Transforming Classroom Practice through Robotics Education

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By

Loh Sau Cheong, Loo Chu Kiong
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FOREWORD

The book, *Transforming Classroom Practice through Robotics Education*, places attention on schools that would like to embark on robotics education in the curricular and non-curricular educational system. Much has been asked by educators on how robotics education can be transmitted in the curriculum, apart from being imparted in the non-curricular educational system. In line with the global move to enhance science, technology, engineering, and mathematics (STEM) education and higher order thinking skills (HOTS) among learners, this book is timely to serve as a practical reading material to inform on the foundational, theoretical, and applied aspects of robotics education and how robotics education can help realize the national philosophy of education.

The idea of writing this book was mooted through research training workshops in robotics education conducted for a group of Malaysian educators and students by Professor Dr Loo and Professor Dr Loh from the University of Malaya, Malaysia. Upon conducting the training workshops, it is felt that school educators and students have to have some materials for reading and referencing before embarking further on robotics education for their schools.

Professor Dr Loo, who is a pioneer of advanced robotics in Malaysia, has always been passionate about bringing robotics into the school, home and community. The programmes 'Now Every School Can Have Robotics' and 'Now Everyone Can Own a Robot at Home' have always been his mission to bring robotics into the Malaysian school and community in a more sustainable manner. With the ever-changing society trend, including Malaysia, these missions will not be far from reach.

As for Professor Dr Loh, she is always dedicated to improving educators' instructional approaches and learners' motivation in learning. As such, she emphasises quality teaching, learning, research and supervision in the context of her being an Educational Psychologist for seventeen years. She sees robotics as an effective tool to elevate students' higher order thinking. Hence, she wishes that robotics can be incorporated into the education system to help students to think and achieve better.

This book is written with clear, easy, and non-technical language covering important aspects of robotics education. In this book, we present a holistic framework that links robotics education with STEM education, constructivism and the national philosophy of education. This is to enlighten the readers and the wider public that, robotics education is gaining importance to provide holistic learning and development among learners, and has to be given importance by schools nowadays. Also, we had shared on how robotics education can be carried out for educators and students and can be effective tools in solving real-life problems or difficulties.

As the society and the world at large marshal for success each day, educators and learners have to be equipped with skills that can help foster dynamic development. Hence, it is our wish that this book can serve as a practical and motivation guide for more and more schools to embark on robotics education.

By:
Loh Sau Cheong, PhD
Loo Chu Kiong, PhD

PREFACE

This book, *Transforming Classroom Practice through Robotics Education* was designed to advance the scientific knowledge frontier regarding robotics and how by practising robotics, schools can help to achieve more rigorous attitude in pursuing mathematics and science among students.

Realising the importance of Science, Technology, Education and Mathematics (STEM) and outcome-based education, we outlined its purpose and explained how STEM and outcome-based education could be mapped to the Malaysian education system. We then introduce robotics technology that encompasses the history of robots, the robotics world and the different types of robots being utilised in industry, agriculture, military, medicine, as well as health care. The cutting-edge robotics surgical system such as the da Vinci Surgical System is also mentioned.

Utilising robots in schools have been the primary focus of this book. Much has been mentioned on how robots are used as a learning object in the schools, including the different types of robotics materials, how can robots play their role as teacher assistants, what are the characteristics of robots as teacher assistants, the use of robot edutainment for remote education which is based on three major aims, namely *learning on robots*, *learning through robots*, and *learning with robots*, and furthermore, how can robots be used with individuals with special needs.

Behind all these practices are the theoretical underpinnings that one should not neglect. Piaget's Learning Theory and the Constructivism Theory have been identified in this book as important theories directly linked to robotics learning. Concerning the two pertinent skills, i.e., creativity and problem-solving skills, these were also emphasised in robotics learning.

We proceed to share on how Transformative Robotics Education can help realise the Malaysia National Education Philosophy by relating the discussion with its goal, framework, its mapping with STEM and constructivism, as well as to share the different stages in transformative robotics education. A module-based robotics education training for schools is also shared in order to shed light to readers. Part of the realisation would be to understand project-based learning using robotics

and robotics as a holistic tool to solve real-life problems. Alongside the implementation would be the assessment aspects where we have discussed the different types of assessments in robotics.

As the society moves towards becoming knowledge-based and with robotics learning gaining its place in the educational system, it will soon play a vital role in the transformation of the education system to achieve the aspirations for Malaysian Students as outlined in the Malaysia Education Blueprint 2013–2025.

We hope that this book will serve as a fundamental reading material for readers who would like to gain knowledge and insights on the *what* and *how* of robotics education.

