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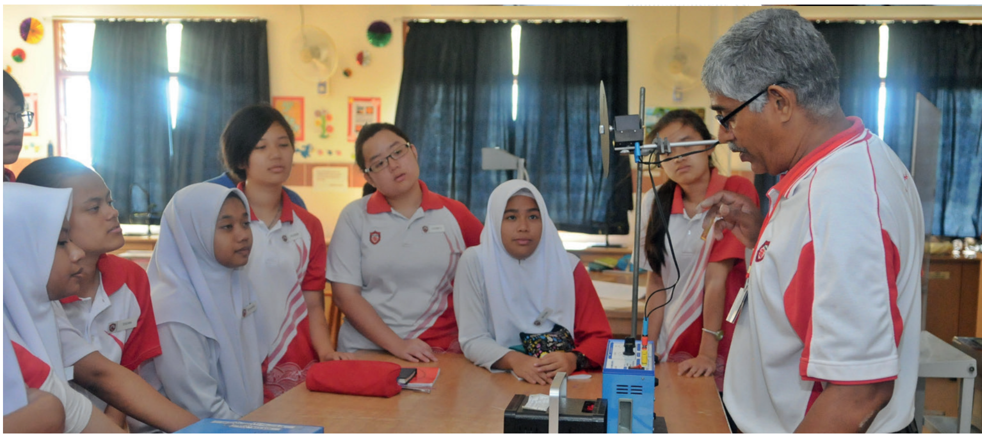
Training Tools for Curriculum Development:

A RESOURCE PACK FOR GENDER-RESPONSIVE STEM EDUCATION



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Training Tools for Curriculum Development: A Resource Pack for Gender-Responsive STEM Education

FOREWORD

The 2030 Agenda for Sustainable Development, adopted by the United Nations General Assembly in 2015, underscores the crucial role that science and technology play in finding innovative solutions for making progress towards a more sustainable, prosperous, and equitable planet. In particular, Sustainable Development Goal 4, *Ensure inclusive and quality education for all and promote lifelong learning*, and its targets, emphasizes the relevance of Science, Technology, Engineering and Mathematics (STEM) to forge sustainable development and sustainable lifestyles.

Despite the progress of the last decades, STEM education remains a daunting challenge worldwide. A lack of professionals in STEM-related fields severely hampers development opportunities in many countries. This is even more critical when viewed through the lens of gender. Women are still largely underrepresented in the STEM fields despite the mounting demand for STEM professionals. Only 28% of the world's scientific researchers were women in 2013 and only 14% of women chose science-related fields when entering higher education, compared to 39% of men, among OECD (Organization of Economic Cooperation and Development) countries in 2010. This constitutes a strong warning that women have been neglected as contributors to this rapidly changing, knowledge-based world.

Ignoring this trend, and neglecting to make sustained efforts to bring more girls and women into the STEM fields, will severely compromise the achievement of the SDGs: one of the pivotal concerns, providing equal opportunity to both girls and boys, will not be met. Vigorous efforts should be made to ensure that girls and women are provided with an equal opportunity to fully develop 21st century competencies. Equipped with these competencies, girls and women can take part in STEM-related fields and thus contribute significantly to development as equally empowered, confident, proactive and responsible citizens.

In light of the urgency to engage more girls in STEM-related fields, the International Bureau of Education (IBE-UNESCO) and the Ministry of Education (MOE) of Malaysia launched the project 'Strengthening STEM Curricula for Girls in Africa and Asia and the Pacific—Phase I', funded by the UNESCO Malaysia Funds-in-Trust under the Malaysia-UNESCO Cooperation Programme (MUCP). Building upon the expertise of Malaysia and the IBE-UNESCO, the project promotes the development of gender-responsive STEM education, encompassing issues relating to policies, curricula, pedagogy, teacher education and professional development in the partnering countries of Cambodia, Kenya, Nigeria and Vietnam.

As a Global Centre of Excellence for curriculum, teaching, learning and assessment, IBE-UNESCO promotes a systemic understanding of quality education and, in particular, a profound awareness of the many ways in which education is development-relevant; STEM education holds particular importance here. IBE visualizes STEM curricula as a key driver of quality education and an influence on educational policies, paving the way to effective, relevant and sustainable learning opportunities, processes and outcomes.

Malaysia is widely recognized as a world leader in fostering STEM education with a gender perspective. STEM is visualized as both a foundation and a key driving force for realizing national development aspirations and goals. Moreover, Malaysia recognizes that, unless more girls are brought into STEM fields, and in equal numbers to boys, these national goals are increasingly remote. This propels Malaysia to develop a set of policies that encourage girls' and women's participation in STEM-related fields across all levels of the education system; these policies encompass issues relating to curricula, pedagogy, teacher education and professional development. Currently, Malaysian women who are pursuing STEM fields of study in higher education make up more than half of enrolled students; among these women, 57% are attaining science degrees and 50% are working towards computer science degrees.

Bringing together the IBE's and Malaysia's expertise, this project reveals once more the importance of South-South Cooperation in enabling the sharing of experience. This sharing has the intent, not of imitating pathways and models, but essentially of providing meaningful insights to facilitate local discussions and developments. The sharing of experience further encourages interaction among the local and global community by promoting a dialogic process in which various actors across the field – government officials, NGOs, the private sector and civil societies of participating countries – are engaged in these discussions.

Through project developments and responding to country's needs, the Minister of Education of Malaysia and the IBE-UNESCO identified the need to develop a training tool, *'A Resource Pack for Gender-Responsive STEM Education'*, within the IBE series of *Training Tools for Curriculum Development*. The overarching objective of the *Resource Pack* is to share a broader understanding of the theory and practice of gender-responsive STEM education, in order to support its effective development at the policy, school, classroom and community levels. The Resource Pack provides comprehensive guidance for national policy makers, curriculum specialists and developers, teachers, teacher educators, school leaders and district level administrators.

The *Resource pack* is currently in use by the project's partnering countries to strengthen STEM education through policy, curricula, pedagogy, and teacher education and teacher professional development. We envision that the *Resource pack* will, in the near future, be used worldwide as a training tool to effectively promote STEM education in national policies.

Marope Mmantsetsa
Director of International Bureau of Education - UNESCO

Dato' Seri Mahdzir Bin Khalid
Minister of Education of Malaysia

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The *Resource Pack for Gender-Responsive STEM Education* represents a collaborative effort of many individuals and organizations. We would like to acknowledge our valued and committed partner, the Ministry of Education Malaysia, as well as the Malaysia-Funds-in-Trust (MFiT), without whose financial support the preparation and publication of the *Resource Pack* would not be possible.

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If we have unintentionally omitted anyone who has collaborated without giving them their due recognition, we apologize and offer our most sincere gratitude for their invaluable support.

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GLOSSARY

Terms	Elaborations
Cascade model of teacher training	The *cascade model of teacher training* is a centralized approach that is suitable for disseminating information and skills among a large number of teachers. A small group of teachers (usually a particularly capable group) is selected to receive intensive training delivered through workshops and training sessions. After receiving training, these teachers provide training to their peers, serving as 'master teachers'. The cascade model is a less costly alternative to training all teachers face-to-face.
Curriculum	*Curriculum* is a description of what, why, how and how well students should learn in a systematic and intentional way. The curriculum is not an end in itself but rather a means of fostering quality learning. The curriculum can also be viewed as a political and social agreement that reflects a society's common vision while taking into account local, national and global needs and expectations.
Curriculum development process	*Curriculum development* is a systematic process whose output is curriculum products (e.g. curriculum plan and documents). The process includes a needs analysis for a country/community, curriculum design, writing of the curriculum specifications, curriculum piloting, dissemination of the curriculum, and implementing, monitoring and evaluating the curriculum.
Engineering design	*Engineering* involves taking ideas and solutions to problems and transforming them into something concrete. Engineers develop products and systems by creatively solving problems that meet human needs. *Engineering design*, the act of producing creatively, is the process that engineers use to solve problems and to develop products.
Gender	*Gender* is the roles and responsibilities of men and women that are created in our families, our societies and our cultures. The concept of gender also includes the expectations held about the characteristics, aptitudes and likely behaviours of both women and men (femaleness and maleness). *Gender* roles and expectations are learned. They can change over time and they vary within and between cultures. *Gender* is not biologically predetermined, nor is it fixed permanently, but can be changed.
Gender bias	*Gender bias* refers to the unequal ways that men and women are treated in society.
Gender-based discrimination	*Gender-based discrimination* refers to prejudicial treatment of an individual woman/man or a group of women/men based solely on perceptions about gender.

Terms	Elaborations
Gender-based violence	*Gender-based violence* is violence that is perpetrated solely based on the victim's perceived gender.
Gender equality	*Gender equality* refers to the equal rights, responsibilities and opportunities of women and men, and girls and boys. *Gender equality* implies that the interests, needs and priorities of both women and men are taken into consideration, recognizing the diversity of different groups of women and men and upholding their human rights.
Gender inequality	*Gender inequality* is a societal process through which people experience differing treatment based on their perceived gender.
Gender parity/disparity	*Gender parity* is the numerical representation of gender equality. Gender parity is achieved if the number of men and women, girls and boys, are relatively equal for a given scenario. *Gender disparity* is a relatively unequal representation of *gender equality* in numerical terms.
Gender responsive	*Gender responsive* refers to a recognition of the varying needs of girls and boys, or men and women, followed by actions that address these varying needs and that prevent gender bias or gender-related discrimination. Moreover, when gender inequality and bias is confronted, the *gender-responsiveness* promotes gender equality.
Gender sensitive	*Gender sensitive* means being sensitive to the ways in which different people think about gender and how this affects attitudes and behavior.
Gender stereotyping	*Gender stereotyping* refers to the practice of ascribing specific attributes, characteristics or roles to an individual woman or man or groups of women/ men only by reason of her or his membership in the social group of women or men.
Inquiry-based learning (IBL)	*Inquiry-based learning (IBL)* is a process that provides opportunities for learners to construct their own understanding of the complexity of the natural and human world around them. Many models of inquiry-based learning share some common features, such as: investigation into a relevant issue, problem or concept; a learner-centred approach; the discovery and examination of a complex understanding of a phenomenon and the involvement of thinking and reflection in the learning process. A curriculum adopting this approach implies that learners work with new and challenging content and concepts, connect new information to former knowledge, select thinking and learning strategies deliberately, and plan, monitor and evaluate their own thinking processes. *IBL in science* and mathematics education is a pedagogical approach in which students are involved in exploring and experimenting in order to acquire knowledge and understanding of phenomena, and to seek solutions to problems.

Terms	Elaborations
In-service teacher training	*In-service teacher training* is the training provided for teachers who are currently teaching in schools. It helps keep teachers up-to-date on advances in knowledge, skills and policies in teaching/education and in their particular subject field. On-going training is, therefore, crucial both for teachers and for students.
Learning environment	*A learning environment* is used in a variety of ways. Essentially, it indicates the learner's immediate physical surroundings (classroom, school), the resources made available to support the learning process, and the social interactions or types of social relationships functioning within this context and having an influence on learning.
Learning style	*Learning style* refers to people's diverse and preferred ways of thinking, processing and understanding information and knowledge. Examples of learning styles are learning through visual or aural modalities. A student may have more than one learning style, with one style being dominant over other styles. If the dominant learning style can be identified, then teaching and learning experiences can be tailored to the student's preferred mode to help that student learn more effectively. Understanding students' learning styles and associated intelligences can assist teachers in determining the best strategic approach to raise levels of learning achievement.
Lesson study	*Lesson study* is a form of school-based in-service training where groups of teachers learn from each other and engage in improving and refining classroom instruction and learning activities together. *Lesson study* often uses the *5E format* of lesson development: engagement, exploration, explanation, elaboration and evaluation.
Personalized learning	*Personalized learning* is a strategy for holding students accountable and responsible for determining their own learning priorities. They are provided with opportunities to access different teaching and learning approaches and resources that meet their needs. *Personalized learning* also challenges teachers and educators to look at the needs of each student and to allow students to learn at their own pace.
Policies	*Policies* refer to the regulations, rules, procedures and other specific instructions formulated by a government for the purpose of good governance and to ensure the smooth implementation of programs in a country. One of the important roles of government agencies is monitoring compliance with policies.
Pre-service teacher training	*Pre-service teacher training* refers to training individuals and equipping them with subject-specific knowledge and with professional competencies for facilitating instruction and learning before they assume a teaching position in a school or in other learning contexts. *Pre-service teacher training* always entails the awarding of a diploma or degree.

Terms	Elaborations
Problem-based learning (PBL)	*Problem-based learning (PBL)* is a learner-centred educational approach, which challenges students to learn through engaging with a real problem in a process that is often unstructured. In the process of finding solutions to the problem, students take an active role in developing both problem-solving skills and subject-specific knowledge.
Project-based learning (ProjBL)	*Project-based learning (ProjBL)* is a structured or semi-structured learning approach that empowers students to take responsibility for their learning. It uses multi-faceted projects as a central organizing strategy so that students can learn through real-life experiences. In *ProjBL*, students build up knowledge and develop skills by working on a project with concrete outputs. Projects are usually carried out over an extended period of time.
Reflective teaching model (RTM)	*A reflective teaching model (RTM)* focuses on empowering teachers to adopt reflective practices as a teaching strategy. It involves a pair of teachers who conduct regular, on-going sessions of joint planning, teaching and reflecting on their practices. Reflecting on one's own practice requires a form of deep thinking in which one poses questions and solves problems.
School-related gender-based violence (SRGBV)	All acts or threats of violence occurring in and around schools, perpetrated as a result of gender norms and stereotypes, and made possible by unequal power dynamics. *SRGBV* may be perpetrated by peers, teachers or other members of the educational community and increasingly includes the use of *ICTs* (cyber-bullying, sexual harassment through social media, etc.).
STEM knowledge	STEM curriculum consists of three elements: knowledge, skills and values/ ethics. *STEM knowledge* comprises the facts, ideas, concepts, principles, and theories in the disciplinary areas of science, technology, engineering and mathematics.
STEM skills	One of the three elements of the STEM curriculum, *STEM skills* relate to the competencies or abilities to explore, investigate, solve problems, and design and produce products. *STEM skills* include science process skills, science manipulative skills, computational thinking skills, mathematical process skills, engineering design thinking skills, ICT skills and other specific technical skills. Technical skills include psychomotor skills, skills in managing and handling materials and equipment, and skills involved in ensuring safety.
STEM values/ethics	One of the three elements of the STEM curriculum, *STEM values and ethics* consist of the ethics, guidelines, scientific attitudes and moral values to be upheld by STEM students and practitioners. Examples of *STEM values and ethics* are rational thinking, objectivity, precision, risk-taking, persistence, commitment and adherence to laboratory rules and safety measures.

Terms	Elaborations
STEM practice	*STEM practice* denotes what scientists, technologists, engineers, mathematians and other professionals do in their jobs where they solve problems and produce solutions. *STEM practice* is also needed in understanding STEM knowledge, skills and values. It includes asking questions and defining problems, developing and using models, planning and carrying out investigations, analysing and interpreting data, using mathematics and computational thinking, constructing explanations and designing solutions, engaging in debate and argument based on evidence, and obtaining, evaluating and communicating information.
Socio-scientific issues-based (SSI) teaching	*Socio-scientific issues-based (SSI) teaching* is a variant of problem-based teaching in which authentic, real-life issues or topics are the central focus, and different socio-scientific perspectives are explored. In this approach, teachers are expected to provide a platform for the students to engage, discuss, debate and investigate a wide range of issues and their ramifications for science, society, politics, economics, or other realms that affect the learner's everyday life.
Teaching and learning (T&L) resources	*Teaching and learning (T&L) resources* are materials that can assist teachers and students in acquiring knowledge, skills and values. These resources are needed especially when a new pedagogical approach, such as the STEM approach, is introduced. Generally, *teaching and learning (T&L) resources* are presented either in printed materials or in a digital format, including textbooks, modules, activity sheets and guidebooks. Developing effective teaching and learning resources requires the developers to understand that students' learning is affected by a myriad of complex and often intersecting factors. These factors include characteristics of students, teachers, family backgrounds, learning environments, school administrators, government policy and guidelines.
Textbooks	*Textbooks* are learning resources provided to students as their main references in schools. They are often provided in printed form. *Textbooks* are the product of writers/educators who translate the specifications of a curriculum into a concrete form to facilitate students' comprehension of the curriculum. *Textbooks* also act as tools for teachers to design and guide their lesson plans and classroom activities.

Note:
- Some definitions of the glossary are adapted from the UNESCO publications.
- For further reference to educational terminology, please refer to the IBE-UNESCO Curriculum Glossary (IBE-UNESCO, 2013).

INTRODUCTION

The acronym 'STEM' refers to the academic disciplines of science, technology, engineering and mathematics. The term is commonly used when addressing education policy and curriculum choices in educational institutions, including primary and secondary schools. The prominence of STEM education and the urgency for its effective implementation intensified because of a global trend of school children's decreasing interest in science and technology subjects during the last decade. This trend has led to an insufficient number of students enrolling in science- and technology-related courses at higher-education institutions and, subsequently, to a depleted science and technology workforce. This phenomenon is a serious concern: it affects the world's economic development and well-being, and the sustainability of human life on this planet.

STEM, however, cannot be viewed merely as subjects offered in schools and universities or solely as career choices. STEM, as a set of disciplines, consists of knowledge, skills and attitudes or ethics practiced by STEM professionals and STEM workers. The knowledge, skills and attitudes/ethics of science, technology, engineering and mathematics are seldom used in insular ways, unrelated to each other. Rather, real-world issues are often solved by integrating all four areas. Thus, to better reflect reality, a more interdisciplinary and applied approach is needed so that the teaching and learning of STEM will be more meaningful and useful to students and to society at large.

It is important to note that the intent is not to eliminate the individual subjects in science (that is, physics, chemistry, biology, earth science), technology (such as computing and design), engineering and mathematics as areas of study. Rather, the intent is to teach these subjects in a more applied manner, using real-world data and introducing practices driven by real-world concerns. A project-based approach, in which students work collaboratively on real-life problems is a meaningful way to integrate science, technology, engineering and mathematics. This can also help to raise students' interest in STEM fields and to provide them with the skills needed to successfully enter the job market.

The concept of STEM can be further clarified by integrating engineering design into the structure of science education. This would be done by raising engineering design to the same level as scientific inquiry when teaching science disciplines at all levels, from kindergarten to secondary schools. The reason is practical, as stated below:

> *We anticipate that the insights gained and interests provoked from studying and engaging in the practices of science and engineering during their K-12 schooling should help students see how science and engineering are instrumental in addressing major challenges that confront society today, such as generating sufficient energy, preventing and treating diseases, maintaining supplies of clean water and food, and solving the problems of global environmental change* (National Research Council, 2012, p. 9).

Currently, girls and women are significantly underrepresented in STEM-related fields of study and work across the world; since girls and women make up 50% of the world's population, there is an urgent need to encourage their participation in STEM fields. To optimize human talent and capacity, governments, specifically Ministries of Education, must formulate favourable policies for fostering girls' participation in STEM disciplines. With that support, more girls would be able to choose, and would feel encouraged to pursue, STEM subjects in schools and in higher education, and would have the right conditions to succeed in STEM alongside boys.

This *Resource Pack* is part of the Malaysia and the IBE project, 'Strengthening STEM Curricula for Girls in Africa and Asia and the Pacific—Phase I', under the Malaysia-UNESCO Cooperation Programme (MUCP) through the Malaysia-Funds-in-Trust (MFiT). The *Resource Pack* is comprised of six modules designed to be a practical guide for developing gender-responsive STEM education. Gender-responsive teachers in STEM understand and respond to the specific needs of girls and boys throughout the teaching and learning process to help ensure that all children – girls and boys – are able to fulfil their potential in STEM. With its aim of promoting gender-responsive STEM education, the modules are directed towards focusing and training the users along the following lines: (i) policy formulation; (ii) curriculum development and design; (iii) strategies for pedagogy, learning and assessment; (iv) teacher education and teacher professional development; (v) resources; and (vi) community involvement.

Developed by Malaysian experts together with experts from the IBE and others through a collaborative process, the *Resource Pack* provides information and guidelines on how to support governments, schools and teachers in developing gender-responsive STEM education, in order to encourage more girls to participate in STEM. The *Resource Pack* is designed to be utilized by officers in Ministries of Education, policy makers, curriculum developers, teacher educators and teachers. The authors' intention is that, through the use of these modules, government officials can formulate policies to support gender-responsive STEM education, develop gender-sensitive STEM curricula, design in-service and pre-service training that will build instructional skill, draw up guidelines to develop gender-sensitive STEM printed and digital resources, and disseminate gender-responsive STEM pedagogies. The modules can be used as a whole package or each module can be used individually, depending on the needs of the country or community. The modules' strategy is to bring the four disciplines of science, technology, engineering and mathematics together by focusing on engineering design and the solving of real-world problems. They also attempt to bridge the gap between girls' and boys' participation in STEM. The goals of utmost importance are finding relevance in learning STEM and developing in both girls and boys the skills required to fulfil each country's needs.

This *Resource Pack* is both built on and aims to promote the principles of gender equality. These principles encompass the equal rights, responsibilities and opportunities of girls and boys, women and men, and ensure that the interests, needs and priorities of girls and boys are taken into consideration. It is essential that anyone who uses this *Resource Pack* both understands and upholds these principles at all times.

EFFECTIVE UTILIZATION OF THE RESOURCE PACK

The *Resource Pack* has been developed as a flexible tool that can be used in a variety of ways, depending on the needs of a country, institution or individual teachers. The six modules can be packaged as a complete accredited course offered by universities and other institutions of higher education and training. The six modules in the Resource Pack may also be repackaged into a unit within an accredited pre-service course.

The *Resource Pack* may be used as a professional development programme for policy makers in a Ministry of Education, curriculum developers, teacher educators, and/or teachers. Once again, this could be a comprehensive programme on its own, or a part of another professional development programme. In both cases, countries and institutions offering such programmes may further customize the *Resource Pack* to meet their specific needs and contexts.

The *Resource Pack* is also intended to be a useful tool for Ministry of Education officials to make appropriate gender-sensitive STEM policies and develop gender-sensitive STEM curricula, for teacher training, and for forming effective Communities of Practice (COP). Individual persons, institutions and countries will use the *Resource Pack* as their own needs dictate. This may mean utilizing all six modules or focusing on specific modules that respond to unique needs. In this regard, the *Resource Pack* will provide an appropriate environment for enlarging and refining comparative perspectives through sharing experiences and case studies.

Ultimately, the expectation for the *Resource Pack* is that it will assist educational practitioners in diversifying their strategies and improving their practice in promoting gender-responsive STEM education. Subsequently, these practitioners will also contribute to the growing body of knowledge in gender-responsive STEM education.

OVERVIEW OF THE MODULES

INTRODUCTORY MODULE
Gender and Sociocultural Practices in STEM Education

This introductory module builds a foundation for the following modules by articulating issues of gender-responsive STEM education. It introduces the role of education in achieving gender equality and women's empowerment. It establishes and elaborates on the impact of sociocultural aspects and cultural practices, and of gender stereotyping and gender-based discrimination, in girls' and women's participation in STEM education. Insights gained through the activities in this module equip and guide the users to view the areas of intervention – such as policies, curricula, pedagogies, teacher education and professional development, resources and community involvement – through a gender lens.

MODULE 1
Formulating Policies for Gender-Responsive STEM Education

This module focuses on formulating gender-responsive STEM education policy and addresses the different stages in the policy design process. It underscores the importance of a needs analysis of the target population and of the context where there is a gap between current and desired conditions. Additionally, this module explores in depth various approaches for developing national and school policies that are gender sensitive so as to advance both the quality of, and the gender equality in, STEM education.

MODULE 2
Developing Gender-Sensitive STEM Curricula

This module outlines the meaning of 'gender-sensitive curricula' and a 'gender-responsive learning environment', and clarifies the role of curriculum in achieving gender equality and gender-responsive STEM education. This module discusses the curriculum development process in general, but also addresses specifically a STEM curriculum framework and a gender-sensitive STEM curriculum.

MODULE 3
Creating Gender-Responsive STEM Pedagogy, Learning and Assessment

This module explores gender-responsive classroom practices through examining current classroom practices and interactions. It also redefines what is meant by 'gender-responsive classroom practices' and suggests how to further promote and ensure these practices. It then identifies concrete and applicable methods for designing gender-sensitive science or mathematics activities. These methods include inquiry-based learning (IBL), problem-based learning (PBL), project-based learning (ProjBL), socio-scientific issues-based (SSI) instruction and engineering design process.

MODULE 4

Teacher Education and Teacher Professional Development to Support Gender-Sensitive STEM Curricula and Gender-Responsive Pedagogies

This module proposes comprehensive approaches to teacher education and professional development to implement gender-sensitive STEM curricula by practicing gender-responsive pedagogies. It presents a variety of models for pre-service and in-service trainings, placing a strong emphasis in particular on fostering gender sensitivity in teachers along with the pedagogical knowledge and skills. It examines the role and the professional profile of teachers, and the ways to enhance teachers' profile by implementing teacher training and professional development effectively.

MODULE 5

Developing Gender-Sensitive STEM Resources

This module presents the principles of developing gender-sensitive STEM teaching and learning resources. It highlights gender-sensitive STEM materials that are crafted for personalized learning and are responsive to different learning styles. This module further suggests various approaches for developing gender-sensitive STEM resources: developing textbooks and other curriculum materials; incorporating ICT into learning and teaching; and designing a gender-friendly inquiry-based learning spaces.

MODULE 6

Raising Community Awareness and Commitment to Policies that Promote Gender-Responsive STEM Education

This module identifies the key stakeholders in the community as well as the role and the impact of each stakeholder. It presents various strategies for raising community awareness and further stimulating community engagement towards developing and implementing gender-responsive STEM education policies.

Training Tools for Curriculum Development:
A Resource Pack for Gender-Responsive STEM Education

GENDER AND SOCIOCULTURAL PRACTICES IN STEM EDUCATION

INTRODUCTORY MODULE

INTRODUCTION

This introductory module articulates gender-responsive STEM education by introducing the role of education in achieving gender equality and women's empowerment. It ascertains the impact of sociocultural aspects and cultural practices, and of gender stereotyping and gender-based discrimination, in girls' and women's participation in STEM education.

The activities proposed in this module discuss the universal meaning of gender equality and women's empowerment, and address cultural practices, gender stereotyping and gender-based discrimination and their impact on girls' participation in STEM. The activities of this module focus on the following:

1. Understanding gender equality and women's empowerment
2. Analysing the impact of the cultural practices on girls' engagement in STEM
3. Identifying gender stereotypes and gender-based discrimination

The aim is to equip the users with a comprehensive gender lens through which policies, curricula, pedagogies, teacher education and professional development, resources and community involvement can be reconceptualised.

Key words

Gender equality, women's empowerment, gender-responsive STEM education, gender stereotyping, gender-based discrimination

ACTIVITY 1

Understanding the role of education in enhancing gender equality and women's empowerment

Over the last century, many countries have made important advances towards gender equality, including women's right to vote and access education. Despite this, gender inequalities remain deeply embedded in every society (UN Women, 2015). Gender equality is unequivocally linked to the right of all children to a good-quality education. Addressing gender inequalities in education requires an approach that ensures that girls and boys, women and men, not only gain access to and complete education cycles, but are equally empowered in and through education (UNESCO, 2016). A gender-responsive education is a critical aspect of this process, and helps to empower girls, as well as boys, by providing good-quality, relevant education that helps enhance girls' and boys' self-esteem, self-respect and their respect for others.

UNESCO (2003) provides the following definitions:

> ***Gender*** *refers to the roles and responsibilities of men and women that are created in our families, our societies and our cultures. The concept of gender also includes expectations held about the characteristics, aptitudes and likely behaviours of both women and men (femininity and masculinity). Gender roles and expectations are learned. They can change over time and they vary within and among cultures. Systems of social differentiation such as political status, class, ethnicity, age, physical and mental disability, and more, all modify gender roles. The concept of gender is vital, because, when applied to a social analysis, it reveals how women's subordination (or men's domination) is socially constructed. As such, the subordination can be changed or ended. It is not biologically predetermined nor is it fixed forever.*
>
> ***Gender Equality*** *means that women and men have equal conditions for realizing their full human rights and for contributing to, and benefiting from, economic, social, cultural and political development. Gender equality is therefore the equal valuing by society of the similarities and the differences of men and women, and the roles they play. It is based on women and men being full partners in their home, their community and their society.*
>
> ***Empowerment*** *is about people – both women and men – taking control over their lives: setting their own agendas, gaining skills, building self-confidence, solving problems and developing self-reliance. No one can empower another: only the individual can empower herself or himself to make choices or to speak out. However, institutions, including international cooperation agencies, can support processes that nurture the self-empowerment of individuals or groups.*
>
> (UNESCO, 2003, p. 1)

Focus of the activity

This activity and the suggested tasks will help participants enrich their understanding of the concepts of gender and gender equality, and of education's role in enhancing girls' and women's empowerment.

TASK 1: Work in small groups

a. Read the articles on 'Gender equality in schools' (Oxfam GB, 2005); 'The education of girls in Kenya: looking back and still looking forward' (Mondoh and Mujidi, 2006); 'We understand better because we have been mothers: teaching, maternalism, and gender equality in Bolivian education' (Reid and Miller, 2014); and the policy brief, 'Gender equality in the mathematics and science school curriculum' (Moletsane and Reddy, 2011).

b. What is the role of education in promoting girls' quality education and in realizing gender equality?

c. In what ways do you think the education in your country promotes or hinders girls' empowerment?

Product

Better understanding of the ways in which education either empowers or excludes girls

ACTIVITY 2

Cultural practices and their impact on girls' participation in STEM

Culture encompasses the customs and general social behaviour of a group of people. It is a people's 'way of life' and 'way of doing things'. Culture passes from one generation to another through family or community traditions and practices, including through education. Traditional, religious and familial cultures can support or undermine gender equality.

Stereotyped attitudes, behaviours and expectations relating to gender can limit girls' and boys' choice of school subject and career, and their aspirations. Sociocultural norms and forms of discrimination have a powerful influence on the social and economic roles that women and men play in all societies, as well as on their differential participation in the labour market. The disproportionately low numbers of women in STEM-related careers globally can be linked to discriminatory social norms about the kinds of occupations that women are, or are not, capable of or suitable for holding. For example, women and girls may avoid STEM courses and careers due to sociocultural beliefs, which lead them to think that women do not possess the ability or intelligence to be successful in STEM (Wang and Degol, 2017).

School lessons that encourage critical reflection can help to break down discriminatory sociocultural norms and gender stereotypes, and help girls and boys broaden their opportunities and choices concerning school subjects and careers.

Focus of the activity

This activity and the suggested tasks will help participants to appreciate how sociocultural influences affect girls' participation in STEM. The activity will also help participants to identify ways for incorporating a better understanding of cultural dynamics into the development of a gender-responsive STEM education.

TASK 1: Work in small groups

a. Discuss the influence of cultural norms and practices on girls' participation in STEM subjects and the development of STEM education in your country.

b. How can a gender-responsive STEM education be used to enhance girls' participation in STEM subjects in your particular country context?

c. How can female STEM role models be used to enhance girls' participation in STEM?

TASK 2: Individual reflection

a. Read the publications 'A Complex Formula: Girls and Women in Science, Technology, Engineering and Mathematics in Asia,' from page 21 to 25 (UNESCO, 2015); 'Girls into Science: A Training Module,' from page 25 to 29 (UNESCO, 2007); and the article on 'Unequal access, unequal participation: some spatial and socio-economic dimensions of the gender gap in education in Africa with special reference to Ghana, Zimbabwe and Kenya' (Shabaya and Konadu-Agyemang, 2004).

b. What are the cultural factors that contribute to girls' unequal access and unequal participation?

c. What are some of the mitigating strategies that can be adopted to address culture-related factors that affect girls' participation in STEM education?

Product

Strategies for mitigating culture-related factors that affect girls' participation in STEM education

ACTIVITY 3

The impact of gender stereotyping and gender-based discrimination on STEM education

WHAT IS GENDER STEREOTYPING?

Gender stereotyping refers to the practice of ascribing attributes, characteristics, or roles to girls and boys, and women and men, only by reason of their membership in the social group of women or men (United Nations Human Rights Office of the High Commissioner [OHCHR], 2016) Gender stereotypes (that is, stereotypes linked to perceptions of maleness or femaleness) lead to assumptions and ideas about girls and boys, women and men, including expectations about how they should look, behave, act and think.

Gender stereotypes are often deeply embedded in society and can lead to the perception that certain ways of being and behaving are 'natural'. Gender stereotyping can limit girls' and boys', women's and men's, capacity to develop their personal abilities, pursue their professional careers and make informed choices about their lives and life plan (OHCHR, 2016). These prejudices can have a far-reaching effect on an individual.

Gender stereotyping may help to explain girls' and women's low participation in STEM subjects and STEM-related careers. For example, families, communities and schools actively engage in socialization processes which children experience from a young age. Socialization can instil in children ideas about what is, or is not, suitable for girls to do, including which subjects they should study in schools. Research has shown that parents with strong math-gender stereotypes and perceptions, such as boys' outperformance in math over girls, have developed expectations for their children, which often led to girls' lower achievement in math (Wang and Degol, 2016). Negative attitudes from and judgements made by teachers and families about girls' abilities to do well in STEM can have an impact on girls' self-confidence and subject choices. Even in countries such as Bulgaria and Argentina, where women represent more than half of the population enrolled in science degrees and working in research, evidence has presented that science is still associated more with men rather than women (Miller, Eagly and Linn, 2015). Further, a girl's fear of failing in certain subjects or of being in the minority in a class can impact her learning outcomes. All of these aspects, and many others, can influence girls' decisions not to pursue STEM subjects (MOE Malaysia, 2015; OECD, 2015). There is much work to be done to dismantle the implicit and explicit gender biases that prevent equal participation in STEM.

GENDER-BASED DISCRIMINATION

Gender-based discrimination is bias regarding a person or a group of people based on ideas, understandings and beliefs about gender. Gender-based discrimination is a violation of human rights and is linked to unequal access to various kinds of resources. These include tangible resources such as schooling, qualifications, jobs and decent wages, and intangible resources such as self-esteem and self-confidence.

Unfortunately, gender-based discrimination is still widespread and persists in different forms in all societies around the world (OHCHR, 2015). Sometimes gender-based discrimination is explicit. However, in the majority of contexts, gender-based discrimination is not explicit, but veiled. Gender-based discrimination can be subtle and reflected in systems and conditions that decrease the opportunities for people, particularly girls and women, to participate equally in society.

Focus of the activity

This activity and the suggested tasks will provide participants with the opportunity to understand how gender stereotypes and gender-based discrimination affect girls' and women's participation in STEM education and STEM-related careers.

TASK 1: Individual reflection

a. Read the paper 'Gender equality and education in the Sustainable Development Goals' from page 13 to 14 (UNESCO, 2016).

b. Identify instances of explicit or subtle gender stereotyping and gender-based discrimination in your country. How do such instances affect girls' participation in STEM education?

TASK 2: Work in small groups and a plenary discussion

a. The following is a list of various different views of women as scientists[1]. Prepare brief remarks on the issues presented.

Scientists are often pictured as men in white coats in laboratories or other science-related contexts. Women are seldom pictured in this role.

- What is the first image that comes to your mind when the word 'scientist' is mentioned? Is the image gender biased?
- To what would you attribute this?

Women who are in professions traditionally assumed to be suitable for men only are often viewed as aggressive.

- Do you agree? Why is this so?

'Would you trust a woman to fly your plane?' Ali G, a British comedian, got into trouble when he jokingly said this to a professor of Gender Studies.

- What are your views on this matter? Discuss your thoughts.

[1] These examples are all taken from UNESCO (2006)

> *'In my view, there will always be certain types of work in the engineering field which women are by nature not capable of handling, given their physical weakness. Women are by nature not strong and building roads, for example, requires both strength and endurance. Look at what happens when a long road has to be built – men stay in steel huts for weeks on end: women can't stand the roughness of such jobs'*

- What does this statement say about the barriers for women in engineering?
- What does it say about the nature of engineering itself?
- Is this a correct representation of what engineers do?

> *'Engineering still carries the image of being hands-on, with grubby machinery and technical based - and I think that does put quite a few people off' (22-year-old female design engineering student in Britain, from a Paul Hill article in the Times Higher Education Supplement).*

- What would be the standard response to this statement in your country?
- Why is that so?

b. Discuss the impact of gender stereotyping and gender-based discriminatory statements and views on STEM education and further explore the strategies for eliminating them from the education system.

c. Ask the groups to share their brief notes in a plenary. Ask one participant from each group to summarize their group's emerging views on gender stereotyping and gender-based discrimination.

Product

Strategies to eliminate gender stereotyping and gender-based discrimination in your country, schools and classrooms

INTRODUCTORY MODULE

TAKE-AWAY POINTS

This introductory module has established the principles of gender equality in order to prepare and guide the users of the Resource Pack, namely policymakers, curriculum developers, teacher educators and teachers, with a critical, comprehensive gender lens. These are three key recommendations:

1. Gender equality is vital for a healthy society and its foundations originate in the education system through teachers, peers, curricula and schooling experiences.

2. Strongly held cultural beliefs can be the origin for gender stereotypes and biases that impact female participation in STEM. Teachers, students, and communities should unpack how girls' participation in STEM is negatively impacted by sociocultural influences.

3. Gender-based discrimination and biases can be systemic and implicit. Gender-responsive STEM education can positively impact girls, boys, women and men.

