have benefited from this initiative. Organised programs used "physics camp" concept which consists of several segments that have different learning approaches. These include murder case investigation, science race, product innovation and design and much more. All segments and programs that were conducted were aimed to fulfil three main objectives. These objectives are: (i) to prove that the perception towards physics as a difficult subject is untrue, (ii) to replace the learning method of memorising with "understanding and remembering" and; (iii) to transfer valuable knowledge from the higher academic institution (UPM) to the community.



2. HOTS BASED ACTIVITY

Higher Order Thinking Skills (HOTS) is an element that has been implemented in our national education system since many years ago but has become more significant than ever in these past five years. Contrary to the aforementioned negative perception towards physics subject, physics has a broad range of applications including in homicide investigation. Linear kinematic motion which is one of the subtopics in the topic of Force and Motion is one of the best examples to demonstrate this statement. This subtopic can be summarised with four individual equations involving parameters like initial and final velocity, time, displacement and acceleration. The fact that these equations are difficult to memorise as well as students' tendency to overlook their applications in everyday life cause the subtopic becomes a frightening subjects for a significant percentage of students. To refute this perception, Putra Outreach Physics team invented an approach which uses "doing is believing".

In CSI: Crime Science Investigation activity which is inspired by the television series CSI: Crime Scene Investigation, students have the chance to perform simulated murder case procedures including collecting and analysing evidence as well as interrogating suspects. Different individuals play these roles, and they work collectively in their respective groups. Various evidence are planted at a crime scene such as footprint, blood, bullet, document etc. Besides that, interrogation is carried out to eliminate the innocents and identify the perpetrator. Students will discuss in groups before presenting their deductions and announce the suspected murderer.



The implementation of the types of evidence and investigation methods can be varied as long as the application of physics is the core element in this activity. An example of evidence that was introduced was a gunshot wound and how physics can be applied to find the murder weapon. By measuring the wound depth, using given bullet deceleration by body tissue and its mass, basic kinematic equations can be used to calculate nozzle velocity. Next, students are required to refer to the ballistic laboratory to obtain the list of possible weapons and their respective nozzle velocities. Following this procedure, appointed detectives start interrogating suspects and matching weapons owned by them. This procedure is only one of at least three investigation procedures that need to be performed to eliminate the innocent people one by one and finally capturing the criminal.

Indirectly, from this activity, critical thinking skills can be nurtured among students and thus stimulating higher order thinking skills in everyday life.



3. INTEGRATING HOTS IN PHYSICAL ACTIVITY

One of the main reasons which inhibit effective teaching and learning session is the static and overly theoretical method of input delivery. The statement “a healthy body leads to a healthy mind”, even though is rather untiringly muttered and becoming cliché, has its truth especially in the context of learning physics. An outdoor-oriented learning approach is proven to be effective because not only it stimulates mind and body simultaneously, its hands-on approach is more efficient to assist students seeing the relation between theories and applications. Bernoulli principle is one of the subtopics in the topic Force and Pressure. This principle relates regional pressure with fluid velocity, and it is fairly straightforward. However, research conducted by Khalijah Mohd Salleh and Abu Bakar Abdullah (2008, USM) found out that this principle is one of the three hardest principles in SPM physics syllabus according to students after Archimedes and Pascal. The research concludes three factors that lead to this observation: weak conceptual comprehension, incompetent mathematical skills and inability to apply physics concepts.

To overcome this problem, Running Physicists; a race inspired by a reality television program The Amazing Race with physics twist was introduced. Similar to the program, a number of checkpoints were placed within activity area at which each station has its own physics-related task and challenge that need to be completed by students before they can advance to the next one. Contradictorily, the winner is not determined by the first group to arrive at the pit stop but rather depends on the total score collected from each checkpoint.