CHAPTER ONE

STEM AND OUTCOME-BASED EDUCATION

1.1 Introduction

During the last decade, the Science, Technology, Engineering, and Mathematics (STEM) majors significantly outpaced the non-STEM majors in attaining jobs. A glimpse at statistics depicts the fast-growing call for degrees in STEM fields which are dependent on math, science, technology, and problem-solving skills, especially in the coming years with an appearance of more interdisciplinary fields such as biomedical engineering, medical science, network system or data communication analysis (National Math+ Science Initiative, 2012). Also, people with a STEM degree, in comparison with other fields, can earn a higher salary, experience more stable employment and experience less job loss.

Technology and engineering, as symbols of innovation and invention, play key roles in many countries' economies, which means the global economy requires educated individuals with high-quality skills. To achieve this goal, countries should establish a qualified and appropriate education system to motivate students more in the STEM-related fields. In fact, using this education system will develop a student's critical thinking levels, problem-solving skills, and team working abilities, and motivate students to participate in the future of their country actively. Nevertheless, a review of the traditional methods of curricula and its instruction indicated its incapacity to motivate students more towards STEM-related fields (Havice, 2009).

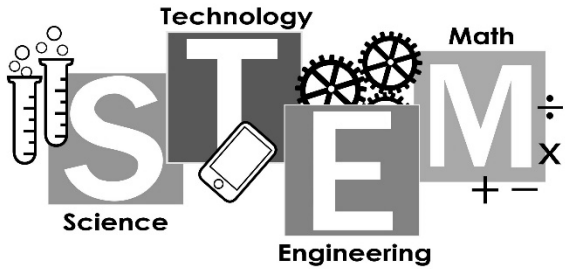
Therefore, educational systems have adopted outcome-based education or OBE as the new paradigm to promote the quality of education based on their desired goals. One of the most important characteristics of OBE is preparing students for their real life by focusing on their learning process and outcome. In fact, OBE empowers students to improve their knowledge and create in them the desire for lifelong learning through the development of an appropriate curriculum. In OBE, the curriculum plays a vital role in

creating a productive atmosphere for students to promote their critical thinking and problem-solving skills (Van der Horst & McDonald, 1997).

The present chapter attempts to present the nature of STEM education and OBE. In the following sections, we are going to discuss more in detail about STEM education and the definitions, purposes, elements, and the benefits of OBE. We will finish the chapter with a brief look at the Malaysian education curriculum, and its relation with STEM and OBE.

1.2 What is STEM Education?

According to the National Science Foundation, STEM is the abbreviation for Science, Technology, Engineering, and Mathematics (Figure 2.1). It is a new concept that has been created through the blending of different disciplines. In fact, the concept of STEM mostly refers to the teaching and learning processes from pre-school to post-doctorate in various educational settings. STEM is a process of learning, providing appropriate opportunities (such as problem-based or project-based) for students to create their learning world (Roberts, 2012).



Adapted from: http://www.edmonds.wednet.edu/STEMexpo

Figure 1.1. STEM

According to Morrison (2006), STEM is a meta-discipline which has been created based on the integration of other disciplinary knowledge in a cohesive teaching and learning paradigm. Kaufmann, Moss, and Osborn (2003) noted, STEM is a trans-disciplinary paradigm with a multi-faceted instruction which guarantees the integration of disciplines. He believed that nowadays, innovation and invention occur through STEM. Morrison and Bartlett (2009) defined STEM as an integrated approach to an

education system's instruction and curriculum. They noted the degree of STEM integration varies from full integration in elementary level with a single teacher to an embedded one in secondary level (Chen, 2001) which assists students to figure out the application of materials completely. Although STEM is mostly defined for Science, Technology, Engineering, and Mathematics, other investigators include other fields such as psychology, social science, physics, chemistry, and computer science (Roberts, 2012).

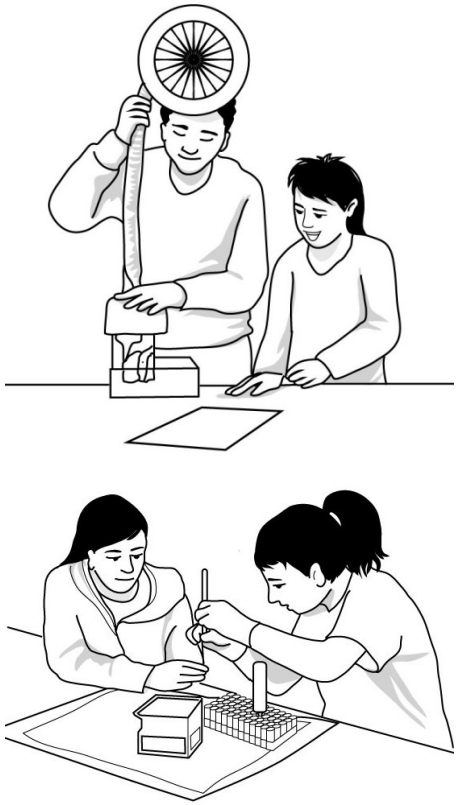
Morrison (2006), based on the nature of STEM, discussed how STEM could help students to experience their surrounding world holistically instead of in bits and pieces. Indeed, STEM education, through the connection of school, work and community, prepares students for the real world competitive economy (Tsupros, Kohler, & Hallinen, 2009).