READING LIST

- Gender Equality in Schools. Education and Gender Equality Series (Oxfam GB, 2005)
- The education of girls in Kenya: looking back and still looking forward (Mondoh and Mujidi, 2006)
- Gender equality in the mathematics and science school curriculum (Moletsane and Reddy, 2011)
- 'We understand better because we have been mothers': teaching maternalism, and gender equality in Bolivian education (Reid and Miller, 2014)
- A Complex Formula: Girls and Women in Science, Technology, Engineering and Mathematics in Asia (UNESCO, 2015)
- Girls into Science: A Training Module (UNESCO, 2007)
- Unequal access, unequal participation: some spatial and socio-economic dimensions of the gender gap in education in Africa with special reference to Ghana, Zimbabwe and Kenya (Shabaya and Konadu-Agyemang, 2004)
- Gender equality and education in the Sustainable Development Goals (UNESCO, 2016)

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NOTES

NOTES

FORMULATING POLICIES FOR GENDER-RESPONSIVE STEM EDUCATION

MODULE 1

MODULE 1

INTRODUCTION

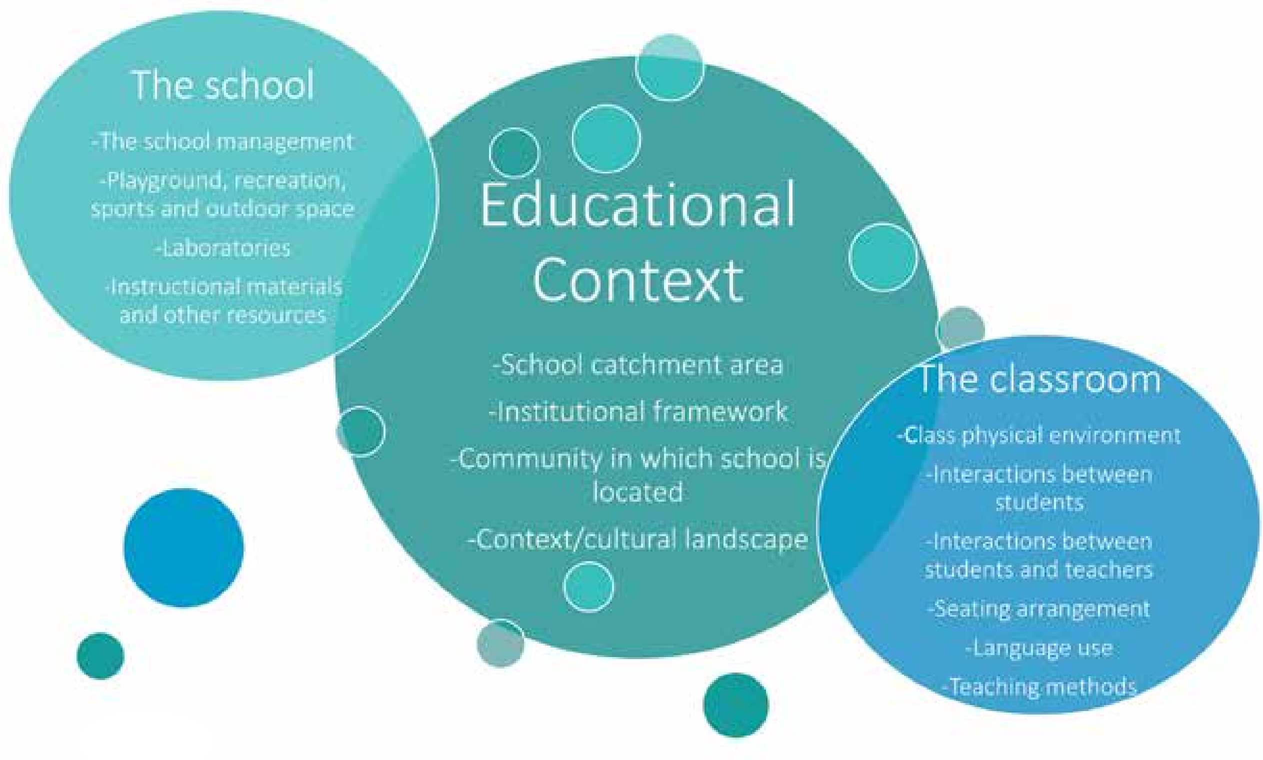
This module focuses on formulating policy, a critical phase which involves identifying a set of policy options to address a problem or agenda. The activities in this module seek to guide policymakers, curriculum developers, teacher educators and teachers through the stages of formulating policies for gender-responsive STEM education. The following list specifies the activities that are fundamental to the process of formulating policy; these activities comprise the sections of this module.

1. *Needs analysis:* How to determine and address needs or gaps between current conditions and the desired state of the education system and the larger socio-political environment, and how to set priorities for action
2. *Developing policies for gender-responsive STEM education:* How to develop a comprehensive set of policies for gender-responsive STEM education across different sectors
3. *Developing a national policy:* How to develop national policies that will address problems that have been identified, and that will improve the provision of quality STEM education that promotes gender equality
4. *Dissemination of policy*: Circulating necessary information to the key stakeholders
5. *Financial planning for policy development*: How to allocate financial resources effectively

RATIONALE FOR FORMULATING POLICIES FOR GENDER-RESPONSIVE STEM EDUCATION

Formulating policy requires the participation of multiple actors who play important roles in the policy design process. Decision makers choose from a set of policy options by judging the suitability, feasibility, efficiency, and political and public acceptance of each option. The adopted policy sets the parameters for addressing the problem or agenda, in this case, implementing gender-responsive STEM education. Policies that support providing gender-responsive STEM education should be conceptualised within a comprehensive framework that addresses the issues identified in the diagram below.

Figure 1.1: What is included in the learning environment?



Source: Adapted from, Strengthening Education Systems in East Africa (2016).

Science, mathematics, engineering and technology (STEM) knowledge and skills are relevant, not just to those who work in STEM-related fields, but in understanding our daily lives, ranging from our day-to-day health and our communication with others, to our knowledge of climate change and sustainable living. STEM skills help to drive innovation and economic growth, and will play a crucial role in meeting the challenges of sustainable development (UNESCO, 2015b). STEM education can also help to develop people's critical thinking skills and their ability to find solutions to everyday problems, no matter where they live in the world. These are fundamental skills for everyone – girls, boys, women and men – regardless of their field or vocation. However, data show that gender inequalities persist globally in STEM education, resulting in fewer girls than boys leaving school with adequate knowledge of STEM or pursuing STEM-related fields in higher education and the job market. This module focuses on the ways that policy plays a role in supporting gender-responsive STEM education.

Key words

Policy formulation, policy design process, gender-responsive, decision makers, needs analysis, determination and prioritization of needs, needs-based formula funding

ACTIVITY 1

Needs Analysis

Formulating educational policies, including policies supporting gender-responsive STEM education, requires a needs analysis, which is the process of identifying and evaluating needs in the target population, and prioritizing these needs according to cost, feasibility and opportunity in order to introduce change and development. Needs is the gap between current and desired results or conditions, which is acknowledged by community values.

The following are ideal steps in a needs analysis (McKillip, 1998).

a. Identify the audience and the objectives for the analysis

b. Describe the target population and the service environment, focusing on:

(i) Direct recipients of the services

(ii) Those providing the services

(iii) Inputs and resources into the solutions

c. Identify the needs and the possible solutions:

Identifying needs involves describing the problems of the target population, generating possible solutions to the problems, and calculating the estimated costs of each possible solution. The problems depict the difference between the current actual status and the desired or expected change, and are the basis for determining the needs

d. Evaluate the identified needs:

Consider the relevance and importance of the needs to the target population

e. Communicate the results to the audience identified in the first step

The identification of needs is best conducted at three levels (Kaufman, 1998): (i) the *mega level*, which concerns gaps in societal results; (ii) the *macro level*, which concerns gaps in organizational results; and (iii) the *micro level*, which concerns gaps in individual or small group results.

Two interdependent processes are essential to determining and prioritizing needs: (i) identifying the desired results through strategic planning and vision-setting, and (ii) identifying the actual, current situation through collecting data. Defining consequences at all three levels can help the organization to identify and prioritize gaps in results, thereby determining needs.

Avoiding pitfalls in a needs analysis is important (Altschuld, 2000). It is thus vital to develop a conceptually coherent, logical and integrated plan for conducting the needs analysis. Aspects of developing a sound plan include identifying the target population; sampling; gathering the right information to measure the need, since levels of need may differ across types of target groups; setting priorities based on collected data; and, using appropriate methods to justify the conclusions.

NEEDS ANALYSIS AT THE MEGA LEVEL: WHERE DO WE STAND?

Driving this needs analysis is the imperative to understand and strengthen girls' and women's relationship to STEM education and work worldwide. Globally, women are underrepresented in STEM fields as students, teachers, professors, researchers and workers. Gender representation in STEM fields is most unequal in countries where girls underperform in STEM subjects at the secondary level. A recent UNESCO report (2015a) illustrates how gender disparities in STEM-related study differ by country and by subject. For example, in Malaysia as of 2012, 72% of students enrolled in pharmacy studies were female as opposed to 36% in engineering. In Mongolia as of 2013, 73% of students in biology were female compared with 30% in computer science and 24% in engineering. In the Republic of Korea as of 2011, 52% of students enrolled in science at the bachelor's degree level were female compared with 20% in engineering, with the proportion declining at the doctoral level to 38% in science and 12% in engineering.

The following are some data on the status of female participation in STEM-related study:

- Globally, STEM-related study has achieved gender parity (that is, equal numbers of men and women) in enrolment at the bachelor's degree level and at the master's level. However, data from 2013 show that men have increasingly been outnumbering women at the PhD level; the gap widens at the researcher level, where only 28.4% of researchers are women. This percentage falls to 17% in South Asia, the region with the smallest proportion of female researchers (UNESCO, 2015a).
- In countries of the Organization for Economic Cooperation and Development (OECD), gender disparity remains very large in the field of engineering, with men accounting for nearly 80% of all doctoral degree holders (OECD, 2015a). Although the share of women graduating as engineers has risen in sub-Saharan Africa since 2000, less than 20% of engineering graduates in 2013 were women. In India, however, there has been a substantial increase in women engineering undergraduates since the 1990s (UNESCO, 2015a).
- Since 2000, the proportion of female computer science graduates has been decreasing, particularly in high-income countries. In Ireland, the Republic of Korea and Sweden, the proportion of female computer science graduates fell from around 40% to under 25% of total graduates. In Malaysia, however, the information technology (IT) sector comprises equal numbers of women and men (UNESCO, 2015a).
- In 2011 in the United States, fewer than one out of four workers in STEM-related employment was female (UNESCO, 2015a).

In a world that is increasingly advanced technologically and scientifically, education is key to scientific progress and crucial to involvement in scientific pursuit. Gaining access to scientific careers, whether in research, practical technology or industry, requires certain levels of education. Young people must have the necessary school-level preparation in order to move to higher education work in science, engineering, mathematics or technology. For example, it is not possible to study for a science degree at the university level without having received adequate mathematics education in secondary school. Since, of course, all children need to reach secondary school with basic competence in literacy and mathematics, addressing gender disparities relating to learning at lower levels of education is also a priority. Gender parity in education and economic opportunity matters in its own right. However, it is notable that gender disparities in education are often associated with gender inequalities in the labour market, with fewer women than men teaching mathematics and science, and fewer women pursuing STEM-related careers. Once in STEM-related careers, women still face discrimination in terms of fewer opportunities for advancing up the career ladder, less access to research funding, and widespread perceptions that women are not as capable in STEM-related fields as men (UNESCO, 2015e). These discriminatory attitudes and practices work together to create a cyclical process that perpetuates gender inequalities in STEM-related study and work.

Focus of the activity

This activity and the suggested tasks will help participants to explore the process of identifying and evaluating needs of a target population, with a particular focus on the needs of girls, and of prioritizing the needs according to the cost, feasibility and opportunity for introducing change and development.

TASK 1: Work in small groups

a. Read the reports 'EFA Global Monitoring Report. Gender and EFA 2000-2015: Achievements and Challenges,' from page 30 to 45 (UNESCO, 2015c); 'A Guide for Gender Equality in Teacher Education Policy and Practices,' from page 28 to 35 (UNESCO, 2015b); and 'Global Education Monitoring Report 2016. Gender Review: Creating Sustainable Futures for All,' from page 9 to 11 and from 30 to 56 (UNESCO, 2016).

b. Read the articles 'Girls' and Women's Education in Kenya,' from page 14 to 16 (Chenge and Sifuna, 2006); 'Gender and education for all: progress and problems in achieving gender equity' (Chisamya et al., 2012); and 'Partnership, participation and power for gender equality in education' from page 3 to 14 (UNGEI, 2012).

c. What are the global, national and regional issues in girls' education that the assigned documents discuss? Make a list of the issues and challenges in girls' education.

d. How are these issues similar or different from those present in your country?

e. In view of Sustainable Development Goal 4 on 'Ensuring inclusive and equitable quality education and promoting lifelong learning opportunities for all' and SDG 5 on 'Achieving equality and empowering all women and girls', how is your country prepared to respond to the international commitments to gender equality and good-quality, inclusive education for all?

TASK 2: Plenary discussion

Each group will share their responses to the questions in Task 1, with a particular focus on the responses of participants' countries to the international commitments.

Product

Countries' response to the status of girls' education in the context of international commitments

TASK 3: Work in small groups and a plenary discussion

a. Divide the whole group into groups of 4 or 5 people and ask each group to appoint a representative who will report back to the whole group on the group's discussion. Ask each participant to reflect on their own secondary school experiences using the following questions, and to discuss their experiences with the group (approximately 2 minutes per person):

- Did you have male or female teachers in STEM subjects?
- In which subjects did you perform well?
- In which subjects were you confident?
- What were your perceptions of science and mathematics?
- Which subjects were you encouraged or discouraged to do?
- Who were the major influences in these decisions and why?
- How did your educational experiences and perceptions shape your career choices?

b. For the plenary, ask the group representative to report back to the whole group, synthesizing the group's discussion.

c. Discuss the gender dimensions of the schooling experiences of the whole group and identify any common trends.

TASK 4: Work in pairs and a plenary discussion

a. Discuss factors contributing to gender inequalities in STEM education in your country.

b. Describe aspects of the STEM educational policies in your country that you think might potentially contribute to gender inequalities in STEM education in your country.

c. Identify possible solutions to problems contributing to gender inequalities in STEM education in your country.

d. Explain key considerations in formulating policies that support gender-responsive STEM education.

e. Ask the participants to display their responses on the wall and do a gallery walk of the whole class.

f. Ask one person in each pair to briefly report their responses to the whole class.

TASK 5: Individual assignment

a. Prepare an outline of a needs assessment proposal that you could use in your country addressing gender inequalities in STEM education.

Product

Outline of a contextualized needs assessment proposal for your country

b. Prepare a letter to the Minister of Education in your country expressing the necessity for conducting a needs assessment on gender equality in STEM education.

Product

Letter to the Minister of Education of your country

ACTIVITY 2

How to develop a comprehensive set of policies to support gender-responsive STEM education across different sectors

The following are important aspects to consider in developing policies to support gender-responsive STEM education:

- National policies encompassing different sectors such as Science and Technology, Gender Equality, Education, etc.
- Policies to retain women and men who are trained in STEM in the country to avoid 'brain drain' and encourage 'brain circulation' and the exchange of ideas
- Policies on mobilizing funds for research into and advocacy for girls' participation in STEM education
- Possibilities for utilizing research findings to demonstrate the impact of STEM policies in countries with successful STEM education
- Adopt an inclusive approach to policy making that includes different voices that are representative of the population, and that ensures the fair representation of women and men in discussions and decision-making when formulating policies and developing STEM curricula

POLICY-MAKING PROCESS: DEVELOPING NATIONAL POLICIES

These are the main steps in the process of making policy. See Figure 1.2 below for a visual representation of the process of national policy development. These steps represent a generic process. Taking into account the gender lens discussed in the introductory module and the needs analysis, consider this process specifically for developing gender-responsive education policy.

a. *Agenda Setting:* Societal issues need to be analysed and documented so as to prioritize them when setting policy. Usually, the issues are taken up by a policy-making body, the legislature or an administrative agency, in order to mainstream them in the policy cycle. In many cases, issues emanate from a situation in which certain results or conditions do not meet the expectations of a given group. This could trigger a public uproar, a crisis or lobbying by interest groups. An issue can move (quickly) into a policy agenda, depending on the amount of public attention that the media and interest groups highlight, creating a perception that the issue requires resolution through the policy process.

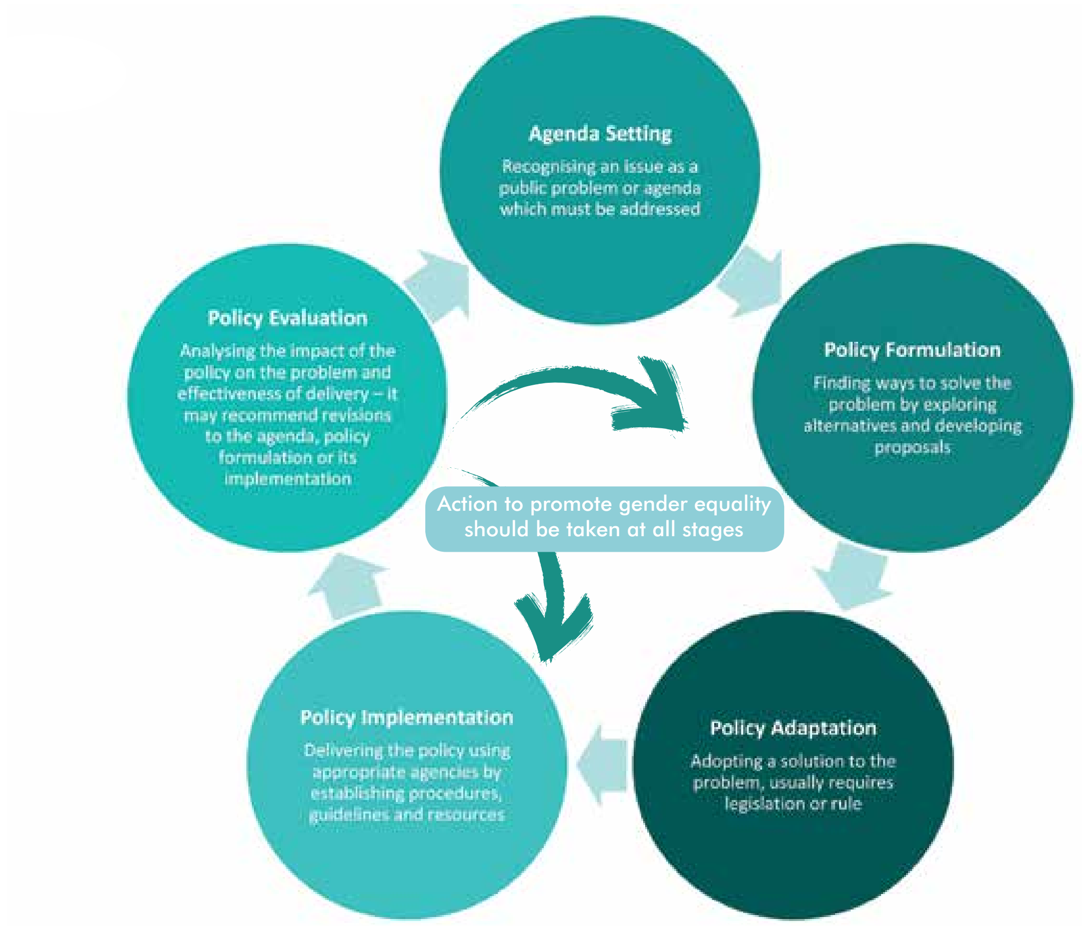
b. *Policy Formulation:* Policy formulation involves policymakers proposing several solutions to address the identified issue. The policy identifies strategies and practical ways of providing efficient and effective interventions. The implications of policies need to be considered thoroughly in order to avoid or minimize negative consequences.

c. *Policy Adoption:* The relevant government bodies have to adopt the policies before they can be implemented. The likelihood of adoption can be affected by the same factors that influence issue identification and agenda setting; these include public attention, media coverage and the views of interest groups, which lead to (un)biased or (un)favourable responses to adopting the policy.

d. *Policy Implementation:* Implementation involves putting the adopted policies into effect. Elements for effective implementation are: (i) organization, in which policies are passed down from Parliament or state and local government to the appropriate agency within the government bureaucracy or bodies created for this purpose; (ii) interpretation, in which the legislative intent has to be clearly and effectively translated into appropriate operating rules and guidelines; and (iii) application, in which resources for implementation are made available, in coordination with existing operations or agencies.

e. *Policy Evaluation:* Both formal and informal approaches can be used to evaluate policies at different points in the policy implementation process. In some cases, there are challenges in evaluating policies and, as a result, policies are not evaluated. For example, policies may be especially difficult to evaluate if they have broad goals that are subject to varied interpretations. Further, scientific research needed for evaluation may be time-consuming and costly, while evaluations using feedback and anecdotal information may be affected by bias.

Figure 1.2: Process for developing policy



Source: Adapted from the Texas Politics Project website (n.d.) and Leach (2003).

DISSEMINATION OF POLICIES

Policies need to be disseminated effectively to the entire population in a well-defined, non-discriminatory and user-friendly way. Appropriate information, education and communication (IEC) materials must be developed to speak to the various members of the society in the ways that would be most meaningful to them.

IMPLEMENTATION OF POLICIES

Effective implementation requires meticulous planning. In many cases, policies are well developed but poorly implemented. An implementation plan that is cognizant of all the contextual issues that may affect implementation should be developed. Policies need to be communicated effectively, with clear implementation guidelines, to all the relevant government agencies or bodies created for that purpose. It is also important to balance political interests to avoid complicating distractions. Further, to ensure that effective policy implementation is possible, the capabilities of implementing agencies need to be evaluated and enhanced where necessary.

MONITORING AND EVALUATION

As policy is formulated, a comprehensive monitoring and evaluation (M&E) plan is also needed to facilitate a feedback mechanism that will help improve policy implementation. M&E also facilitates tracking results for interventions and strategies to ensure both girls' and boys' inclusion in STEM-related education. Education data – statistics and information – should always be disaggregated by sex, along with other key social dimensions that are relevant to the particular context, such as race and ethnicity. This helps in understanding if the policy is working: that is, are girls and boys benefiting equally from the policy? If not, which girls and/or which boys are disadvantaged? For example, if a school has a newly established library, it would be important to learn, among other things, how many boys/girls are using the library. What is the most popular reading time for boys/girls? What type of material are boys/girls reading? Are there particular groups of girls who are not accessing the library? If so, why?

Focus of the activity

This activity and the suggested tasks will help participants to develop gender-sensitive national policies about STEM education.

TASK 1: Individual reflection

a. Read the report, 'Applying a gender lens to science, technology and innovation,' from page 17 to 27 (UNCTAD, 2011).

b. Read the following extract in Box 1.1.

Box 1.1: Policies and programmes to promote gender equality in STEM

In the Republic of Korea, a number of policy measures and initiatives specifically related to education, gender and STEM have been initiated in order to address the underrepresentation of women in STEM fields. Over the last 14 years, these include the Women into Science and Engineering (WISE), gender inclusive curricula, fellowship opportunities for female students in science and engineering, broader job training opportunities for women, as well as the 2002 Act: Fostering and Supporting Women Scientists and Technicians (Choi and Kim, 2014). In addition, the Center for Women in Science, Engineering and Technology (WISET) was established in 2011, which will be further explored later in this chapter in the section on career orientation. Other examples of policies that promote gender equality in STEM can be found in other countries. In Thailand, the successful Development and Promotion of Science and Technology Talents Project (DPST), founded in 1984, now has almost equal numbers of male and female graduates. The project helps nurture friendship among project participants, provides exposure to role models, organizes field trips, and promotes 'learning for learning's sake', meaning that female and male students are encouraged to have a positive attitude towards mathematics and science, regardless of whether they excel in the subject or not (APEC, 2010, p. 11). Such policies and programmes are a positive step towards providing support for learning in mathematics and science, as well as in stimulating interest in STEM fields among both female and male students.

Source: Minor modification has been made to the excerpt from UNESCO (2015a).

TASK 2: Work in small groups

a. Identify some of the national, regional and international agreements that you think support girls' and young women's participation in STEM education.

b. How have policies in your country been aligned to these national, regional and international agreements?

c. Ask the groups to report their findings in a whole class plenary. During the session, ask the participants to identify areas of significant national weakness that hinder gender equality in STEM education, and to suggest and prioritize some interventions to implement that will contribute significantly to meeting internationally agreed targets relating to gender equality in STEM education.

TASK 3: Individual assignment

a. Identify key stakeholders involved at each stage in the development of educational policies in your country. Is there gender equality at each level of decision-making, and thus an environment that is conducive to promoting gender equality in STEM education?

b. Describe your country's process for formulating policy. Are the issues of gender equality, and girls' low and inequitable participation in STEM education specifically, addressed from the beginning of the process and at every stage?

c. Develop a plan on how to ensure that gender inequalities in STEM education are addressed in your country's policy-making process.

Product

A plan on how to ensure that gender inequalities in STEM education are addressed and that the principles of gender equality are adhered to throughout the policy-making process

ACTIVITY 3

Developing policies that support gender-responsive STEM education at the school level

Schools play a critically important role in shaping girls' and boys' experiences of STEM education. Many countries see a marked decline in the number of girls taking advanced-level STEM subjects in the upper secondary grades, a situation which urgently needs to be addressed. Instruction in mathematics and science subjects during the middle school years often contributes to students' selection of STEM disciplines in the upper secondary grades. Then, in turn, differences in the teaching of mathematics and sciences at the secondary level can have a strong impact on girls' and boys' achievement in these subjects, which impacts their higher education subject choices (OECD, 2015a). School-based efforts to expand girls' choices include curriculum and pedagogy that promote gender equality, and the effects of teachers' professional development. Girls and boys can perform equally well in mathematics and science if they are given equal opportunities to develop the self-confidence and the skills to realize their potential.

Depending on a country's form of education governance, schools may enjoy different degrees of autonomy in making policies on STEM and other curriculum-related issues. Even when national, regional, state or county governments develop the policies, schools may have to adapt these policies for day-to-day school operations. It is therefore important that schools are empowered to be able to develop policies that support gender-responsive STEM education and meet the needs of all their students, both girls and boys.

Focus of the activity

This activity and the suggested tasks will help participants to explore the process of developing policies that support gender-responsive STEM education at the school level.

TASK 1: Individual reflection

Read the documents 'Gender Inequalities in education in South Africa' (Rarieya, Sanger, and Moolman, 2014) and 'Girls into Science: A Training Module' from page 114 to 120 (UNESCO, 2007).

TASK 2: Work in small groups

a. Read and discuss the 'Analysis matrix for gender equality in schools' below.

Table 1.1: Analysis Matrix for Gender Equality in Schools

UNIT OF ANALYSIS	INDICATORS	WHAT ARE THE GENDER INEQUALITIES IN YOUR SCHOOL?
INSTITUTIONAL STRUCTURES	• Balance of representation of women and men on the school board • Balance of representation of female and male teachers and other school staff • Balance in the assignment of duties and responsibilities to women and men for issues relating to STEM education • Differences in women and men's access to professional development in STEM education (sponsored training, scholarship, exchange or exposure visits) and upward mobility (promotion, salary raises, recognition) • Distance of schools from villages, and the resulting impact on females and males (staff and students); for instance, more impact on girls'/women's access than boys'/men's due to safety concerns • Educational infrastructure that is equally and safely accessible for female and male students and school staff (playgrounds, labs, latrines, school rehabilitation, etc.) • Differences between women's and men's access to leadership positions in education institutions for teachers and other staff • Institutional policies, or their absence, that deter/address sexual harassment, bullying and other forms of school-related gender-based violence (SRGBV) • Equality between women and men in decision making within the school (for instance, are men and women equally represented, is their presence equally valued, are their voices/opinions equally listened to, etc.) • Differences between girls' and boys' school retention rate, including differences in girls' and boys' grade and age of dropping-out	

UNIT OF ANALYSIS	INDICATORS	WHAT ARE THE GENDER INEQUALITIES IN YOUR SCHOOL?
CULTURE AND CUSTOM	• Any gendered social norms and traditions celebrated or tolerated in the school that negatively affect girls and/or boys (including rituals) • Polices supporting adolescent girls' and boys' needs (for example, access to sanitary towels for girls, and clean and safe toilets for all children; comprehensive sexuality education) • Policies addressing gender-based violence and supporting students who have experienced it in any form • Household demands and domestic burdens placed on girls and boys that impact negatively on their schooling • Differences between women's and men's access to school spaces • Distance to school and effect on mobility of girls and boys • Permissible interactions between girls and boys • Differences between women's and men's access to school-related activities • Differences between mothers' and fathers' roles and interactions with school (for example, which parent comes to school events, or participates in parent-teacher associations).	
GOVERNANCE	• Robust and enforced school policies and Codes of Conduct for teachers and other school staff on school-related gender-based violence (for example, bullying, sexual violence) • Existence of any school rules and regulations that discriminate against either women or men • Differences between girls' and boys' opportunities to become student leaders, along with girls' and boys' actual representation as student leaders • Extent to which girls and boys are consulted on general school governance • Policies specifically promoting gender equality	

b. What policies would you propose at the school level to address gender inequalities and promote gender equality?

TASK 3: Plenary discussion

a. Share your proposed policies in the plenary.

b. Discuss the following questions: Are there similarities across groups? What are the possible explanations for such similarities?

Product:

List of proposed policies to address gender inequalities and to promote gender equality at the school level

ACTIVITY 4

Developing a national policy: how to develop national policies that will improve the provision of quality and equitable STEM education

The focus of this section is to examine the steps that different countries are taking to develop participation and performance in the STEM disciplines. Once those steps are understood, the effort is on drawing from them possible lessons and ideas for developing a national STEM policy and strategy that promote gender equality in STEM education for your own country.

In the *STEM: Country Comparisons* project, Marginson and colleagues (2013) commissioned and then analysed 22 studies of STEM policies and practices around the world. They also developed 24 key findings on challenges with STEM participation, and ideas for tackling these challenges. The report highlights the following points:

STEM disciplines have become important everywhere: STEM is a vital concern of policy makers across the world. This is due in particular to the general need for improving the quality of the human capital supply in the labour market. It is due also to the need for expanding the high-skilled group of workers capable of generating high-quality STEM-related research, innovation and technological change. STEM-related qualifications and skills, such as critical thinking and problem solving, can help prepare graduates in a broad range of occupations, including non-STEM occupations, and can contribute to citizenship, global economic competition and social creativity.

Deepening and broadening STEM: In many countries, the goal is to develop the STEM skills of all students' (including girls and marginalized groups) through delivering broad and in-depth STEM education. Enhancing all STEM education, will help increase general scientific literacy among the population, and expand the talent pool of STEM students in higher education and of STEM experts in the labour market.

Countries strong in STEM are diverse in their economic, political, social and educational contexts: Countries strong in STEM: (i) have school teachers who are held in high esteem, earn higher salaries and work within more meritocratic career structures; (ii) are committed to developing quality discipline-specific learning materials that focus on knowledge, and have teachers who are fully qualified in their specific discipline; (iii) have instituted reform in curricula and pedagogy that are focused on making science and mathematics more engaging and practical through problem-based and inquiry-based learning that fosters creativity and critical thinking, while maintaining high-quality content; (iv) have developed innovative policies to enhance STEM participation among formerly excluded groups and low-achieving students; and (v) have developed strategic national STEM policy frameworks which provide positive conditions for various activities. These activities feature centrally driven and funded programmes including curriculum reform and new teaching standards, world-class university programmes, decentralized programme initiatives and partnerships, and networks that link STEM activities in educational institutions with industry, business and research.

Framing a national STEM policy: Several countries have committed to STEM or a broader science and technology agenda through legislation, policies or strategy statements. A national policy establishes a framework for STEM-specific objectives, facilitates the implementation of STEM-specific strategies and programmes and, in many cases, is supported by structures that coordinate STEM concerns across different bodies and sectors. A national STEM policy generally emphasizes the development of human capital for the labour market, which is considered important for economic growth and well-being. The STEM strategies and programmes vary in breadth and scope but generally span school-level education, vocational education and training, higher education, research and development, and programmes related to innovation, employment and industry development.

Different approaches have been implemented across English-speaking and Western European countries, Asian countries, and developing countries: English-speaking countries, such as Canada, New Zealand, the United States, and Western European countries with high-performing education systems and unmet demand for STEM-qualified positions, commonly have national STEM-related policies. The policy coverage in these countries varies, depending on the scope of government responsibility. Asian countries and regions with high-performing education systems and growing economies, such as South Korea, Japan, China and Taiwan, have established national policies around science and technology, and university- and industry-driven research and development. Developing economies such as Brazil, Argentina and South Africa have national policies focused on quality education systems and emerging industry development, rather than STEM-specific policy.

Approaches to girls' and women's participation in STEM: National policy on girls' and women's participation is focused on gender equality in STEM education and careers. Approaches vary but include political will, legislation, greater understanding of issues relating to gender equality, mandated involvement of women in decision-making bodies and appointment to senior positions, appropriate human resource processes and adequate funding systems. Many countries struggle with the issue of girls' and women's low representation in STEM and pursue various gender-equality policies and strategies. Measures to improve gender equality in STEM include: (i) system-wide targets on an equitable percentage of women in STEM disciplines; (ii) scholarships and fellowships reserved for female students and researchers; and, (iii) strategic reservation of funds for women and/or allocating greater points in funding selection processes to projects that include women researchers.

To attract more girls and women to STEM, countries also need to address the lack of female role models and girls' unfamiliarity with STEM careers or their reluctance to pursue them. Mentoring programmes have been successful in several countries at encouraging female participation in STEM. These include peer-to-peer support among students and systematic mentorships for female students, from the primary to the doctoral level, with professionals and professors working in STEM fields.

Some countries also strategize on school curricula and pedagogies in STEM disciplines that promote gender equality in STEM education. These strategies include: (i) curriculum design and professional development to generate greater teacher awareness on encouraging girls' involvement in STEM; (ii) content, pedagogy and resources relevant to the diverse learning styles and preferences of girls and boys; (iii) greater focus on inquiry-based teaching in order to ensure that STEM teaching is interesting and relevant to both girls and boys; and (iv) providing science experiences from an early age. Other strategies for increasing female participation in STEM include career counselling and flexible workplace arrangements.

Focus of the activity

This activity and the suggested tasks will guide participants on how to develop national policies for improving the quality and the gender equality in STEM education provision.

TASK 1: Individual assignment

Describe the policy approaches used in your country to enhance girls' and women's participation in STEM.

TASK 2: Work in small groups

Select three countries from different regions of the world and compare their policy approaches for developing a national STEM policy and strategy with the policy approach in your country.

ACTIVITY 5

Financial planning for gender-responsive STEM Education as part of national and school policy development

As part of the procedures for needs assessment and policy planning, planning for the disbursement of financial resources is vital in ensuring the success of any policy, curriculum and programme, including gender-responsive STEM education. In determining the budget allocations for gender-responsive STEM education, a systematic approach, such as needs-based formula funding, should be applied. Needs-based formula funding 'is a specific approach to design a funding formula so that the amount which is allocated to each school is directly derived from an analysis of what the school needs to spend in order to provide a specified quality of education for its students' (Ross and Levačić, 1999, p.26).

Table 1.2 shows a hypothetical example of the relationship among components, dimensions and indicators in developing a school funding formula. Schools may be funded per capita for students as in Dimension 1(a) or allocated a sum for running a particular programme, as in Dimension 2(a). Increased funding may be offered to offset the needs of low-income students or students in special education as in Dimensions 3 (a) and (d) and costs associated with rural schooling, school size and overall school maintenance as in Dimensions 4(a), (b) and (c) (Ross and Levačić, 1999).

Table 1.2: Hypothetical example of the relationship among components, dimensions and indicators in developing a school funding formula

COMPONENTS	DIMENSIONS	INDICATORS
1. Basic student allocation	1(a) Total enrolment 1(b) Grade level differentiation	1(a) Total full-time equivalent (FTE) at time of school census 1(b) Total FTE in each grade level
2. Curriculum enhancement	2(a) Specialist curriculum 2(b) Specialist school	2(a) FTE enrolled in foreign languages 2(b) Total FTE (if technology school)
3. Student supplementary educational needs	3(a) Socio-economic disadvantage 3(b) Non-fluency in language 3(c) Low educational achievement 3(d) Disabilities, impairments, and learning difficulties	3(a) % students on welfare benefits 3(b) % of students below cut-off (language test) 3(c) Number of students below 20th percentile (general ability test) 3(d) Number of students formally assessed
4. School site needs	4(a) School size 4(b) Location (in terms of isolation) 4(c) Site maintenance costs (clean, heat, maintain)	4(a) Primary FTE<200/Secondary FTE<600 4(b) Kilometers to town of 50,000+ persons 4(c) Interior area of school in m^2

Source: Ross and Levačić, (1999), p. 43.

Taking this approach, a set of fundamental questions should be raised and addressed during the financial planning stage: What are the financial resources needed to implement STEM education, particularly for girls? Towards which acquisitions and/or resources will the budget allocation for gender-sensitive teaching and learning (T&L) be directed? Will the process of T&L of STEM education be carried out outside the classroom? Will the process of T&L of STEM education involve experiments in a laboratory? Who is the target group that will benefit from the budget that has been allocated, girls, or boys, or both?

It is worth noting that allocating funds to gender-responsive STEM education is an indication of tangible commitment to that effort. The questions posed above are broad, fundamental questions about how that commitment will be realized. The questions in Table 1.3 represent more specific, targeted concerns about how funds will be used, and for which purposes. The particular questions in Table 1.3 try to identify fundable needs so as to enhance gender-responsive STEM Education in the interest of engaging more girls in STEM work. Identifying specific areas of need is basic for developing a school funding formula. For instance, assuming a need for laboratory equipment to implement the curriculum, a school funding formula will need to determine which and how much equipment and resources are needed in order to deliver specific areas of the curriculum or programme. Schools may be funded per capita for students or allocated a sum for running a particular programme.

Table 1.3: Checklist for the needs-based formula funding for STEM Education for Girls

NO.	QUESTIONS	YES	NO	NOTES
1.	Does the STEM T&L for girls need additional teaching resources (physical or human resources)? If yes, please list all the teaching aids needed and the associated cost.			
2.	Will there be outdoor activities, for example, visits to a science museum to gather information on STEM innovations? If yes, please list all the outdoor activities and the related cost.			
3.	Does the STEM T&L involve conducting experiments in a laboratory? If yes, please list all the materials needed for the experiments, for example, the amount of chemicals and the associated cost.			

Focus of the activity

This activity and the associated tasks will help participants to explore the budgetary process that supports gender-responsive STEM education at the school level.

TASK 1: Individual reflection

a. Read the following book: ‘Needs-Based Resource Allocation in Education via Formula Funding of Schools’ from page 42 to 47 (Ross and Levačić, 1999).

b. How can Table 1.2 above be adapted to address the gender needs? Discuss with your group the elements to be added when considering budgets for gender-responsive STEM education and complete Table 1.4 below.