The tasks at checkpoints supposedly tackle various branches of physics based on SPM syllabus. One of the tasks prepared for students was to discharge water from inside a bottle using two straws. Although this task seems easy initially, it is quite challenging due to the facts that students were not allowed to suck out the water and need to ensure that water was discharged in fine spray form. To solve this task, Bernoulli principle concept needs to be applied. It is necessary for students to position the straws at 90° to each other with the first straw is immersed in water while the second one is held horizontally. A strong, sudden blow is applied at one end of the second straw and this causes a high-velocity air flow on top of the first straw. Based on the principle, a region with the high-velocity flow of fluid experiences lower air pressure compared to atmospheric pressure. Consequently, higher atmospheric pressure exerts a pushing force that causes water to exit through the first straw in the form of water spray.



4. THE IMPORTANCE OF HOTS FOR INNOVATIVE INVENTIONS

A new generation of graduates that have science background who fail to solve problems at their workplace as well as having limited innovation skills are examples of implications due to the lack of HOTS. It is widely known that students learn diverse topics at school such as force, pressure, momentum, electric, electronic as well as other laws and principles. Topic-specific oriented teaching method has been causing some students to be unable to relate lessons in different subtopics and topics. This scenario tends to inhibit their ability to apply these various branches of physics to reach certain goals in their daily life.

Hence, an activity namely ‘Youreka!’ is designed by the team solely to fulfil this objective. This activity requires students to make full use of materials given with additional materials are readily available from a “store” to design and produce an innovative invention. An amount of time is allocated for students before presentation and trial sessions. Inventions are evaluated from several aspects including aesthetic values, performance as well as the balance between cost and the choice of materials used. The concept of pseudo-money is used to “purchase” additional materials from the store throughout the activity. Therefore, it is crucial for students to be able to make reasonable judgements before using their “money” to buy additional materials that are capable of producing better inventions.



'Youreka!' typically requires students to invent simple vehicles or devices as part of the activity. Past inventions include water rocket equipped with parachute, car which utilises air as thrust and much more. Meanwhile, solar cooker water wheel or windmill to generate electricity and others, depending on facilitators' instruction. For the example of water rocket, some of the initial materials prepared are a 1.5 L water bottle, garbage plastics, cotton string, manila cards, small stones as well as different stationeries. Time allocated for this activity is around 45 minutes at which in this period, the store is opened for students to obtain additional materials. Bottle caps, water bottles of assorted sizes, garbage plastics of different thicknesses, folio front plastic covers and others can be purchased, some of them serve only to confuse students. At the end of the activity, water rockets are tested using a homemade launcher, prepared by facilitators before the activity. Besides the said criteria, high scores are awarded to the rocket that can maintain considerable time in flight as well as the successfulness of the parachute to delay the landing of the rocket.

Overall, this innovation-oriented activity not only can improve HOTS among students but also train the essential soft skills including communication, entrepreneurship and critical thinking problem-solving skills.



5. ENJOYABLE AND CREATIVE LEARNING METHOD

As mentioned earlier, a strategic and creative approach is much needed to help the routine of memorising facts as to becomes easier and efficient for students. Mnemonic and turning sentences into songs methods are some of the best examples to achieve this aim. Mnemonic is a very popular learning method, especially in mathematics and science subjects. This method uses first letters in each term in a lengthy list of fact to compose a logical sentence which is much easier to be remembered. For example, to memorise electromagnetic waves spectrum, students need to remember 9 terms namely radio wave, microwave, infrared, visible light, ultraviolet, X-ray and gamma ray. Instead of memorising these terms as they are which is a tedious task, students can use their first letters which are R, M, I, V, U, X and G to construct a sentence as follows: Real Monkeys Invented Very Useful Xmas Gifts. There are endless lists of terms and facts that can be adapted and made easy by this method as long as students have unlimited creativity while being assisted by facilitators.