Moreover, the infusion of STEM disciplines in an education system not only improves students' academic life, but it also boosts their social life. STEM enables them to improve their exploration, critical thinking and problem-solving skills by providing the appropriate atmosphere for students to be in touch with real-world problems, which can affect all aspects of their academic and social life. For example, the American Society of Engineering Education (ASEE) noted, the essence of engineering design is in the integration of fashion by discovering the surrounding environment, which is achievable through STEM and its pedagogical strategies.

Lantz (2009) noted how technology, with its components and flexible nature, assists students to understand STEM better. Indeed, students' computer knowledge (CAD and CAM as professional applications, animations, and computer simulations) facilitates the process of learning and enables them to explore the STEM subjects in more detail.

The main aim of STEM education is to fulfil the students' learning process through enabling them to transfer their learning. In other words, STEM education efforts enable students to apply their previous knowledge to solve the new problem. Hence, teachers find that problem-based curriculums for students motivate them to understand their surrounding environment as well as encouraging them to participate further in the classroom activities with more enjoyment and satisfaction (Havice, 2009). Even the literature showed that STEM education, in comparison with traditional education, motivated students to better classroom engagement and teamwork, which will develop their soft skills, confidence, and

insights about their personalities as vital factors in becoming leaders in business and industry (Deslauries, Schelew, & Wieman, 2011).



Adapted from: http://armytechnology.armylive.dodlive.mil/index.php/tag/stem/

Figure 1.2. Students in STEM courses

One of the current key challenges of STEM education is the lack of a thoughtfully planned STEM curriculum. As Lantz (2009) discussed, a lack of classified STEM program or curriculum can be a cause to disappear, if the teachers change their teaching assignments, or if they retire or leave the education system. Hence, a clear indication of who is going to implement STEM education is vital. In this regard, Morrison (2006) outlined some functions for STEM programs to enable students to achieve the desired results, such as: promoting students' problem-solving skills

(being able to recognise the problem, ask the question, design solutions, collect data, organise them, make conclusions, and finally apply them); logical thinking skills (applying logical thought process in STEM fields to design innovative solutions); innovating and inventing skills (using STEM concepts creatively and applying them to the design process); self-reliance; and developing their technology literature (understand the skills needed, develop them, and apply them).

Therefore, the STEM curriculum needs to be designed based on international standards to support all concepts of STEM education and its trans-disciplinary nature. In this regard, Lantz (2009) noted some elements which should be integrated into any STEM curriculum designs. For example, the first one, Understand by Doing (UbD) paradigm, refers to the three main stages of curriculum development such as desired results, evaluating the evidence, and learning plans. The second one, inquiry-based teaching and learning, emphasises the important role of a structured and open inquiry design in the STEM curriculum. Researchers believe that inquiry-based teaching strategies assist students to better understand teaching concepts with more positive attitudes towards STEM concepts in comparison with expository learning (Odom, 1996; Brown, 1997). The third one, the problem-based learning (PBL) strategy, is a student-centred instruction. PBL aims to motivate students to solve the problems and reflect their experiences through collaboration with other students. In this kind of curriculum, the teachers play the facilitator's role. The 5E teaching, learning and assessing cycle is another strategy which consists of engagement, exploration, explanation, elaboration, and evaluation (Colburn & Clough, 1997). The final element considered in designing STEM curriculum instruction considers the digital teaching technologies. In fact, usage of technology in curriculum design makes the curriculums web-based and more accessible for both disabled and non-disabled students, assisting teachers to update the curriculums readily and increase students' choice in completing their digital curriculum (interactive whiteboard, digital camera, digital microscopes, and students' response systems).

Moreover, STEM curriculum instruction, which is based on students' collaboration and problem-solving, provides a better chance for teachers to evaluate students' learning process. In fact, the teachers in a STEM education system can evaluate students based on their performance, demonstration, and construction in comparison with traditional modes of assessments. In this regard, Lantz (2004) discussed how the traditional mode of student learning assessment, which is based on selected

responses, is insufficient to provide enough evidence of the students' degree of conceptual understanding.

1.3 What is Outcome-Based Education?

With the emergence of the "quality movement" in manufacturing and business, the modern education system transformed from mainly content-based to outcome-based Education (OBE) (Oliver, 1998). OBE pioneers believe that students, through OBE, can gain more skills and knowledge; they also assert that OBE has the appropriate capacities to enable students to create a qualified life in society for themselves through improvement of their performance.