Table 1.4: Hypothetical example for formula funding exercise

COMPONENTS	DIMENSIONS	INDICATORS
1. Basic student allocation	1(a) Total enrolment 1(b)	1(a) Total full-time equivalent (FTE) at time of school census 1(b)
2. Curriculum enhancement	2(a) 2(b)	2(a) 2(b)
3. Student supplementary educational needs	3(a) 3(b) 3(c) 3(d)	3(a) 3(b) 3(c) 3(d)
4. School site needs	4(a) 4(b) 4(c)	4(a) 4(b) 4(c)

Source: Adapted from Ross and Levačić, (1999).

TASK 2: Work in small groups

a. Table 1.5 below gives an example of formula funding as part of implementing a gender-responsive STEM curriculum. Come up with your own examples and complete the table (refer to Appendix 1.1 and Appendix 1.2).

Table 1.5: An example of formula funding for the implementation of gender-responsive STEM Education

ITEM	SPECIFIC CONTENT AREA	INDICATORS	FORMULA
Laboratory equipment (burette)	Titration	Number of students (a) Number of burette (b)	Cost per burette x (a) x (b)
Plastic Parachute Activity (refer to Appendix 1.1)			
	Density (refer to Appendix 1.2)		

b. Identify the areas of need for enhancing gender-sensitive STEM education in your country and develop your own funding formula.

Product

A funding formula with suggestions on financial resources needed for gender-responsive STEM education

EVALUATION OF BENEFITS AND EFFECTIVENESS OF GENDER-RESPONSIVE STEM EDUCATION

Following the budget allocation, and throughout the execution of the budget, evaluation is needed to ensure that gender-responsive STEM education is successfully implemented; 'successful implementation' is specifically assessed here in terms of the *benefits* of the programme and its *efficacy*. Benefits can be measured by students' future income while effectiveness refers to learning outcomes measured by international, national and regional assessments. Education is an investment for individuals, families, societies and the government. As such, education involves sacrificing current consumption for future benefits such as higher future earnings. Broadly, a *cost/benefit analysis* (CBA) or a *cost/effectiveness analysis* (CEA) can be conducted to evaluate a return on investment (ROI) in education. The CBA relies on monetary measures of the costs associated with a programme or policy and the benefits that result from their implementation over a specific period of time. An age-earnings profile is developed within the CBA to evaluate the efficacy of the STEM education overall, and how it directly relates to wages and employment opportunities for all students, women and men. For example, how do the earnings of an individual who received a STEM-integrated education during primary and secondary schooling compare to a similarly educated person without a STEM background? Moreover, how does high-quality and gender-responsive STEM education impact the earnings of a person compared to a peer who was educated in a more traditional setting? By contrast, the CEA, calculated within a school system, compares the impact of STEM funding on learning outcomes measured by variables such as exam results, test scores, and retention or completion rates. The outcomes of the CBA and CEA will help policymakers to identify the gaps in the programme or policy and the opportunities specifically related to girls in STEM. Furthermore, the results of the CBA and CEA analyses will determine the direction of STEM education funding from early childhood and beyond. The CBA and CEA are part of the larger needs analysis and should be utilized as a tool in developing policies at the school and national level.

Focus of the activity

This activity and the suggested tasks will help participants to explore the process of evaluating the benefits and effectiveness of STEM education that support gender-responsive STEM education at the national level.

TASK 3: Work in small groups

a. Identify and compare the earnings of jobs requiring STEM qualifications and those that do not require STEM qualifications for girls and boys in your country.

b. Identify effectiveness of gender-responsive STEM education by comparing test scores of male and female students in STEM and non-STEM tracks in your country.

c. Discuss why evaluating the benefits and effectiveness of gender-responsive STEM education is necessary and significant, and how the findings can be applied and used for developing and enhancing policy and curriculum and their implementation in your country.

MODULE 1

TAKE-AWAY POINTS

This module has outlined key aspects of the process of developing policies that will support gender-responsive STEM education. The following two key recommendations encapsulate the module:

1. Principles of gender equality need to be reflected at each level of policy making in order to help ensure a policy-making environment that is conducive to developing policies that support gender-responsive STEM education.

2. Those who design policy must conduct a needs analysis of the national and local contexts in order to identify the current issues regarding gender inequalities in STEM education in these particular contexts. This is necessary in order to ensure that any policies that are developed are bothappropriate and effective.

READING LIST

- Education For All Global Monitoring Report 2015. Gender and EFA 2000-2015: Achievements and Challenges (UNESCO, 2015c)
- A Guide for Gender Equality in Teacher Education Policy and Practices (UNESCO, 2015b)
- Global Education Monitoring Report 2016. Gender Review: Creating Sustainable Futures for All (UNESCO, 2016)
- Girls' and Women's Education in Kenya: Gender Perspectives and Trends (Chege and Sifuna, 2006)
- Gender and education for all: progress and problems in achieving gender equity (Chisamya et al., 2012)
- Partnership, participation and power for gender equality in education (UNGEI, 2012)
- Applying a gender lens to science, technology and innovation (UNCTAD, 2011)
- Gender Inequalities in education in South Africa (Rarieya, Sanger, and Moolman, 2014)
- Girls into Science: A Training Module (UNESCO, 2007)

APPENDIX 1.1

PLASTIC PARACHUTE[2]

During class, we have talked about animals need for food to survive. Currently, Country X is having a horrible dry season. The panda species in Country X is suffering; in fact, many have died. The panda's main food is bamboo shoots and when there is less bamboo, the panda population will be aff ected.
What is the best way to send bamboo shoots to the panda species? How you can help to send bamboo shoots and water to save the panda species from extinction? *(Source: Fox, 1984)*

- Teacher helps to create a brainstorm session to gather student's responses. Teacher should leave the answers open by not restricting students' suggestions. *(5 minutes)*

Design challenge (One of the design ways)
Design and build a parachute that can fly for at least 10 seconds from the place where it is floated. Supplies such as food and water must be tied to the parachute without falling to the ground.

Criteria:
Your parachute must:

- Consist of plastic.
- Be able to fly without floating from left to right or otherwise.
- Be able to fly with the supplies even with the increase of the wind speed.

Materials: *(What can you use?)*
(Your teacher might give you the materials you can use in a paper bag to help you keep track of them.)

- Pipe cleaner
- Polystyrenes
- Wooden bead
- Small nuts with equal size

Tools: (You many use these things to help you build. They may not become part of your prototype.)

- Scissors
- Plastic bag
- Adhesive tape
- Thread ball

Be sure to be careful when using the scissors while cutting.
You do not need to use all of the materials and tools.

Curriculum Learning Outcomes:
At the end of this unit, students learn the importance of survival of the species. Students are encouraged to think critically on how to design a parachute using the given materials and tools in order to rescue the panda species which faces extinction due to deforestation and the dry season.

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[2] Extracted from the on-going Ph.D. work of Kamaleswaran s/o Jayarajah, University of Malaya.
Title of thesis: The development of year five Children's Engineering Teaching Module (CETM)

APPENDIX 1.2

Lesson plan

LOWER SECONDARY SCIENCE

School	SMK Jalan Pasir Putih, KU	Date	6 September 2011
Class	Form 1	Number of student	30
Time	10.30 – 11.40 AM	T&L duration	80 minutes
Subject	Science	Topic	Density
Topic	Understanding the concept of density		
Theme (for Lesson Study)	Appreciate density in everyday life		
Focus	Density		
Rational	Exposure and awareness among students regarding the concept of density		
Learning objective	Appreciate the importance of density		
Learning outcomes	At the end of the lesson, students will be able to : 1. Convey the meaning of density based on their understanding 2. Explain, with example, the application of density in life		
Basic knowledge	Mass and volume		
Scientific skill and Thinking skill	1. Problem solving 2. Making inference 3. Visualization		
Scientific attitude and Noble value	Appreciating the contributions of science and technology		
Teaching resources	1. Reference	Text book, Curriculum Document	
	2. Apparatus	500 ml beaker, small bottle, spatula, electronic balance.	
	3. Materials	Sand, water	
Teaching approach		Inquiry-based and hands-on activity	

LEARNING DEVELOPMENT	CONTENT/ CONCEPT	TEACHING & LEARNING PROCESS (TEACHER & STUDENT ACTIVITIES)	NOTES
Phase I Engagement (Duration: 10 min)		Teacher provides a container of water. Students are asked to find some objects around them, (such as leaves, stone, paper, etc.) to put in the water. Students will take turn to put the objects in the water. Observations are made each time a student put the object into the water. Observation must include: 1) What objects are put into the water? 2) Float or sink? 3) Why is that? At the end of this activity, teacher asks: *What are we going to learn today?*	
Phase II Exploration (Duration: 30 min)	Density is mass over volume (mass/volume)	Teacher asks the students to work in groups of 3 or 4 students. Teacher explains about the purpose of today's activity, i.e. to produce three positions of small bottle in a 500 ml beaker. Teacher provided electronic balance, sand, spatula, and small bottles with same size. Each group should fill the 500 ml beaker with water. Each group must design and produce three positions of small bottles in the water. Students need to record data i.e. the mass of sand that inserted into each small bottle.	

LEARNING DEVELOPMENT	CONTENT/ CONCEPT	TEACHING & LEARNING PROCESS (TEACHER & STUDENT ACTIVITIES)	NOTES
Phase III Explanation (Duration: 30 min)	Density involving mass and volume	Each group must explain what they were doing. They need to show the data that has been recorded, together with the three small bottles at different position in the water. Students tabulate their data in a table: <table><tr><td>Bottle</td><td>Mass of sand (g)</td><td>Position of bottle in the water</td></tr><tr><td>**1**</td><td></td><td></td></tr><tr><td>**2**</td><td></td><td></td></tr><tr><td>**3**</td><td></td><td></td></tr></table>Teacher explains the relationship between mass and volume to determine density.	The mass of sand that is put into the bottle will determine the position of the small bottle in the water
Phase IV Evaluation (Duration: 10 min)	Application of the concept of density in daily life.	Each student is given a worksheet with respect to the mass and volume, and the possibility of it sinking or floating in water. Students are also asked to justify their choice. Teacher and students discuss their answers and about making inferences about the concept of density. Video presentation can be shown to improve students' curiosity and awareness of density and its applications. Students are asked to give examples of other applications in daily life related to density.	Worksheet Cartesian Diver Video

REFLECTION	
Before teaching (During planning the lesson: describe the thoughts, challenges, or difficulty in negotiating and planning) (1) Students may not have a good understanding of the concept of density	**After teaching** (What has been experienced and learned from this lesson; how it affects you ...) (1) Such activities make learning more fun and less stress for teachers and students. (2) Many more effective teaching methods can be used.

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NOTES

DEVELOPING GENDER-SENSITIVE STEM CURRICULA

MODULE 2

MODULE 2

INTRODUCTION

This module concerns developing gender-sensitive STEM curricula. The module highlights the interrelation between developing gender-sensitive STEM curricula and developing a stimulating gender-responsive learning environment. Additionally, it guides the users through an analysis, and then the practice, of curriculum development. The activities in this module will guide curriculum developers, building on the knowledge acquired from the introductory module around gender stereotyping and gender discrimination, through the two primary stages of developing a gender-sensitive curriculum:

1. Stimulating a gender-responsive learning environment
2. Developing gender-sensitive STEM curricula

WHAT IS GENDER-SENSITIVE CURRICULUM?

Curriculum, which is the programme for learning, encompasses what to teach, how the content is organized, how to teach, and how to evaluate student learning. In all curriculum development, it is necessary to understand the different needs of the students who will experience the curriculum. Embedded within a curriculum is the vision that a society aspires to shape, along with the knowledge, skills and values that the curriculum promotes; thus, a curriculum reflects the society itself (IBE-UNESCO, 2015). Developing a gender-sensitive curriculum also requires considering the effect that ideas and assumptions about gender have on children's learning experiences.

A gender-sensitive curriculum encourages teachers and students to be aware of the ways in which different people think about gender, and how this shapes attitudes and behaviour. Stereotypical ideas, perceptions or assumptions about gender can include ideas about what interests, or does not interest, girls and boys, and the kinds of endeavours where they will, or will not, show an aptitude. Such stereotypes have an impact on girls' and boys' subject choices, their participation in class, their learning experiences, their motivation and aspirations, and the teachers' expectations and pedagogy. These, in turn, have an impact on children's learning outcomes and future life choices. A gender-sensitive curriculum is, thus, a crucial element in a gender-sensitive school environment that provides all girls and boys with the appropriate conditions to fulfil their potential.

Gender-sensitive curricula for STEM in particular helps to ensure that all girls and boys will have equal opportunities to develop an interest in STEM subjects and to participate, learn and achieve their potential in STEM.

WHAT IS A GENDER-RESPONSIVE LEARNING ENVIRONMENT?

A gender-responsive learning environment is cognizant of girls' and boys' different needs. Further, it is an environment where participants proactively recognize, address and prevent any form of gender stereotyping or gender-based discrimination that might perpetuate gender inequalities and stand in the way of gender equality in teaching and learning.

Key words

Gender-sensitive STEM curricula, gender-responsive learning environment, curriculum development process, learning styles, STEM practice

ACTIVITY 1

Catering to students' different learning needs and differentiation for gender inclusion

Good-quality, gender-responsive education requires teachers to use diverse teaching and assessment styles in order to address the different learning needs of all children, and reduce gender-bias in teachers' and students' attitudes, practices and expectations of boys and girls (UNESCO, 2015b). This requires both good-quality teaching and a favourable, positive classroom environment. A comprehensive review of 489 studies of pedagogy, curricula, teaching practices and teacher education in primary and secondary education across sub-Saharan Africa, North Africa, the Middle East, East Asia, the Pacific, Central Asia, South Asia and Latin America and the Caribbean identified important and effective components for making classroom learning more inclusive (Westbrook et al., 2013). First, schools and teachers need to ensure the provision of inclusive, safe and supportive school and classroom environments. In these environments, teachers will provide positive feedback, value the participation of all students, and draw on the diversity of students' backgrounds and experiences. Second, in order to foster engaging and effective teaching practice, teachers need to be trained and supported in the use of flexible teaching styles, incorporating a combination of whole class, group and pair work, as well as diverse learning materials beyond the textbook. The students then have opportunities to discuss, ask questions and work collaboratively with their peers, as well as the teacher, on a range of tasks. There is increasing international consensus on the value of student- or learner-centred pedagogies for all students, which involve group work and reflection and which promote critical thinking (Jha et al., 2012; Oloyede et al., 2012; Sperling and Winthrop, 2015; UNICEF, 2012). Numerous studies have also found that effective teachers – those who improve student learning outcomes – have positive attitudes towards both teaching and their students, show equal respect for girls and boys and have similar expectations for girls' and boys' capabilities and learning performances (Chismaya et al., 2012; Postles, 2013; Unterhalter, 2014; Westbrook et al., 2013).

Focus of the activity

This activity and the suggested tasks help participants gain a deeper understanding of the importance of integrating activities that engage different learning styles in classrooms, and how to apply this understanding in developing a gender-sensitive STEM curriculum.

TASK 1: Work in small groups

Discuss different learning styles and how thinking critically about them and addressing them in the classroom can enhance girls' participation in STEM.

TASK 2: Individual assignment

a. Read these articles: 'Gender Equality and Development: Addressing Gender Inequalities in Curriculum and Education: Review of Literature and Promising Practices to Inform Education Reform Initiatives in Thailand' (World Bank, 214); and 'Gender inequity in science and mathematics education in Africa: the causes, consequences, and solutions' (Asimeng-Boahene, 2006).

b. Highlight policies and curricula supporting gender-responsive teaching that have been developed and implemented in schools in your country.

c. Describe strategies adopted in the education system of your country to accommodate students' different learning needs, especially those that target the needs of girls and boys.

ACTIVITY 2

Creating a gender-responsive learning environment

Learning institutions can develop and implement policies that aim to create gender-responsive learning environments. This means that teachers/educators understand and respond to the varying needs of all girls and boys in the teaching and learning process, while ensuring that gender inequalities are addressed. A learning environment that is stimulating in terms of ambience, physical setting and interactions plays a very important role in learning (UNESCO, 2015b). A stimulating and gender-responsive learning environment is one in which all girls and boys feel safe to express themselves and safe to participate, and where both girls and boys feel valued and involved in the teaching and learning process. Developing these kinds of learning environments addresses students' need, which is often under-represented, to be empowered to take charge of their actions without inhibitions or discrimination based on gender, and to be accorded the freedom and capability to succeed.

Focus of the activity

This activity and the suggested tasks will help participants explore the kind of learning environment that would stimulate gender equality in learning, specifically in STEM education.

TASK 1: Work in small groups

a. Read 'EFA Global Monitoring Report 2015, Chapter 5: Goal 5: Gender Parity and Equality', from page 174 to 181 (UNESCO, 2015b).

b. Discuss how school and classroom environments affect girls' participation in STEM.

TASK 2: Individual assignment

a. Read the article, 'The high school environment and the gender gap in science and engineering' (Legewie and DiPrete, 2014).

b. Discuss the following gender-responsive approaches and policies in the school environment, drawing parallels with your country. As you do so, think about cultural expectations of girls in your country (that is, culturally, girls are 'supposed to…'/'brought up to be…').

- Linking science and mathematics concepts to life experiences
- Environment that promotes self-confidence and individual success
- Female role models as guest speakers
- Workshops and in-service training for teachers

TASK 3: Work in small groups

Prepare a memorandum to the Minister of Education in your country on the importance of creating a gender-responsive learning environment that promotes girls' and boys' equal participation in STEM education.

Product

Memorandum to the Minister of Education

ACTIVITY 3

Curriculum development process: needs analysis

Curriculum development is a laborious process that requires a systematic and thorough analysis of the needs and visions of the country/community, followed by a creative process of formulating curriculum design, and subsequently a comprehensive process of writing the curriculum specifications. 'Curriculum' in this case references the following elements: (a) what the society envisions; (b) which educational goals the school seeks to attain; (c) which educational experiences students should be given that are likely to attain these goals; (d) how these educational experiences can be organized effectively; and, (e) which benchmarks can be used to assess whether these goals are being attained (Tyler, 1949). Answers to these questions provide input for formulating aims and objectives, subject content, learning experiences, and the evaluation of learning.

Curriculum design is influenced by the curriculum developers' philosophical, psychological and social views concerning the needs and function of the society, the community, the individual learner and of learning itself. Tyler (1949) articulated three sources of curriculum design: knowledge or organized subject matter, society and the learner. Doll (1964) expanded on this thinking by stating five sources: science, society, the eternal and the divine, knowledge and the learner. These sources of curriculum design have direct impacts on the goals and objectives of the curriculum as well as macroscopic and microscopic curriculum design.

Since males and females each make up approximately half of the population, the need to provide gender-inclusive education for the sake of the total population is clear. A gender-sensitive curriculum is necessary to support both the needs of individual learners, and on a larger scale, the needs of a society at large.

Focus of the activity

This activity and the suggested tasks are designed to help the participants understand the importance of a needs assessment in the process of developing curriculum.

TASK 1: Work in small groups

a. Read the following articles on Malaysia's experience in conducting a needs assessment and in developing the national pre-school, 'Quality Assurance Practices in Developing and Implementing the Early Learning Development Framework (Curriculum) in Malaysia' (Ng, 2013) and science curriculum, 'Creating Thoughtful Classroom – Implementation of Thoughtful Science Curriculum by Master Teachers' (Ng, 2011).

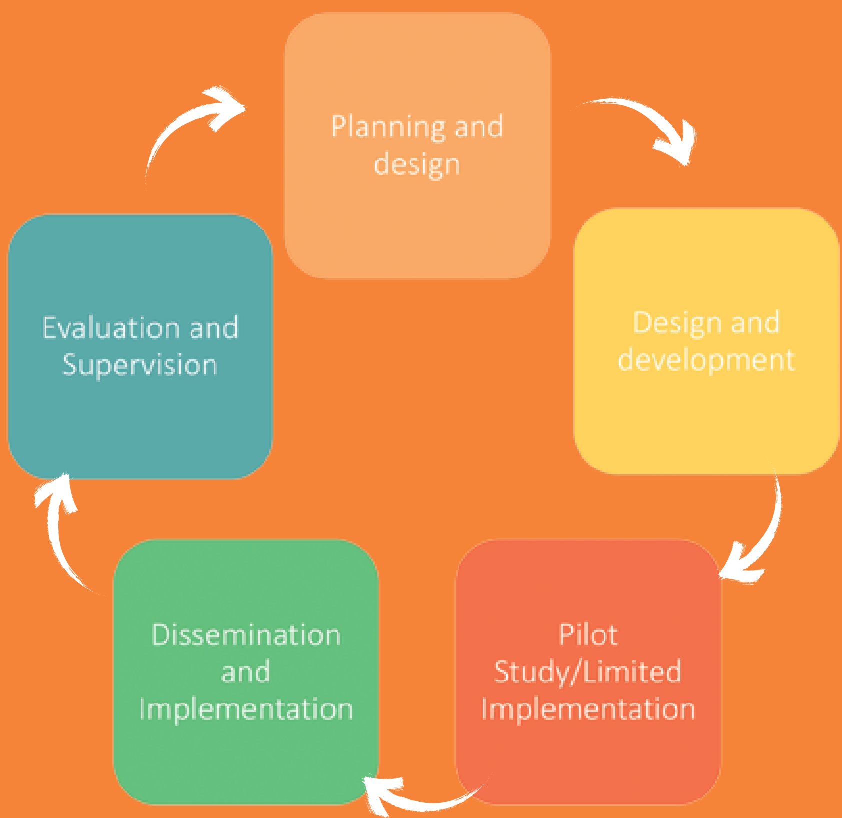
b. See below, in Box 2.1, the curriculum development cycle adopted by Malaysia.

Box 2.1: Curriculum development cycle of Malaysia

A curriculum development cycle adopted by Malaysia is shown in Figure 2.1 (Curriculum Development Division Malaysia, 2015; Sharifah Nor Puteh, 1998). In this model, the first step in curriculum development is needs analysis. Needs analysis entails conducting arm-chair research or collection of data through empirical studies. Meta-analysis of existing data, research findings, consolidation of ideas from various national plans and reports, as well as international reports and academic studies are being conducted to determine the direction and needs of the country. New empirical studies are also carried out to determine the actual gaps and specific needs of the country. Findings from the needs analysis will guide the curriculum developers in formulating the curriculum design that will fullfill the vision of the country or community

Source: Curriculum Development Division MOE Malaysia (2015).

Figure 2.1: Curriculum Development Cycle Model Adopted by the MOE Malaysia



Source: Curriculum Development Division MOE Malaysia (2015).

a. Discuss the model your country uses for curriculum development/design. Awareness of curriculum development models is important as we think about how to create gender-inclusive STEM curricula in later Modules.

TASK 2: Work in small groups

a. Reflect upon the earlier activities/discussions from the Introductory Module and from this Module concerning the cultural impact on gender participation in STEM, gender stereotyping, gender discrimination, different learning needs and gender-responsive learning environment.

b. Discuss these questions:

(i) What do you perceive as appropriately gender-sensitive in your country with regards to STEM curriculum and related practices?

(ii) What are your country's specific needs and/or areas of growth in terms of gender sensitivity and gender inclusiveness in STEM?

(iii) What specific changes need to be made in your curriculum in the areas of gender and STEM?

ACTIVITY 4

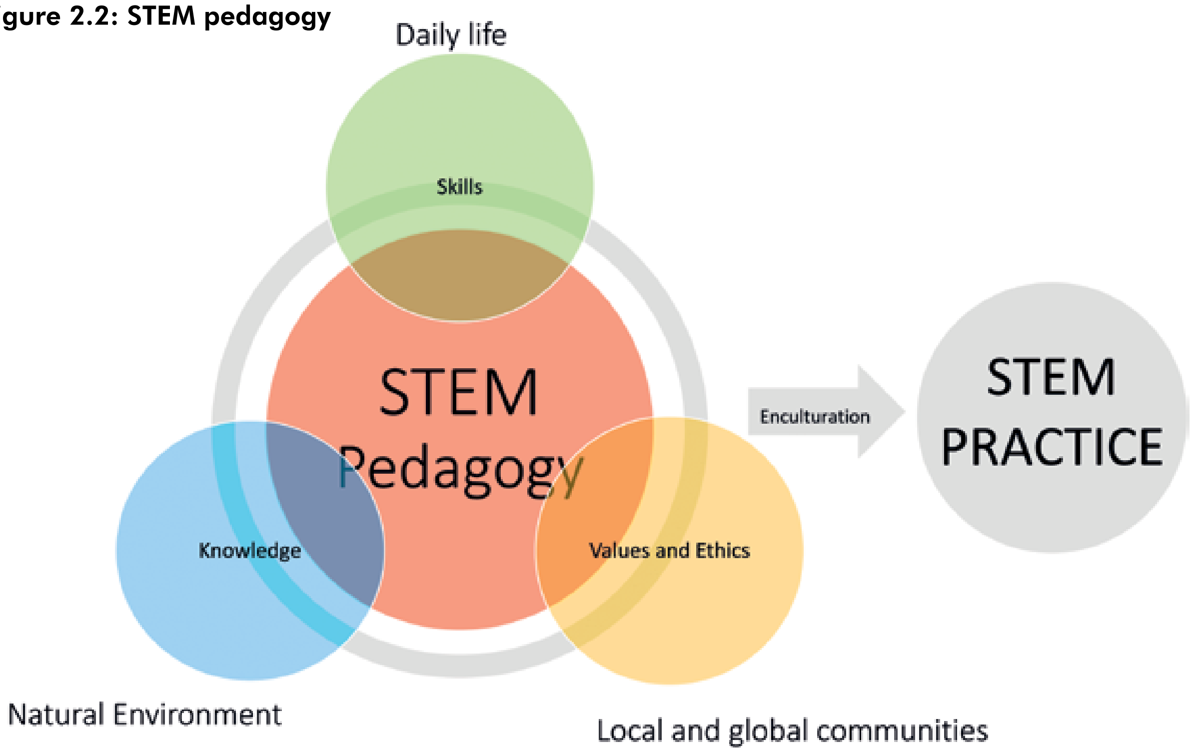
Curriculum development process: gender-sensitive STEM curriculum framework

CONCEPTUAL FRAMEWORK OF STEM CURRICULUM

STEM can be understood from a variety of perspectives, for example: STEM as an amalgam of studies or subjects; STEM as a pedagogical approach; or, STEM as a set of skills or practices (Curriculum Development Division [CDD] MOE Malaysia, 2016a). First, as an amalgam of studies or subjects, STEM encompasses all science and technology subjects including science, mathematics, information communications technology (ICT), engineering and agriculture. These subjects can be clustered or packaged together and offered to students to prepare them for their choice of a STEM career. For example, in Malaysia, such STEM learning packages, which serve to encourage more students to enrol in STEM subjects, are offered to students to provide them with better options for their future careers. Examples of such learning packages (Appendix 2.1 for a full list) include purely science, science and other STEM subjects, and science and religious studies (CDD MOE Malaysia, 2016a).

Second, STEM as a pedagogical approach refers to a strategy of teaching and learning which applies STEM knowledge, skills and values to solving problems in the context of everyday life, community and societal issues. This approach requires students to inquire, explore, solve problems, and make decisions to develop all-around STEM skills and knowledge (see Figure 2.2).

Figure 2.2: STEM pedagogy



Source: CDD MOE Malaysia (2016a).

STEM Curriculum consists of three elements: *knowledge, skills and values/ethics* (CDD MOE Malaysia, 2016a).

STEM knowledge comprises facts, ideas, concepts, principles and theories in STEM disciplines; science concepts and mathematical theorems are examples of STEM knowledge. Students acquire STEM knowledge through investigative activities in the classroom or outside the classroom. This knowledge includes a number of discipline-specific core ideas and cross-disciplinary concepts that students need to learn with increasing depth and sophistication from kindergarten through secondary school (National Research Council, 2012). Frequently, the way in which STEM is taught excludes girls from participating due to gender stereotypes, expectations and biases. Acquiring STEM knowledge needs to be progressive and dynamic so that students, girls and boys, keep up with the latest developments.

STEM skills relate to acquiring the competencies or abilities to explore, investigate and solve problems, and to design and produce products. The products can be in the form of an idea, a solution or an object. STEM skills include science process skills, science manipulative skills, computational thinking skills, mathematical process skills, engineering design thinking skills, ICT skills and other specific technical skills. Technical skills, which can have many similarities, include psychomotor skills, skills in managing and handling materials and equipment, and skills involved in ensuring safety.

STEM values and ethics consist of the ethics, guidelines, scientific attitudes and moral values that STEM students and practitioners uphold. Inculcating STEM values and ethics is important for producing students who are both knowledgable and competent students as well as possessed of high moral values and ethics. Examples of STEM values and ethics are rational thinking, objectivity, precision, risk-taking, persistence, commitment, and adherence to laboratory rules and safety measures.

STEM curriculum encompasses teaching and learning within the formal school timetable, as well as extra-curricular or co-curricular activities outside the classroom. The ultimate aim of the STEM curriculum is to produce STEM-literate populations, increase the STEM labour force, and promote innovation for advancing STEM fields and bettering human life. Presently, STEM curriculum in many countries is affected by cultural influences such that boys are more frequently encouraged to join science, technology, engineering and math fields. This Resource Pack promotes understanding about creating gender-sensitive curricula that will open up the STEM fields to all children.

STEM education should adopt a life-long learning approach. Learning begins in early childhood and continues through post-formal schooling, where on-the-job training and adult education courses teaching the latest technologies institutionalize continuous capacity building. Figure 2.3 is an example of the mapping of STEM curriculum in Malaysia. This STEM curriculum focuses on developing interest in STEM during early childhood, acquiring STEM knowledge and developing STEM skills and values through primary and secondary school, and progressing on to STEM career training in higher education. The focus is on scientific investigation and exploration as well as problem solving and innovation. The Malaysian framework is gender-responsive by ensuring that all students nurture an interest in STEM in the first years of schooling. Additionally, it demonstrates the importance of real-world connections in the classroom and the need for all students to develop and build STEM skills through secondary school.

Figure 2.3: The mapping of STEM curriculum in Malaysia

OUTCOME : STEM Wokforce / STEM Literate Society (New horizon/frontier)

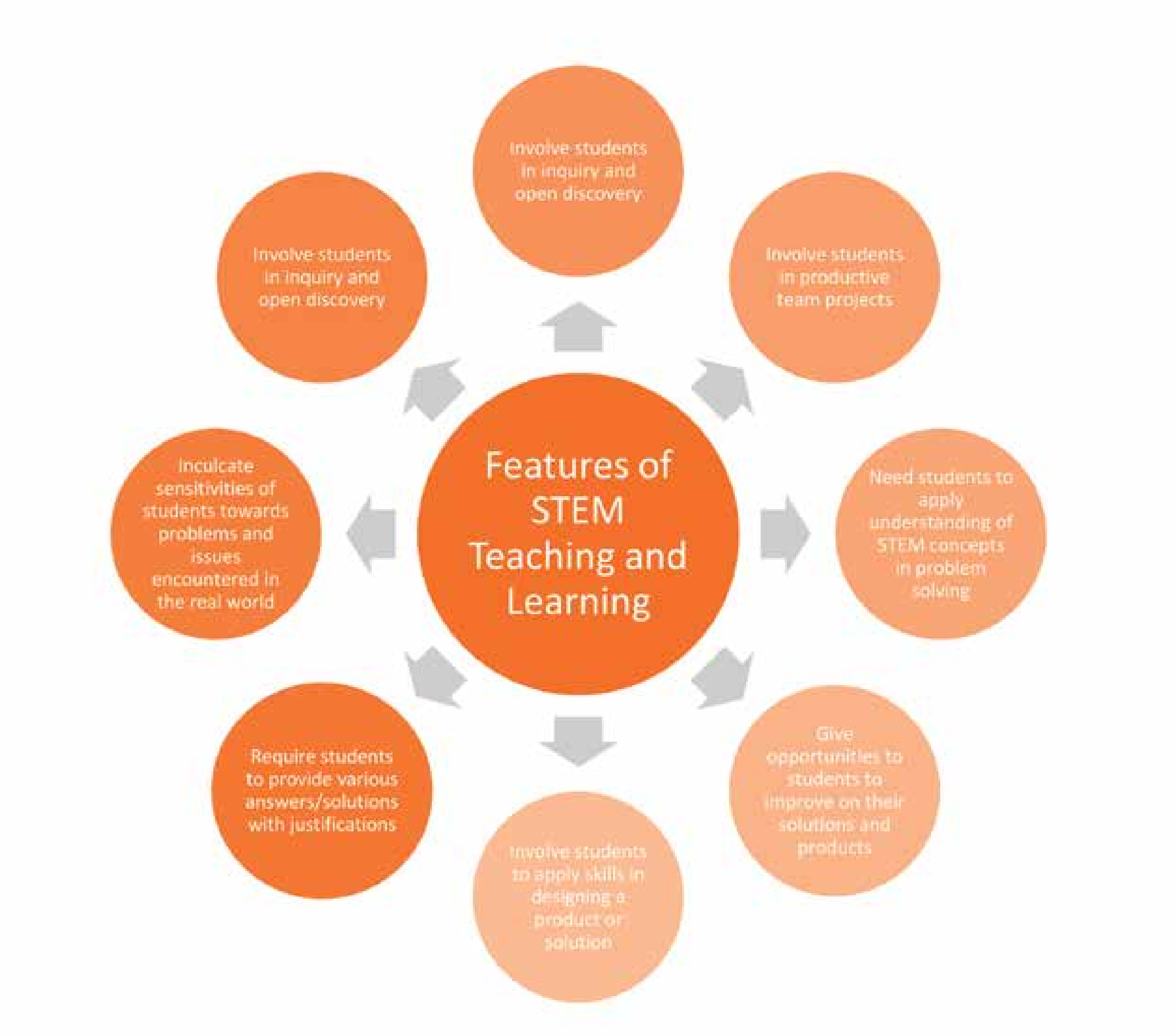
LEVEL	FOCUS	LEARNER	PRACTITIONER	MODALITY
INDUSTRY / COMMUNITY	Work, Advance & Innovate	Productive and Engaged citizens	Experiential - Lifelong Learning	Experiences
TERTIARY	Challenge & Prepare	21st Century Skills	Work and Research Trans Discipline Approach	Meaningful Learning and Research Experiences
UPPER/POST SECONDARY	Enhance STEM Skills	Demonstrate STEM Principles at Advanced Level	Advanced Knowledge and Develop Skills	STEM Skills and Readiness
LOWER SECONDARY	Develop & Build STEM Skills	Analyse Global Issues and Develop Solutions	Intermediate Knowledge and Develop Skills	Lifelong Passion and Interest
PRIMARY	Make Connection / Build Foundation	Investigate and Explore	Effective Teaching to Sustain Interest	Meaningful Experience
EARLY CHILDHOOD	Nurture / Inspire Interest	Inquistive and Engaged	Teach and Inspire	Explore

Source: EPRD MOE Malaysia (2016).

FEATURES OF STEM TEACHING AND LEARNING STRATEGIES

What does a STEM lesson look like? The seven features of STEM teaching and learning shown in Figure 2.4 provide tips and pointers on how to plan and conduct a STEM lesson.

Figure 2.4: Features of STEM teaching and learning



Source: CDD MOE Malaysia (2016b).

In preparing and conducting STEM lessons, teachers play the role of facilitator, coach and adviser. The influence teachers have on student self-perception and interest in STEM is invaluable. Teachers provide continuous inspiration and coaching, and give students opportunities to internalize STEM knowledge and skills, and to apply them to making decisions and solving problems. Table 2.1 describes teachers' suggested roles and tasks in STEM lessons.

Table 2.1: Teachers' roles and tasks in STEM lesson

TEACHERS' ROLE	TEACHERS' TASK
Arouse students' minds and inspire their thinking	• Attract the interest of both female and male students, motivate them and provide relevance to the lessons learned • Prepare materials that attract the attention and interest of both female and male students, such as a short video on the science concepts to be learned
Prepare lessons to enable students to apply and integrate STEM knowledge, skills and values	• Plan practical lessons involving inquiry, which give both female and male students opportunities to apply and integrate STEM knowledge, skills and values to solve problems
Guide and develop students' thinking skills	• Engage female and male students in inquiry and project based activities. • Prepare thought-provoking, probing questions to guide female and male students to interpret and evaluate data and draw conclusions
Guide students to find relevant information from various sources	• Prepare thought-provoking, probing questions to guide female and male students to interpret and evaluate data and draw conclusions. • Provide guidance about how to obtain reliable information. • Help both female and male students to think deeply about issues explored. Guide them to think critically, creatively and innovatively.
Listen to and identify the different strengths and needs of the students	• Allocate sufficient time for both female and male students to share findings, conclusions and products through various activities and the use of a variety of media. • Develop a systematic mechanism for assessing students' progress. • Provide a communication channel for both female and male students to have discussions with teachers.
Guide students to do self-evaluations and peer-evaluations	• Prepare questions to assist both female and males students in making and justifying critical and objective evaluations • Prepare opportunities for peer evaluation among and between female and male students.
Provide constructive comments and suggestions	• Provide input to female and male students on their strengths and weakness, and ways that they can improve their learning • Encourage both female and male students to persist and improve their products based on feedback.
Encourage teamwork	• Plan opportunities for students to work together. • Instruct students to form groups/split students into groups. • Encourage students to work together.

STEM PRACTICE

Developing a STEM Curriculum Framework is based on the premise that students cannot fully understand STEM core ideas or knowledge without engaging in both inquiry and the application of STEM skills. At the same time, they can only acquire the competencies of STEM skills in the context of specific situations.

By engaging in learning through STEM pedagogies, students can acquire what might be termed the 'culture' of STEM practice, as shown in Figure 2.2 and Table 2.2. These eight practices are not linear nor do they operate in isolation; rather, they are interconnected. Once students are enculturated with STEM practice, they have internalized STEM philosophy and are likely to apply these practices continually in their everyday lives. They can then use their understanding to investigate the natural world through the practice of scientific inquiry, or solve meaningful problems through engineering design. Engaging in STEM practice helps students to understand STEM-related jobs such as engineering and research science, and can indirectly encourage them to pursue STEM careers.