Melody and music are proven to have a significant stimulating power to our right brain. Besides encouraging both sides of our brain to work simultaneously, by using rhyming song lyrics, students can remember factual sentences with ease. Knowing the importance, Putra Outreach Physics team introduces a creative and interesting activity. This activity can be carried out in a competition-like manner where groups compete to compose the best and most catchy songs together with body movements and formation that are related to the subject being discussed.

As a conclusion, Putra Outreach Physics is one of more than thousands of societies and individuals who are contributing to the development of physics among community, teachers and students. Besides seeing an improvement in students' achievements, the team also hopes to be a role model to encourage more individuals to join them in this noble effort. The synergy of all parties will indeed help in achieving the aim for the betterment of the country and the world.

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CHAPTER TEN

FACTORS INFLUENCING THE DEVELOPMENT OF CAREER INTEREST IN STEM AMONGST FORM 4 SCIENCE STUDENTS

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Abstract

Science, Technology, Engineering and Mathematics (STEM) education is the integration of elements from science, technology, engineering and mathematic field. The goal is to provide community education STEM potential in science and technology as to ensure the involvement of more students in the field of STEM career. Hence, the purpose of this study is to identify the main factors which affect the interest of the student STEM career. The study was done because of the global demand STEM careers are increasing rapidly. This study uses qualitative methods in data collection involving six students in form four from science stream classes at SMK Bandar Baru Salak Tinggi Sepang, Selangor. It covers the factors that catalyse the main factors that affect the consistency students choosing a STEM career. Firstly, is the influence of the environment on the importance of science to students. Second, students thought that a career in science is only limited to become scientists. Information from the study showed motivation and attitudes of students have become the key in influencing interest in STEM careers. In addition, the parents and the achievement is also a catalyst to increase student interest.

Keywords: Interest in STEM careers; Qualitative Research; Motivation; Attitude towards science; Secondary School

1. INTRODUCTION

A general statement on Science education in Malaysia concludes that the National Education Policy (NEP) introduced the 60:40 ratio policy of Science students to Arts students since 1967, and its overall implementation in 1970 (MOE, 2013). This policy refers to the target of the Malaysia Education Development Plan (MEDP) 2013-2025, and in adding on to the ratio of students who are involved in STEM education. The MEDP 2013-2025 is a long-term education plan introduced by the Ministry of Education in the transformation of the nation's education system. The problem of the dwindling number of students in the Science Stream is not only a problem in Malaysia, but is also a global problem every year. (Akarsu & Kariper, 2013; Forbes & Skamp, 2015; Gamse, Martinez, & Bozzi, 2016; Mamlok-naaman, 2011).

The learning of Science subjects is becoming more significant and various learning methods are being developed to enhance students' understanding and interest towards STEM. The approach of STEM has been integrated into the school curriculum in order for the students to absorb the values of science and technology (MOE, 2013). This is to ensure that students would be able to apply STEM in fulfilling the needs for skilled workers. Several important steps in preparing students for STEM education have been outlined in the MEDP 2013-2025, among which is to increase students' interest in the field of science. MEDP 2013-2025 also focuses on the development and awareness of STEM, in every students in Malaysia.

The awareness on the importance of STEM has brought huge changes in the education system in the whole country. These changes have been carried out in the effort to introduce STEM education at school level in order to ensure that the education system is on par with global needs (English, 2016; Knezek, Christensen & Tyler-Wood, 2011). Student-centred teaching and learning would create positive learning environments, which can contribute towards the empowerment of science knowledge and careers in STEM. Therefore, students would be able to embrace science education better. This is also to ensure the consistency in students choosing STEM as a career (Bell, 2016; Osman & Marimuthu, 2010; Sahin, Gulacar & Stuessy, 2015). Therefore, identifying the factors that could influence students' interest in Science is the key to increasing the number of students opting for careers in STEM. This could be supported by relevant theories that contribute to a more meaningful learning and teaching process.