OBE is defined as an approach in which two main things should be considered: first, the end-result of each learning program, and second, the instruction of the learning process. Indeed, it is believed that teachers have to design the learning instructions based on the outcome of the learners' progress, through the assessment of their learning progress continuously (Van Der Horst & MacDonald, 1997). Malan (1997) noted the foundation of OBE is accepting the concept that process and instruction of learning (description of qualification, designing of curriculum, and assessment of students) should be based on the student's learning activities.

Spady (1994) highlighted how the traditional educational approach mostly emphasised the subject-specific content, and to some extent, the ability of students to solve the problems, and their co-operative abilities. OBE, on the other hand, focuses on cross-curricular results of students and their abilities in their future life roles such as being responsible citizens and productive workers. According to Oliver (1998), traditional education, to improve students' knowledge, is content-driven, skills-driven, and a teacher-centred learning process; whereas OBE is based on self-paced or learner-driven learning processes with their teachers' support, allowing students to extract their knowledge through any sources of information. Malcolm (2000) indicated that the main weakness of the traditional education system is that the input is mostly based on the context: what the teachers and learners bring to learn and is managed locally, while the output measurements are based on standards. Therefore, in OBE, the key aim in designing the OBE instruction and curriculum is less prescribing of what is taught and how it is taught.

Spady (1994) noted the ultimate aim of OBE is to provide the knowledge for students based on the importance of knowledge and skills that are vital

for them to be able to do some specific duties. Thus, he presented the first version of OBE based on the concepts of the 80's and 90's research as a learning approach, vital for all students to ensure success at the end of their learning process. Indeed, he defined the outcome in OBE as the specific and clear learning outcomes which expected students to gain experience at the end of their learning process. Hence, to guarantee the aims of OBE, the education systems have to consider well-organised curriculum, instruction, and assessment criteria to achieve it.

Incidentally, Spady (1994) presented the first version of OBE named traditional OBE. Traditional OBE was a content-based approach to education, and an attempt to design a flexible timetable for schools without any aim to change the structure of curriculums. The aim of traditional OBE is mainly to master the content with a focus on recollection and comprehension, whereas student participation is less important in this approach. Thus, he considered that the paradigm for OBE was based on three main philosophies. The first one is that all students have the ability to learn and be successful in their education but not in the same way and on the same day. The second one refers to the fact that successful learning promotes more successful learning, and the last one is that school conditions directly influence the learning success.

Killen (2000) depicted the content of the second version of OBE as transitional OBE. This means ensuring learners' accountability and was mostly adopted in Australia and the United Kingdom. Indeed, this version of OBE attempted to provide an appropriate learning content for students to meet the needs for accreditation of agencies. Transitional OBE is considered the second phase of OBE, which uses the content as the vehicle to achieve higher skills for competence such as critical thinking, problem-solving, communication and technology skills. In fact, it lies between the traditional and transformational types of OBE in both scope and purpose. The main focus of transitional OBE is on the curriculum and interaction between learners and teachers (Brady, 1995). Indeed, transitional OBE attempts to look at the quality of education and its specific outcomes (skills, knowledge, values, and attitudes) for students to prepare them for a competitive society.

Biggs and Tang (2007) discussed the third version of OBE, *transformation OBE,* which refers to the enhancement of outcomes through the designing of a clear statement of instruction, and considering acceptable standards for students, which, besides evaluating the result of the learning process, illustrate what is going to be expected from them. Transformation OBE is

known as the last and most sophisticated OBE version. It not only moves away from the traditional curriculum; it also moves from the prescribed structures of education. Transformation OBE attempts to answer what students should learn through schools and how it should be structured to accomplish the desired outcomes. Indeed, the curriculums are designed based on future-driven outcomes to equip students with the proper knowledge, competence, and orientation for their real life after school (Brady, 1995). Therefore, in transformation OBE, the students and curriculums should integrate together (Oliver, 1998) to create citizens with proper skills, knowledge, and attitudes. Hence, teachers use various types of content and teaching methods to support achieving the desired outcomes for students. Indeed, teachers attempt to select and design the appropriate instructional strategies to assist students to achieve their desired skills, knowledge, and values.

OBE is a result-oriented approach with the belief that all students have the potential, ability and capability to learn that happens over an extended period. Indeed, OBE is a flexible, empowerment-oriented learning approach that equips students with appropriate knowledge and skills to enable them to transfer their success to their real life after school (Malan, 2000). Jackson (2002) defines OBE as a student-centred approach with outcome-oriented results based on specific instructions. He noted, OBE can consist of three main components such as an explicit statement of learning based on outcomes, the defined process of instruction to enable students to achieve the desired outcomes, and the specific criteria to evaluate the desired outcomes. Baxen and Souden (1999) showed how OBE better allows education stakeholders form instructional procedures, assessment and improve their validity and clarity.