Table 2.2: STEM practices

No.	PRACTICE	ELABORATION
1	Asking questions and defining problems	• Students explore and investigate to identify problems related to real-life situations.
2	Developing and using models	• Students develop and use models in the form of replicas, diagrams, mathematical representations (graphs, formulas), analogies, and simulations.
3	Planning and carrying out investigations	• Students plan and conduct investigations through inquiry.
4	Analysing and interpreting data	• Students collect, analyse, interpret and present data so that the audience can understand and apply what they have learned.
5	Using mathematics and computational thinking	• Students use mathematics (logic, geometry and calculus) to represent physical variables and establish relationships in making quantitative predictions. • Students use computational thinking to design strategies to find and organize data, design algorithms, use and form simulations and develop systems.
6	Constructing explanations and designing solutions	• Students express their understandings by using their own words, graphics and formulas based on their own observations and findings. • Students design and repeat the process to improve their products and solutions systematically.
7	Engaging in debate and argument based on evidence	• Students engage in debates and discussions to defend and explain their findings, solutions and products based on data.
8	Obtaining, evaluating, and communicating information	• Students collect and evaluate data, and communicate their ideas and findings through various methods with clarity and confidence.

Source: Adopted from Next Generation Science Standards (2013).

Focus of the activity

This activity and the suggested tasks will help participants to understand the development of STEM practice and the implementation of a conceptual framework for STEM curriculum.

TASK 1: Work in small groups

There are different opinions on STEM curriculum:

(i) 'STEM – as a single but amalgamated subject area – should replace the regular science and mathematics subjects in school'.
(ii) 'STEM – as a single, amalgamated option – should be integrated into the existing science, mathematics, technology and engineering subjects'.
(iii) 'STEM is just jargon which emcompasses all traditional science and technology subjects and does not mean anything new'.

a. Discuss in groups and present your views on this issue. Connect your input to the context of your own countries.

b. Produce a proposal on how STEM curriculum can be developed and implemented in your countries.

Product

Proposal on strategies for implementing STEM curriculum

TASK 2: Work in small groups

Develop a mapping of a STEM curriculum framework from early childhood to secondary school.

TASK 3: Work in small groups

a. In the Malaysian education system, STEM learning packages are provided to assist students in making decisions about their career. Comment on the learning packages in Appendix 2.1 and discuss the relevance to your country context.

b. Produce a STEM Learning Package for your country.

Product

Contextualized STEM Learning Package

ACTIVITY 5

Curriculum development process: designing and developing a gender-sensitive STEM curriculum

Gender-responsive education values and respects diversity. It promotes gender equality by helping to break down gender stereotypes and hierarchies, and encourages students to challenge preconceived ideas, narrow concepts and prejudices relating to understandings of gender.

A gender-sensitive curriculum promotes equal opportunities for both girls and boys, and nurtures the talents of all children, without prejudice. Using a gender-sensitive STEM curriculum can help facilitate greater and more equal access for girls and boys to higher education and subsequently to STEM-related careers. In most countries, the ratio of males and females in the total population is about 50:50. Secondary-level qualifications in STEM subjects are usually a precondition for admission to higher education in STEM. Thus, increasing the number of girls in quality STEM education at the secondary school level is likely to help increase the number of women with a bachelor's degree in STEM. This could benefit the whole country by increasing the number of skilled practitioners in STEM-related careers. Different people bring different skills, knowledge and experience. If utilized effectively, diversity can provide the impetus, skills and vision for innovation and progress. Thus, it is important that both girls and boys are provided with opportunities to develop their full potential. Curriculum content needs to be developed in order to engage both girls and boys in STEM and to address their diverse learning needs and interests.

HOW DO WE DEVELOP A GENDER-SENSITIVE CURRICULUM?

As a programme of learning, curriculum includes both specific subject content and a broader perspective that includes accessibility, participation, and co-curricular activities. This section explores the process of developing a gender-sensitive curriculum, including co-curricular activities. However, in order to determine the scope of desired change, it is first necessary to build consensus around a country's or a community's current needs. Decisions on how gender inequalities are addressed in the curriculum and in teaching and learning materials need to be sensitive to the broader sociocultural context, striking a balance between local constraints and aspiration.

The following questions can act as reference points for consideration when developing a gender-sensitive curriculum.

ACCESS AND OPPORTUNITY FOR PARTICIPATION

- Is information concerning STEM course/subjects/activities equally available to girls and boys? Is STEM education for girls and boys promoted actively and deliberately?
- Is there a deliberate effort to motivate and encourage girls to participate in STEM?
- Are there any prior qualifications or skills required to learn STEM in your institution? Do these prerequisites impede the recruitment of girls for STEM? If so why?
- Are there extra charges (for instance, tuition fees or other levies) on STEM subjects or STEM activities? In a community where resources are scarce, parents might give priority to boys' schooling. Girls' opportunities to learn STEM might then be jeopardized if participating in STEM incurs additional costs.
- Are the times set for learning STEM or participating in STEM activities suitable for all children? For example, in a culture where girls need to help with housework after school, the need to return to school after normal hours for STEM could present a barrier to girls' participation in STEM education.
- Does the society at large hold any prevailing cultural discriminatory beliefs such as 'Girls are not supposed to…'? If yes, do they influence girls' decisions to engage/not engage in STEM?

PLANNING FOR DEVELOPMENT AND IMPLEMENTATION OF A GENDER-SENSITIVE STEM CURRICULUM

- Does the curriculum include positive representations of women working in STEM-related professions? Are women and men equally represented in different STEM-related fields? Can students find male and female role models in STEM fields in society as well as among teaching staff?
- Are teachers or facilitators well equipped and ready to teach or guide girls and boys equally? Are teachers trained to cope with the different needs and expectations of all children?
- Are the teaching teams or program facilitators composed of women and men? A gender-mixed composition of teachers/facilitators can be more creative and provide more comprehensive and realistic solutions covering various perspectives.
- Are there efforts to identify and motivate girls and boys to be enrolled in STEM subjects/courses/activities? An example is encouraging more girls to take up technical courses and subjects, such as engineering, where girls are often particularly under-represented.
- Is the curriculum plan flexible enough to cater to students with less available time and fewer financial resources due to cultural backgrounds or family-related tasks, so that all students can have an equal chance to complete their course/subject/programme successfully? For example, are learning materials available for students who cannot attend all learning units, for instance, for girls or boys who have to assist their parents in their work?
- Do entrance exams, if any, contain tasks for different learning styles? Are there tasks for groups with different kinds of relevant previous knowledge?
- Are women and men equally engaged in developing, mentoring, and promoting a STEM curriculum, or assisting in its implementation?

- Are girls and boys actively asked to participate in evaluating and further developing the curriculum?
- Are sex-disaggregated data collected on entrance, graduation and dropout rates in the STEM subjects/courses/activities? Are these data being used to advise the curriculum developers on the learning needs and learning objectives of the STEM course/subjects/activities?

DETERMINING LEARNING NEEDS AND LEARNING OUTCOMES FOR A GENDER-SENSITIVE STEM CURRICULUM

- Who is represented in the curriculum development panels tasked with defining the curriculum's learning needs and learning outcomes? Are men and women involved in making decisions about learning needs and learning objectives?
- Are gender experts external to the process engaged in developing the curriculum?
- Are the learning needs of girls and boys discussed and considered at the outset of developing the curriculum?
- Is students' existing knowledge taken into consideration when developing the learning outcomes? In some contexts, girls may have had less exposure to STEM-related skill development than boys, such as with ICT skills.
- For subjects, such as physics, in which girls may be particularly under-represented or under-performing, is there reflection and discussion on how to engage girls and boys equally?

CONTENT OF THE CURRICULUM DOCUMENTS AND TEACHING & LEARNING (T&L) MATERIALS

- Do the curriculum and the teaching and learning materials developed promote gender equality? Have you taken a close look at your curriculum to identify possible gender stereotyping or gender-based discrimination?
- Does the selection of topics, examples or language take girls' and boys' interests into account?
- Does the curriculum content promote equal opportunities for girls and boys, and are values and attitudes promoting gender equality explicitly presented thematically or integrated within the STEM topics?
- Does the content of the curriculum or the teaching and learning materials contain a one-sided presentation or representation of women or men, or sexist examples?
    - Are men and women equally represented when referring to people in STEM-related fields?
    - Have stereotypical representations and language been avoided?
    - Are women and men presented and promoted explicitly as being equally proactive, capable and successful in all the different STEM-related fields?
    - Do the teaching and learning materials show instances where traditional divisions of labour or roles are reversed? An example is a female doctor working alongside a male nurse.
- Is gender-equitable research used in presenting teaching and learning content?
    - Are all data or information that is used gender-disaggregated?
    - Are gender differences analysed and addressed in the research examples?
    - Is there any effort to create awareness based on the data presented, for example, regarding gendered divisions of labour?

- Do the curricular or teaching and learning materials consider research findings on the different learning needs of children?
- Do the materials explicitly relate STEM to its impact on society and environment? An example is material based on findings showing that women are more likely to choose STEM courses related to society and the environment, such as medical sciences.
- Are any guidelines provided for addressing the different learning styles that may influence the learning achievement of different children?
- Are materials accessible to all individuals? This is especially necessary in societies where girls, in particular, may have home-based responsibilities or tasks that might affect their full participation in school.

TEACHING AND LEARNING, OR IMPLEMENTATION OF PROGRAMME

- Does the teacher's behaviour in the classroom promote gender equality?
  - Does the teacher direct more questions to either boys or girls?
  - Does the teacher intentionally or unintentionally demonstrate gender stereotyping?
  - Do the activities orchestrated by the teacher engage girls and boys equally?
  - Are gender-related discriminatory interactions between students or between the teacher and students identified and corrected in class by the teacher?
- Does the teacher explicitly promote equal opportunities for both girls and boys to participate and learn in the classroom?
- Are girls and boys addressed and engaged actively and equally during teaching and learning?
- Does the teacher monitor interactions by male and female students for equality? For instance, do girls and boys get an equal chance to speak and answer questions?
- Are the teacher's expectations for girls' and boys' abilities and performance in STEM education equally high?

ASSESSMENT

- Have requirements and success criteria been clearly defined and communicated to all students?
- Are the requirements, success criteria and types of items in assessment equally relevant to and appropriate for girls and boys?

Focus of the activity

This activity and the suggested tasks help participants gain a deeper understanding of the processes involved in developing a gender-sensitive STEM curriculum.

TASK 1: Work in small groups

a. Read through the questions listed above on 'How to develop a gender-sensitive curriculum'.

b. What are some of the outstanding issues not addressed in your national curriculum? Which issues that would promote or hinder girls' and boys' equal participation in STEM education are addressed?

TASK 2: Individual assignment and work in pairs

a. Read the articles on 'Gender discrimination in curriculum: a reflection from Punjab Textbook Board' (Jabeen, Chaudhary, and Omar, 2014); and School-based curriculum development for improving girls' performance in SMT (Mulemwa, 2002).

b. Discuss the process of developing the content of the curriculum documents and teaching & learning (T&L) materials that promote girls' and boys' equal participation in STEM education.

c. Discuss ways in which students can be involved in developing gender-sensitive STEM curriculum.

d. Write a newspaper article on the merits of developing a school-based curriculum to promote equal participation of girls and boys in STEM education.

Product

A newspaper article on the merits of developing a school-based curriculum to promote equal participation of girls and boys in STEM education

TASK 3: Individual reflection

a. Use the assessment checklist below to assess the extent of the development of gender-sensitive curricula in your country.

Table 2.3: Assessment checklist in developing gender-sensitive STEM curricula, and teaching and learning materials

NO.	CONCRETE MEASURES	YES	NO
1	Gender equality in composition of panels/working groups that develop curricula or T&L materials		
2	Subject-matter gender expertise is engaged		
3	Issues related to girls and boys are explicitly discussed and addressed by the content developers		
4	Target group for each activity clearly defined and the group's needs analysed, eliminating implicit assumptions especially those due to gender stereotypes		
5	Gender awareness training for teachers/facilitators of STEM education		

NO.	CONCRETE MEASURES	YES	NO
6	Advisory, networking assistance and offers of mentoring for teachers/ facilitators on gender-responsive teaching		
7	Gender equality explicitly promoted in the curricula content		
8	Active promotion of commitment to gender equality among all people involved in developing and delivering the curriculum		
9	Develop girls' interest in STEM through activities such as open days, STEM days, capitalizing also on female role models as well as male role models		
10	Collect and analyse sex-disaggregated data of entrants/graduates/ participants to highlight where there are gender disparities and to monitor improvement		
11	Scholarship or financial assistance to under-represented students		
12	Transparency in all dealings and requirements		

b. Use the principles checklist below to assess if the curriculum is adhering to the principles.

Table 2.4: Principles for developing a fair curriculum for all children

NO.	ADHERENCE TO PRINCIPLES	YES	NO
1	Enhance girls' and boys' potential, building up the talents and innovativeness of all children to their fullest, without prejudice		
2	Treat girls and boys with equal respect and promote collaboration		
3	Eliminate explicit or implicit gender-based discrimination, avoid gender stereotypes		
4	Provide equal opportunities to girls and boys		
5	Ensure that the needs of all girls and boys are addressed at all levels of curriculum development		
6	Ensure that all students can equally benefit from the curriculum		
7	Ensure that all contents are gender-sensitive and promote gender equality		

Product

A completed assessment checklist

ACTIVITY 6

Curriculum development process: writing a gender-sensitive STEM curriculum

In writing a curriculum document, the first task is to determine the *macroscopic* and *microscopic curriculum design*. Macroscopic curriculum design refers to the broad frameworks of curriculum design involving choices on basic values (Klein, 1991). The curriculum design needs to fulfil the needs of the country or the community. For instance, if the country's need is to develop gender-sensitive STEM skills and STEM innovation among its students, the curriculum framework, learning outcomes and learning activities need to reflect that. The STEM curriculum framework presented in Activity 8 is an example of macroscopic curriculum design. It emphasizes the acquisition of STEM knowledge, skills, ethics and values, as well as STEM practices.

Microscopic curriculum design is concerned with how the four components of curriculum (learning objectives, learning experiences, subject matter, and evaluation) are organized into a coherent system (Cheung and Ng, 2000; Klein, 1991). Curriculum documents in different countries adopt slightly different approaches. Some curriculum documents clearly state the learning objectives only, and have general outlines for learning experiences and principles of evaluation; others provide prescribed activities and detailed evaluation standards. Decisions on the curriculum design should represent rigorous efforts by the whole curriculum development team taking the factors that influence curriculum implementation into consideration.

Focus of the activity

This activity and the suggested tasks help participants to understand the process of writing a gender-sensitive STEM curriculum.

TASK 1: Work in small groups

a. Read below the Discipline-Cognitive (DC) Curriculum Design that articulates the purpose of the schooling system in Malaysia.

Box 2.2: Discipline-Cognitive (DC) Curriculum Design of Malaysia

In the Malaysian Science curriculum developed in 2000, the Curriculum Development Division, MOE Malaysia created the Discipline-Cognitive processes Curriculum Design (DC Design). Under the framework of DC Design, intended learning outcomes are written with a combination of acquisition of knowledge and mastery of cognitive skills (Ng, 2010). An example of this learning objective is 'compare and contrast mitosis and meiosis'. This DC Curriculum Design is continually being improved on in developing the STEM curriculum in Malaysia (CDD MOE Malaysia 2016b).

DC Design holds to the principle that learning can only be achieved through thinking and doing, and not only memorisation of facts and knowledge. Learning objectives or learning outcomes in a curriculum document must state explicitly these knowledge and cognitive skills. DC Design is in tandem with the ideas of a thinking curriculum (Fennimore and Tinzman, 1990; Resnick and Klopfer, 1989). According to Fennimore and Tinzmann (1990), a thinking curriculum fulfils the dual agenda of integrating content and process, and allows students to be taught content through processes encountered in the real world: the examples of the processes are problem solving, decision making, evaluating and comparing. DC Design is also aligned with the idea that Perkins (1992) advocates, that acquisition of content knowledge should be brought about by 'learning experiences in which learners think about and think with what they are learning' (p. 8).

b. Based on the case study of Malaysia and the discussions in Activity 8, develop a suitable curriculum design for a gender-sensitive STEM curriculum in your country.

TASK 2: Work in small groups

The thematic approach is one way of organizing content: themes often run across years of learning or across subjects. These themes provide the story line of the whole curriculum. They indicate the disciplinary structure or essential organizing principles chosen for the particular subject. Themes are useful in reflecting gender sensitivity as well as STEM.

a. Reflect on the following themes:
   i) Production and management of chemicals
   ii) Heritability and variation in living things
   iii) Energy around us

b. Do these themes fulfil the objectives of STEM curriculum? If not, convert the themes above with a STEM approach.

c. Come up with three to four gender-sensitive STEM themes.

Product

A list of gender-sensitive STEM themes

TASK 3: Work in small groups

Meta-representational terms are words that describe the process of thinking and ways of expressing thoughts. Olson & Astington (1990) and Astington & Olson (1990) stressed that the ability to talk about thinking depends on the use of these meta-representational terms. Meta-representational terms are useful to describe STEM activities. An example is below.

Table 2.5: Example of meta-representational terms

LEARNING AREA	LEARNING OUTCOME
Force and Motion	• *Plan and carry out* experiment to find the relationship between force, mass and acceleration. • *State* the relationship between force, mass and acceleration. • *Explain* impulse and force of impulse. • *Illustrate* effect of force of impulse in our daily life.

Source: Extracted and translated from PPK (2000b), p. 48-49.

Meta-representational verbs can be categorized based on Bloom's Taxonomy as Table 2.6 shows. The list of meta-representational verbs in the table is not exhaustive.

a. Adding to the list in Table 2.6, write a few examples of learning outcomes adopting gender-sensitive STEM curriculum design that use these verbs.

Table 2.6: List of meta-representational verbs

	META-REPRESENTATIONAL VERBS USED IN WRITING LEARNING OUTCOMES/ OBJECTIVES	EXAMPLES OF LEARNING OUTCOMES FOR GENDER- SENSITIVE STEM CURRICULUM DESIGN
To know - *recall*	• Define • Describe • Identify • Label • List • Pair • Name • State • Draw • Write • Sketch	

	META-REPRESENTATIONAL VERBS USED IN WRITING LEARNING OUTCOMES/ OBJECTIVES	EXAMPLES OF LEARNING OUTCOMES FOR GENDER- SENSITIVE STEM CURRICULUM DESIGN
To understand *- translating material or idea from one form to another, interpret material or idea, estimate future trend*	• Change • Estimate • Explain • Giving example • Measure • Determine • Convert • Compare and contrast • Predict • Making inference • Relate • Attribute • Classify	
To apply *- using material and/or idea in new and concrete situation*	• Calculate • Count • Show • Innovate • Generating idea • Generalize • Clarify with example	
To analyse *- separating information into its component in order to understand its organizational structure and relationship between the components*	• Analyse • Clarify through example • Choose • Making assumption • Clarify • Solving problem • Sequencing • Prioritizing • Making a space-time relationship • Conclude • Controlling variable	

	META-REPRESENTATIONAL VERBS USED IN WRITING LEARNING OUTCOMES/ OBJECTIVES	EXAMPLES OF LEARNING OUTCOMES FOR GENDER- SENSITIVE STEM CURRICULUM DESIGN
To synthesize *- combining components to produce whole idea or new and creative structure*	• Combine • Plan • Make concise • Form/Build • Generating framework • Invent • Design • Conceptualise • Making analogy • Forming mental picture • Define operationally • Communicating • Experimenting • Making hypothesis	
To evaluate *- evaluate idea/material/ information/ method based on specific criteria for specific purpose*	• Assess • Criticize • Interpret • Support • Justify • Identify biases • Making decision	

Source: Extracted and translated from PPK (2000a), p. 29-31; (2000b), p. 28-30; (2000c), p. 29-31.

MODULE 2

TAKE-AWAY POINTS

This module has outlined ways to ensure that a STEM curriculum is gender sensitive and will both promote and be supported by a gender-responsive learning environment. Two key recommendations are these:

1. All STEM-related curriculum materials need to promote the principles of gender equality. In order for a STEM-related curriculum to be gender sensitive, it must meet the needs and interests of both the girls and boys for whom it has been developed with equal effectiveness.

2. Gender-sensitive STEM curriculum must be designed to enable the teachers who will use it to develop gender-responsive learning environments where both girls and boys are equally able to thrive and achieve their potential in STEM subjects.

READING LIST

- Gender Equality and Development: Addressing Gender Inequalities in Curriculum and Education: Review of Literature and Promising Practices to Inform Education Reform Initiatives in Thailand (World Bank, 2014)
- Gender inequity in science and mathematics education in Africa: The causes, consequences, and solutions (Asimeng-Boahene, 2006)
- Education For All Global Monitoring Report 2015. Gender and EFA 2000-2015: Achievements and Challenges (UNESCO, 2015b)
- The high school environment and the gender gap in science and engineering (Legewie and DiPrete, 2014)
- Quality Assurance Practices in Developing and Implementing the Early Learning Development Framework (Curriculum) in Malaysia (Ng, 2013)
- Creating Thoughtful Classroom – Implementation of Thoughtful Science Curriculum by Master Teachers (Ng, 2010)
- Gender discrimination in curriculum: a reflection from Punjab Textbook Board (Jabeen, Chaudhary, and Omar, 2014)
- School-based curriculum development for improving girls' performance in SMT (Mulemwa, 2002)

APPENDIX 2.1

STEM LEARNING PACKAGES OFFERED TO MALAYSIAN UPPER SECONDARY SCHOOL

(1) PURE SCIENCE PACKAGE	
Core Subjects (Compulsory)	**Pure Science Subjects (Minimum 3 Subjects)**
- Malay Language (National Language) - English Language - Mathematics - Islamic/Moral Education - History - Health Education/Physical Education	- Physics - Chemistry - Biology - Additional Mathematics

(2) PURE SCIENCE + OTHER STEM ELECTIVE SUBJECTS PACKAGE		
Core Subjects (Compulsory)	**Pure Science Subjects (Minimum 3 Subjects)**	**Others Selective Subjects (Minimum 1 Subject)**
- Malay Language (National Language) - English Language - Mathematics - Islamic/Moral Education - History - Health Education/ Physical Education	- Physics - Biology - Chemistry - Additional Mathematics	- Technical Communication Graphic - Basic Sustainability Design - Computer Science - Agriculture - Home Science - Sport Science

(3) PURE SCIENCE AND RELIGIOUS STUDY PACKAGE		
Core Subjects (Compulsory)	**Pure Science Subjects (Minimum 3 Subjects)**	**Islamic Study Elective Subjects (Compulsory)**
- Malay Language (National Language) - English Language - Mathematics - History - Health Education/ Physical Education	- Physics - Chemistry - Biology - Additional Mathematics	- Al-Quran & As-Sunnah Education - Islamic Shariah Education - Arabic Language

(4) SCIENCE AND ADDITIONAL SCIENCE PACKAGE		
Core Subjects (Compulsory)	**STEM Elective Subjects (Compulsory)**	**Other Electives**
- Malay Language - English Language - Mathematics - Science - Islamic/Moral Education - History - Health Education/ - Physical Education	- Additional Science - Additional Mathematics	- Any other elective subjects, including non-STEM subjects

(5) OTHERS	
Core Subjects (Compulsory)	**Others (Minimum 2 Subject)**
- Malay Language - English Language - Mathematics - Science - Islamic/Moral Education - History - Health Education/Physical Education	- Technical Communication Graphic - Basic Sustainability - Design - Computer Science - Agriculture - Home Science - Sport Science

Note:
- Core subjects are compulsory to be taken by all students
- Each student is advised to take a maximum of 10 subjects
- Students who take a minimum of 2 Pure Sciences are exempted from taking Core Science.

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NOTES

NOTES

CREATING GENDER-RESPONSIVE STEM PEDAGOGY, LEARNING AND ASSESSMENT

MODULE 3

MODULE 3

INTRODUCTION

This module concerns creating gender-responsive STEM pedagogy and inclusive learning and assessment. Teachers who practice gender-responsive teaching should be trained in gender sensitivity as an initial step towards inclusive STEM pedagogy. They understand and respond to girls' and boys' unique needs, while at the same time recognizing, addressing and helping to prevent gender stereotyping and forms of gender-based discrimination throughout the teaching and learning process. Teachers who practice gender-responsive teaching encourage girls' and boys' equal participation and involvement in order to ensure that all children, regardless of their sex, can achieve their potential. This includes ensuring girls' and boys' equal access to learning resources and their equal involvement in class activities.

The activities in this module seek to guide curriculum developers in using effective approaches in creating gender-responsive STEM pedagogy, and inclusive learning and assessment. Specifically, the module deals with:

1. Designing learning activities that will interest and engage both girls and boys in science, mathematics or other STEM subjects, while taking children's diverse learning needs into consideration.
2. Problem-based STEM instruction for enhancing gender-responsive instruction, and approaches for addressing both girls' and boys' involvement in problem-based learning.
3. Strategies for using project-based learning in creating gender-responsive STEM pedagogy, and inclusive learning and assessment.
4. Strategies for incorporating social dynamics into designing gender-responsive STEM pedagogy, and inclusive learning and assessment.

The term 'STEM' is a generic label for any event, policy, programme, or practice that involves one or several of the STEM disciplines (science, technology, engineering and mathematics). Strategies for ensuring that all children will be exposed to and engaged in STEM include the use of Inquiry-based Learning (IBL) and the Engineering Design Approach (EDA). These methods are grounded in the importance of ensuring that students fully understand what they are learning, rather than simply memorize information. The inquiry-based learning model teaches science through a process of exploring the world. This promotes an environment where students ask questions, make discoveries, and conduct experiments in the quest for new understanding. This approach helps to make science appealing to all children and builds a love for science. In inquiry-based learning, girls and boys are guided in gradually developing scientific concepts and ideas through learning how to investigate and how to build knowledge and understanding of the world around them. In an engineering design approach, students use what they have learned to solve everyday problems. They are led to understand the relationship between components of STEM disciplines and how such relationships help to solve problems in STEM-based programmes.

The approaches discussed in this module offer opportunities for policy makers, curriculum developers, teacher educators and teachers to deepen their understanding of the central issues in adopting the appropriate pedagogies for teaching STEM. In developing a gender-responsive STEM pedagogy, it is important to understand and accommodate all children's different learning needs and interests.

Key words

Gender-responsive classroom practices, gender-responsive STEM pedagogies, inclusive learning and assessment, inquiry-based learning, confirmation inquiry, structured inquiry, guided inquiry, open inquiry, problem-based learning, project-based learning, socio-scientific issue-based instructions

ACTIVITY 1

Gender-responsive classroom practices

Inclusive classrooms recognize that children are active participants in their own learning, and value and accommodate children's different learning needs. Inclusive, gender-responsive learning environments need well-trained teachers who are aware of how their own attitudes and preconceptions about gender can affect their teaching; who take steps to prevent gender bias and gender-based discrimination in their teaching and in their classrooms; and, who are supported in using different approaches and strategies to engage all children positively and effectively in lessons.

Focus of this activity

This activity allows the participants to reflect on classroom practices: what is taught, how teaching and learning take place and who receives encouragement to engage in certain classroom activities. The activity is designed to foster an understanding of what 'gender-responsive classroom practices' mean – how to ensure that all teaching, learning, and classroom interactions engage all students, both girls and boys[3], positively.

TASK 1: Work in small groups

a. Discuss the following questions, reflecting on your own teaching and learning experiences:

(i) In your experience, what kinds of teaching approaches are commonly used in STEM classrooms? Have you experienced any classroom practices that discourage the equal participation of boys and girls? Which practices encourage the equal participation of boys and girls?

(ii) In your experience of lesson planning, how are the needs and interests of all students taken into account?

(iii) Have you encountered any differences in the ways in which teachers interact with girls and boys?

(iv) How are the classrooms that you are familiar with arranged? What kind of classroom arrangement could help promote the equal participation of boys and girls?

(v) How gender-sensitive are the teaching and learning materials with which you are familiar?

(vi) Where does your understanding of gender in the classroom come from? How do your sociocultural beliefs impact your teaching practices? How does your perspective on gender influence students' learning?

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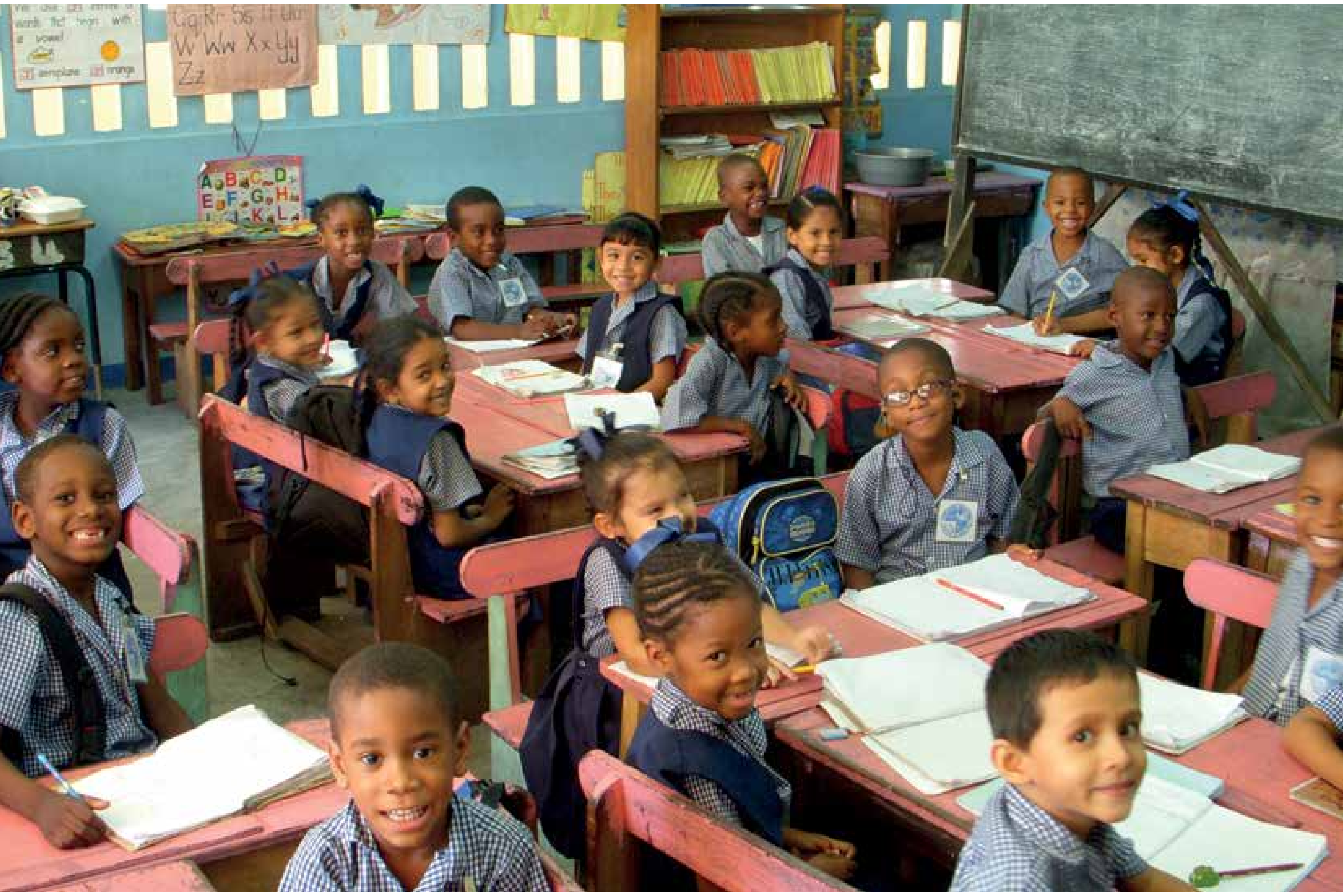
[3] This activity is based on FAWE's 'Gender Responsive Pedagogy: A Teacher's Handbook' (Mlama et al., 2005).

TASK 2: Work in pairs

a. Do Activity 1, the Spinning Top Challenge[4], as a learner (refer to Appendix 3.1). Carrying out this and the other activities in this Module will help you, as a curriculum developer, teacher educator or teacher, to experience a learner's learning process and, so, to apply that knowledge in your instruction so as to support all students.

b. Suppose you are developing a lesson with this activity. What are the ways to design and facilitate gender-responsive classroom practices, engaging all students in all teaching, learning, and classroom interactions?



[4] Spinning Top Challenge activity has been adapted from Fundamentals of Inquiry Facilitator's Guide (Exploratorium, 2006).

ACTIVITY 2

Designing science or mathematics activities that will engage girls and boys: Inquiry-Based Learning (IBL)

In order to meet the challenge of 21st century learning, Inquiry-Based Learning (IBL) is considered a viable approach for promoting the knowledge and the skills that students need to understand the relevant events and phenomena in their current and future lives. IBL should enable students to understand key science concepts (that is, 'big ideas'), acquire scientific skills and develop approaches to seek solutions to problems. All students need to be empowered to learn independently and collaboratively. There is also a need to strike a balance between conceptual learning and learning to learn.

IBL has proven to be a useful tool for promoting STEM inquiry among girls and boys from a very early age. IBL is effective when it is embedded in an engaging and relevant curriculum. Through this approach, students are immersed in experiences that provide them with opportunities to question, collaborate, think critically, solve problems, communicate and discover new knowledge. In developing their own inquiring minds, students explore materials and events, ask questions, investigate, record and present their work. By reflecting on what they have done and what it means, the inquiry process allows them to create new theories or ideas about how the world works.

When IBL is used as an approach in gender-responsive STEM education, science activities are designed to relate to both girls' and boys' needs and interests, and to build on their existing knowledge, so that all children see the relevance of science to their everyday lives. Through the IBL approach, girls and boys are given equal opportunities to participate in activities, ask questions, conduct experiments and evaluate results.

The following are descriptions of students' activities in inquiry-based learning.

Students…

- Pursue questions which they have identified as their own even if introduced by the teacher
- Do not previously know the answer to the questions they investigate
- Have enough background knowledge to engage with the question
- Make predictions based on their emerging ideas about the topic
- Take part in planning investigations to test their predictions
- Conduct investigations themselves
- Use appropriate sources and methods for data collection that are relevant to testing their predictions
- Discuss their findings in relation to their initial expectations or predictions
- Draw conclusions and try to explain their findings
- Compare their findings and conclusions with the findings and conclusions of others
- Keep notes and records as they undertake their investigations and studies
- Engage in discussion about their methods in investigations and the results

Using IBL as an approach in gender-responsive STEM education encourages girls and boys to question, conduct research on real issues affecting them or the community, and make discoveries on their own. It is a dynamic approach to learning that involves exploring the world, asking questions, making discoveries, and rigorously testing those discoveries in the search for new understanding.

In the context of inquiry-based teaching and learning, there are various levels of inquiry. Heather Banchi and Randy Bell (2008) outlined four levels of inquiry-based learning in science education: *confirmation inquiry, structured inquiry, guided inquiry and open inquiry.*

a. *Confirmation inquiry:* In confirmation inquiry, after the teacher has taught a particular science theme or topic, he or she then develops questions and a procedure that guides students through an activity where the results are already known. This method is useful when reinforcing concepts already taught, for teaching students how to follow procedures and to collect and record data correctly, and for confirming and deepening students' understanding.

b. *Structured inquiry:* In structured inquiry, the teacher provides the initial question and an outline of the procedure to be followed in answering the question. Students are expected to explain their findings by evaluating and analysing the data they collect.

c. *Guided inquiry:* In guided inquiry, the teacher provides students with the research question only. The students are subsequently responsible for designing and following their own procedures to answer the question and then to communicate their results and findings.

d. *Open inquiry:* Students formulate their own research question(s), design and follow their own procedures, and communicate their results and findings. This type of inquiry is often typical of science fairs, where students drive their own investigative questions.

IBL INSTRUCTIONS TO ENGAGE BOTH GIRLS AND BOYS

Higher-level thinking and learning processes are enhanced by experience, observation and interaction with other students. By integrating IBL into the teaching of STEM in a gender-responsive way, both girls and boys have an opportunity to direct their learning and communicate what they have learned through real life experiences. The learners deepen and consolidate their learning when they are provided with opportunities to apply such learning in meaningful contexts. Inquiry-based learning serves as a platform for all children to be engaged in hands-on investigation of the solutions to STEM problems. It transforms traditional classrooms from being teacher centred to student centred. The three key, focal areas for promoting girls' and boys' engagement in STEM are: *(a) designing instruction to encourage discovery by doing, and experiencing activities related to children's daily lives; (b) engaging in programmes that expose girls and boys to relevant, real-life experiences; and, (c) enhancing girls' and boys' own perceptions of their ability to excel in STEM careers.* Consequently, effective gender-responsive STEM teaching should involve inquiry-based lessons where all children, both girls and boys, are given opportunities to conduct hands-on investigations that encourage critical thinking and problem solving. The lessons should not be prescriptive: the teacher should play the role of a facilitator, providing just enough guidance and monitoring for students to be successful.

Inquiry-based learning instruction can be conducted using the following approaches: (i) *Problem-Based Learning (PBL)*; (ii) *Project-Based Learning (ProjBL)*; and (iii) *Socio-Scientific Issue-Based Instruction (SSI).* These approaches are discussed further in the following activities.

Focus of the activity

This activity and the suggested tasks help participants understand the ways in which to design an activity for students in science, mathematics or other STEM subjects, taking into consideration differences in children's learning needs and interests.

TASK 1: Individual reflection and work in small groups

a. Read the documents 'Inquiry-Based Science Education: Increasing Participation of Girls in Science in sub-Saharan Africa. Policy-Makers' Booklet' (Academy of Science of South Africa, 2011); 'Inquiry-Based Science Education: Applying it in the Classroom: Methodological Guide'. (Saltiel, n.d.); and 'Inquiry-Based Science Education in Secondary School Informatics -Challenges and Rewards' (Nikolova and Stefanova, 2014).

b. Discuss the impacts and challenges of applying IBL in teaching practices and the effective ways in which IBL can be incorporated into teaching practices to promote inclusive STEM education that connects with girls' and boys' interests.

TASK 2: Work in small groups

a. Ask participants to identify an area of STEM and design a learning activity (maximum length: 40 minutes).

b. Emphasize that the learning activity should reflect the IBL approach, which stresses the relevance to girls' and boys' daily lives.