2. THE DEVELOPMENT OF STEM EDUCATION

STEM has been a global discussion for more than a decade. Such discussions are driven by global economic changes which only seek for more experts in STEM field. It becomes more worrying when there is an increase in the demand for experts. However, the awareness on careers in STEM and science education is still vague (Fadzil & Saat, 2014; Gottfried et al., 2016). Preparing students on the importance of STEM is vital so as to ascertain their understanding is clear on careers relating to STEM. Therefore, establishing and enhancing positive interest towards Science at secondary school level, is very important towards the preparation. (Gamse et al., 2016).

The importance of STEM education development at secondary school level, has given a positive advancement towards improving the "Kurikulum Standard Sekolah Menengah" (KSSM). The KSSM has become more comprehensive by integrating STEM. The KSSM was implemented in 2017 and has introduced STEM as one of the six core features in the design of the KSSM.

The MOE is seriously looking at the awareness of students, teachers and parents on STEM education. Other than that, student-centred learning is considered as the platform and preparation for careers in STEM (Bergeron & Gordon, 2015; Zeynep et al., 2016). The MEDP 2013-2025, in its action plan, has outlined the establishment of STEM in the education system in the form of three waves, in the effort to establish STEM at secondary school level. The first wave is the effort to increase the number of students choosing Science stream. The second wave is to increase the support from various parties involving the informal learning sector. The Government as well as the private sectors and NGOs, should complement each other in carrying out various programs related to increasing knowledge and skills, as well as instilling awareness of the importance of STEM for the future. The final wave is to evaluate the efforts that have been implemented and make improvements, by setting up an action plan for the next innovation (MOE, 2013).

3. CAREERS IN STEM AREAS

STEM education is a multidisciplinary teaching and learning system. It combines Science, Technology, Engineering and Mathematics as a teaching method which connects knowledge with careers (Bergeron & Gordon, 2015). Learning outcomes of high quality can provide impact on students' learning experiences, and can be measured through achievement, self-efficacy and student-attitude, which are also known as cognitive factors. (Bandura, 1991). STEM is considered as a quality education since it enables students to create awareness and provide early preparation for students when choosing a career in STEM (Kelley & Knowles, 2016; Kier et al., 2014). Students are able to make better decisions when they are provided with accurate information about careers in STEM. Wrong perceptions about careers in STEM would only contribute to an inaccurate measurement of students' career aspirations (Wyss et al., 2012). These decisions are influenced by students' behavioral factors in being inclined to choose STEM related careers, as they realise the need and importance of science education for the future (Gottfried, 2016). According to Bandura, (1977) significant learning should build interaction between and should complement cognitive as well as behavioral factors, with the environment, as a result of learning.

MOE pays great attention to the preparation in producing quality experts in STEM. It is evident in, MEDP 2013-2025, which outlined the importance of STEM awareness on teachers, students and parents through the three implementation waves. These efforts are made to ensure that STEM awareness can be nurtured in every society especially in students, for them to increase their career interest in STEM. Such pressure occurs when the global demand for STEM experts is increasing but the decrease in the number of students' participation in Science stream is getting critical (Badri et al., 2016; van Tuijil & van der Molen, 2015). The increase of experts in STEM has also been reported by Employment Projections Program, U.S Bureau of Labor Statistics (2014). Their analysis exposed that STEM career demands from 2012 until 2022, would undergo a great increase as compared from 2012 (refer to Figure 1).