The teachers' role in OBE is mainly to facilitate the learning process and promote the learner-centred approach by motivating students in critical thinking, stimulating creativity and self-learning. Malcolm (2000) demonstrated how, in reality, the quality of OBE is mostly related to the teachers, their knowledge, their familiarity with different types of teaching methods and the degree of accessibility to learning materials. Hence, to guarantee the quality of OBE, the education systems have to provide the appropriate infrastructure for teachers such as equity, accountability, plus sufficient support and guidance in the content specification.

Pretorius (1998) listed some characteristics of OBE as follows:

- OBE is a student-centred approach with the philosophy that all students have the ability to learn if given sufficient time to do so;
- OBE highlights the point that the outcome is the starting point of learning, and learning is mostly based on the performance skills;
- OBE mostly emphasises problem-solving skills and skills which are required for everyday life and a career environment rather than only memorising the specific amount of scientific information;
- The focus of OBE is on the future, and the skills students need in their community;
- OBE is flexible enough for the self-motivation of students to participate in classroom activities to attain their desired outcomes;
- OBE provides opportunities and considers enough time for students to achieve the ultimate outcomes;
- The success of students in OBE is based on whether the students achieve their required outcome regardless of the achievement of the rest of the other students;
- Students' progress is based on demonstrated achievements; and
- OBE provides flexible opportunities for teachers to define proper teaching strategies for the curriculum to assist students to achieve the desired outcomes.

In summary, OBE is an educational process that focuses on achieving certain specified outcomes regarding individual student learning. Outcome-Based Education (OBE) means clearly focusing and organising everything in an educational system around what is essential for all students to be able to do successfully at the end of their learning experiences. This means starting with a clear picture of what is important for students to be able to do, then organising the curriculum, instruction, and assessment to make sure this learning ultimately happens (Spady, 1994). Hence, OBE is a process that involves the restructuring of curriculum, assessment and reporting practices in education to reflect the achievement of higher order learning and mastery rather than the accumulation of course credits.

1.3.1 Purpose of Outcome-Based Education

The key aim of OBE is to prepare students for their real life, and their performance tasks through focusing on the process of learning and the ultimate outcomes. Therefore, the main purpose of OBE is to empower the students through the promotion of their knowledge and skills (Malcolm, 1999). OBE attempts to create lifelong learning for students by providing a

flexible curriculum and education system. In other words, OBE attempts to create equity and balance for all students by promoting their critical thinking and problem-solving skills (Van der Horst & McDonald, 1997). Fleisch (2002: 117) claims that "OBE's purpose is to shift the focus of school teaching away from the objectives derived from syllabi content to structuring learning experiences around what students should know by the time they leave the formal school system."

The essential need of OBE is the mind shift in designing the curriculum, and the instruction of empowering the students. Therefore, to accomplish the OBE aims with the focus on the end result of the learning process, the education system has to assist students to demonstrate their achievements, and realise their potential by giving them sufficient time, and defining multiple teaching methods and assessment tools (Mdikane, 2004).

Spady (1994) illustrated the OBE purpose under two broad categories: (a) ensuring all students have access to proper and qualified education (skills, knowledge, and competence) which prepares them for their future work duties; (b) guaranteeing that the structure and performance of schools have sufficient capabilities to support students based on the OBE criteria. In fact, the hidden point of OBE is that all students have the sufficient talent to achieve their desired knowledge depending on the teacher's beliefs, attitudes, and knowledge to consider different types of curriculum and learning opportunities for each student. In the next section, we will discuss more the key elements of OBE which will assist an education system to accomplish the goals.

1.3.2 Elements of Outcome-Based Education

Outcome-based Education or OBE needs some foundations and infrastructures such as careful planning, to achieve the successful and desired outcomes. Careful planning is one of the main elements of successful curriculum implementation in OBE, which means an education system should consider some strategies to conceptualise the curriculums to guarantee students' achievements of desired outcomes. Therefore, to support this, some scholars like Killen (2000) and Spady (1998) assumed two broad elements for OBE such as Principles and Outcomes. Below, we will discuss the aspects of OBE in more detail.

1.3.2.1 Principles

Spady (1998) illustrated four principles (design down, clarity of focus, expanded opportunities, and high expectations) for OBE with a focus on teachers and their support in the design and implementation of OBE. The principles are OBE's main focus which drives the outcomes, and they guide teachers into putting the principles into action. Indeed, teachers, through the creative, systematic and simultaneous application of OBE principles, can contribute to the effectiveness of OBE. In the next paragraphs, we will discuss these principles in more detail.