TASK 3: Plenary discussion

a. Ask each group to present its learning activity, and micro-teach the lesson.

b. Encourage peer feedback, especially on whether they think the activity will interest and engage girls and boys equally. What could be changed or improved?

c. Use the conceptual framework of the IBL approach to discuss the participants' presentations.

d. Ask participants to revise their learning activities according to the feedback, and share with other groups.

Product

Learning activities for STEM, reflecting gender sensitivity and inclusive learning

ACTIVITY 3

Using problem-based learning (PBL) and project-based learning (ProjBL) as approaches in gender-responsive STEM education

PROBLEM-BASED LEARNING (PBL)

Problem-based learning (PBL) is a learner-centred educational approach, whose focus is empowering students to engage in self-directed learning. PBL is an exciting approach to classroom learning that challenges girls and boys to learn through engaging in a real problem. Because it is a learner-centred approach, the teacher should facilitate the experience so that both girls and boys have equal opportunities to participate in their groups and take an active role in developing both their problem-solving skills and subject knowledge. When the teacher manages the approach effectively, it can enhance the interests, motivations and learning experiences of both girls and boys.

The PBL approach facilitates a fundamental shift from a focus on teaching to a focus on learning.
In this approach, teachers should provide equal opportunities for girls and boys to:

- Learn within the contexts of tasks, issues, and problems that are aligned to real-life concerns
- Take responsibility for their own learning by trying out what they know and discovering what they need to learn
- Foster collaboration with their peers and develop the social skills for achieving higher performance through teamwork that engages girls and boys equally
- Improve their communication skills
- Acquire effective reasoning and self-directed learning, in order to increase motivation for life-long learning.

PROJECT-BASED LEARNING (ProjBL)

Project-based learning (ProjBL) is a structured or semi-structured learning approach that empowers students to take responsibility for their learning. As such, it is also a useful approach for engaging girls and boys in STEM education because it has the flexibility to accommodate the range of interests and needs of all students.

ProjBL adopts multi-faceted projects as a central organizing strategy so that students can learn through real-life experience. In ProjBL, students build up knowledge and develop skills by working on a project with concrete outputs. These projects could include research papers, scientific studies, multimedia presentations, video documentaries, art installations, or even musical and theatrical performances that demonstrate the findings. Projects are usually carried out over an extended period of time, and investigate and address an engaging and complex question(s), problem(s), or challenge(s). STEM education, as a form of ProjBL, includes instructional practices that are experiential and entail teamwork, and hands-on activities which are important for developing skills needed in the 21st century: higher order thinking skills (HOTS); and, communication, collaboration and creativity (Partnership for 21st Century Skills, 2009).

ENHANCING GIRLS' INVOLVEMENT IN STEM THROUGH PROJECT-BASED LEARNING

Using the project-based learning platform, teachers can encourage all students – both girls and boys – to perform challenging tasks. The teacher should encourage girls and boys to engage in the projects that interest them or that focus on their areas of interest. Given equal opportunities to build on their individual areas of interest, girls and boys are likely to discover exciting and challenging projects that will be relevant to their interests. Pursuing such projects may open up areas of science, technology, engineering, and mathematics that are new to them and that they will enjoy. This is particularly beneficial for girls: because women are currently under-represented in many STEM fields, girls may feel that these fields are not suitable, interesting, or relevant to them. If students are uncertain about which project to choose, teachers can direct them to read previous project reports, which could be in the library or other accessible collections. Examples of such resources include the Science Buddies' Project and specialist STEM magazines. In this capacity, the teacher acts as facilitator. In order to make the process meaningful for students, the teacher should guide and encourage students in selecting the appropriate areas of STEM education for investigation; further, teachers should help them to review resources, share success stories, make science history notes, and write book reviews.

Focus of the activity

This activity and the suggested tasks aim to familiarize participants with applying problem-based and project-based STEM instructions and the ways to use them effectively to ensure that girls and boys are equally interested and engaged in STEM-related activities.

TASK 1: Work in small groups

a. Read the articles 'Investigative primary science: a problem-based learning approach' (Etherington, 2011) and 'Project-based learning for the 21st century: skills for the future' (Bell, 2010).

b. Experience the problem-based learning activity as a learner (refer to Appendix 3.2).

c. In your group, describe how to apply problem-based learning in teaching practices that promote inclusive STEM education that fosters the interests and addresses the needs of girls and boys.

TASK 2: Work in small groups

a. Read the article 'Considerations for teaching integrated STEM education' (Moore and Roehrig, 2012).

b. Ask each group to discuss the challenges of implementing appropriate teaching practices that promote inclusive STEM education that meets the needs of both girls and boys in your country

c. Prepare an action plan on how to implement teaching practices based in inclusive STEM education that cultivate the passions of students while promoting gender equality.

TASK 3: Plenary discussion

a. Ask all groups to share their action plans in a plenary.

b. Encourage peer review of the action plans, paying particular attention to whether the plans address the needs and interests of both girls and boys.

c. Ask participants to revise and share their action plans.

Product

Action plan on implementing teaching practices that promote inclusive STEM education that meets the needs of both girls and boys

TASK 4: Plenary discussion

The following is a post-field reflection from a student. Read it and then discuss the questions that follow.

Box 3.1: Post Field Reflection

During my field visit to Lake Victoria, I worked with my peers and teachers to develop an observation plan on the effects of dumping plastic waste in the lake and its effect on marine life. I had to plan the observation plan by myself, which helped me learn more about the process of carrying out field observations. While we were at the Mara Forest, we learnt a lot about the gradual reduction of fish in Lake Victoria due to the effects of plastic waste. This opened my eyes about the human impact on the environment along with learning what I can do to reduce my individual impact on the environment.

a. What are the benefits of field visits, such as the one in the example, for promoting participation of girls and boys in STEM education?

b. Identify at least three other areas of STEM education in which field visits could be used to promote girls' and boys' interest in STEM education.

ASSESSING PROBLEM-BASED AND PROJECT-BASED LEARNING

Aligning instruction using problem-based or project-based learning with assessment is paramount for ensuring that what teachers have taught and what students have learned is suitably measured; this includes cognitive and social skills in real world scenarios. Therefore, both formative and summative assessments are crucial for measuring problem-based or project-based learning effectively.

1) Formative Assessment

Formative assessment is also referred to as 'assessment *for* learning'. Its primary purpose is to assess a student's progress and achievement while a learning programme is occurring, in order to support and enhance the student's learning by adapting the educational process to meet the learner's needs. It encompasses *authentic assessment, portfolio assessment, performance assessment, peer assessment and self-assessment.*

a. *Authentic Assessment:* In authentic assessment, students are given the opportunity to apply what they learn in class to a real-world situation. Using real-world scenarios, students are asked to participate actively in performing, creating or producing the desired products. For example, authentic assessment could be used to assess children's developing use of technology for biochar production. Producing biochar can improve the efficiency of energy conversion of biomass, which, in turn, can reduce the impact of pollution on the household user. Teachers are interested in the processes that students use to prepare the product or materials, and in the tangible outcomes from the learning.

b. *Portfolio Assessment:* Portfolio assessment is a deliberate, systematic collection of a student's work over a period of time that is intended to show the student's change and progress over that time. It also helps in making predictions about the student's future performance. A student's work shows the process of how she/he learned and is evidence of that learning. The portfolio includes samples of the student's work, usually selected by the teacher based on the student's presentations.

c. *Performance Assessment:* Performance assessment refers to any type of assessment that provides opportunities for students to demonstrate what they know, putting what they have learned into a meaningful context. It is used to emphasize 'doing' in open-ended activities for which there is not a single correct answer. Examples of performance assessment include project work reports, presentations and writing assignments.

d. *Self-Assessment:* Self-assessment comprises students' own judgments about their achievement and learning processes, and also about actions they need to take to make progress in their learning. Student self-assessment encourages self-reflection, which is necessary for gaining confidence in the performance of tasks; self-assessment also encourages students to think about the purpose of the task and to reflect on what and how much they are learning. Examples of self-assessment include logbooks, checklists and journals.

e. *Peer Assessment:* Peer assessment involves cross-referencing evidence on an individual's contribution to the completion of group tasks. It entails judgments on individual responsibilities that are performed for the benefit of the group. It allows students to discuss work together in a way that they understand, and helps them identify their strengths and weaknesses constructively.

2) Summative Assessment

Summative assessment, also called 'assessment *of* learning', refers to an evaluation of student achievement that is planned in advance. It is used to assess students' mastery of content; the results are presented as grades or numeric scores based on students' performances at a pre-determined time or at the end of an academic year or course.

3) Rubrics

A rubric is a scoring guide that contains criteria used to evaluate student performance for a particular task. It consists of a set of complex criteria and performance indicators arranged according to expected levels of proficiency or performance that have been determined subjectively. There are several points that need to be taken into consideration when constructing a rubric: (i) know the goals of instruction; (ii) know the specific skills that you want students to develop throughout the activity; (iii) know the required learning outcomes; and (iv) determine the type of rubric – either holistic or analytic – that best fits the given task.

Focus of the activity

This activity and the suggested tasks aim to familiarize participants with strategies of using problem-based and project-based learning in creating gender-inclusive STEM pedagogy, learning and assessment.

TASK 5: Individual assignment

a. Study the sample evaluation rubric below (Table 3.1).

b. Complete the Component and Maximum Score, and the Expectation/Quality columns.

Table 3.1: Sample Evaluation Rubric

Project Title	
Project Theme (e.g. Conservation)	
Presenters' Names and Class	

COMPONENT & MAXIMUM SCORE	EXPECTATION/ QUALITY	MARKS	REMARKS
Proposal development (5 marks)	Comprehensive proposal with introduction; statement of the problem; objectives; methodology; etc.		
Collaboration (? Marks)			
Planning Skills (? Marks)			

Product

Completed sample evaluation rubric

TASK 6: Work in small groups

a. Study the lesson plan in Appendix 3.3.

b. How could the plan be improved to promote the participation of all children using the problem-based and project-based learning approaches?

c. What kinds of assessments (formative/summative) would you carry out to evaluate students' learning process? Once determined, please describe the assessment strategy.

d. Revise the lesson plan.

Product

Revised lesson plan

ACTIVITY 4

Socio-scientific issues-based (SSI) instruction

Socio-scientific issues-based (SSI) instruction combines the use of controversial, socially relevant real-world issues with course content to engage students in their learning. SSI teaching, a variant of problem-based teaching, explores different socio-scientific perspectives focusing on real-life issues or topics. Since SSI instruction also centres on real issues that are relevant to students' everyday lives, it is another approach that can help increase girls' interest in learning science. Using SSI instruction, teachers provide a platform for students to engage, discuss and debate. Issues for debate must be open-ended regarding students' expected responses so as to promote exploration and inquiry among students, and to help students integrate the multiple disciplines that are linked to the topic. Through the SSI approach, students can investigate a wide range of issues and their ramifications for science, society, politics, economics, or other realms that affect the learner's everyday life.

Furthermore, an SSI teaching approach is valuable in that girls and boys are challenged to explore the controversy around an issue which is informed by science, to consider the social aspects (moral, ethical, economic, etc.) and other individuals' or groups' perspectives, and to develop a position based on investigation. For example, while students will not be able to solve the issue of global warming, they will be able to develop a position based on their research findings as they explore the issue and learn how it links with different scientific concepts.

ENHANCING GIRLS' INVOLVEMENT IN STEM THROUGH SSI-BASED INSTRUCTION

Teachers play a vital role in ensuring that there are equal opportunities for female and male students to share their ideas, argue and debate. The key to implementing an SSI-based approach successfully is to find current socio-scientific issues that are relevant to the specific girls and boys in the class and to align this inquiry with the teacher's content learning goals for the course. Issues should be multidisciplinary, self-guided and open-ended so that a particular issue can be addressed in more than one subject area. For example, captive breeding in zoos could be a point of engagement to teach students about natural selection, biodiversity, inbreeding, and basic principles of genetics.

SSI-based instruction could adopt the pedagogy of the 3-Stage Learning Model of contextualization, de-contextualization and re-contextualization, as illustrated in Figure 3.1.

Figure 3.1: The 3-Stage Learning Model

CONTEXTUALIZATION Scenario	**DE-CONTEXTUALIZATION** Active Approach to Learning (i.e. inquiry, PBL)	**RE-CONTEXTUALIZATION** Decision-making Knowledge Transfer
Science learning initiated by a familiar contextual frame of reference, linked to a need in the eyes of students Socially relevant and interesting, looking at an issue involving science	Meeting the science learning needs by decontextualized scientific learning Exploring the science ideas through active engagements of students	Consolidation of the scientific learning through transference to the contextual frame and promoting socio-scientific decision making Revisiting the scenario and making decisions using the gained knowledge and understanding
Stems from a social context involving science	**Takes place in a science context (non-social)**	**Enhancing scientific literacy in a socio -scientific context**

Source: Adapted from Holbrook and Ramnikmäe (2010); Oyao et al. (2012).

ASSESSMENT OF SSI-BASED INSTRUCTION

Classroom observation can be used as a form of assessment of girls' and boys' learning in SSI-based instruction during discussion or debate on controversial issues. Most teachers can 'read' whether their students are bored, frustrated, excited or motivated by observing their behaviour. Picking up on these cues, a teacher can adjust the instruction to ensure that both girls and boys are equally engaged and interested, and have equal opportunities to participate.

It is also beneficial for teachers to make observational/anecdotal notes. These notes serve to record and describe who is most apt to voice their opinion, present their ideas and eventually show how persuasive they are at convincing their peers. Teachers also need to create equal chances and opportunities for both girls and boys to participate, and offer differentiated instruction to speak to learners' diversity. There are three types of classroom observations:

a. *Narrative observation:* Narrative observation comprises a teacher's notes with description of what he or she sees in the classroom. It is a qualitative, as opposed to a quantitative, assessment.
b. *Semi-structured observation:* A teacher can create semi-structured observations to identify specific behaviours or factors that may affect a student's academic performance; semi-structured observation guides usually rate the frequency of a behaviour.
c. *Highly structured observation:* Highly structured observations are checklists that a teacher uses to note whether a behaviour or factor is present and to what degree. These observations frequently include statistical comparisons that allow the teacher to determine how a student's behaviour compares to other students of the same age.

Focus of the activity

This activity and the suggested tasks aim to familiarize participants with strategies for incorporating social dynamics into STEM pedagogy, learning and assessment that engages with and addresses the needs of both girls and boys.

TASK 1: Work in small groups

a. Read the extract below and then discuss the questions that follow

STEM curriculum needs to be regularly revised to ensure it is up-to-date and is relevant, gender-sensitive and appropriate for all students, whether girls or boys. Effective STEM teaching in schools must be meaningful and practical for all students, whether girls or boys. Thus the applications of science concepts, particularly physical science, to life learning and life skills need to be tailored to the daily lives and interests of both the girls and boys in the class.

b. Using the 3-Stage Learning Model of contextualization, de-contextualization and re-contextualization, and referring to scenarios in your country, describe how STEM instruction can be structured to relate to everyday life experiences of girls and boys. Discuss how this can lead to innovation in STEM education or to better understanding of the current innovation. (See the Table 3.2 below for an example).

Table 3.2: Example of implementing 'The 3-Stage Learning Model'

CONTEXTUALIZATION Scenario	**DE-CONTEXTUALIZATION** Active Approach to Learning (i.e. inquiry, PBL)	**RE-CONTEXTUALIZATION** Decision-making Knowledge Transfer
Air pollution from vehicles, including cars, buses and lorries, has caused the hazardous emission of solid particles and gases in the air.	Science content learned/extracted: pollutants such as carbon monoxide, sulphur oxides, nitrogen oxides and lead. When reacting with rainwater, they can produce acid rain that is harmful to humans, plants, and other living things. It also can damage buildings or metallic surfaces, etc.	Students will revisit the scenario and consolidate the science content. They have to demonstrate the ability to make useful decisions and suggestions about the issues addressed. For example: in order to reduce the hazardous effect of pollution from the vehicle, people could use a more eco-friendly car, like a hybrid car.

TASK 2: Individual reflection

Table 3.3 is a sample matrix for analysing a lesson on its gender responsiveness. Review and adapt it to suit your context.

Table 3.3: Sample Gender-Responsiveness Lesson Analysis Matrix

	INDICATOR FOR ANALYSIS	WHAT NEEDS TO BE DONE
1	What does the lesson plan look like? Does it address the different interests of girls and boys and the learning needs of all students?	
2	Are there any considerations for using mixed-sex learning groups, teams, etc. and ensuring equitable interactions between boys and girls? If only single-sex groups are allowed, are strategies in place to ensure that all groups are participating equally and that their input is equally valued?	
3	Which measures are taken to prevent discriminating practices of any kind?	
4	Are girls and boys equally encouraged to express their thoughts/ideas/ feelings?	
5	Is the classroom inclusive of girls and boy? That is, are all children, whether girls or boys, given equal opportunities to participate? Is the involvement of girls and boys equally valued?	
6	Does the classroom environment value and promote diversity?	

Product

Reviewed Gender-Responsiveness Lesson Analysis Matrix

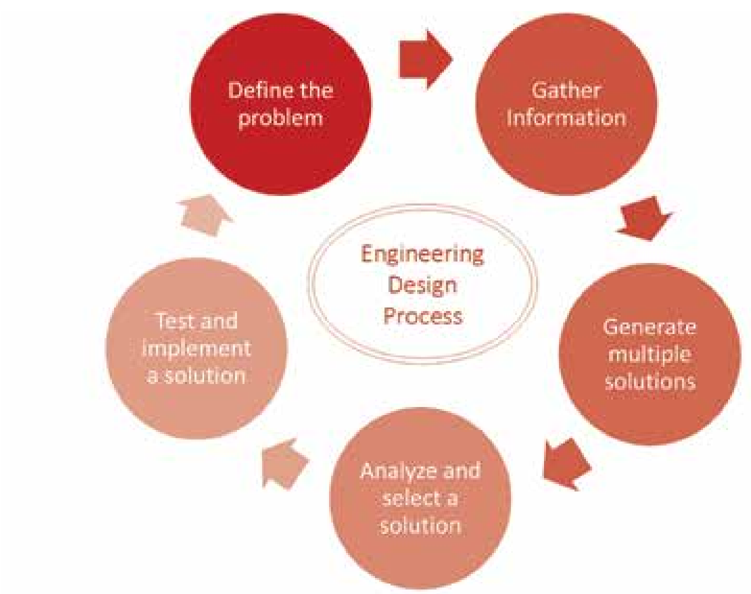
ACTIVITY 5

Designing science or mathematics activities that will engage girls and boys: Engineering Design Process

Engineering is the creative process of turning abstract ideas into physical representations (that is, products or systems). Engineers apply their creative energies to producing products or systems that meet human needs. This creative act is called design. Engineering design is the process that engineers use to solve engineering problems and develop products (Wang et al., 2011), recognizing that there are multiple solutions to most problems (Mann et al., 2011). It also encapsulates the essence of the engineering profession and is widely used in industry. The Accreditation Board for Engineering and Technology (ABET, 2009) defined 'engineering design' as 'the process of devising a system, component or process to meet desired needs' (p. 3). It is a decision-making process, often iterative, in which the basic sciences, mathematics, and engineering are applied to converting resources optimally for meeting the stated needs. What distinguishes engineering design from other types of problem solving is the nature of both the problem and the solution. Design problems are open-ended in nature, which means that they have more than one possible solution (Khandani, 2005).

While there are many models of the engineering design process, they all follow a step-by-step procedure, with the design occurring over a period of time (Figure 3.2). The five steps used for solving engineering design problems are: (1) define the problem; (2) gather pertinent information; (3) generate multiple solutions; (4) analyse and select a solution; and (5) test and implement the solution (Khandani, 2005).

Figure 3.2: Engineering Design Process



Source: Khandani (2005).

The continuous, iterative process of engineering design starts with defining the problem, which usually entails listing product or consumer requirements and information about product functions and features. The details of the design (that is, information about product functions and features) are then identified. The next steps involve generating multiple alternatives to achieve the goals and requirements of the design, with inputs from tests, manufacturing and marketing teams. The more promising alternatives are then selected for further analysis after considering cost, safety and other criteria. The design and analysis step enables a complete study of the solutions and results in identifying a final design that best fits the product requirements. A prototype of the design is then constructed, and functional tests are performed to verify, and possibly modify, the design.

In the context of education, engineering design has been treated as a pedagogical strategy for bridging science and mathematics concepts in solving ill-defined problems, developing creative thinking, formulating solutions and making decisions, and considering alternative solutions to meet a variety of constraints (Ruhizan et al., 2012; Samsudin et al., 2007; Wang et al., 2011). Engineering requires the use of scientific and mathematical concepts to address the types of ill-structured and open-ended problems that occur in the real world (Sheppard et al., 2009). Using engineering design as a context for these problems is a natural way for students to learn through integrating STEM. Using engineering contexts as opportunities for students to develop real-world representations can also be a catalyst for developing related scientific and mathematical concepts by using multiple representations (concrete models, pictures, language and symbols), and facilitating translations between and among them (Moore et al., 2013).

The professional engineering design process often consists of a dozen or more steps and may be too complex for younger learners. English and King (2015) developed a framework for the engineering design process that takes account of younger learners (Table 3.4). The process described in the framework reflects the multifaceted nature of a design approach. English and King consider the application of STEM knowledge during this process to be a key component of students' learning in solving engineering-based problems.

Table 3.4: Process of engineering design

PROBLEM SCOPING	IDEA GENERATION	DESIGN & CONSTRUCT	DESIGN EVALUATION	REDESIGN
Understanding the boundaries of a problem	Brainstorming and Planning	Model Development	Meeting Constraints	Model Redevelopment
- Clarify and restate the goal - Identify constraints - Consider problem feasibility - Add context - Experiment with materials - Establish collaboration	- Share and formulate ideas - Discuss strategies - Develop a plan	- Sketch design - Interpret design - Transform design to model	- Test model - Check constraints - Assess goal attainment	- Review first design - Sketch new design - Transform design to revised model
STEM CONTENT KNOWLEDGE				

Source: English and King (2015).

The simplified engineering design framework has also been adapted for elementary school students. For example, the Engineering is Elementary (EiE) curriculum, developed by the Museum of Science in Boston, features lessons and learning activities for elementary students that use the five steps of the engineering design cycle: ask, imagine, plan, create, and improve (Table 3.5).

In summary, engineering design, used aws a pedagogical strategy, helps to bridge science and mathematics concepts to solve open-ended problems, to develop creative thinking and analytical skills, to make decisions, and to consider alternative solutions for addressing a variety of constraints.

Table 3.5: Engineering Design Cycle

DESIGN PROCESS	DESCRIPTION
Ask	What is the problem? How have others approached it? What are your constraints?
Imagine	What are some solutions? Brainstorm ideas. Choose the best one.
Plan	Draw a diagram. Make a list of materials you will need.
Create	Follow your plan and create something. Test it out!
Improve	What works? What doesn't? What could work better? Modify your design to make it better. Test it out!

Source: Museum of Science-Boston (2009).

ENHANCING ALL CHILDREN'S PARTICIPATION IN THE ENGINEERING DESIGN PROCESS

As this module has highlighted repeatedly, hands-on activities are more interesting and appealing to all children – both girls and boys – compared to less active ways of engaging with science. The Engineering Design Process provides girls and boys equally with an authentic opportunity to develop an interest for science through exploration, discovery and investigation. Integrating engineering instruction and problem solving into school science courses connects curriculum to the real world, thus providing an authentic purpose for learning and solving problems. Students often use cooperative learning through teamwork to research and complete tasks, to test theories, and to plan and implement processes and solutions. Learning is maximized because both female and male students are equally involved in exploration and discussion; they share prior knowledge, and collaborate with and learn from each other to discover or create new knowledge. Children's awareness of the ways that the scientific and technological products resulting from engineering design are relevant to their everyday lives will promote their interest in studying STEM. Relevant, interesting topics and lessons can serve as a basis for teaching engineering design and can help all children to appreciate how their daily lives are affected by STEM outcomes and their applications.

ASSESSMENT OF ENGINEERING DESIGN PROCESS

There is a substantial literature on innovations in assessment (Ashton et al., 2006; Foegen et al., 2007; Kimbell et al., 2007). Innovative assessments in engineering design process include:

- **a.** E-portfolios and comparative judgment techniques
- **b.** Group and peer assessments
- **c.** Measurements of a wide range of outcomes, such as dispositions towards a future study.
- **d.** Aptitude surveys which provide information on students' perceptions and their learning styles, which give students opportunities to reflect on their knowledge and learning preferences
- **e.** Conceptual diagnostic tests, which assess students' understanding of a given topic and help teachers to gauge students' prior knowledge, in order to identify their strengths and weaknesses
- **f.** Scoring rubrics which can be used to assess scientific communication and should be linked to an assignment's goals. Rubrics' expectations and their criteria for achieving established standards should be stated clearly. Examples of rubrics include project development rubrics, individual and group presentation rubrics, and ideation rubrics

Sondergeld et al. (2016) suggest that comprehensive STEM lesson plans should measure both lower- and higher-level skills. For example, using the hierarchical structure of Bloom's Revised Cognitive Taxonomy, the authors suggest the following:

a. Lower level skills:

- Taxonomy level: applying
- STEM examples: deduce the type of chemical reactions that occur during cellular respiration

b. Higher level skills:

- Taxonomy level: creating
- STEM examples: design a chamber that will act as a closed system for a chemical reaction to demonstrate the law of conservation of mass

Focus of the activity

This activity and the suggested tasks will help participants to gain a thorough understanding of the delivery of the Engineering Engagement Programme, to experience hands-on activities related to the engineering design process, and to determine the learning resources required.

TASK 1: Work in small groups

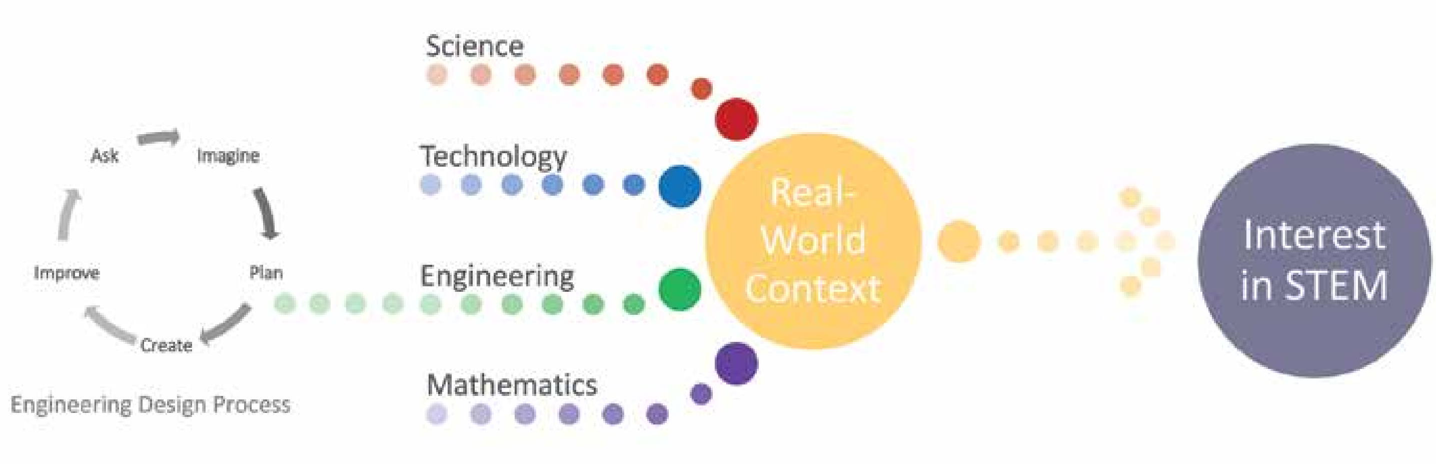
a. Read the case study of Malaysia in Box 3.2 for its experience in adapting Engineering Design Process for STEM education.

Box 3.2: Malaysia's experience in adapting Engineering Design Process for STEM education

BITARA STEM UKM: Science of Smart Communities

BITARA STEM UKM: Science of Smart Communities is a science, technology, engineering and mathematics (STEM) integrated programme that uses an engineering design process as a bridge to connect STEM subjects together. It is an integrated STEM education programme used in non-formal settings conducted by the Faculty of Education, in collaboration with the Faculty of Building and Engineering, the Faculty of Science and Technology, the Faculty of Information Technology (IT) and the Faculty of Allied Science, at the National University of Malaysia (UKM) to promote interest in STEM and provide a fun learning experience among middle secondary school students (Figure 3.3). The application of an engineering design process in the module is based on the five cycles of: (1) ask, (2) imagine, (3) create, (4) test, and (5) improve. The application of STEM content knowledge during the design process is the key component of students' learning in solving engineering-based problems; effective lessons require solving real-world problems and tasks through teamwork.

Figure 3.3: Conceptual framework of BITARA STEM UKM: Science of Smart Communities



Source: Sattar et al., in press. BITARA STEM Module: Energy (n.d.).

b. Discuss the Engineering Design Process and how to promote and encourage girls' participation in your context using this strategy.

TASK 2: Work in small groups

a. Read the publication by the Royal Academy of Engineering on 'Enhancing STEM Education in Secondary Schools: Outputs of the Engineering Engagement Programme' (Royal Academy of Engineering, 2013).

b. Discuss the delivery of the Engineering Engagement Programme and relate it to your country context.

c. Describe the gender-sensitive learning resources used in delivering the Engineering Engagement Programme and relate this to your country context.

TASK 3: Work in small groups

a. Carry out these STEM hands-on activities which focus on the engineering design cycle: Activity 1: Plastic Parachute (refer to Appendix 3.4-A), and Activity 2: Humanoid Robot (refer to Appendix 3.4-B).

b. Reflect on these learning experiences and relate them to your country context, with reference to Appendix 3.5.

c. Notes on Conducting the Hands-On Activities and checklists:

- Conceptual and thinking skills
- Relevance for boys and girls
- Classroom management
- Materials
- Assessment

d. Reflect on the following questions: Why is this type of learning activity gender-responsive? Why would this be preferred over a lecture or a video? How does this help engage students that are typically excluded from STEM learning?

e. Below is an example of STEM content and skills on the energy module activity, Solar Car. Choose one activity from the task and create a table taking into account the STEM content and skills. Assess to ensure that it will engage all students.

Table 3.6: Content and Skills in Solar Car Module

<table>
<tr><th colspan="4">MODULE: ENERGY
ACTIVITY: SOLAR CAR</th></tr>
<tr><th>Science</th><th>Mathematics</th><th>Technology</th><th>Engineering</th></tr>
<tr><td>Solar panel:
electricity generation principal,
lever principal</td><td>Illuminating angle</td><td rowspan="4">Assembling, fixing, sticking technology</td><td rowspan="4">Engineering design process:
Ask: Can the solar car move?
Imagine: Design the shape of the solar car.
Create: According to the results of discussion, select appropriate body of trolley and materials for tires and decide where to place motor, solar panel and gears.
Test: Test the solar car performance.
Improve: Make changes to improve the solar car performance.</td></tr>
<tr><td>Electromotive force (EMF):
Fleming's left hand rules</td><td>Voltage, power, force, current, magnetics field</td></tr>
<tr><td>Velocity:
Physical strength, drag, gear ratio</td><td>Ratio</td></tr>
<tr><td>Stability:
Friction force, normal force, external force</td><td>Gravity, weight</td></tr>
</table>

TASK 4: Individual assignment

Prepare a proposal for presentation to your country's Ministry of Education on the most appropriate approaches for assessing STEM education in your country. In the proposal, identify the formative and summative assessment practices that your country needs to adopt.

Product

Proposal on appropriate assessment approaches

MODULE 3

TAKE-AWAY POINTS

This module has explored different pedagogical approaches that may help close gender disparities in STEM and support gender-responsive STEM education. Two key recommendations are these:

1. Gender-responsive STEM education requires gender-responsive pedagogical approaches that recognize, address, and begin to dismantle gender inequalities in all aspects of the teaching and learning process, and that encourage both girls and boys to participate, enjoy and excel in STEM.

2. Lessons that use inquiry-based and hands-on learning approaches, and that have content that is relevant to students' daily lives, can help encourage more girls to participate and do well in STEM subjects.

READING LIST

- Inquiry-Based Science Education: Increasing Participation of Girls in Science in Sub-Saharan Africa. Policy-Makers' Booklet (Academy of Science of South Africa, 2011)
- Inquiry-Based Science Education: Applying it in the Classroom: Methodological Guide (Saltiel, n.d.)
- Inquiry-Based Science Education in Secondary School Informatics - Challenges and Rewards (Nikolova and Stefanova, 2014)
- Investigative primary science: a problem-based learning approach (Etherington, 2011)
- Project-based learning for the 21st century: skills for the future (Bell, 2010)
- Considerations for teaching integrated STEM education (Moore and Roehrig, 2012)
- Enhancing STEM Education in Secondary Schools: Outputs of the Engineering Engagement Programme (Royal Academy of Engineering, 2013)

APPENDIX 3.1

SPINNING TOP CHALLENGE

PROCEDURES:

1. Using a compass and posterboard *, draw a 4-inch circle. Cut it out.

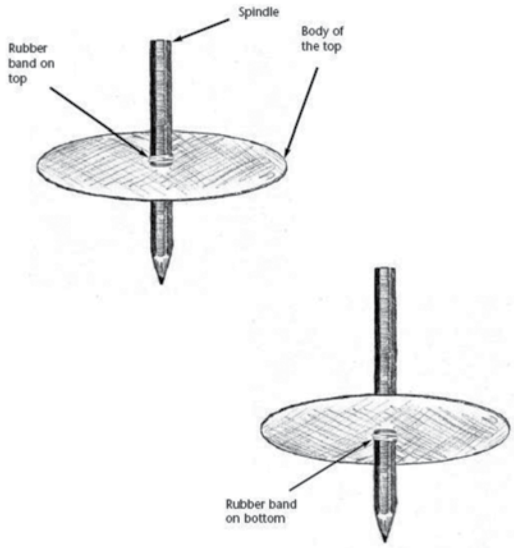
   (Note: * can be replaced with paper plate or plastic plate).

2. Insert a small scoring pencil through the center of the circle so that the pointed end extends about ¾ inch through the circle.

3. Push a twisted rubber band up tight against each side of the circle to stabilize the pencil so it is perpendicular to the circle.

4. Practice spinning the top a few times to make sure the pencil stays firmly attached and perpendicular to the circle.

5. You may (use masking tape) attach pennies on the top surface of the top as shown in Diagram I or Diagram II or Diagram III below.



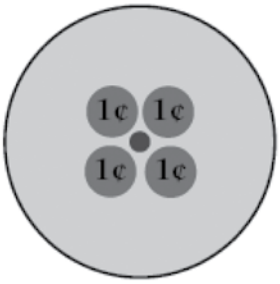


Diagram I

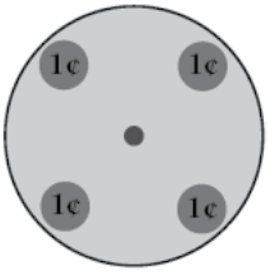


Diagram II

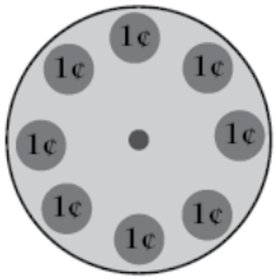


Diagram III

6. Practice spinning the top and record the times.

   (Note: A spin is considered ended when the top stops moving.)

   SPIN 1

   SPIN 2

   SPIN 3

7. The challenge is:

   Make a top that can spin as long as possible!

All the best!

APPENDIX 3.2

PROBLEM-BASED LEARNING (PBL) UNIT KIT [5]

The following Problem-Based Learning (PBL) Unit Kit is adapted from a problem case lesson exemplar in the module series on Improving Science and Mathematics Learning in the 21st Century, entitled *Making Sense of Science through Inquiry: Problem-Based Learning at Work,* published by SEAMEO RECSAM (Mangao et al., 2014). The work of the SEAMEO RECSAM regular course participants who developed the original lesson exemplar is hereby acknowledged.

Title: Staying Alive: Realising the Importance of a Healthy Respiratory System

Unit Overview: Students will learn about the process of respiration and how to maintain a healthy respiratory system. Students are given different scenarios that cover topics like stimulating the mechanism of human breathing via construction of a model, explaining the harmful effects of substances to the respiratory system and the importance of maintaining good air quality in the environment. On each of the scenarios, students need to apply their prior knowledge on what they know about the structure, function and care of the respiratory organs. They will be using ICT skills to gather information for the case scenario. After that, students are to present their findings and solutions through PowerPoint Presentations and by creating a model.

Learning Objectives

At the end of the unit, the students should be able to:

- Discuss the human breathing mechanisms;
- Collect and interpret data on various substances that are harmful to the respiratory system;
- Use ICT skills to research and present the report;
- Practice good habits to improve the quality of air;
- Design and construct a human respiratory model;
- Understand the importance of a healthy respiratory system; and
- Work and communicate effectively in groups.

Content/Skills

- Human breathing mechanism
- The harmful effects of substances to the respiratory system
- The importance of maintaining good air quality in the environment
- Communication and presentation skills
- ICT skills
- Ability to work in teams

[5] This activity is based on FAWE's 'Gender Responsive Pedagogy: A Teacher's Handbook' (Mlama et al., 2005).

Problem-Based Learning Case Scenarios

Case Scenario 1: Gasping For Air: Illustrating the Breathing Mechanism

You are an instructional materials development specialist stationed at the State Education Department. One day, Miss Aminah, a newly-appointed teacher in a rural school, came to your office and presented her problem. Miss Aminah is going to teach a lesson on human breathing and her school principal will visit her class. She thinks she knows the subject matter very well. She plans to create a model to show the breathing process but is not so sure if it is the right or most appropriate approach or design.

Case Scenario 2: You Smoke, You Die. Dare to Try?

In a village in Indonesia, a 2-year-old boy was found smoking 40 cigarettes a day. Every year, more and more children and teenagers begin smoking. The chances that they will be diagnosed with lung, mouth or throat cancer have also increased dramatically. Recent statistics from the American Cancer Society indicate that individuals who begin to smoke at or before the age of 19 continue to be smokers when they become adults.

You are a freelance health consultant. The Health Ministry commissioned you to prepare a report on why teenagers smoke.