Selected STEM occupations with fast employment growth, projected 2012–22

| Occupation | Employment growth, projected 2012–22 (percent) | Employment | | Median annual wage, May 2013 | Typical entry-level education ¹ |
|--|--|------------|----------------|------------------------------|--|
| | | 2012 | Projected 2022 | | |
| Information security analysts ² | 37% | 75,100 | 102,500 | \$88,590 | Bachelor's degree |
| Operations research analysts | 27 | 73,200 | 92,700 | 74,630 | Bachelor's degree |
| Statisticians | 27 | 27,600 | 34,900 | 79,290 | Master's degree |
| Biomedical engineers | 27 | 19,400 | 24,600 | 88,670 | Bachelor's degree |
| Actuaries ³ | 26 | 24,300 | 30,600 | 94,340 | Bachelor's degree |
| Petroleum engineers | 26 | 38,500 | 48,400 | 132,320 | Bachelor's degree |
| Computer systems analysts | 25 | 520,600 | 648,400 | 81,190 | Bachelor's degree |
| Software developers, applications | 23 | 613,000 | 752,900 | 92,660 | Bachelor's degree |
| Mathematicians | 23 | 3,500 | 4,300 | 102,440 | Master's degree |
| Software developers, systems software | 20 | 405,000 | 487,800 | 101,410 | Bachelor's degree |
| Computer user support specialists ⁴ | 20 | 547,700 | 658,500 | 46,620 | Some college, no degree |
| Web developers | 20 | 141,400 | 169,900 | 63,160 | Associate's degree |
| Civil engineers | 20 | 272,900 | 326,600 | 80,770 | Bachelor's degree |
| Biological science teachers, postsecondary | 20 | 61,400 | 73,400 | 75,740 | Doctoral or professional degree |
| Environmental science and protection technicians, including health | 19 | 32,800 | 38,900 | 41,700 | Associate's degree |

Source: Office of Occupational Statistics and Employment Projections - BLS

Figure 1: STEM Occupations with Fast Employment Growth, Projected 2012-2025

This report is similar to the Technical Science Strategy Report by the MOE, which found that the demand for STEM-based labour had also increased. (refer to Figure 2).

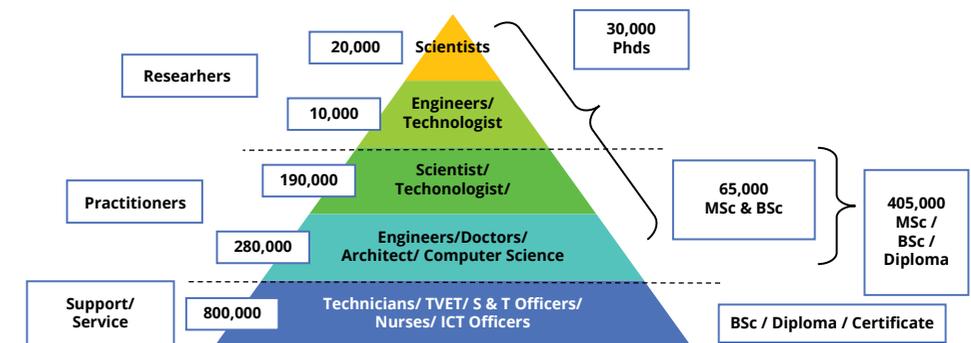


Figure 2: Technical Science Strategy Report by the MOE

However, the trend for secondary students' lack of interest in choosing the Science stream, is the starting point in the dwindling numbers of Science students at institutions of higher learning. (Bergeron & Gordon, 2015; English, 2016; Franz-Odendaal, Blotnicky, French, & Joy, 2016; Halim et al., 2015; Wyss et al., 2012). Moreover, previous studies have shown that the development of students' career interest only begins at secondary school level (Fadzil & Saat, 2014; Kelly & Knowles, 2016; Zeynep et al., 2016). Students would choose a career in STEM areas after they have identified the connection between knowledge in science and STEM career choice (Nwankwo & Okoye, 2015; van Tuijil & van der Molen, 2015; Wong, 2016). There are two factors that influence students' career choice and consistency in the areas of STEM; The first is external influence (parents, teachers and friends) and the second is internal influence (motivation, self-efficacy, attitude and achievement) (Bell, 2016; Korkmaz, 2015). Therefore, it is vital to identify the main factors that influence students' career interest in STEM.