According to Spady, curriculum design in OBE should be consistent, creative, and systematic. Hence, he considered ***"design down"*** as the first principle which refers to teachers attempting to design and develop curriculums based on students' learning outcomes. It means that teachers, have to start from the last stage (learning outcome) to identify what should be learnt, and which unnecessary curriculum details should be removed, in order to develop the curriculum. Learners' success is one of OBE's priorities, so Spady introduced ***"clarity of focus"*** as the second principle which assists teachers to have a clear image of the learning process and curriculum implementation they like to demonstrate. Teachers motivate students to work together to attain the outcome through explaining, sharing, and modelling the desired outcomes. Indeed, the outcome is the final departure for both teachers and students.

The third principle under the title ***"expanded opportunities"*** pointed out the important role of opportunities in OBE which supports students to be successful and achieve their desired outcomes. Therefore, OBE brings up four different methods to accomplish this principle, e.g.: restructuring the timetable to make it more reasonable for students to fulfil the OBE requirements; applying various teaching methods; increasing opportunities for students and improving their success rate in OBE; balancing the comparative assessment among students which can hinder their actual performance, and; developing the curriculum to facilitate the learning process and student participation.

Spady defined the last principle as "high expectations" which refers to the level of expectations that students are exposed to. In fact, since the standards of knowledge, skills, and performance are rising, both in educational systems and work, a challenging curriculum is vital to enable students to achieve the desired outcomes.

In addition to Spady's proposal, Killen (2000) highlighted some principles for OBE and discussed such principles as vital for decision makers, curriculum designers, and teachers in OBE to assist students in attaining their desired outcomes. The following is some of the principles Killen considered for OBE:

- A positive attitude is vital for OBE
- The focal point of OBE is that all students have the sufficient learning potential and it is the education system's duty to develop their talents.
- The main role of an education system is to define the proper ways for students to be successful.
- A feeling of excellence is for all students, and it should not be restricted to a limited number.
- Education systems should assist students to collaborate with each other rather than compete with each other.
- Education systems should avoid excluding students from an activity in a school based on disability, race or gender.
- OBE is based on a clear focus for significant outcomes;
- Outcomes in OBE are useful, practical, and ethically defensible;
- The curriculum and the instructions in OBE are based on students learning outcomes;
- All students in OBE, despite their differences, are expected to improve their aptitude, and achieve their highest performance level by allocating proper time for them;
- OBE considers more than one routine instruction opportunity for students to provide the chance for them to demonstrate their learning; and
- In OBE students are expected to take some responsibility for their learning and outcomes.

1.3.2.2 Outcome

According to Burns and Squires (1997), the first critical activity in OBE is defining the usable learning outcomes. They discussed how the school community mainly decides what is going to be presented to students to make them ready to contribute to their society. Niebuhr (1996) noted that the outcome is not only learning concepts, a grade or a test score; in fact, it is the actual demonstration of learning in a valid context. An outcome is the culminating demonstration of the learning experiences which are dependent on the students' capabilities. Hence, the outcome happens in the

context of the performance, which directly influences what and how it is implemented. Indeed, he noted that outcomes in OBE are the final result of various types of learning processes such as formal, non-formal or even informal. According to Niebuhr, the process of defining curriculum in OBE is totally different from the traditional one, and in OBE, the teachers develop the curriculum based on students' specific outcomes within a particular specific context.

Assessment is another criterion that should be considered in OBE. Indeed, in OBE there is a number of assessment standards that illustrate the level of learning, knowledge, skills, values, and attitudes expected from students for each grade (Teacher's Resource Book, 2004). The key objective of assessment in OBE is to improve the students' learning process by providing proper opportunities for students, besides demonstrating what they have learned, also to assist them to identify what they still need to learn. Indeed, since the process of learning is not only adding information to the mind, but also restructuring prior knowledge, assessment helps students to become aware of what they could add to their prior knowledge. Unlike traditional education, the philosophy of assessment in OBE is not to fail students nor filter them out from the educational opportunities or deny them from further education both temporarily or permanently. The core philosophy is to provide proper opportunities for all students with various levels of learning capacities by considering flexible time, sources, and opportunities. In fact, such a philosophy does not mean the lack of importance of assessment standards, but it emphasises the important role of providing multiple opportunities to illustrate their competence and skills.

Crespo et al. (2010) demonstrated that the outcome in OBE consisted of three main components. These are knowledge (principles, theories, and facts which are related to the field of study), skills (ability to employ the knowledge to complete a task or solve a problem), and competence (ability to use the knowledge and skills in real life situations which depicts the personal and professional development of students). He discussed how the outcome in OBE refers to what students know and understand through the learning process and their ability to complete the learning process, while their knowledge, skills, social and methodological abilities should be captured to finish the learning process.