Case Scenario 3: Clean Attitude, Clean Air, and Clean Lungs

One day, David went to the city by bus to visit his friend. Along the way, he saw many things and experienced events that made him feel very concerned about his health. Firstly, he saw a heavy traffic jam in a very crowded and busy street where vehicles also produced black emissions. Secondly, he saw four guests smoking in his friend's house. David felt difficulty breathing and had a sore throat.

You are a physician. David came to you for help. He would like to know how he could protect himself from the dangers of emissions from vehicles and smoke from cigarettes. He also asked you to discuss how the community can help make the air clean and safe. You have to come up with a presentation using available technologies.

PBL PROBLEM BLUEPRINT CASE PLAN 1

Title: Gasping For Air: Illustrating the Breathing Mechanism

Learning Objectives

At the end of the lesson, students should be able to:

- Explain the changes in air pressure in the thoracic cavity during the process of inhalation and exhalation;
- Build a functional model to demonstrate the breathing mechanism in human.

Problem Scenario

You are an instructional materials development specialist stationed at the State Education Department. One day, Miss Aminah, a newly-appointed teacher in a rural school, came to your office and presented her problem. Miss Aminah is going to teach a lesson on human breathing and her school principal will visit her class. She thinks she knows the subject matter very well. She plans to create a model to show the breathing process but is not so sure if it is the right or most appropriate approach or design.

Key Facts (3-4)

- You are an instructional materials development specialist stationed at the State Education Department.
- Miss Aminah is going to teach about human breathing process
- Miss Aminah plans to create a model to show the breathing process

Viable Hypotheses (Possible Solutions, at least 2-3)

- Research about the human respiratory system
- Look for sample models in the Internet
- Follow the model from the product companies or distributors
- Create a model using available materials

Learning Areas (Content topics/skills)

- Human respiratory system
- Inhalation and exhalation
- Research skills
- Processing skills

Problem Specifics

- Role: Instructional materials development specialist
- Setting: School
- Time Frame: 80 minutes
- Challenge/Outcome: Create a lung-chest model and make a presentation

Presentation Flow/ 'Cycles'

- Students research sample models of human breathing system in the Internet
- Students discuss in groups how to design the model
- Students draw, assemble and create a model
- Students make a presentation of their model
- Students follow this PBL processes to tackle the problem scenario

Facts	Need to know	Learning issues	Plan of Action to address learning issues	Possible solutions	Presentation and Reflection

Sources of Facts

- PBL Scenario
- Textbooks
- List of available materials
- The Internet

General Notes (Information to the Teacher)

The students will be organised into small groups and each group member will have a specific role to do. They will be given enough time as well as the resources to do their research and prepare their presentation.

Resources for Learning Issues

- the Internet
- Textbook

Laboratory/Activity Correlates

Each group will create a lung-chest model to show what happens to the respiratory organs during the inhalation and exhalation processes.

Final Product (Graded)

Lung-chest model and group presentation on the human breathing mechanism.

Assessment:

- The presentation (rubric-based)
- Peer assessment
- Self assessment

Hand-out #1

PROBLEM SCENARIO

You are an instructional materials development specialist stationed at the State Education Department. One day, Miss Aminah, a newly-appointed teacher in a rural school, came to your office and presented her problem. Miss Aminah is going to teach a lesson on human breathing and her school principal will visit her class. She thinks she knows the subject matter very well. She plans to create a model to show the breathing process but is not so sure if it is the right or most appropriate approach or design.

FACTS	NEED TO KNOW	LEARNING ISSUES	PLAN OF ACTION	POSSIBLE SOLUTIONS

Hand-out #2

TASK SHEET

Make a drawing of the model and label the diaphragm, lungs, trachea and thoracic cavity.

Then, use appropriate available materials to create a functional model of the human breathing system.

Describe how your model works by refering to the diaphragm, lungs, rib cage, and the volume of thoracic cavity and air pressure in the thoracic cavity during *inhalation and exhalation*.

PROCESS	DIAPHRAGM	LUNGS	RIB-CAGE	THORACIC CAVITY	
				VOLUME	PRESSURE
Inhalation					
Exhalation					

PRESENTATION

1. Construct the prototype of the lung chest model based on your design using the available materials.
2. Prepare a short presentation to explain the choice of materials and how the design of your prototype will serve its purpose.

Hand-out #3

PEER AND SELF ASSESSMENT FORM

CATEGORY	4	3	2	1	SCORE Write name of each group member in each column
Contribution	Routinely provides useful ideas when participating in the group and in classroom discussion. A highly responsible member who contributes a lot of effort.	Usually provides useful ideas when participating in the group and in classroom discussion. A strong group member who tries hard.	Sometimes provides useful ideas when participating in the group and in classroom discussion. A satisfactory group member who does what is required.	Rarely provides useful ideas when participating in the group and in classroom discussion. May refuse to participate.	
Problem-solving	Actively looks for and suggests solutions to problems.	Refines solutions suggested by others.	Does not suggest or refine solutions, but is willing to try out solutions suggested by others.	Does not try to solve problems or help others solve problems. Lets others do the work.	
Attitude	Never is publicly critical of the project or the work of others. Always has a positive attitude about the task(s).	Rarely is publicly critical of the project or the work of others. Often has a positive attitude about the task(s).	Occationally is publicly critical of the project or the work of others. Usually has a positive attitude about the task(s).	Often is publicly critical of the project or the work of others. Often has a negative attitude about the task(s).	
Focus on the task	Consistently stays focused on the task and what needs to be done. Very self-directed.	Focuses on the task and what needs to be done most of the time. Other group members can count on this person.	Focuses on the task and what needs to be done some of the time. Other group members must sometimes nag, prod, and remind to keep this person on task.	Rarely focuses on the task and what need to be done. Lets others do the work.	
Working with others	Almost always listens to, shares with, and supports the efforts of others. Tries to keep people working well together.	Usually listens to, shares with, and supports the efforts of others. Does not cause 'waves' in the group.	Often listens to, shares with, and supports the efforts of others but sometimes is not a good team member.	Rarely listens to, shares with, or supports the efforts of others. Often is not a good team player.	
				TOTAL SCORE	

Hand-out #4

RUBRIC FOR MODEL AND GROUP PRESENTATION

Group No: ....

Group No. Being Assessed:.. Date: ....

CATEGORY	4	3	2	1	SCORE
Construction Materials	Appropriate materials were selected and creatively modified in ways that made them effective.	Appropriate materials were selected and there was an attempt at creative modification to make them even better.	Appropriate materials were selected.	Inappropriate materials were selected and contributed to a product that performed poorly.	
Scientific Knowledge	Explanations by all group members indicate a clear and accurate understanding of the scientific principles underlying the construction and modifications.	Explanations by all group members indicate a relatively accurate understanding of the scientific principles underlying the construction and modifications.	Explanations by most group members indicate a relatively accurate understanding of the scientific principles underlying the construction and modifications.	Explanations by several members of the group do not illustrate much understanding of the scientific principles underlying the construction and modifications.	
Function	Model functions extraordinarily well.	Model functions well.	Model functions pretty well but with minor defects.	Model has major defects and could hardly function.	
Use of ICT	Group members are able to make use of good ICT skills extensively in the research and presentation.	Group members are able to make use of appropriate ICT skills extensively in the research and presentation.	Group members are able to make use of minimal ICT skills extensively in the research and presentation.	Group members are not able to make use of good ICT in the research and presentation.	
Group Work	The group functioned exceptionally well. All members listened to, shared with and supported the efforts of others; the group (all members) was almost always on-task.	The group functioned pretty well. Most members listened to, shared with and supported the efforts of others; the group (all members) was almost always on-task.	The group functioned fairly well but was dominated by one or two group members. The group (all members) was almost always on-task.	Some members of the group were often off-task.	
				TOTAL SCORE	

Hand-out #5

RUBRIC FOR ORAL PRESENTATION

Group ....
Presentation Date ....
Peer Evaluator...
Student Presenter ....

RATING SCALE RUBRIC FOR ORAL PRESENTATION

THE PRESENTER	STRONGLY AGREE	AGREE	DISAGREE	STRONGLY DISAGREE
1. Clearly stated the purpose of the presentation.	❐	❐	❐	❐
2. Was well organised.	❐	❐	❐	❐
3. Was knowledgeable about the subject.	❐	❐	❐	❐
4. Answered questions authoritatively.	❐	❐	❐	❐
5. Spoke clearly and loudly.	❐	❐	❐	❐
6. Maintained eye contact with the audience.	❐	❐	❐	❐
7. Appeared confident.	❐	❐	❐	❐

8. What grade are you awarding this presentation?	OUTSTANDING (A)	VERY GOOD (B)	ADEQUATE (C)	MARGINALLY ADEQUATE (D)	INADEQUATE (E)
	❐	❐	❐	❐	❐

9. Learned something new today or information was presented by the student presenter in a manner that provided me with a great or deeper understanding of what happens during breathing.

(Circle one) YES NO

APPENDIX 3.3

LESSON PLAN

Lower Secondary Science

<table>
<tr><td>School</td><td>SMK Jalan
Pasir Putih, KU</td><td>Date</td><td>6 September 2011</td></tr>
<tr><td>Class</td><td>Form 1</td><td>Number of student</td><td>30</td></tr>
<tr><td>Time</td><td>10.30 – 11.40 AM</td><td>T&L duration</td><td>80 minutes</td></tr>
<tr><td>Subject</td><td>Science</td><td>Topic</td><td>Density</td></tr>
<tr><td>Topic</td><td colspan="3">Understanding the concept of density</td></tr>
<tr><td>Theme
(for Lesson Study)</td><td colspan="3">Appreciate density in everyday life</td></tr>
<tr><td>Focus</td><td colspan="3">Density</td></tr>
<tr><td>Rational</td><td colspan="3">Exposure and awareness among students regarding the concept of density</td></tr>
<tr><td>Learning objective</td><td colspan="3">Appreciate the importance of density</td></tr>
<tr><td>Learning outcomes</td><td colspan="3">At the end of the lesson, students will be able to :
1. Convey the meaning of density based on their understanding
2. Explain, with example, the application of density in life</td></tr>
<tr><td>Basic knowledge</td><td colspan="3">Mass and volume</td></tr>
<tr><td>Scientific skill and Thinking skill</td><td colspan="3">1. Problem solving
2. Making inference
3. Visualization</td></tr>
<tr><td>Scientific attitude and Noble value</td><td colspan="3">Appreciating the contributions of science and technology</td></tr>
<tr><td rowspan="3">Teaching resources</td><td>1. Reference</td><td colspan="2">Text book, Curriculum Document</td></tr>
<tr><td>2. Apparatus</td><td colspan="2">500 ml beaker, small bottle, spatula, electronic balance.</td></tr>
<tr><td>3. Materials</td><td colspan="2">Sand, water</td></tr>
<tr><td colspan="2">Teaching approach</td><td colspan="2">Inquiry-based and hands-on activity</td></tr>
</table>

LEARNING DEVELOPMENT	CONTENT/ CONCEPT	TEACHING & LEARNING PROCESS (TEACHER & STUDENT ACTIVITIES)	NOTES
Phase I Engagement (Duration: 10 min)		Teacher provides a container of water. Students are asked to find some objects around them, (such as leaves, stone, paper, etc.) to put in the water. Students will take turn to put the objects in the water. Observations are made each time a student put the object into the water. Observation must include: 1) What objects are put into the water? 2) Float or sink? 3) Why is that? At the end of this activity, teacher asks: *What are we going to learn today?*	
Phase II Exploration (Duration: 30 min)	Density is mass over volume (mass/volume)	Teacher asks the students to work in groups of 3 or 4 students. Teacher explains about the purpose of today's activity, i.e. to produce three positions of small bottle in a 500 ml beaker. Teacher provided electronic balance, sand, spatula, and small bottles with same size. Each group should fill the 500 ml beaker with water. Each group must design and produce three positions of small bottles in the water. Students need to record data i.e. the mass of sand that inserted into each small bottle.	

LEARNING DEVELOPMENT	CONTENT/ CONCEPT	TEACHING & LEARNING PROCESS (TEACHER & STUDENT ACTIVITIES)	NOTES
Phase III Explanation (Duration:30 min)	Density involving mass and volume	Each group must explain what they were doing. They need to show the data that has been recorded, together with the three small bottles at different position in the water. Students tabulate their data in a table: <table><tr><th>Bottle</th><th>Mass of sand (g)</th><th>Position of bottle in the water</th></tr><tr><td>**1**</td><td></td><td></td></tr><tr><td>**2**</td><td></td><td></td></tr><tr><td>**3**</td><td></td><td></td></tr></table>Teacher explains the relationship between mass and volume to determine density.	The mass of sand that is put into the bottle will determine the position of the small bottle in the water.
Phase IV Evaluation (Duration:10 min)	Application of the concept of density in daily life.	Each student is given a worksheet with respect to the mass and volume, and the possibility of it sinking or floating in water. Students are also asked to justify their choice. Teacher and students discuss their answers and about making inferences about the concept of density. Video presentation can be shown to improve students' curiosity and awareness of density and its applications. Students are asked to give examples of other applications in daily life related to density.	Worksheet. Cartesian Diver Video

REFLECTION	
Before teaching (During planning the lesson: describe the thoughts, challenges, or difficulty in negotiating and planning) (1) Students may not have a good understanding of the concept of density	**After teaching** (What has been experienced and learned from this lesson; how it affects you ...) (1) Such activities make learning more fun and less stress for teachers and students. (2) Many more effective teaching methods can be used.

APPENDIX 3.4A

PLASTIC PARACHUTE[6]

During class, we have talked about animals need for food to survive. Currently, Country X is having a horrible dry season. The panda species in Country X is suffering; in fact, many have died. The panda's main food is bamboo shoots and when there is less bamboo, the panda population will be affected.

What is the best way to send bamboo shoots to the panda species? How you can help to send bamboo shoots and water to save the panda species from extinction? *(Source: Fox, 1984)*

- Teacher helps to create a brainstorm session to gather student's responses. Teacher should leave the answers open by not restricting students' suggestions. *(5 minutes)*

Design challenge (One of the design ways)

Design and build a parachute that can fly for at least 10 seconds from the place where it is floated. Supplies such as food and water must be tied to the parachute without falling to the ground.

Criteria:

Your parachute must:

- Consist of plastic.
- Be able to fly without floating from left to right or otherwise.
- Be able to fly with the supplies even with the increase of the wind speed.

Materials: *(What can you use?)*

(Your teacher might give you the materials you can use in a paper bag to help you keep track of them.)

- Pipe cleaner
- Wooden bead
- Polystyrenes
- Small nuts with equal size

Tools: (You many use these things to help you build. They may not become part of your prototype.)

- Scissors
- Adhesive tape
- Plastic bag
- Thread ball

Be sure to be careful when using the scissors while cutting.
You do not need to use all of the materials and tools.

Curriculum Learning Outcomes:

At the end of this unit, students learn the importance of survival of the species. Students are encouraged to think critically on how to design a parachute using the given materials and tools in order to rescue the panda species which faces extinction due to deforestation and the dry season.

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[6] Extracted from the on-going Ph.D. work of Kamaleswaran s/o Jayarajah, University of Malaya.
Title of thesis: The development of year five Children's Engineering Teaching Module (CETM)

Group members:

1. .... 4. ....
2. .... 5. ....
3. .... 6. ....

1. What is the problem? (2 minutes)

State the problem in your own words.

....
....
....
....

2. Brainstorm solutions. (4 minutes)

Sketch some possible solutions.

3. Create the prototype you think is best. (40 minutes)

4. Test your prototype. (3 minutes)

Circle your answer.

a.	Does your plastic parachute fly freely when there is wind?	YES	NO
b.	Does the height of where the plastic parachute floated influence the total time the plastic parachute flies?	YES	NO
c.	Do all the supplies, such as food and water, fly without falling to the ground?	YES	NO
d.	Can the plastic parachute fly better if bigger plastic is used?	YES	NO
e.	Can the plastic parachute fly further if heavier supplies are tied to it?	YES	NO
f.	Is the wind speed important for the plastic parachute to fly?	YES	NO
g.	Does every supply that you tie to the plastic parachute take the same time?	YES	NO
h.	Are you confident your plastic parachute will reach Country X with all the supplies?	YES	NO

5. Evaluate your prototype. (2 minutes)

a. Was it the best solution? Would one of your other ideas have been better? Why or why not?

....

....

....

....

b. How can you make your parachute design better? What will you do?

....

....

....

....

6. Present your prototype. (4 minutes)

....

....

....

....

Well done!

RUBRIC: DESIGNING A PLASTIC PARACHUTE

NO.	CRITERIA ASSESSED	NO EVIDENCE 0	ATTEMPTS TO MEET CRITERIA, SHOWS LIMITED UNDERSTANDING 1	MEETS SOME CRITERIA WITH ROOM FOR IMPROVEMENT 2	MEETS MOST CRITERIA WITH ROOM FOR IMPROVEMENT 3	MEETS ALL CRITERIA 4
A. Teacher-student brainstorming session						
1.	Student argues with teacher or with classmates or has little or nothing to do the discussion.					
2.	Student offers some ideas to the group but the ideas are not original, are not presented in sufficient detail, or are only vaguely related to the problem being considered. Student generally respects others' ideas.					
3.	Student offers reasonable ideas based on everyday experience and respects the ideas offered by others.					
4.	Student offers unexpected, creative or unique ideas relevant to the task and respects the ideas offered by others.					
B. Stating the problem						
5.	Student restates the problem by trying to use own words.					
6.	Student uses own words and shows a clear understanding of the problem.					
7.	Student uses own words with clear understanding by including previous knowledge they had learned.					
8.	Student's answer leads to a decision for creating a solution by using own words, showing clear understanding and examples of using previous knowledge.					
C. Brainstorming solutions						
9.	Student sketches choosing what he/she wishes to include.					
10.	Student freely sketches different parts of a prototype.					

NO.	CRITERIA ASSESSED	NO EVIDENCE 0	ATTEMPTS TO MEET CRITERIA, SHOWS LIMITED UNDERSTANDING 1	MEETS SOME CRITERIA WITH ROOM FOR IMPROVEMENT 2	MEETS MOST CRITERIA WITH ROOM FOR IMPROVEMENT 3	MEETS ALL CRITERIA 4
11.	Student freely sketches different parts or all the parts of a prototype.					
12.	Student freely sketches (parts or all) of a prototype freehand.					
13.	Student freely sketches (parts or all) of a prototype using ruler.					
14.	All the 4 sketches of solutions differ in size, measurement and pattern whether it's freehand or ruler or both					
15.	All the 4 sketches differ in size, measurement and pattern whether it's freehand or ruler or both. Student adds some additional notes related to the design process.					
16.	All the 4 sketches differ in size, measurement and pattern whether it's freehand or ruler or both. Student adds some additional notes by giving some insightful ideas to smooth the design process.					
D. Creating the best solution						
(I) Designing the prototype using hands-on participation						
17.	Student fixes the gadget by trial and error.					
18.	Student uses the provided resources effectively in an organized way by trying out various means.					
19.	Student uses resources in the most effective manner using a trial-and-error method and is not afraid to be different from other group members.					
20.	Student incorporates information based on previous lessons, experience and observation beyond the classroom in trying out various means in a structured mode. Student is unafraid to be different from others.					

NO.	CRITERIA ASSESSED	NO EVIDENCE 0	ATTEMPTS TO MEET CRITERIA, SHOWS LIMITED UNDERSTANDING 1	MEETS SOME CRITERIA WITH ROOM FOR IMPROVEMENT 2	MEETS MOST CRITERIA WITH ROOM FOR IMPROVEMENT 3	MEETS ALL CRITERIA 4
(II) Designing the prototype by showing an interest to fulfil a defined goal collectively						
21.	Student urges group members not to waste time in completing the prototype.					
22.	Student wants to complete the task on time and is eager to have a completed prototype.					
23.	Student encourages group members to produce a prototype that fulfils the design challenge and its criteria in the given time frame.					
24.	Student argues with group members stressing that his/hers is the correct step in fulfilling the design challenge of the prototype. Student gives explanation either verbally or non-verbally (gestures & facial expression).					
(III) Designing the prototype using observation & verbal interaction						
25.	Student observes other group members and follows them on designing a prototype.					
26.	Student observes other group members but does not follow them on designing a prototype.					
27.	Student observes other group members, does not follow but shares his/her view on how the prototype should be designed.					
28.	Student accepts criticism from other group members when his/her ideas are shared voluntarily.					

NO.	CRITERIA ASSESSED	NO EVIDENCE 0	ATTEMPTS TO MEET CRITERIA, SHOWS LIMITED UNDERSTANDING 1	MEETS SOME CRITERIA WITH ROOM FOR IMPROVEMENT 2	MEETS MOST CRITERIA WITH ROOM FOR IMPROVEMENT 3	MEETS ALL CRITERIA 4
E. Testing the prototype						
29.	Student observes the designed prototype.					
30.	Student observes, touches and checks the completed prototype.					
31.	Student observes and handles the prototype and asks group members' opinion.					
32.	Student argues with group members on the necessity of making adjustments or amendments to the designed prototype.					
F. Evaluating the prototype						
33.	Student wants to bring home the prototype.					
34.	Student explains why he/she wants to bring home the prototype.					
35.	Student reasons why the prototype need amendments and gives logical suggestions.					
36.	Student argues how the suggestions will be carried out or how the suggestions will help to improve the prototype.					
G.Presenting the prototype						
37.	Student presents by using own words and speaks at an understandable rate.					
38.	Student describes how they designed the prototype by trying to refer to the prototype.					
39.	Student answers the questions from other group members by providing reasons or explanation.					
40.	Student tries to answer questions such as 'how' and 'why' about their designed prototype.					

APPENDIX 3.4B

HUMANOID ROBOT[7]

Robots are becoming important to mankind, especially in countries such as America, Germany, France, Japan and South Korea. These countries use several sophisticated robots to help them do their daily work. Malaysia is also using robots but Malaysia wishes to design more robots that look like human or humanoid robots.

The humanoid robots are similar to a human being. In fact, humanoid robots can walk like a human being. These robots will help Malaysia in the robotics industry, in domestic or home use, in medicine, in service, in the army and in entertainment, space and competitions. How can you help Malaysia in designing humanoid robots? (Source: Amin, 2013)

- Teacher helps to create a brainstorm session to gather student's responses.
- Teacher should leave the answers open by not restricting students' suggestions. (5 minutes)

Design challenge:

Design and create a flexible humanoid robot. The flexibility of the humanoid robot must be good because they must stand without your support.

Criteria:

The humanoid robots must:

- Consist of all the parts provided.
- Have a head, arm and legs like a human being.
- Have different appearances when compared to each other.
- Be able to be renovated and designed by using your imagination.

Materials: (What can you use?)

(Your teacher might give you the materials you can use in a paper bag to help you keep track of them.)

- Card boards • Old newspapers • Manila cards

Tools: (You many use these things to help you build. They may not become part of your prototype.)

- Scissors • Pencil • Glue

Be sure to be careful when using the scissors while cutting thick cards.

You do not need to use all of the materials and tools.

Curriculum Learning Outcomes:

- At the end of this unit, students learn to design a model that is strong and stable.

[7] Extracted from the on-going Ph.D. work of Kamaleswaran s/o Jayarajah, University of Malaya.
Title of thesis: The development of year five Children's Engineering Teaching Module (CETM)

Group members:

1. .... 4. ....
2. .... 5. ....
3. .... 6. ....

1. What is the problem? (2 minutes)

State the problem in your own words.

....
....
....
....

2. Brainstorm solutions. (4 minutes)

Sketch some possible solutions.

3. Create the prototype you think is best. (40 minutes)

4. Test your prototype. (3 minutes)

Circle your answer.

a.	Does your designed model stand independently?	YES	NO
b.	Does your model represent a human?	YES	NO
c.	Does the change of color in the card make a difference in your model's flexibility?	YES	NO
d.	Do the space area and height have an influence in designing your model?	YES	NO
e.	Did you use only the tools and materials listed on the activity outline?	YES	NO
f.	Could your model be used in designing a real robot to help human beings?	YES	NO

5. Evaluate your prototype. (2 minutes)

a. Was it the best solution? Would one of your other ideas have been better? Why or why not?

....

....

....

....

b. How can you make your parachute design better? What will you do?

....

....

....

....

6. Present your prototype. (4 minutes)

....

....

....

....

Well done!

RUBRIC: DESIGNING A HUMANOID ROBOT

NO.	CRITERIA ASSESSED	NO EVIDENCE 0	ATTEMPTS TO MEET CRITERIA, SHOWS LIMITED UNDERSTANDING 1	MEETS SOME CRITERIA WITH ROOM FOR IMPROVEMENT 2	MEETS MOST CRITERIA WITH ROOM FOR IMPROVEMENT 3	MEETS ALL CRITERIA 4
A. Teacher-student brainstorming session						
1.	Student argues with teacher or with classmates or has little or nothing to do the discussion.					
2.	Student offers some ideas to the group but the ideas are not original, are not presented in sufficient detail, or are only vaguely related to the problem being considered. Student generally respects others' ideas.					
3.	Student offers reasonable ideas based on everyday experience and respects the ideas offered by others.					
4.	Student offers unexpected, creative or unique ideas relevant to the task and respects the ideas offered by others.					
B. Stating the problem						
5.	Student restates the problem by trying to use own words.					
6.	Student uses own words and shows a clear understanding of the problem.					
7.	Student uses own words with clear understanding by including previous knowledge they had learned.					
8.	Student's answer leads to a decision for creating a solution by using own words, showing clear understanding and examples of using previous knowledge.					
C. Brainstorming solutions						
9.	Student sketches, choosing what he/she wishes to include.					

NO.	CRITERIA ASSESSED	NO EVIDENCE 0	ATTEMPTS TO MEET CRITERIA, SHOWS LIMITED UNDERSTANDING 1	MEETS SOME CRITERIA WITH ROOM FOR IMPROVEMENT 2	MEETS MOST CRITERIA WITH ROOM FOR IMPROVEMENT 3	MEETS ALL CRITERIA 4
10.	Student freely sketches different parts of a prototype.					
11.	Student freely sketches different parts or all the parts of a prototype.					
12.	Student freely sketches (parts or all) of a prototype freehand.					
13.	Student freely sketches (parts or all) of a prototype using ruler.					
14.	All the 4 sketches of solutions differ in size, measurement and pattern whether it's freehand or ruler or both.					
15.	All the 4 sketches differ in size, measurement and pattern whether it's freehand or ruler or both. Student adds some additional notes related to the design process.					
16.	All the 4 sketches differ in size, measurement and pattern whether it's freehand or ruler or both. Student adds some additional notes by giving some insightful ideas to smooth the design process.					
D. Creating the best solution						
(I) Designing the prototype using hands-on participation						
17.	Student fixes the gadget by trial and error.					
18.	Student uses the provided resources effectively in an organized way by trying out various means.					
19.	Student uses resources in the most effective manner using a trial-and-error method and is not afraid to be different from other group members.					

NO.	CRITERIA ASSESSED	NO EVIDENCE 0	ATTEMPTS TO MEET CRITERIA, SHOWS LIMITED UNDERSTANDING 1	MEETS SOME CRITERIA WITH ROOM FOR IMPROVEMENT 2	MEETS MOST CRITERIA WITH ROOM FOR IMPROVEMENT 3	MEETS ALL CRITERIA 4
20.	Student incorporates information based on previous lessons, experience and observation beyond the classroom in trying out various means in a structured mode. Student is unafraid to be different from others.					
(II) Designing the prototype by showing an interest to fulfil a defined goal collectively						
21.	Student urges group members not to waste time in completing the prototype.					
22.	Student wants to complete the task on time and is eager to have a completed prototype.					
23.	Student encourages group members to produce a prototype that fulfils the design challenge and its criteria in the given time frame.					
24.	Student argues with group members stressing that his/hers is the correct step in fulfilling the design challenge of the prototype. Student gives explanation either verbally or non-verbally (gestures & facial expression).					
(III) Designing the prototype using observation & verbal interaction						
25.	Student observes other group members and follows them on designing a prototype.					
26.	Student observes other group members but does not follow them on designing a prototype.					
27.	Student observes other group members, does not follow but shares his/her view on how the prototype should be designed.					
28.	Student accepts criticism from other group members when his/her ideas are shared voluntarily.					

NO.	CRITERIA ASSESSED	NO EVIDENCE 0	ATTEMPTS TO MEET CRITERIA, SHOWS LIMITED UNDERSTANDING 1	MEETS SOME CRITERIA WITH ROOM FOR IMPROVEMENT 2	MEETS MOST CRITERIA WITH ROOM FOR IMPROVEMENT 3	MEETS ALL CRITERIA 4
E. Testing the prototype						
29.	Student observes the designed prototype.					
30.	Student observes, touches and checks the completed prototype.					
31.	Student observes and handles the prototype and asks group members' opinion.					
32.	Student argues with group members on the necessity of making adjustments or amendments to the designed prototype.					
F. Evaluating the prototype						
33.	Student wants to bring home the prototype.					
34.	Student explains why he/she wants to bring home the prototype.					
35.	Student reasons why the prototype need amendments and gives logical suggestions.					
36.	Student argues how the suggestions will be carried out or how the suggestions will help to improve the prototype.					
G.Presenting the prototype						
37.	Student presents by using own words and speaks at an understandable rate.					
38.	Student describes how they designed the prototype by trying to refer to the proto-type.					
39.	Student answers the questions from other group members by providing reasons or explanation.					
40.	Student tries to answer questions such as 'how' and 'why' about their designed prototype.					

APPENDIX 3.5

NOTES ON CONDUCTING THE HANDS-ON ACTIVITIES

Before conducting the activities

Read through the activity tasks with the participants by putting emphasis on:

- The Design Challenge
- The need for participants to perform each of the design process steps

During the activities

After they test their products, ask them to do a presentation for for other groups to be evaluated based on the rubric entitled 'Test your product'. The function and the use of designing the parachute and the Humanoid Robot and the holistic rubric is discussed in Appendix 3.4-A and 3.4-B.

After conducting the activities

Discuss and reflect on the following issues:

- Conceptual and thinking skills involved
- Relevance to girls and boys
- Classroom management
- Materials
- Assessment

Guidelines for discussion

Engineering and Science concepts

CONCEPT/ ACTIVITY	PLASTIC PARACHUTE	HUMANOID ROBOT
Science	**Gravity:** Gravity accelerates all objects at the same rate, regardless of their mass or composition. **Air resistance:** Resistance and friction cause changes in acceleration. Air resistance slowed down the heavier piece. Air resistance opposes the direction that the object is moving and slows it down.	**Surface area:** The larger the surface area, the more stable the robot is.
Engineering	**Aerodynamics:** The larger the plastic parachute, the greater its air resistance. Parachutes use a large canopy to increase air resistance. This gives a slow fall and a soft landing. **Fluid flow:** Fluid flow teaches the student to observe the structural twist characteristics of the plastic parachutes under various situations. The behaviour of canopy inflation and descent plays an important role in reducing the design cost of the parachutes. **Overall:** Student must realize that parachutes are used to deploy troops and support into war zones, deliver supplies and cargo, save lives, decelerate aircraft, and more recently, for the sport of skydiving. The simple concept has evolved into a masterful invention that can be steered and manipulated almost like an airplane, just by using lift, drag, and gravity.	**Mobility/Controllability:** Students can figure out how the robots can have adequate power for moving. **Motor control schemes:** Students can modify the humanoid robot prototypes according to how they want it to function for daily purposes. Students can transform the robots by switching the parts of the robots and creating different new types of robots. Students can figure out the motor control scheme while creating the humanoid robots.

Examples of questions for discussions and reflection with an emphasis on inclusive teaching: girls and boys

a. Relevance to boys and girls

- Is the context to be solved in the activities of the Plastic Parachute and the Humanoid Robot relevant to the boys' and girls' concerns and interests?
- Based on the inclusive checklist for teachers[8] below, choose relevant points in the checklist for discussion based on the country context.

Check your gender-inclusive practice in schemes of work and individual lessons	I do this routinely	Needs further development
Have you asked your class what they think physics is, and why physics is useful to study? Did you monitor the answers from the girls and the boys?		
Have you got 'real-world' examples to use to introduce each new topic?		
Do you select analogies, examples and themes for assignments that both genders are equally likely to be able to relate to (e.g. tennis and cycling in addition to football and cars)?		
So that work has a clear rationale, do you make a point of following the sequence: applications - principles - applications?		
Do you give examples of careers that use the knowledge and skills developed in the topic?		
Do you expose your students to a diverse range of scientists?		
Do you use a variety of questioning techniques?		
Do you adopt styles of questioning that take account of some girls' stated preferences for time for reflection and discussion?		
In group and project work, do you ensure that roles are rotated so that all students have equal access to equipment, and take a turn doing note-taking and clerical activities?		
Do you monitor the proportion of time that you spend interacting with boy in comparison with the time spent interacting with girl?		

[8] This checklist has been extracted from Institute of Physics (2009).

b. Classroom management

- Would such an activity be possible in your country context?
- How would you ensure that boys and girls will have equal participation during the activities?

c. Materials

- Are the materials for the activities accessible?
- How would you improve the content of the activities in terms of inclusivity?

d. Assessment

- Discuss the project development rubrics for assessing the design and the process of learning.
- Is it achievable? Relate to the country context.
- What improvements are needed to the rubric?

Below is an elaboration of using the rubrics:

Each of the engineering design process activities has some criteria to be fulfilled while designing the prototype. When designing the plastic parachute, the student must design a parachute that must:

- Consist of the plastic.
- Be able to fly without floating from left to right or otherwise.
- Be able to fly with the supplies even with an increase of the wind speed.

During the teacher-student brainstorming session in the plastic parachute activity, it was observed that most of the students:

a. Argued with the teacher or with classmates,
b. Offered some ideas,
c. Offered reasonable ideas and
d. Offered unexpected, creative and unique ideas

For each of the (a), (b), (c) and (d) actions from the students, the teacher can evaluate whether they were trying to meet the criteria suggested in the plastic parachute activity. For example, during the brain-storming session, if a student (a) argued with classmates about using the plastic to design the plastic parachute, then the teacher can tick in the box provided to what extend the student has argued (refer to the rubric in Appendix 3.4-A). If the student argued about using the plastic and not other materials, then teacher can tick either in (meets some criteria with room for improvement) for 2 points or (meets most criteria with room for improvement) for 3 points. If the teacher feels that the student argued with justifications, the teacher can tick in (meets all criteria) for 4 points. Hence, if the student argued while in the brainstorming session, the student has fostered argumentative skill (see below the Holistic Rubric).

HOLISTIC RUBRIC

NO.	CHECKLIST FOR HOLISTIC RUBRICS (Based on early engineering articles, Engineering is Elementary [EiE] program, Children's Engineering journals, HOTS rubrics (Allen, 2006) and Delphi findings, 2014)	ELEMENTS OF HOTS based on Delphi findings (based on emerged themes), literature reviews & HOTS rubrics (Allen, 2006)
A. Teacher-student brainstorming session		
1.	Argues with teacher or with classmates or has little or nothing to do the discussion.	• Argumentative
2.	Offers some ideas to the group but the ideas are not original, are not presented in sufficient detail, or are only vaguely related to the problem being considered. Generally, respects others' ideas.	• Argumentative • Transforming ideas into practical situations
3.	Offers reasonable ideas based on everyday experience and respects the ideas offered by others.	• Argumentative • Transforming ideas into practical situations • Motivating discoveries
4.	Offers unexpected, creative or unique ideas relevant to the task and respects the ideas offered by others.	• Argumentative • Transforming ideas into practical situations • Motivating discoveries • Exploring future technologies
B. Stating the problem		
5.	Restates the problem by trying to use own words.	• Independent thinking
6.	Uses own words and shows a clear understanding of the problem.	• Independent thinking • Designing process
7.	Uses own words with clear understanding by including previous knowledge learned.	• Independent thinking • Designing process • Bridging the gap
8.	Answers lead to a decision for creating a solution by using own words, showing clear understanding and examples of using previous knowledge.	• Independent thinking • Designing process • Bridging the gap • Deductive reasoning
C. Brainstorming solutions		
9.	Sketches choosing what he/she wishes to include.	• Opportunity
10.	Freely sketches different parts of a prototype.	• Opportunity • Optimizing alpha-brain waves
11.	Freely sketches different parts or all the parts of a prototype.	• Opportunity • Optimizing alpha-brain waves
12.	Freely sketches (parts or all) of a prototype freehand.	• Opportunity • Optimizing alpha-brain waves • Flexible thinking
13.	Freely sketches (parts or all) of a prototype using ruler.	• Opportunity • Optimizing alpha-brain waves • Transferable skills
14.	All the sketches differ in size, measurement and pattern whether it's freehand or ruler or both.	• Opportunity • Optimizing alpha-brain waves • Transferable skills • Flexible thinking
15.	All the sketches differ in size, measurement and pattern whether it's freehand or ruler or both. Adds some additional notes related to the design process.	• Opportunity • Optimizing alpha-brain waves • Transferable skills • Flexible thinking • Designing process

NO.	CHECKLIST FOR HOLISTIC RUBRICS (Based on early engineering articles, Engineering is Elementary [EiE] program, Children's Engineering journals, HOTS rubrics (Allen, 2006) and Delphi findings, 2014)	ELEMENTS OF HOTS based on Delphi findings (based on emerged themes), literature reviews & HOTS rubrics (Allen, 2006)
16.	All the 4 sketches differ in size, measurement and pattern whether it's freehand or ruler or both. Adds some additional notes by giving some insightful ideas to smooth the design process.	• Opportunity • Optimizing alpha-brain waves • Transferable skills • Flexible thinking • Designing process • Systemic thinking
D. Creating the best solution		
(I) Designing the prototype using hands-on participation		
17.	Fixes the gadget by trial and error.	• Inductive reasoning
18.	Uses the provided resources effectively in an organized way by trying out various means.	• Inductive reasoning • Strategic thinking
19.	Uses resources in the most effective manner using trial-and error-method and is not afraid to be different from other group members.	• Inductive reasoning • Strategic thinking • Engineering thinking
20.	Incorporates information based on previous lessons, experience and observation beyond the classroom in trying out various means in a structured mode. Unafraid to be different from others.	• Inductive reasoning • Strategic thinking • Engineering thinking • Divergent mode thinking • Designing process
(II) Designing the prototype by showing an interest to fulfil a defined goal collectively		
21.	Urges group members not to waste time in completing the prototype.	• Emphasizes team work
22.	Wants to complete the task on time and eager to have a completed prototype.	• Emphasizes team work • Problem-solving skills
23.	Encourages group members to produce a prototype that fulfils the design challenge and its criteria in given time frame.	• Emphasizes team work • Problem-solving skills • Encouragement
24.	Argues with group members stressing that his/hers is the correct step in fulfilling the design challenge of the prototype. Gives explanation either verbally or non-verbally (gestures & facial expression).	• Emphasizes team work • Problem-solving skills • Encouragement • Engineering thinking
(III) Designing the prototype using observation & verbal interaction		
25.	Observes other group members and follows them in designing a prototype.	• Structured cooperation in collaboration learning
26.	Observes other group members but does not follow them in designing a prototype.	• Structured cooperation in collaboration learning • Independent thinking
27.	Observes other group members, does not follow but shares his/her view on how the prototype should be designed.	• Structured cooperation in collaboration learning • Independent thinking • Evaluating

NO.	CHECKLIST FOR HOLISTIC RUBRICS (Based on early engineering articles, Engineering is Elementary [EiE] program, Children's Engineering journals, HOTS rubrics (Allen, 2006) and Delphi findings, 2014)	ELEMENTS OF HOTS based on Delphi findings (based on emerged themes), literature reviews & HOTS rubrics (Allen, 2006)
28.	Accepts criticism from other group members when his/her ideas are shared voluntarily.	• Structured cooperation in collaboration learning • Independent thinking • Evaluating • Engineering thinking
E.	**Testing the prototype**	
29.	Observes the designed prototype.	• Opportunity
30.	Observes, touches and checks the completed prototype.	• Opportunity • Fostering curiosity
31.	Observes and handles the prototype and asks group members' opinion.	• Opportunity • Fostering curiosity • Making decision
32.	Argues with group members about the necessity of making adjustments or amendments to the designed prototype.	• Opportunity • Fostering curiosity • Making decision • Measuring intelligence
F.	**Evaluating the prototype**	
33.	Wants to bring home the prototype.	• Encouragement
34.	Explains why he/she wants to bring home the prototype.	• Encouragement • Inductive reasoning
35.	Reasons why the prototype needs amendments and gives logical suggestions.	• Encouragement • Inductive reasoning • Building aesthetically and technically
36.	Argues how the suggestions will be carried out or how the suggestions will help to improve the prototype.	• Encouragement • Inductive reasoning • Building aesthetically and technically • Mechanical reasoning
G.	Presenting the prototype	
37.	Presents by using own words and speaks at an understandable rate.	• Explains using own words
38.	Describes how they designed the prototype by trying to relate to the prototype.	• Explains using own words • Idea connections
39.	Answers the questions from other group members by providing reasons or explanations.	• Explains using own words • Idea connections • Nurturing thought-provoking atmosphere
40.	Tries to answer questions such as 'how' and 'why' about their designed prototype.	• Explains using own words • Idea connections • Nurturing thought-provoking atmosphere • Critical thinking skills

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NOTES

TEACHER EDUCATION AND TEACHER PROFESSIONAL DEVELOPMENT TO SUPPORT GENDER-SENSITIVE STEM CURRICULA AND GENDER-RESPONSIVE PEDAGOGIES

MODULE 4

INTRODUCTION

This module will guide policymakers, curriculum developers, teacher educators and teachers through effective approaches to teacher education and teacher professional development in supporting gender-sensitive STEM curricula and gender-responsive pedagogies. This module covers these areas:

1. Pre-service teacher training
2. In-service teacher training, an integral part of teacher professional development

Through pre-service and in-service training, teachers are instructed how to implement gender-sensitive curricula using gender-responsive pedagogy. By having a gender lens as the foundation for teacher education, teachers will recognize that gender equality and STEM instruction are inextricably linked and eliminate prevailing gender-biased attitudes and perspectives. To implement effective STEM instruction, one must simultaneously promote gender equality in practice, language, activities and interactions with students and engage students in high quality and rigorous content.