4. STATEMENT OF PROBLEM

Students' awareness on the importance of STEM education has already been a priority in the education system (Bouvier, 2011; Gottfried et al., 2016; MOE, 2013; Unfried, Faber, Stanhope, & Wiebe, 2015; Zeynep et al., 2016). Such awareness occurs when there is a high market value and demand for experts in the areas of STEM. However, the number of students in the Science stream at secondary school level is decreasing (Blankenburg, Höffler, & Parchmann, 2016; Jensen & Sjaastad, 2013; KPM, 2013; Welch, Dunbar, & Rickels, 2015). Therefore, it is important to identify students' motivation especially Science stream students to ensure that their choice of being in the Science stream is not a burden but would bring a positive impact in their career path.

Previous studies have shown that the motivation to learn Science is closely related to students' awareness on the importance of Science and the level of students' exposure about careers in STEM (Bergeron & Gordon, 2015; Blankenburg et al., 2016; Gottfried et al., 2016; Hayden, Youwen Ouyang, Scinski, Olszewski, & Bielefeldt, 2011; Ibrahim, Aulls, & Shore, 2016; Jensen & Sjaastad, 2013; Mamlok-naaman, 2011) as well as parents' influences to provide encouragement in shaping students' consistency in choosing STEM as their career (Akarsu & Kariper, 2013; Bergeron & Gordon, 2015; DeWitt & Archer, 2015; Gottfried et al., 2016; Ishak, Low, & Lau, 2011; Muhammad et al., 2015; Perera, 2014; Rodrigues, Jindal-Snape, & Snape, 2011).

Students have the assumption that Science is a difficult subject when they obtain low grades and they feel that being a scientist is the only career in Science (Andersen et al., 2014; Bell, 2016; Hayden et al., 2011; Jaber & Hammer, 2016; Kihwele, 2014). Such assumptions portray the negative attitudes of students towards Science and careers in STEM areas. Students get insufficient exposure on the importance of Science and its connection to careers in STEM areas, although the global demand for experts in the field is getting higher (Gottfried et al., 2016; Korkmaz, 2015; Rodrigues et al., 2011; Tyler-Wood, Knezek, & Christensen, 2010; Wyss, Heulskamp, & Siebert, 2012). Lack of exposure would only stir various negative speculations towards Science which could influence students' achievement and thus influence students' participation in Science stream. In addition, previous studies have shown that achievement in Science would influence students' positive attitudes towards it (Ahmad Nurulazam Md Zain, Mohd Ali Samsudin, Rohandi, & Azman Jusoh, 2010; Bouvier, 2011; Hacieminoglu, 2016; Huang, Chiu, & Hong, 2015).

Therefore, this study looks into students' perceptions and identifying the main factors and the catalyst to increase students' interest in empowering Science and its significance in STEM careers

5. RESEARCH QUESTIONS

Based on the research objectives, the research questions are as follows:

- What are the key factors that influence students to learn Science?
- How do these factors influence students' career interest in STEM

6. METHODOLOGY

A case study has been carried out to explore the questions related to the factors that influence students' interest in STEM-related careers. It has the following objectives:

1. To identify key factors that influence students to learn Science.
2. To observe the students' interest in choosing STEM-related careers.

Six respondents were chosen to answer semi-structured questions that had been validated by an expert in this field. The interview questions were constructed in semi-structure forms in order to provide standardisation on students' feedback and also to have clearer information on the research objectives (Punch, 2001). The findings of the study were based on the results of interviews with Form Four Science stream students of Sekolah Menengah Bandar Baru Salak Tinggi, Selangor, selected through random sampling. The detailed interview questions were developed based on the research objectives. Subsequently the questions were verified by an expert Science Educator. The researcher had obtained the necessary permission before conducting the 45-minute-long session with each student. The audios of the interview sessions were recorded and respondents' keywords transcriptions were done by the researcher as suggested by Osborne and Freyberg (1985).

7. RESULTS

From the students' feedback, the factors influencing students' career interest in STEM are categorised under two dimensions: Students Learning of Career-focused Science (cognitive factors) and behavioral factors in choosing STEM and the dimensions were divided into two variables.