1.3.3 The Benefits of Outcome-Based Education

In OBE, the objectives are based on the well-articulated learning outcomes of students. Thus, professionals focusing on OBE key characteristics considered three main advantages. The first benefit is the flexible description of competence or learning outcomes (detailed, well-written). Indeed, it enables both teachers and students to have a bigger picture of the learning process and behaviours expected from them. Also, it assists teachers in preparing a stable and suitable direction for the presented courses and syllabuses. The second advantage is that it provides sufficient opportunities for teachers to select and adjust proper methods of teaching which can support students in achieving their desired outcomes. The third advantage also comes back to the clear statement of objectives in OBE which empowers teachers to develop various assessment methods based on expected outcomes. In general, OBE not only enables teachers and the education system to think deeply about what they are going to achieve, but also pushes them forward to take the first step towards designing a systematic approach in education.

Meyer (2000) also highlighted several advantages of the OBE, as follows:

- Students in OBE are aware of what is expected from them based on the principles of OBE;
- OBE provides flexibility for all role-players (from consultants to stakeholders) to be involved in the learning process;
- Assisting the teachers to develop the well-defined evaluation criteria;
- Promoting the achievements of specific skills, knowledge, and competence;
- Fostering better integration of education, higher education, and the workplace;
- Assisting students to accept their own learning responsibilities; and
- Preventing students from duplicating previous learning situations.

Davis (2003) noted some advantages of OBE with different themes such as relevance (developing the suitability between education and practice), controversy (developing the creation of fundamental questions vital for the learning process), clarity (clarifying learning processes for both students and teachers based on defined aims and outcomes), providing a robust framework (for integrating the curriculums), accountability (through presentation of clear statements about what the curriculum is going to achieve), self-directed learning (enables students to be more responsible

about their own learning by providing a clear picture of what they are going to achieve), flexibility (assist students in achieving their desired outcome in education, not based on specific strategies, but based on different learning styles and innovative teaching methods), and finally by facilitating the curriculum assessment (in OBE, the outcome provides a proper framework for students' examinations).

Meyer (2000) discussed how the successful adoption of OBE does not happen overnight and some readiness is vital for both students and teachers. In fact, since the process of developing the learning materials requires both time and resources, it is very slow. On the other hand, all teachers should retrain to promote their awareness, knowledge, values, and skills to be able to implement OBE.

Despite all the advantages discussed by various scholars, some opponents consider some disadvantages of OBE, especially for pre-university students. Some examples are the imposition of constraints, a lack of proper emphasis on attitudes and values, and prevention of learning by discovery. The key concerns of the imposition of constraints are mostly related to pre-university education. Indeed, they believe that education should be open-ended and take the students to where they can develop. The second disadvantage discussed is that in OBE, the values and process of skills are ill-defined. They have been buried in a morass of pedagogic claptrap because of omitting the traditional academic content. The opponents bring up the last disadvantages as prevention of learning by discovery. In fact, they presume that education should be valued for its own sake, not for the pre-identified outcomes, and believe the OBE inhibits the students from this value (Davis, 2003; McKernan, 1993).

1.4 The Malaysian Education Curriculum

Since the first decade of the 21st century, the concept of OBE has emerged in curriculum development. The key principle of OBE is to develop an education program and learning process through the identification of the outcomes. In OBE, the curriculum content is driven by outcomes which are specified for education programs instead of a predetermined set of contents. Indeed, identification of competencies is vital for students to make them ready for the workplace (Kim, 2012).

Outcome-based education or OBE intends to make education more accountable to meet the real needs of students. Hence, the curriculum in OBE is defined as an instrument to enable students to achieve and

demonstrate the proper knowledge, skills, values, and attitudes in a specific subject at a particular grade (Wilmot, 2003). Certainly, the key aim of curriculum development in OBE is to facilitate the self-learning for students aside from providing suitable opportunities for teachers to present students' progress based on students' learning. Therefore, in OBE, the stakeholders attempt to develop the most relevant, criterion-based outcomes with a focus on students' performance and skills (Asimi, 2014). In other words, in OBE, education mostly relies on the students' attempt, not on their similar success to other learners.

In 1957, after Malaysia's independence, the government concentrated mostly on education as the main tool for creating national values, identity, and nation-building. In 1988, the Malaysian government legislated the National Education Philosophy (NEP) with the aim to promote the quality of education to meet the vital needs of the Malaysian society in the twenty-first century. Moreover, the objective of NEP was to support students to acquire their potential skills (Khalid, Harun, Muda, & Isamil, 2011). Hence, the Malaysian educational system considered this curriculum as one of the most suitable vehicles to achieve their desired goals. Reviews of the literature indicated that Malaysian curriculum development was an ever-changing process influenced by the current trend and issues happening in Malaysia and around the world at the time. Thus, the ever-changing process of Malaysian curriculum was because of trying to keep up the exact values and identity of Malaysia while following the demands of globalisation. Some of the reports and inspections which were carried out and contributed to the changing Malaysian curriculum during the last decades are the Razak Report in 1956; Rahman Talib Reports in 1960; Cabinet Report in 1979; and the Education Act in 1996.