Studies have shown that teacher professional learning is correlated with improved student learning when it a) focuses on teachers' understanding of the content they will teach; b) is sustained over time; and, c) provides opportunities for professional dialogue and critical reflection (Darling-Hammond, 2008; DuFour and DuFour, 2010; Timperley, 2008; U.S. Department of Education, 2000; Weiss et al., 1999; Zucker et al., 1998). Smith (2001) observed that 'professional development of teachers should be situated in practice' (p. 7). The everyday work of teaching should become the object of ongoing investigation and thoughtful inquiry (Ball and Cohen, 1999). Greatness by Design (2012), a report on California's teachers, explains that high-quality professional learning is connected to practice, focused on student learning, and aligned with school improvement efforts. Professional learning opportunities should be on-going and include both externally provided professional development opportunities as well as activities that are embedded in the job, such as common planning time and collaborative opportunities for examining student work or tools for self-reflection. Thus, it is necessary for professional learning, pre-service and in-service, to be informed by gender-responsive pedagogy. Professional development and teacher education must go beyond general education theory to begin dismantling the gender divide in STEM careers and the lack of participation by both young girls and women. Good opportunities for teacher's development, including gender-responsive pedagogy, contribute to increased teacher knowledge and skills; they also contribute to changes in instructional practices that support and enhance student learning.

Good quality, gender-responsive STEM education combines knowledge with experience, and is tailored to ensure that the interests and needs of both girls and boys are addressed. In order to provide good-quality teaching, teachers need to be knowledgeable and experienced in their subject, and well trained in both gender sensitivity and effective, gender-responsive teaching methods.

Both pre-service and in-service professional development programmes can be effective tools in developing and maintaining teachers' subject knowledge and their teaching skills. These programmes should also provide training on gender-sensitive curricula and gender-responsive pedagogies.

Key words

Teacher education, teacher professional development, cognitive, physical and affective development of students, professional learning, professional dialogue, instructional practices, instructional methods, teacher preparation programmes

ACTIVITY 1

Pre-service teacher training

Generally, pre-service teacher training is designed to equip individuals with subject knowledge and with the personal and professional competencies necessary for facilitating instruction and learning, both in school and in other learning contexts. Teachers are expected to facilitate all students' learning of subject matter, to promote students' development of skills and to foster positive attitudes and good values among students so that they can realize their full potential.

Gender-sensitive STEM curricula are unlikely to exist as a stand-alone entity; rather, they are integrated into and applied in the related subjects of mathematics, science, technology or engineering. Pre-service education should help expose trainees to a variety of contextual learning and hands-on activities that they can use in their classrooms to teach STEM that is relevant to the needs and interests of their future students. A particular focus should go to female students who are not typically engaged with STEM at the same levels as male students. Gender-sensitive STEM-related curricula are dynamic; they entail applying learning in real-life situations that are relevant and interesting to both girls and boys. Learning that is relevant and that improves daily living can strengthen all students' belief and confidence that they are capable learners.

Darling-Hammond (2006) conducted an in-depth study of seven renowned teacher education programmes and found marked differences in design and delivery. However, a common approach among all the programmes was the strong emphasis on preparing teachers to develop and deliver learner-centred lessons. These pre-service teacher programmes supported focused, in-depth learning that resulted in powerful thinking and proficient performance from students. In addition, they were responsive to individual student's experience, interest, talents and needs, and cultural backgrounds.

Focus of the activity

This activity and the suggested tasks should help participants to identify ways in which pre-service teacher education can support teachers to use gender-sensitive STEM curricula and gender-responsive pedagogies.

TASK 1: Individual reflection

a. Read the reports, 'EFA Global Monitoring Report: Teaching and Learning: Achieving Quality for All', from page 236 to 249 (UNESCO, 2014); 'Investing in Teachers is Investing in Learning: A Prerequisite for the Transformative Power of Education' (UNESCO, 2015); and 'Professional development for teachers on gender equity in the sciences: initiating the conversation' (Battey et al., 2007).

b. What are your main takeaways from these articles? Why is professional development for teachers so necessary with regard to gender equality?

TASK 2: Work in small groups

a. Using the experience of your country, complete the Pre-service Teacher Education Programme Scan below.

b. What other issues would you consider important for scanning the pre-service teacher training programmes in terms of their support of gender-sensitive STEM curricula and gender-responsive pedagogies?

Table 4.1: Pre-service Teacher Education Programme Scan

	ISSUE FOR SCANNING	STATUS	POSSIBLE ACTION
1	Does your country have a policy to deliberately recruit female and male teacher trainees for STEM education?		
2	How does the pre-service teacher education programme train teachers to use gender-sensitive STEM curricula and gender-responsive pedagogies?		
3	Does the pre-service teacher-training programme contain a component for training teachers to use gender-sensitive STEM curricula and gender-responsive pedagogies?		
4	How rich is the research base in your country on gender-sensitive STEM curricula and gender-responsive pedagogies? To what extent does such research inform the design of the teacher training programmes?		

TASK 3: Individual assignment

Prepare a proposal on how the pre-service teacher training programmes in your country can be improved to better train teachers to use gender-sensitive STEM curricula and gender-responsive pedagogies.

Product

Proposal on how to improve pre-service teacher training programmes to help raise teacher awareness of and skills in using gender-sensitive STEM curricula and gender-responsive pedagogies

ACTIVITY 2

In-service teacher training as part of teacher professional development

Since the 1980s, the development of in-service teacher education can be divided into three waves. In the first wave paradigm of the 1980s and 1990s, known as *Effective Education Movements*, in-service teacher training was designed to equip prospective teachers with the necessary subject knowledge, professional skills and attitudes to deliver knowledge effectively to students. In the second wave in the 1990s, the basic requirement of the *Quality/Competitive Education Movements* extended the mandate of providing quality services to stakeholders, such as policy-makers, teacher employers, prospective teachers and the community. In the 2000s, the third wave of in-service teacher training, the *World Class Education Movements*, has worked to develop prospective teachers as facilitators with a complex, multiple-intelligences perspective and a high level of professional competence for creating unlimited opportunities for students' learning and sustainable development. While information and communications technology (ICT) has been in use since the 1980s, it is now used more intensely in building a networked environment for teachers' individualized, localized and globalized professional learning and multiple-intelligences development (Cheng, 2007). Moreover, the current emphasis is on equipping prospective teachers, not only with 21st century knowledge and skills, but also with the ability to integrate them into their classroom practice. The goal overall is to enable children to meet the demands of a global economy, engage in good citizenship and participate fully in a vibrant civil society (Greenhill, 2010).

Gender awareness training through workshops and in-service training for mathematics and science educators should become an integral part of the school curriculum to help produce competent teachers who promote gender equality in their classrooms. For mathematics and science teachers, this requires developing focused, institutionalized and regular in-service training. Gender awareness training helps teachers to promote gender equality actively through their instruction. The training should enable teachers to understand how their teaching, as well as the teaching and learning materials in their classrooms, do or do not promote gender equality and ensure equal opportunities for all their students to participate, learn and reach their potential. For example, teachers may benefit from critically and continuously assessing whether or not male and female students' voices are equally represented in classroom discussions. Similarly, educators will be encouraged to reflect on the influence of typical gender roles on their curricula and instruction, and adopt ways to dismantle these stereotypes. Trainings can address both specific concerns, like these, and overarching concerns of gender-responsive STEM instruction.

In-service teacher training is an important component of on-going teacher development. It helps to keep teachers current on advances in knowledge, skills and policies in teaching/education and in their particular subject area. Ongoing training is thus crucial for teachers and for students. In order to be fully effective, in-service training programmes should contain course content that is designed carefully. Besides exposure and immersion through training, a teacher's skill and understanding is also developed through personal reflection and interactions with colleagues. Mentoring is also important for building confidence among teachers through sharing experiences, and supporting and reaffirming good practice.

Aspects of in-service training to consider regarding gender-responsive STEM education include:

- Identifying relevant content knowledge and strategies to promote gender equality
- A training strategy in which effective programmes for in-service training on gender awareness can be initiated for large numbers of teachers, over a variety of areas and operating in very different contexts
- Monitoring and evaluation (M&E) of the related curricula in targeted schools
- Teachers' thinking and continuous learning on how to use gender-sensitive STEM curricula and gender-responsive pedagogies
- Applying ICT in classrooms to improve teacher professional development and to benefit students' learning and diverse needs
- Awareness and appreciation of the need to meet girls' and boys' needs and interests in STEM education in order to improve girls' participation and achievement in STEM

In-service teacher training can be developed and delivered in a single school, across a number of schools in a district, or even at the state or national level (MacNeil, 2004).

Training can be delivered through the following models:

a) Cascade Model

This centralized approach is suitable for disseminating information and skills within a large number of teachers. It involves delivery through workshops and training sessions that explore gender issues related to curricula, and that demonstrate pedagogical skills. In the cascade model, a small group of teachers is selected to receive intensive training, after which they provide training to their peers, serving as 'master teachers'.

For this model, the Southeast Asian Ministers of Education Organisation Regional Centre for Education in Science and Mathematics (SEAMEO RECSAM) provides two types of training: customized training or in-country training. For *customized training*, participants gather in SEAMEO RECSAM where the training is conducted. The length of the training varies from one to four weeks. For *in-country training*, specialists from SEAMEO RECSAM are sent to the designated country, where the training is usually held for one week for 30 hours. The content in both types of trainings can be tailored to the needs of the particular countries.

TASK 1: Work in small groups

a. What are the most common challenges with using the cascade model for teacher in-service in your country?

b. What are the benefits of using the cascade model for teacher in-service in your country?

c. What are the best conditions for using the cascade model for teacher in-service in your country?

TASK 2: Individual assignment

Prepare a proposal on how your country can use the cascade model for teacher in-service to facilitate gender-sensitive STEM curricula and pedagogies.

Product

Proposal on how to use the cascade model for teacher in-service training to facilitate gender-sensitive STEM curricula and pedagogies

b) Reflective Teaching Model (RTM)

This approach focuses on empowering teachers to adopt reflective practice as a teaching strategy. It involves a pair of teachers who conduct consistent, on-going sessions of joint planning, teaching, and reflecting on their practice. Reflecting on one's own practice requires a form of deep thinking in which one poses questions and solves problems. This reflection is encouraged in the planning and debriefing phases of the RTM for continual improvement. For RTM to be a successful practice among teacher teams, a central professional development support group including a gender expert is needed to monitor and maintain teachers' enthusiasm for making the related and intended transformations in their teaching practices and, ultimately, in their schools.

TASK 3: Work in small groups

a. What are the most common challenges with using the Reflective Teaching Model in your country?

b. What are the benefits of using the Reflective Teaching Model in your country?

c. What are the best conditions for using the Reflective Teaching Model in your country?

TASK 4: Individual assignment

Prepare a proposal on how your country can use the Reflective Teaching Model to facilitate gender-sensitive STEM curricula and pedagogies in your country.

Product

Proposal on how to use the Reflective Teaching Model to facilitate gender-sensitive STEM curricula and pedagogies

TASK 5: Work in small groups and a plenary discussion

a. Discuss the similarities and differences between the Cascade Model and the Reflective Teaching Model.

b. In light of promoting and cultivating gender-responsive pedagogies among teachers of your country, which model will be more beneficial? If you could integrate the two models to fit your country's context (that is, its financial, geographic and social situation), which aspects would you incorporate?

c. Develop a national teacher training model that promotes gender-responsive STEM education based on task 5b.

Product

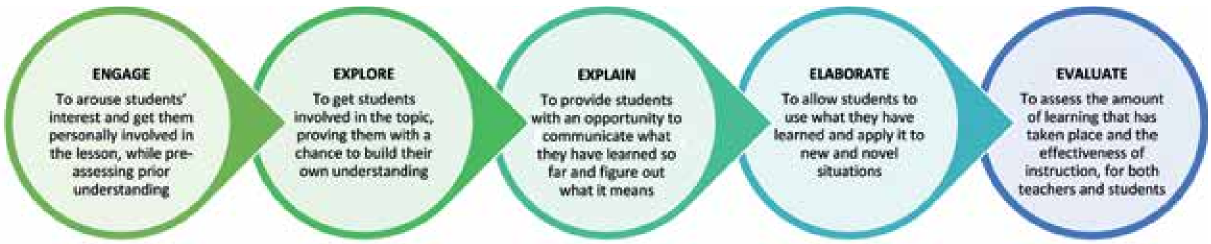
A national teacher training model promoting gender-responsive STEM education

ACTIVITY 3

Continuing professional development through Lesson Study

Lesson Study can be used as an approach for fine-tuning STEM classroom teaching and learning activities. Lesson Study is a school-based in-service training. A small group of STEM education teachers form the Lesson Study group and learn from each other, fostering closer collegiality, in exploring the conceptual meaning of any STEM lesson. The Lesson Study approach involves a continuous process of improving and refining classroom instruction and learning activities. Each lesson involves drafting a lesson plan based on the *5E format*, denoting the five stages of lesson development: *engagement, exploration, explanation, elaboration* and *evaluation*. Figure 4.1 highlights the components of a 5E lesson plan.

Figure 4.1: 5E components



Source: Based on, and adapted from, Bybee (1997); NASA Digital Learning Network (n.d.); and CSOPE (n.d.).

When using the 5E lesson plan format, the facilitator/teacher needs to incorporate and integrate STEM elements into each lesson intentionally, particularly in the exploration, explanation and elaboration phases, with special emphasis on learning through real-world situations and in relation to local contexts. The lesson plan should be jointly written by the team members. Table 4.2 provides a format of the 5E lesson plan.

Table 4.2: Format of the 5E Lesson Plan

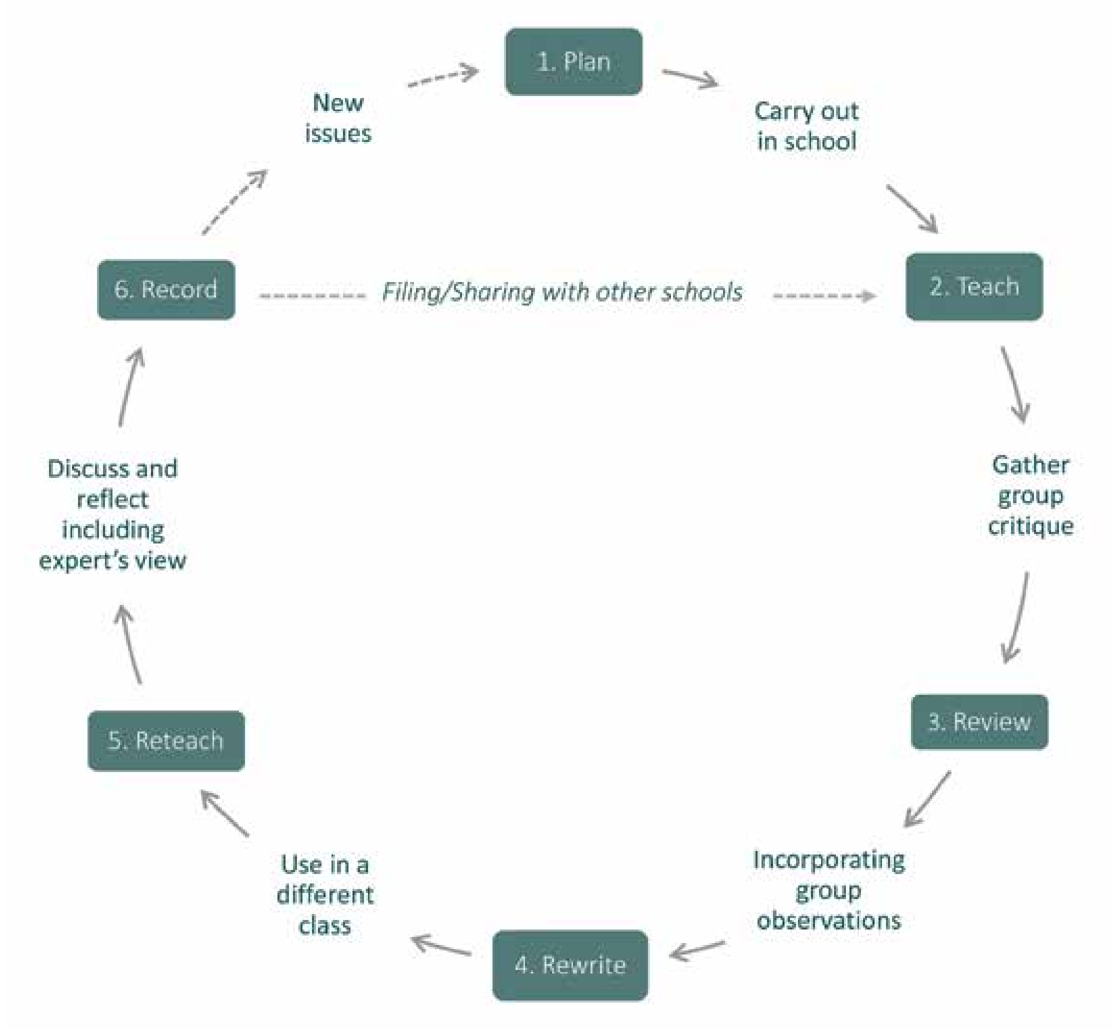
5E LESSON PLAN FORMAT

Date:	Time: ....
School:	Teacher: ....
Year/Form:	Topic: ....
Learning Area:	Learning Objectives: ....
Learning Outcomes:	Scientific Skills: ....
Thinking Skills:	Scientific attitudes and values: ....
Teaching Aids/Resources:	

STEPS AND (DURATION)	CONTENTS	TEACHING AND LEARNING ACTIVITIES	REMARKS
Engagement (............mins.)			
Exploration (............mins.)			
Explanation (............mins.)			
Elaboration (............mins.)			
Evaluation (............mins.)			

When using the Lesson Study approach, the team members need to carry out at least two teaching and learning cycles in their own classes for each lesson. After the first lesson, team members should confer again to modify or refine the lesson, which will be tried out in another class at the same level. Figure 4.2 illustrates the process of the Plan, Teach, Review, Rewrite, Re-teach and Record (PT4R) Model for conducting Lesson Study. This process of improving lessons should be continuous in order to adapt to and suit different learning conditions and contexts.

Figure 4.2: PT4R Model to Conduct Lesson Study



Source: Lee (2010).

Focus of the activity

This activity and the suggested tasks are designed to help participants use the Lesson Study approach effectively.

TASK 1: Work in small groups

a. Refer to Appendix 4.1 to further your understanding of the 5E lesson plan format.

b. Study the lesson plan in Appendix 4.2.

c. Discuss to what extent this lesson follows the 5E lesson plan format.

d. How would you improve the lesson to follow the 5E lesson plan format, particularly to address issues of gender-sensitive STEM curricula and gender-responsive pedagogies?

e. Revise the lesson plan.

f. How would you encourage teachers in your country to use the 5E lesson plan format?

Product

Improved lesson that follows the 5E lesson plan format

TASK 2: Work in small groups

a. Which other innovative in-service teacher training models and pedagogical practices can be used to build teachers' capacity?

b. Write a proposal on how your country can improve teacher capacity through in-service programmes, particularly on issues of gender-sensitive STEM curricula and gender-responsive pedagogies.

Product

Proposal on how to use in-service programmes to improve teacher capacity on issues of gender-sensitive STEM curricula and gender-responsive pedagogies

ACTIVITY 4

Profile and role of teachers in implementing gender-responsive STEM education

Teachers are instrumental in implementing any educational change, including curriculum change, pedagogical shifts, assessment and other areas. Therefore, teachers' professional profile and role in ensuring gender responsive STEM education needs should be explicit

The European Agency for Development in Special Needs Education (2012) identified the essential skills, knowledge and understanding, and attitudes and values needed by everyone entering the teaching profession, regardless of the subject, specialization or age they will teach or the type of school they will work in. The Agency identified *four critical profiles* that all teachers should possess: (i) *valuing learner diversity*; (ii) *supporting all learners*; (iii) *working with others*; and (iv) *continuously engaging with personal professional development*.

Focus of the activity

This activity and the suggested tasks are designed to help participants understand the roles and profiles of teachers and to enhance the development of these profiles in teachers through teacher training and professional development.

TASK 1: Work in small groups

a. Read the article, 'Teacher Education for Inclusion: Profile of Inclusive Teachers' (European Agency for Development in Special Needs Education, 2012).

b. What are the gender dimensions in these four profiles?

c. In your country, what are the challenges facing teacher training in developing teachers with the profiles described?

d. What can your country do to enhance the development of these profiles in teachers?

TASK 2: Individual reflection

a. Write an article for publication in a local newspaper on why teacher education needs to focus on developing the four profiles in teachers to ensure gender-responsive STEM education in your country.

Product

Newspaper article on why teacher education needs to focus on developing the 4 profiles in teachers to enhance gender-responsive STEM education in your country

DEVELOPING TEACHER STANDARDS FOR SCIENCE AND MATHEMATICS

Teacher Standards delineate the criteria, the abilities and the performance expected of teachers in conducting their teaching and learning. Teacher Standards provide input and benchmarks for exemplary teaching. The SEAMEO Regional Centre for Education in Science and Mathematics (RECSAM) initiated the Southeast Asia Regional Standards for Mathematics Teachers (SEARS-MT) and the Southeast Asia Regional Standards for Science Teachers (SEARS-ST), to be used as benchmarks for monitoring improvement in teacher quality. As a regional centre, RECSAM acknowledges the diversity in the SEAMEO region and the importance of providing quality science and mathematics teachers for sustained academic achievement; this academic achievement, in turn, contributes to sustained economic growth. Both SEARS-MT and SEARS-ST document sets of standards for the qualities that a mathematics and science teacher in the SEAMEO region should attain in the 21st century. Specifically, SEARS-MT and SEARS-ST can be used as a guide for enhancing the professional development of mathematics and science teachers in these three ways:

a. Provide benchmarks or aspirational goals for relevant educational agencies in formulating policies to improve the quality of teacher development programmes that prepare and equip pre-service and in-service mathematics and science teachers.

b. Structure teacher education programmes in both pre-service and in-service teacher preparation.

c. Develop teacher professionalism at the personal level. Teachers can use this document as a roadmap to guide their own personal professional development as a mathematics or science teacher.

SEARS-MT consists of four main dimensions: (a) Professional Knowledge, (b) Professional Teaching and Learning Process, (c) Personal and Professional Attributes, and (d) Professional Communities (Thien, 2016; Zakaria and Thien, 2016). SEARS-ST consists of four dimensions: (a) Professional Knowledge, (b) Professional Practice, (c) Professional Attributes and Ethics, and (d) Professional Development (SEAMEO RECSAM, n.d.). Details of each dimension and its underlying components and elements are presented in the tables in Appendix 4.3 and 4.4, respectively.

Focus of the activity

This activity and the suggested tasks are designed to help participants understand the Teacher Standards and use the standards effectively.

TASK 1: Work in small groups

a. Study both SEARS-MT and SEARS-ST in Appendix 4.3 and Appendix 4.4.

b. Discuss the suitability or relevance of the dimensions of SEARS-MT and SEARS-ST in your country context.

c. How can these tools help to assess gender equity in the classroom? Which specific components address individual student's needs and how can they be highlighted to ensure gender-responsive teaching and learning environments?

TASK 2: Work in small groups

Prepare a draft of STEM-based local descriptors for mathematics or science teachers that can be proposed for use in your own country.

Product

A draft of STEM-based local descriptors for mathematics or science teachers

MODULE 4

TAKE-AWAY POINTS

This module has addressed the importance of training teachers of STEM in gender sensitivity so that they can properly deliver gender-responsive STEM education. Two key recommendations are these:

1. Ensure that all teachers of STEM have the necessary knowledge to understand and use gender-sensitive curricula and resources.

2. Ensure that all teachers of STEM are adequately trained in and supported in using gender-responsive pedagogies in their day-to-day teaching.

READING LIST

- Education for All - Global Monitoring Report 2013/4: Teaching and Learning: Achieving Quality for All (UNESCO, 2014)
- Investing in Teachers is Investing in Learning: A Prerequisite for the Transformative Power of Education (UNESCO, 2015)
- Professional development for teachers on gender equity in the sciences: initiating the conversation (Battey et al., 2007)
- Teacher Education for Inclusion: Profile of Inclusive Teachers (European Agency for Development in Special Needs Education, 2012)

APPENDIX 4.1

5E Lesson Plan Format

5E AIMS AND DEFINITIONS	THE TEACHER	THE STUDENT
Engage		
To arouse students' interest and get them personally involved in the lesson, while pre-assessing prior understanding. • Generate interest • Access prior knowledge • Connect to past knowledge • Set parameters around the focus • Frame the idea	• Raises questions and problems. • Elicits responses that uncover students' current knowledge about the concept/topic. • Generates interest and curiosity • Taps into what students know or think about the topic	• Asks questions, such as: - 'Why did this happen?' - 'What do I already know about this?' - 'What can I find out about this?' - 'How can this problem be solved?' • Shows interest in topic • Responds to questions, demonstrating her/his own initial understanding
Explore		
To involve students in the topic, providing them with a chance to build their own understanding. • Experience key concepts • Discover new skills • Probe, inquire, and question experience • Establish relationships and understanding	• Acts as a facilitator • Observes and listens to students as they interact • Asks high-quality and rigorous inquiry-oriented questions • Provides time for students to think and reflect • Encourages cooperative learning	• Tries alternatives to solve problems and discusses them with others • Considers all possibilities while exploring solutions • Conducts experiments, predicts, and forms hypotheses or makes generalizations • Actively listens to their peers • Shares ideas and suspends judgment • Records observations and/or generalizations
Explain		
To provide students with an opportunity to communicate what they have learned so far and figure out what it means. • Connect prior knowledge and background to new discoveries • Communicate new understandings • Connect informal language to academic language	• Provides pertinent definitions, explanations and new vocabulary • Uses students' previous experiences as the basis for explaining concepts • Encourages students to explain their observations and findings in their own words • Listens and builds upon discussion from students	• Explains possible solutions or answers to other students • Listens to other students' explanations, evaluates them, and asks questions • Listens to and tries to comprehend explanations offered by the teacher • Refers to previous activities • Uses previously recorded observations and findings in explorations, hypotheses, and explanations

5E AIMS AND DEFINITIONS	THE TEACHER	THE STUDENT
Elaborate		
To allow students to use their newly acquired knowledge and continue to explore its implications. • Apply new learning to a new or similar situation • Extend and explain concepts being explored • Communicate new understanding with academic language	• Expects students to use vocabulary, definitions, and the explanations provided in a new context • Encourages students to apply and extend the new concepts and skills to new situations. • Reminds students of, and refers students to, alternative explanations • Uses information learned previously as a vehicle to enhance additional learning	• Applies new terms and definitions • Expects students to use vocabulary, definitions, and the explanations provided in new formulations • Assesses evidence carefully when drawing conclusions and offering solutions Records observations, explanation, and solutions
Evaluate		
For both students and teachers, determine how much learning and understanding has taken place. • Assess understanding (self, peer and teacher evaluation) • Demonstrate understanding of new concept by observation or open-ended response • Apply knowledge within a situation • Show evidence of growth and achievement	• Assesses students' knowledge and skills • Observes students as they apply new concepts and skills • Looks for evidence that students have changed their thinking • Allows and encourages students to assess their own learning and group process skills • Asks open-ended questions, such as 'Why do you think...?' 'What evidence do you have?' 'What do you know about the problem?' How would you answer the question?'	• Demonstrates an understanding or knowledge of concepts and skills • Evaluates his/her own progress, knowledge and skills gained • Answers open-ended questions, by using observations, evidence, and previously confirmed explanations

Source: Based on, and adapted from, Bybee (1997); NASA Digital Learning Network (n.d.); and CSOPE (n.d.).

APPENDIX 4.2

Lesson plan

Class: Secondary Form One (equivalent of Grade 7)

Subject: Chemistry

Topic: Water and hydrogen

Subtopic: Sources of water

Objectives

By the end of the lesson, the learner should be able to

a. state sources of water; and

b. describe an experiment to show that water is a product of burning organic matter.

Real Life Experiences Involving Content in this Topic

Possible real life experiences involving content in this topic include the uses of water. Students have probably been involved in chores such as cleaning, washing or cooking. Water is one of the substances that are used in these chores. They may already know that water is used for farming, drinking, transport, and in industry. Useful as water may be, there are many problems associated with it. These problems include shortage of water as a result of drought, loss of lives as result of floods, and water borne diseases. By allowing students to talk about such problems, you will be linking the students' learning with their everyday experiences. As a consequence, students are likely to be more engaged in thinking of what they can do to solve these problems.

Problematized Scenario

The problematized scenario should be used during the introduction of the lesson. The scenario as described in the lesson plan is likely to hook the students and get them interested in learning this content. This is because it involves making decisions, which some of them may have faced or face in their day-to-day lives.

The problematized scenario of the excerpt of the newspaper article as proposed by the teacher could also be used as a hook in teaching content in this topic. The scenario could be used to further students' learning beyond the classroom where a teacher could ask them to act as the expert on common water pollutants. In this regard, they may be required to prepare a speech they would deliver during a local 'Baraza' (meeting involving people in a given community and their leaders) to sensitize people on their behaviour to help curb water pollution in the area.

Relation of Problematized Scenario with Life Situation in the Community

The scenario can also be used to extend students' learning beyond the classroom. It can encourage students to become involved in projects through which they can develop and hone their research and investigative skills. For example, students can be asked to identify a problem associated with water such as water shortage, or the need for safe water for drinking and cooking, as well as work on projects that can be used to address the problems.

Lesson Flow

Introduction (max 7 min)

After distributing poster notes to the students, **tell** them that they will write something on them shortly. Most students are likely to choose tap or mineral water and give the reason that the water is clean. **Probe** the students to determine what they mean by clean. **Avoid** judging students' ideas as being wrong or right. Further questions that can be raised as result of this scenario include: What are the sources of the water samples? Why would they not choose the other water samples? At these points, **let** the students identify the water sources they are familiar with. What sources of water are likely to have water that is safe to drink? Is appearance a reasonable criterion for deciding whether or not water is safe to drink? What can be done to make water that is not safe to drink safe?

It is important to appreciate that some of these questions have no right and wrong answers. Thus, further investigations may need to be conducted (see relation of problematized scenario with real life situation in the community) to fully answer them. **Inform** the students that they will be required to come up with projects that can further answer questions raised by the scenario and **pose** the question, 'are the sources of water identified the only ones?' as a way of introducing the content of the lesson.

Lesson Development (max 27 min)

Through the lesson development, students need to come to the understanding that water can also be obtained when organic matter burns in air. But it is not just water that is produced. Carbon (IV) oxide is also produced. Since they are already familiar with the test for carbon (IV) oxide from the previous topic of air and combustion, they will need to be taken through how to test for water. This is why we propose conducting the lesson development through two sessions, the teacher demonstration and the class activity.

i) Teacher demonstration (max 6 min)

Here you will demonstrate the test for water. This test should precede the class activity because students need this knowledge in order to successfully navigate the class activity. Inform the students that there are two chemicals they need to be familiar with that are used in the test for water (i.e., anhydrous copper (II) sulphate and anhydrous cobalt chloride). **Write** the chemical names on the blackboard and **show** the students so that they see their appearance. For this demonstration, you may need just one of the chemicals. The test for water using the other chemical can be described (see test for water below). In addition to the chemical(s), you will need droppers, test tubes, water from at least two different sources (e.g., tap water and mineral water), common substances such as kerosene, and laboratory reagents such as aqueous sodium hydroxide, concentrated hydrochloric acid or concentrated sulphuric acid. Extra care needs to be observed when handling the concentrated acids. **Let** the students move to the demonstration table and stand in a way that allows them to have a clear view of the demonstration.

Test for water

(1) Using anhydrous copper (II) sulphate.

To a small amount (about 1 cm^3) of the substance to be tested, add about half a spatula-end full of white anhydrous copper (II) sulphate. If the substance is water or contains water, the anhydrous copper (II) sulphate will turn blue.

(2) Using anhydrous cobalt chloride.

(Mostly comes in the form of a paper. But it can also be in the form of crystals.)

Add 1-2 drops of the substance to be tested to a piece of blue anhydrous cobalt chloride paper. If the substance is water or contains water, the paper will turn pink.

Since the student worksheet does not have the procedure for the test for water, **allow** about 1-2 minutes for students to describe the test in the worksheet before proceeding to the class activity.

ii) Class activity (max 21 min)

Apparatus and materials for each group of students

Test tube holder, 1 birthday candle, half-full test tube of ice-cold water but not freezing, a glass rod, about 1 cm3 calcium hydroxide (lime water) solution, about 2 g of anhydrous copper (II) sulphate in 10 ml beaker, match box.

Divide the students into groups of five. Prior to conducting the class activity, **allow** students about ½ min to write what they think are the products of a burning candle. **Explain** what the students are expected to do in the activity. Remember to talk about any safety concerns before allowing the students to conduct the activity as per their worksheets.

Class discussion (max 10 min)

Call the class to attention to allow for a discussion of the findings. Allow the students to discuss and come to the realization that the products of a burning candle are water and carbon (IV) oxide. **Remember,** the syllabus does not require the students to know the equations of reactions leading to the formation of these products. However, this is a good area you can ask the students to research as way of determining the likely composition of a candle.

Conclusion (max 6 min)

Harmonize the students' thinking and ideas, restate the main ideas of the lesson and give assignment.

Evaluation

Ability of the students to conduct the class activity and to write their observations. Ability of the students to describe the test for water in addition to describing an experiment to show that water is one of the products of a burning candle. Ability of the students to research and present reports of their research, verbally and in writing.

Students' Responsibilities

Students are required to collaborate in carrying out the class activity and discuss their observations. However, each student is supposed to make individual entries on the worksheets. In order to ensure that all students participate in giving the findings of the activity, the teacher should choose members of the groups randomly.

Reflection

This is a lesson that can open discussions with students in areas beyond those covered in the class and projects proposed. For example, through the proposed assignment, students could be led to the realization that:

- Even though water is useful, burning organic matter is one of the ways greenhouse gases are introduced in the atmosphere.
- Problems associated with greenhouse gases include global warming, flooding, and drought (hence water shortage), among others.

As such, other projects can be undertaken.

Extend and Elaborate!