Table 1 shows the factors that were considered by the respondents as influencing the interest of students in choosing STEM-related careers.

Table 1: Dimensions and Factors influencing Students Interest in STEM.

| DIMENSION | FACTORS | RESPONDENT |
|---|---|--|
| 1) Cognitive (Students Learn Career-focused Science) | • Achievement | Respondent 1 Respondent 2 Respondent 4 Respondent 6 |
| | • Students' Ability to Empower Science | Respondent 2 Respondent 3 Respondent 5 Respondent 6 |
| 2) Behavioral | • Motivation | Respondent 1 Respondent 2 Respondent 3 Respondent 4 Respondent 5 |
| | • Parental Involvement | Respondent 1 Respondent 2 Respondent 3 Respondent 4 Respondent 5 Respondent 6 |

7.1 Students Learning of Career-focused Science

The awareness to learn Science refers to the students' preparedness to embrace scientific knowledge, which focuses on students' achievement in schools. This factor includes the aspect of students' achievement in Science.

- **Achievement**

Question 1: Do you need to get good results in sciences in order to have a career in STEM?

Generally, all students felt that a good achievement gives an advantage to them to choose a good career in STEM. Amongst the answers given were:

"...I want to have the title Doctor...I passed all my Science subjects" (P1)

"...I love Physics...because Physics is the best...I want to become a pilot..." (P2)

"I passed Science because I like things that involve research such as the earth..." (P4)

"...I will make sure my result maintains because I want to take up Science at university later..." (P6)

Briefly, it shows the students were consistent in saying that good achievements in Science would fulfil their career choice in STEM. The students were more focused on excelling in Science when they realised the importance of scientific knowledge in their career. Good results and clear career objectives have resulted students to feel more comfortable to be in the Science stream.

- **Students' Ability to Master Science**

Question 2: What other factors do you think have influenced you to continue in the Science stream?

In addition to achievement, the students' success in Science could develop students' positive attitudes towards Science. Amongst the views were:

"Science is interesting and I think to get an A is not difficult, I just need to understand the concept..." (P2)

"...I can get A and A- in this class..." (P3)

"I can carry this subject...I would continue till next year..." (P5)

"...I like Science" (P6)

This analysis shows the relationship between students learning of Science and the focus on careers in STEM. The focus on careers in STEM would exist when they are able to master their science knowledge by getting good results. The mastery of Science-based subjects and achievement are the cognitive factors in this study. The findings of this study were on par with the theories used, which were Social Cognitive Learning Theory by Bandura (1991) and Social Career Cognitive Theory (2016), which stressed on the continuity of students' knowledge and career-focused based. Therefore, the objective of learning Science especially for students in the Science stream is clearer and more meaningful.

7.2 Behavioral Factor

Behavioral factor refers to students' feedback or reaction as a result of external motivation or influence. The result of the interview analysis for the behavioral factor, found that motivation and parents are the factors for students' career interest in STEM.

- **Motivation to Learn Science**

Question 3: Your result shows that you are doing very well in the three Science subjects (Physics, Chemistry and Biology). What are the main factors that contribute to your excellence in Science?

In general, almost all students expressed their opinion towards the importance of motivation when learning science. Among the responses given include:

"...I am able to pass my Science well" (P1)

"I always create my I-Think map in every lesson in Science class" (P2)

"I like to read Science book first when I study..." (P3)

"...Science stream gives me a chance to achieve my ambition" (P4)

"...I think it's easy to grasp the Science concept..." (P5)

Other than that, motivation encourages students to understand Science concepts easily. High motivation in learning Science is also important for students to focus on clearer career paths.

Parental Involvement

- **Parental Involvement**

Question 4: What roles do parents play in deciding your future? How important is parental involvement in your choice of career?