The Education Act 1996 developed the fundamental platform for curriculum policies in Malaysia via legislating specific laws and defining the direction in curriculum development. To continue, the Malaysian National Education Philosophy (NEP) noted that the Malaysian educational system had made ongoing attempts to enable students to develop their potential capacities in all aspects such as intellectual, spiritual, emotional, and physical. Indeed, NEP aimed to train knowledgeable, skilled students to overcome the growing needs of the millennium. To achieve this, the NEP envisaged that the defined goals are achievable through concentrating on the science, technology, information technology besides focusing on the moral, work ethics, and values fit for the information age.

In 1993, the Ministry of Education in Malaysia noted that the main effort of the Malaysian education system was to provide a proper atmosphere for Malaysian citizens to develop their knowledge, promote their moral standards, and develop their responsibilities to capture the high level of human well-being (Nagappan, 2001). Therefore, the educational system in Malaysia, defined a new philosophy for curriculums to enable the holistic development of students in all aspects through transmitting proper knowledge, and skills, with the hope to foster healthy attitudes and the creation of moral values. In summary, the key aim of the new curriculum philosophy is to improve the quality of education to capture the goals of NEP in the information age. General education and usage of the integrated approach in designing curriculum were considered to be the new theoretical principle of the national curriculum in Malaysia.

The Malaysian Ministry of Education set up various committees to develop the curriculum, such as the State Education Departments, the Division Education Offices, the Educational Planning Committee, the Central Curriculum Committee, the Curriculum Implementation Committee, the State Curriculum Committee, the Division Curriculum Committee, and the School Curriculum Committee. However, the Ministry of Education puts the key responsibility for initiating the curriculum development on the shoulders of the Curriculum Development Centre (CDC).

The Ministry of Education realised the curriculum had had a strong impact on students' achievement and their learning quality through conducting various investigations. Furthermore, the point that Malaysian education system should consider is that by only defining a new subject such as ICT in school cannot guarantee the computer literacy of students or meet their future needs in the workplace. In fact, to capture the effectiveness and efficiency of the learning process, developing the curriculum is vital to cover the knowledge, skills, and values that are essential for the information age (UNESCO, 2011).

In 2011, the new Primary School Standard Curriculum or better known as *Kurikulum Standard Sekolah Rendah* was implemented. Subsequently, the Secondary School Standard Curriculum or *Kurikulum Standard Sekolah Menengah* was also launched. The new curriculums are modular-based and focus on the students' learning process, thus, enabling them to be more responsible towards their own learning. Moreover, the new curriculums emphasise on creativity, innovation and entrepreneurship across the disciplines.

1.5 How Do STEM and Outcome-Based Education Relate to the Malaysian Education System?

Malcolm (1999) demonstrated that education, its basic ideas, and various types and forms, depends mostly on politics, history, cultural norms, committees, interest groups, and educational leadership.

The Malaysian government, to meet the real needs of Malaysian society in the 21st century, focused on the quality of education through training the Malaysian citizens (Khalid et al., 2011). Indeed, by considering the vision for Malaysia in 2020, the education ministry tried to move the country up towards a developed nation within a stipulated time. The Malaysian government concluded that to have an industrial society, they need individuals with high knowledge and skills in science, technology, engineering, and mathematics to enable them to meet the needs of our global world.

In this regard, the Malaysian Ministry of Education codified the new National Education Blueprint (2013 - 2025) in October 2011. The new blueprint aimed to figure out, and evaluate the current situation of the Malaysian education system based on their performance and challenges, to promote the quality of their education system based on international standards, and finally introduce the newest aspirations for both teachers and students. Therefore, a holistic transformation program is needed to include all key changes to enable the Malaysian education system to prepare students for the new skills and knowledge which are demanded in the 21st century. Thus, the Malaysian education system focused on the quality of education on STEM (science, technology, engineering, and mathematics) and OBE (outcome-based education) to achieve their desired economic or national development. Indeed, increasing the quality of learners is set as one of the key elements of the Government Transformation Program.

The Malaysian education system stakeholders believed that the keystone and the best tool for creating knowledgeable students is a well-designed education system with a focus on STEM subjects. Indeed, the main aim was to promote the students' level of critical thinking, problem-solving, and improve their knowledge (Khalid et al., 2011). They demonstrated that STEM, by connecting school, work, and community, not only makes students ready for the real world's competitive economy, it also boosts their social life (Tsupros, 2009). In other words, STEM assists students to use their knowledge in related contexts which makes the learning process