All the students who were interviewed agreed that parental involvement is one of the main factors for students to choose a career in STEM. Amongst the feedback were :

"...my parents always care about my achievement..." (P1)

"...encouraging me and always give me a moral support to be a Doctor" (P2)

"Engineer is my ambition and my parents always support me to become engineer" (P3)

"They send me for tuition so that I can empower Science subject..." (P4)

"...they encouraged me to choose the Science stream because a career in Science is better and I like it.." (P5)

"My parents help me a lot when I study for Science subject..." (P6)

The feedback above shows that parental involvement is one of the main factors in giving encouragement and attention to students' progress in learning Science. The students also feel that parental financial assistance in sending them to tuition centres has an impact to their motivation to keep on learning Science. It is clear that the commitment portrayed by parents led the students to learn Science and be consistent in choosing STEM areas as their career choices.

Therefore, this is in line with the theories chosen to explain the connection between parental influence and students' learning motivation towards STEM careers which are the Social Cognitive Learning Theory by Bandura (1991) and Social Career Cognitive Theory (SCCT) (2013). These theories stress on the ability of students to build their behavior from positive motivation as well as being able to accept other people's views and judgments, in influencing students to learn Science and to have careers in STEM areas.

The factors being highlighted in the findings of the study are reinforced with the theories which have clear connection with students' ability to master science, achievement, motivation and parental involvement in influencing students'

career interest in STEM. In addition, the findings of the study can also be used as additional references in Science education especially career-based Science learning in STEM areas at secondary school level in Malaysia, and also to recommend the combination of theories from this study (Figure 3). The significant information from this study can be used to identify the key factors influencing Science students' career interest in STEM.

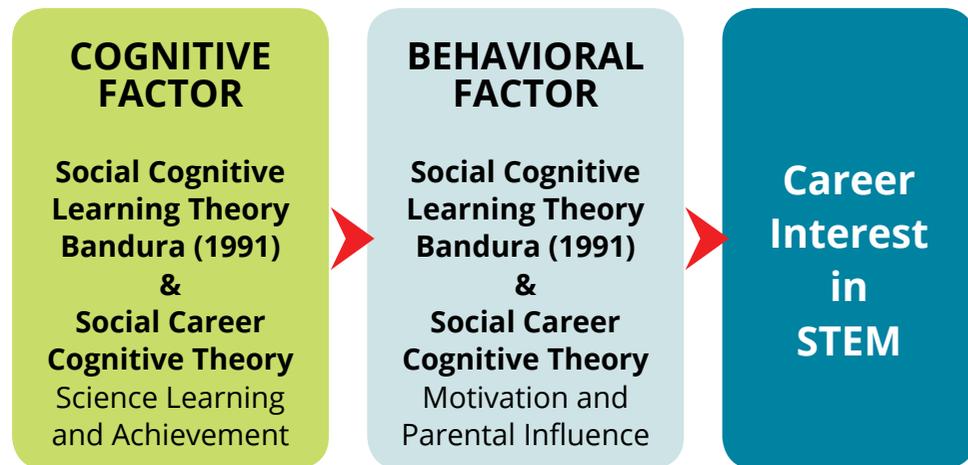


Figure 3: The Combination of Theories in Shaping Students' Career Interest in STEM

8. CONCLUSION

Every student has different attitudes and motivation in learning Science. Parental influence and achievement would further enhance students' behavioral and cognitive factors to learn Science. A good mastery of Science would affect students' consistency to choose careers in STEM. In line with this, the reinforcement of teachers' teaching pedagogy would ensure a good achievement in Science subjects as well as to provide a new dimension on students' attitude towards learning Science and further nurture students' career interest in STEM. Hence, parents also play a role in developing students' positive motivation to embrace the learning of Science. Parental encouragement would be the key to students' consistency in choosing careers in the areas of STEM. The combination of these two factors would bring about a new dimension to the learning model which focuses on Science learning, leading to students' career interest in STEM.

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