APPENDIX 4.3

Southeast Asia Regional Standards for Mathematics Teachers (SEARS-MT)[9]

Standards and Indicators of Professional Knowledge

STANDARDS	INDICATORS
Knowledge of Mathematics	- Knowledge of the discipline of mathematics - Knowledge of key concepts, procedures, and processes that are relevant to mathematics - Knowledge of mathematics curriculum - Knowledge of making relations between mathematics and other disciplines
Knowledge of Students	- Knowledge of motivational and engagement levels of students for learning mathematics - Knowledge of socioeconomic, cultural, ethnic and religious backgrounds of students - Knowledge of physical, social and intellectual developmental characteristics of the students
Knowledge of Students' Learning of Mathematics	- Knowledge of how students' prior knowledge impacts on learning - Knowledge of students' conceptions and misconceptions about mathematics - Knowledge of potential difficulties faced by the students in learning particular mathematics concepts - Knowledge of the application of learning and instructional theories in the teaching of mathematics - Knowledge of the repertoire of effective teaching strategies
Knowledge of Intellectual Quality	- Knowledge of strategies for supporting creativity and innovation - Knowledge of strategies for developing students' higher order thinking skills in mathematics - Knowledge for making complex relations between and representations of core topics - Knowledge of supporting students to develop complex mathematical thinking and decision-making - Knowledge of cross-curricular relations with mathematics
Knowledge of ICT	- Knowledge of ICT integration in the teaching and learning - Knowledge of how particular software supports a mathematics concept - Knowledge of use of ICT to model context and solve problems - Knowledge of students' knowledge and use of ICT - Knowledge of application/software development specifically on mathematics lessons

[9] SEAMEO RECSAM (n.d.).

Standards and Indicators of Professional Teaching and Learning Process

STANDARDS	INDICATORS
Mathematical Tasks and Discourse	- Engage and enrich students in mathematical thinking through discourse - Communicate thinking through various means of representations and reasoning - Facilitate student use of conjecturing, reasoning, proving, modelling, and verifying to solve mathematical tasks - Provide students with mathematical activities, problem-solving tasks and real-life investigations to meet the needs of all students
Planning for Learning Process	- Plan for an effective and safe learning environment to cater to the diversity of all students - Incorporate a variety of commercial and self-developed learning resources and instructional materials with appropriate teaching strategies
Implementing Teaching Strategies	- Use of effective communication and promotion of classroom discussion - Use of strategies to challenge students' thinking and engage them actively - Manage the learning environment effectively - Negotiate mathematical meaning and modelling mathematical thinking and reasoning
Monitoring, Assessment and Evaluation	- Provide on-going, constructive and purposeful feedback for learning - Develop and use a range of appropriate assessment tasks and strategies - Regularly assess and report student learning outcomes - Analyse students' learning through assessment - Utilise the performance data to inform teaching practice - Maintain on-going and informative records of student progress and learning outcomes
Reflection of Teaching and Learning	- Document the reflection of teaching practice post-lesson analysis - Utilise the record of reflection for self-improvement

Standards and Indicators of Personal and Professional Attributes

STANDARDS	INDICATORS
Personal Attributes	- Exhibit enthusiasm and confidence for both mathematics and teaching mathematics - Show a conviction that all students can learn mathematics - Commit to setting high achievable standards for the mathematics learning of each student - Exhibit care and respect to students and colleagues
Personal Professional Development	- Commit to lifelong learning and personal development - Enhance their understanding of mathematics and skills in mathematics teaching - Have informed views on relevant current trends in mathematics education including - knowledge of national priorities and associated policies - Participate in a range of professional activities
Personal Responsibilities towards Community	- Contribute to the communities relevant to their professional work - Advocate for mathematics learning in their school and in their wider community - Facilitate effective communication with parents/caregivers and stakeholders regarding students' learning and progress - Create opportunities for mathematics learning beyond the classroom

Standards and Indicators of Professional Communities

STANDARDS	INDICATORS
Professional Ethics	- Adhere to the codes of conduct - Demonstrate professionalism - Practice professional autonomy (e.g. willingness to perform duty above expectation)
Professional Communities at Schools	- Enrich the educational context for students (e.g. co-curricular activities, advisor for mathematics club, mathematics competition, mathematics project) - Participate in the school-based professional learning community (e.g. mentoring, lesson study, action research, journal contribution)
Professional Communities outside Schools	- Affiliate with professional organisation (national and local government, international organisation, private company, journal publication) - Take part in professional community networking among practitioners of schools, educational institutes, and/or universities

APPENDIX 4.4

Southeast Asia Regional Standards for Science Teachers (SEARS-ST)[10]

Components and Elements of Professional Knowledge

COMPONENTS	ELEMENTS
Knowledge of Science Teaching and Learning	- Knowledge of a range of relevant theories, models and practices in science teaching and learning - Knowledge of current research in science teaching and learning (e.g. new approaches in creating positive teaching and learning environments) - Knowledge of the repertoire of effective science teaching strategies - Knowledge of strategies to address needs of diverse learners (e.g. ability, cultures) in diverse teaching and learning environments - Knowledge of curriculum - Knowledge of assessment
Knowledge of Students	- Knowledge of students' motivation and engagement in learning science (e.g. attitudes toward science, students' educational expectations, readiness to learn) - Knowledge of students' background (e.g. socioeconomic, home environment support, cultural, ethnic and religious) - Knowledge of developmental characteristics of the students (e.g. physical, social, emotional, spiritual and intellectual) - Knowledge of students' learning needs (e.g. literacy, special needs, etc.)
Knowledge of Students' Learning of Science	- Knowledge of the impact of students' prior knowledge and skills on their science learning - Knowledge of factors that promote science learning (e.g. school resources, teaching and learning approaches of science, contexts, school climate, etc.) - Knowledge of potential difficulties in learning particular science concepts - Knowledge of the application of learning and pedagogical theories in the teaching of science - Knowledge of students' learning progression

[10] Thien (2016); Zakaria and Thien (2016)

COMPONENTS	ELEMENTS
Knowledge of Enhancing Students' Thinking	- Knowledge of strategies for supporting creativity and innovation in science - Knowledge of strategies for developing students' higher order thinking (including metacognitive) skills in science - Knowledge of strategies for developing students' ability in making interconnections between key concepts in science
Knowledge of ICT	- Knowledge of integration of ICT in the teaching and learning of science (e.g. supporting learning of concepts, modelling, solving science problems, etc.) - Knowledge of application of ICT in the assessment of science learning - Knowledge of application of ICT in administration (e.g. monitoring and recording) - Knowledge of developing students' ability in using ICT in learning science
Knowledge of Health and Safety	- Knowledge of safety related to science activities (e.g. handling laboratory equipment and chemicals, disposing waste, doing field work, etc.) - Knowledge of risk assessment related to science activities (e.g. slippery floor, current health threat, etc.) - Knowledge of emergency procedures - Knowledge of health and safety regulation policy and law - Knowledge of safety procedures and practices in the country

Components and Elements of Professional Practice

COMPONENTS	ELEMENTS
Plan and Design Effective Learning Experiences	- Plan and design a range of meaningful and relevant learning activities that are aligned to the curriculum (e.g. learning objectives, methods and assessment) - Plan and design assessments to inform teaching and learning - Plan to use appropriate teaching and learning technologies and tools that aid teaching and advance learning
Implement Teaching and Learning Plans	- Promote student scientific inquiry to develop deep understanding and foster values and attitudes related to science - Engage students in reflecting on the nature of science - Use appropriate strategies to foster key skills and to address the needs of diverse learners as well as diverse teaching and learning environments - Use appropriate questioning and discussion techniques to challenge students' thinking and engage them effectively - Communicate effectively to convey expectations for learning, directions, procedures, and explanation of content - Use appropriate scientific language and correct concepts - Manage student behaviour effectively (e.g. expectations for, monitoring of and response to student behaviour) - Establish a positive culture for learning (e.g. create an environment of value, respect and rapport) - Manage safe classroom and laboratory routines, procedures, transitions, materials and supplies effectively - Use technologies and tools effectively to aid teaching and advance learning - Provide effective enrichment and enhancement of experiences for science learning beyond the classroom
Implement Assessment Plans	- Use a range of types and strategies of assessments continuously (in terms of the cognitive, skills and affective domains) - Set and share assessment criteria with students - Give timely, specific, relevant and accurate feedback to advance student learning - Describe, analyse, evaluate and document student performance data - Use performance data to inform and improve teaching practice and student learning - Communicate learning results to students, parents and other stakeholders
Reflect Critically on Teaching and Learning	- Use data about learning to reflect on and assess student learning - Use data about learning to reflect on and evaluate teaching practice - Use evidence to reflect on and identify areas for professional growth

Components and Elements of Professional Attributes and Ethics

COMPONENTS	ELEMENTS
Personal Attributes	- Passionate about science and teaching science - Be able to apply a range of ways of teaching and managing the classroom appropriate to the needs of their students - Reflect regularly on own practices for continuous improvement - Be open and prepared to implement new ideas with regards to teaching and learning - Be a positive role model who is inquisitive as well as open to new ideas and evidence in science - Act with integrity and with a strong awareness of their personal and professional responsibility
Personal Responsibilities Towards Others	- Demonstrate caring and approachable attributes - Show positive expectations and support for the total development of the students - Impart values, knowledge and skills enthusiastically - Empower students to take charge of their own science learning (and advancement) - Engage in school and community science activities to promote science learning - Demonstrate and encourage scientific ethics - Implement health and safety measures
Professional Ethics	- Comply with the Professional Code of Ethics for teachers - Model personal and social responsibility for citizenship (e.g. sustainability of living environment, co-existence of humans, well-being, safety of children, etc.) to contribute to the harmony and betterment of the nation and the world at large

Components and Elements of Professional Development

COMPONENTS	ELEMENTS
Reflecting on Evidence	- Collecting classroom evidence (e.g. students' work, portfolio, observation, etc.) - Analyzing the evidence collected in relation to students' outcomes (e.g. students' work, portfolio, observation, etc.) - Identifying own professional strengths and weaknesses to inform professional development needs - Reflecting with peers (e.g. coach or mentor) to improve professional practice
Developing and Implementing Action Plans	- Identifying professional development needs - Formulating professional development goals - Developing strategies for achieving professional goals - Implementing action plans - Reviewing achievement of action plans - Revising action plans for further improvement
Enriching Professional Knowledge	- Keeping abreast of contemporary scientific developments (e.g. reading publications, attending meetings, workshops, colloquia, etc.) - Keeping abreast of contemporary pedagogies - Keeping abreast of educational policies - Engaging with scientists and science educators
Collaborating with Professional Learning Communities	- Participating in professional groups (e.g. professional associations, department team, lesson study groups, etc.) at school, state, national and/or international levels - Sharing exemplary practices within and beyond the school (e.g. participating in professional learning communities, delivering professional development courses and workshops either orally or in written form) - Becoming a mentor or a coach

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NOTES

DEVELOPING GENDER-SENSITIVE STEM RESOURCES

MODULE 5

MODULE 5

INTRODUCTION

This module discusses developing gender-sensitive STEM resources. These are resources that adhere to the principles of gender equality to help ensure that both girls and boys have equal opportunities to participate and learn in STEM subjects. Programme for International Student Assessment (PISA) 2012 compiled and presented statistically significant information regarding students' beliefs about their abilities and their own learning of OECD countries. One aspect of gender inequality that is observed in STEM is that female students tend to have lower confidence in STEM subjects than do male students (OECD, 2015). In order to progress towards gender equality in STEM, curricula and resources should reflect the need to increase girls' self-confidence, while maintaining that of boys. By using or referencing the tools outlined below, stakeholders may begin to alleviate the gender gap in STEM. The activities in this module seek to guide policy makers, curriculum developers, teacher educators and teachers to mainstream gender-responsive STEM education on the following:

1. Principles of developing gender-sensitive STEM teaching and learning resources
2. Learning styles and Multiple Intelligences
3. Personalized learning
4. Methodologies and procedures for developing textbooks and other resources
5. Digital resources for personalized learning
6. Setting up a gender-friendly STEM inquiry-based learning space (that is, one that addresses the needs and interests of all children, whether girls or boys)

STEM teaching and learning resources can assist teachers and students in acquiring STEM knowledge, skills and values. These resources are needed, especially when STEM pedagogy is adopted as a fresh approach. Generally, teaching and learning (T&L) resources are presented either as printed material or in digital format, including textbooks, modules, activity sheets and guidebooks. Developing effective teaching and learning resources requires the developers to understand that students' learning is affected by a myriad of complex and often intersecting factors. These factors include characteristics of students and teachers, of family backgrounds, learning environments, school administrators, government policy and guidelines. This module talks about principles to consider when developing gender-sensitive STEM resources and suggests procedures for developing these resources, as well as how to set up a gender-friendly, inquiry-based STEM learning space so that both girls and boys have equal opportunities to participate and learn. We emphasize that the instructions in this module are intended to guide, rather than prescribe.

Key words

Gender-sensitive STEM resources, teaching and learning (T&L) materials, inquiry-based learning space, STEM approach, digital resources, personalized learning

ACTIVITY 1

Eight principles of developing gender-sensitive STEM teaching and learning resources

a) Ensure that every student's personal needs are addressed with a specific focus on gendered challenges

Each student comes to school with a unique set of needs and abilities that are shaped, in part, by family background, prior experience, and the value system of that student's society. Developers of teaching and learning resources need to consider students' diverse experiences and needs, whether biological, physical, emotional or social, when developing these resources. Resources should be designed to respond to target the learners' unique needs. Teachers of STEM must always bear in mind that girls and boys may lack necessary prerequisites that will affect their learning. These may include a lack of prior opportunities for learning, such as a lack of access to computers; in some contexts, this may disadvantage girls disproportionately.

b) Vary teaching and learning strategies to appeal to both girls and boys

Resources need to provide varied and relevant strategies for teaching and learning, along with suggested teaching and learning activities, in order to address learners' diverse learning 'styles' and 'intelligences'. This will help to attract more girls and boys into STEM fields through resources that are more engaging and interesting for all learners. This may also help to overcome boredom or a lack of curiosity among students due to repetitive instructional practices.

c) Allow both female and male students to construct their own understanding

Traditional teaching practices often feature highly didactic approaches in which the teacher dominates the lesson time and takes almost total control of students' learning. STEM pedagogies, on the other hand, are inquiry-based, exploratory in nature, and emphasize learner engagement and collaboration; as discussed in Module 4, this can help teachers to deliver lessons that are interesting and relevant to both girls and boys. Thus, a didactic teaching style needs to give way to a constructivist view of learning, in which students are allowed to explore independently and take control of their learning. Teaching and learning resources, in turn, need to provide learning activities that allow for such exploration. Resource developers need to identify concepts, skills and attitudes, and then provide the learning experiences that scaffold students' learning by delivering basic information and providing the structure of learning.

d) Reflect reality in STEM practice

One of the challenges that teachers of science and mathematics face is using inductive inquiry as a vehicle for teaching science and mathematics concepts. Throughout the world, students are often asked to conduct empirical inquiry activities in order to arrive at the conclusion that the scientific community has already accepted; an example here is a scientific law. Often, students do not arrive at the preferred conclusion because of the many factors that can affect experiments. As a result, teachers guide the activities and, in many cases, dictate the conclusions. Having a teacher arrange students' experimental findings to match those of scientists is like telling those students that their experimental findings are flawed and without value. Students might begin to think that scientific inquiries should be predictable, and that there is an absolute, preordained truth. In real life, scientific procedures are not necessarily sequential: scientists often change their hypotheses and methods, and science facts are true only until proven false. In other words, guided inductive inquiries can lead students to develop unrealistic ideas about the nature of science. Thus, students also need to be encouraged to engage in deductive empirical activities, using open inquiry. Students should be told that scientific 'truths' generally arise only after many tests and extensive debates among scientists. This points to the fact that STEM practice needs to reflect reality. Although work in STEM has made great contributions to societies and the environment, it is also associated with many of their problems. Certain technologies, for example, have generated negative side effects, some with life-threatening consequences, such as pollution. STEM resources need to reflect these realities, since STEM pedagogies focus on solving problems in the context of societal issues and real-life obstacles. Situating STEM education in authentic contexts makes the lesson content relevant to girls' and boys' daily lives, which can encourage more girls to take up STEM subjects.

e) Provide skills apprenticeships

Scientists, technologists and engineers are highly skilled professionals whose work requires them to identify problems, plan investigations, or produce prototypes and solve problems. Often, students do not develop the competencies associated with practices in STEM fields because the teacher and/or textbooks tend to control the activities of empirical inquiry or project-based learning in schools. The teachers or the textbooks often generate the questions that students themselves should have asked, and design the investigation rather than allowing students to navigate these processes. Study design, data analysis, the presentation of findings, conclusions and methods of reporting are often dictated. This external control of knowledge and these prescribed processes can leave students relatively unskilled, always dependent on someone else to guide them; in many cases, this undermines their ability and confidence in developing critical thinking skills and initiative. Effective STEM teaching and learning resources that are gender-sensitive should provide all students with equal opportunities to engage in student-directed, open-ended science inquiry and/or technological design projects. STEM resources should be designed to support all students' participation in the learning activities.

f) Merging science, technology, engineering and mathematics education

In many countries, science, technology, engineering and mathematics are taught separately in school. However, a multidisciplinary and interdisciplinary approach is needed in teaching STEM concepts for STEM education to achieve the desired impact on the society. When teaching science, the application of scientific principles to solving real life problems should be integrated into the learning activities. At the same time, when technology is taught, students need to be guided in using scientific and mathematical concepts to solve problems. To support this approach, STEM resources need to create opportunities for multidisciplinary project-based or problem-based learning that will bring the four disciplines together. Through these multidisciplinary activities, the STEM resource developer will help to spread the idea that the expectations for learning relate not only to products (such as laws and theories) but also to the process of learning and cognition; this approach will help to de-emphasize rote learning. The resources should emphasize the students' role as producers of knowledge and problem solvers, not mere recipients of knowledge or instruction. By elevating the role of students in the classroom through an integrated STEM instructional approach, girls and boys will have repeated opportunities to develop competencies and to critique their own thinking and skills. Additionally, providing a platform for students by merging the STEM disciplines will enhance students' understanding that societal STEM issues are interrelated. For example, it is imperative to have perspectives from various fields when discussing food preparation and waste management. This promotes the broad perspective that science, mathematics and engineering thinking are closely interrelated and part of our everyday lives.

g) Integrate assessment and evaluation with teaching and learning

Socrates said that 'The unexamined life is not worth living': it is always important to review and evaluate one's actions. Assessment helps in determining whether or not teaching goals and lessons' standards are met, and whether girls and boys are learning and achieving equally. Moreover, by frequently and informally assessing students, teachers will have greater awareness of their students' progress and self-confidence regarding STEM content. Thus, resource developers need to include quality and adequate assessment in instructional materials.

h) Provide all students, both girls or boys, with relevant education and learning experiences

A common issue raised in STEM education is the relevance of STEM knowledge. The curriculum content and the learning experiences should be designed to address the needs and interests of all learners. To get the most out of their learning, students need to be able to connect the content of the STEM resource to their lives.

Focus of the activity

This activity and the suggested tasks will help the participants to gain a better understanding of the principles for developing gender-sensitive STEM teaching and learning resources.

TASK 1: Work in small groups

a. Identify some instructional materials in STEM from your country.

b. Analyse them to find out the extent to which they conform to the eight principles of developing gender-sensitive STEM teaching and learning resources.

c. Suggest ways in which the materials can be improved to better conform to these eight principles.

Product

Suggestions on how instructional materials can be improved to conform to the eight principles of developing gender-sensitive STEM teaching and learning resources

ACTIVITY 2

Learning styles and multiple intelligence

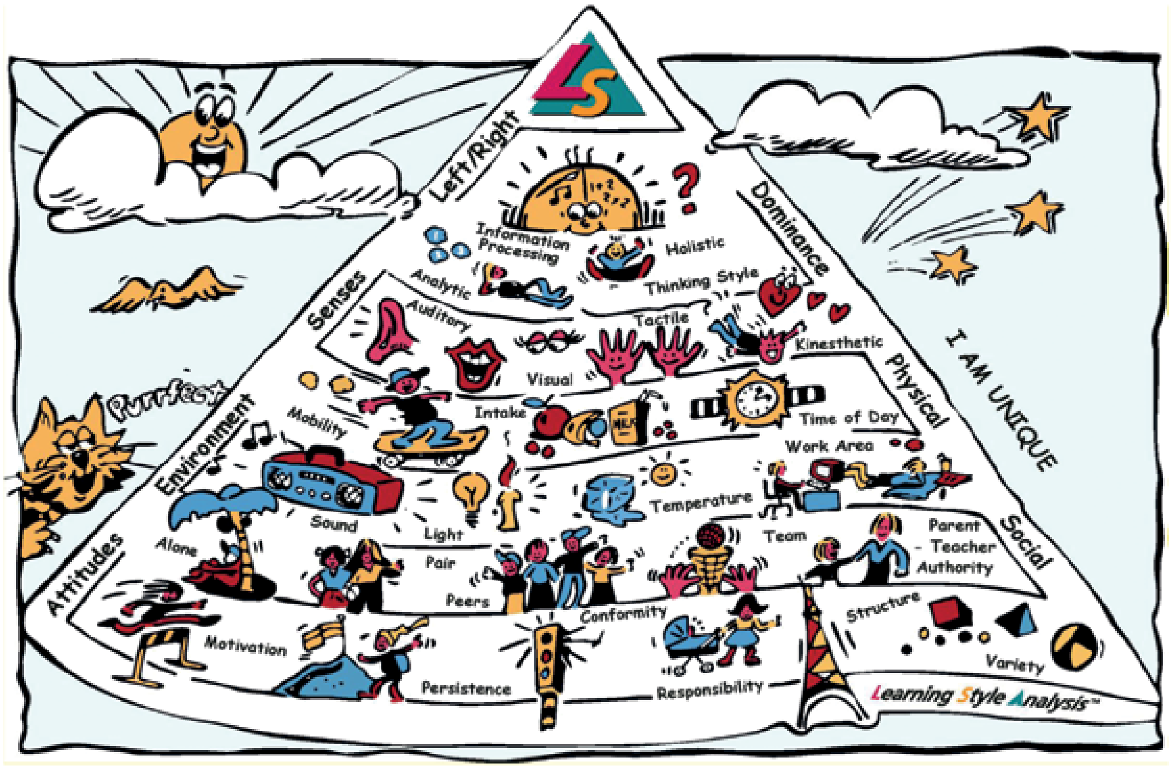
LEARNING STYLES

There is considerable research on people's different learning styles, that is, the diversity in people's preferred ways of thinking, processing and understanding information (Allen, Scheve and Nieter, 2010). Learning styles can be categorized as visual, verbal, aural, physical, logical, social or solitary. A student may have more than one learning style, with one style predominating. If the dominant learning style can be identified, teaching and learning experiences can then be tailored to the student's preferences to foster more effective learning (Overview of Learning Styles, 2016).

Understanding students' learning styles and intelligences can help teachers in determining the best strategies for raising levels of learning achievement. It can also guide teachers in designing the most appropriate teaching and learning techniques for stimulating both girls' and boys' participation and learning in STEM. An important step towards personalized learning, so that students can learn successfully and effectively in their preferred ways, is to factor in students' need for a favourable, stimulating and interesting learning environment (Department for Children, Schools and Families, 2008).

Prashnig and Dunn (2004) developed a tool, the Learning Style Analysis, which assesses a student's learning style by looking at 49 elements in six basic areas.

Figure 5.1: Learning Style Analysis (LSA) Pyramid Mode



Source: Prashnig (n.d.).

a. Left/Right Brain Dominance:

- Sequential or simultaneous brain processing strategies
- Reflective or impulsive thinking styles
- Overall analytic or holistic/global learning styles

b. Sensory Modalities:

- Auditory (hearing, talking, inner dialogue)
- Visual (reading, seeing, visualizing)
- Tactile (manipulating, touching)
- Kinesthetic (doing, feeling)

c. Physical Needs:

- Mobility (preferences for moving or being stationary)
- Intake (eating, nibbling, drinking, chewing, etc.)
- Time of day preferences (personal bio-rhythm)

d. Environment:

- Sound (needing music/sound or wanting it quiet)
- Light (needing bright or dim lighting)
- Temperature (needing cool or warm)
- Work area (wanting formal or informal/comfortable design)

e. Social Groupings:

- Working alone, in a pair, with peers, or in a team
- Authority (wanting to learn with a teacher or a parent)

f. Attitudes:

- Motivation (internally or externally motivated for learning)
- Persistence (high, fluctuating, or low)
- Conformity (conforming or non-conforming/rebellious)
- Structure (being self-directed or needing directions, guidance from others)
- Variety (needing routine or changes/variety)

The first four areas consist of natural characteristics (that is, biologically or genetically determined) that are relatively immutable and enduring; accommodating to these characteristics will support successful learning. The final two areas are conditioned or learned elements that are less fixed and more amenable to change for effective learning (Sternberg, Zhang and Rayner, 2011). Identifying students' preferred modes of learning from this analysis can be the catalyst for improving their academic performance. At the same time, students can be helped to minimize or avoid the use of their non-preferred modes so that learning is not hindered.

MULTIPLE INTELLIGENCES

Gardner's (1999) Multiple Intelligences (MI), determined through lengthy research and observation, is an 8-part typology of human intelligences with consequences for learning and teaching.

a. **Verbal-linguistic:** the capacity to use language, as used in reading, writing, telling stories, memorizing dates, and thinking in words.

b. **Logical-mathematical:** the capacity for understanding cause and effect, and for manipulating numbers, quantities and operations, as used in math, reasoning, logic, problem solving, and recognizing patterns.

c. **Spatial-visual:** the capacity for representing the spatial world internally in one's mind, as used in reading maps and charts, drawing, solving mazes and puzzles, imagining and visualizing.

d. **Bodily-kinesthetic:** the capacity for using one's whole body or parts of the body, as used in athletics, dancing, acting, crafting, and using tools.

e. **Musical:** the capacity for thinking in music; for hearing, recognizing, and remembering patterns, as used in singing, identifying sounds, and in remembering melodies and rhythms.

f. **Interpersonal:** the capacity for working with others, as used in understanding people, leading and organizing others, communicating, resolving conflicts, and selling.

g. **Intrapersonal:** the capacity for understanding ourselves, as used in knowing the self, recognizing one's own strengths and weaknesses, and setting personal goals.

h. **Naturalistic:** the capacity for discriminating among plants, animals, rocks, and the world around us, as used in understanding nature, making distinctions, identifying flora and fauna.

Focus of the activity

This activity and the suggested tasks will help participants to gain a better understanding of the types of learning materials that support different learning styles. Supporting different learning styles in STEM lessons can help ensure that girls' opportunities to enjoy and do well in STEM education will equal those of boys.

TASK 1: Individual reflection

a. Read the papers, 'Howard Gardner's Theory of Multiple Intelligences' (Northern Illinois University, 2016); 'Debating Learning Styles. Creative Learning System' (Prashig, n.d.); and 'Learning Styles vs. Multiple Intelligences (MI): Two Concepts for Enhancing Learning and Teaching' (Prashnig, 2009).

b. Outline the key concepts in Prashnig (2004) six basic learning style areas and Gardner's eight types of intelligences (Gardner, 1999).

c. In what ways are they similar or different?

d. How can developers of STEM materials use information on learning styles to ensure that learning materials will be appropriate, enjoyable and accessible for all children?

Product

Responsiveness of STEM materials to children's different learning needs

ACTIVITY 3

Personalized learning

Emerging technological advances and globalization increase the importance of lifelong learning to guarantee that people have opportunities to stay current with skills and changes in knowledge; this is essential for developing a better-quality labour force (Ghebllawi, Norlia and Jamil, 2011). These trends, in turn, establish the need for personalized and flexible learning without constraints of time and place (Hummel, Manderveld, Tattersall and Koper, 2004). Teachers can personalize their instruction and methods of assessment by taking their students' different intelligences and potentials into consideration (Northern Illinois University, 2016).

UNESCO (2012a) defines personalized learning as 'a methodology, according to which teaching and learning are focused on the needs and abilities of individual learners within classroom groups supervised by the teacher' (p. 3). According to West-Burnham (2010), 'personalizing learning is a strategy focusing all of a school's resources to ensure that the potential of each learner is realized by ensuring that the learning experience is appropriate to them personally and that they are able, with support, to decide what they learn, how they learn, when they learn and who they learn with' (p. 11). These definitions affirm that the goal of personalized learning is to provide quality learning for every child. Further, it provides the means fort sustaining excellence and moving towards equity (West-Burnham, 2010). Personalized learning provides each child with an opportunity to succeed, regardless of his or her socio-economic background, gender, ethnicity or disability (Department for Children, Schools and Families, 2008).

Bray and McClaskey (2013) characterize students who practise personalized learning as those who:

- Know how they learn best
- Self-direct and self-regulate their learning
- Design their own learning path
- Have a voice and choice about their learning
- Co-design their curriculum and learning environment
- Are able to learn any time and anywhere
- Have high-quality teachers who are partners in learning
- Use a competency-based model to demonstrate mastery
- Are motivated and engaged in the learning process

For successful personalized learning, and to ensure that both girls and boys receive good-quality STEM education, school leaders and teachers will need to develop strategies that build involvement and commitment from parents and from the community in general.

Focus of the activity

This activity and the suggested tasks will help the participants to gain insight about the challenges in implementing personalized learning, and to find solutions appropriate to their specific context.

TASK 1: Individual assignment

Complete the table below to review the extent to which your country's schools and teachers promote personalized learning.

Table 5.1: Checklist to review schools and teachers for personalized learning

ISSUE	STATUS	PROPOSED ACTION
Do teachers practice student-centred learning? Do they encourage both female and male students to talk, to explain or ask questions?		
Do teachers support self-accessed and self-paced learning?		
Is there strong co-operation between teachers and parents, communities, NGOs?		
Do teachers of different subjects collaborate to produce rich projects/problems/tasks for both their female and male students?		
Are there strong, visionary school leaders who are willing to promote and invest in personalized learning for students?		
Are there adequate school regulations, pre-/in-service teacher trainings, instructional materials, school infrastructures and the availability and regulation of funds that promote personalized learning?		
Are resources readily available for both female and male students (for example, computer rooms, libraries, etc.)? Are they well-equipped and maintained? Do both female and male students have access to these resources at any time?		

TASK 2: Work in small groups

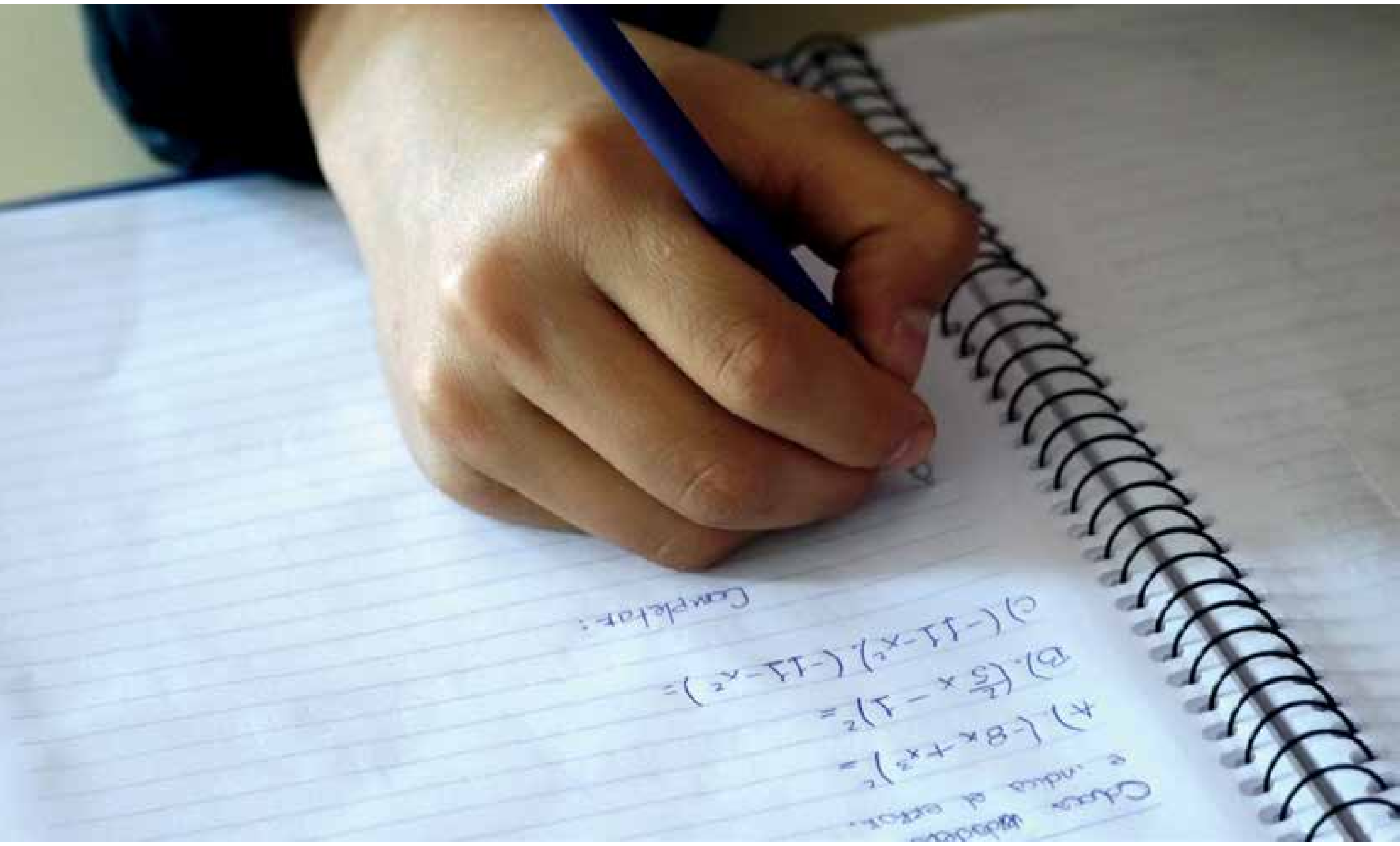
a. Identify strengths, weaknesses, opportunities and challenges for practising personalized learning in schools in your country.

b. Do the instructional materials in your country promote the adoption of personalized learning?

c. Discuss some of the ways you can foster the adoption of personalized learning through the design of appropriate instructional materials. Furthermore, identify ways in which personalized learning contributes to girls' increased participation in STEM.

Product

Ways of fostering the adoption of personalized learning through the design of appropriate instructional materials



ACTIVITY 4

Resources that promote gender-responsive STEM education

An evidence-based approach supports the development of quality, gender-sensitive STEM resource materials. Figure 5.2 provides a model of necessary evidence-based procedures in producing such resources.

Figure 5.2: The process of developing STEM resources

Source: CDD MOE Malaysia (2014).

a. *Needs Analysis:* The learning needs, learning styles and other important characteristics of the target group of both female and male students need to be well analysed and defined. The data are collected from all the relevant stakeholders, including learners, teachers and school administrators.

b. *Conceptualization of Modules:*

- The Ministry of Education (MOE)'s project team determines the objectives and the specification of the STEM modules. Experts in science, technology, engineering and/or mathematics then explore the theoretical framework of the STEM approach and the principles underpinning the approach. The MOE authority subsequently approves the objectives and the specifications of the STEM modules, and the principles and theoretical framework.

- A steering committee, a panel of writers and a technical committee are established. The steering committee consists of experts from the fields of science, technology, engineering and mathematics, and experts in gender. Their role is to manage and monitor the development of the modules. They are part of the team who draft and approve the objectives and specifications of the STEM modules. The panel of writers are experts in STEM content and pedagogy: they write the modules. The technical committee is responsible for making sure that the modules are developed according to the specifications approved by the steering committee. They confirm that the quality of the modules is aligned with the STEM approach and the STEM principles approved in the needs analysis; they are independent of the steering committee and the panel of writers.

c. *Writing Workshop:* The panel of writers drafts the modules based on the specifications outlined by the steering committee within the specified timeframe.

d. *Technical and Content Evaluation***:** The technical committee evaluates and edits the first draft of the modules; the gender expert ensures that all the materials are gender sensitive.

e. *Piloting in Schools:* Each module is piloted in selected schools to guarantee its quality and its freedom from any errors. A crucial element of this process is assuring that the modules are gender sensitive and are meeting the needs of all students, both girls and boys.

f. *Final Editing based on Feedback of Piloting:* Based on the feedback from the pilot, the modules are improved, and readied for validation by the subject and pedagogical experts in the technical committee.

g. *Publishing the Modules:* The steering committee is responsible for publishing the final drafts of the modules either in hard copies or uploaded in gazetted websites.

OUTLINE OF QUALITY STEM TEACHING AND LEARNING RESOURCES

STEM teaching and learning resources should be comprehensive, self-explanatory and self-evaluative as well as motivating. The following is a proposed outline of quality STEM teaching and learning resources.

1) Overview

The Overview provides a summary of the content and the flow of activities throughout the whole module. It is designed to help teachers understand the resources and carry out the lessons more effectively, ensuring the principles of gender equality in the teaching and learning process. Teachers are advised to go through the Resource Overview before conducting the T&L. The Overview's content includes the knowledge to be imparted, the skills to be developed and the pedagogical approaches, including gender-responsive pedagogy.

2) Teaching Guide

The Teaching Guide is designed to provide teachers with ideas on processes that they can adopt or adapt to conduct the lessons based on the learning standards. The Guide includes comprehensive guidelines for conducting learning activities that are gender sensitive, questions to be asked to stimulate critical thinking and reflection among girls and boys, answers to the questions, points to be emphasized and highlighted, and alternative strategies teachers could use if they do not have the equipment required.

3) PowerPoint/ Prezi Presentation (optional)

The PowerPoint or Prezi presentations are designed to stimulate and engage all students, both girls and boys, to achieve the intended learning outcomes. When using this resource, the teacher can start the lesson by introducing the content through video clips. Presentations in PowerPoint or Prezi are the key points, and display important knowledge pertinent to the topics concerned. Presentations provide the visual and auditory representations that students with diverse learning styles need. Using these presentation slides, teachers can navigate among the points with ease.

4) Students' Worksheets (optional)

The Students' Worksheets are designed to engage girls and boys equally, and support their learning through exposure to real-life and meaningful contexts. The activity sheets introduce the scenarios and engage girls and boys in questions to enhance their understanding. The sheets ask students to conduct a range of activities: to collect, organize, analyse and interpret data; to make and verify conjectures; to carry out scientific and mathematical investigations or explorations to solve problems; and, to communicate the outcomes of their inquiry or investigation along with their solutions to the problems. Students can also carry out peer assessments to help them evaluate and review their inquiries and their performance in solving problems collaboratively.

5) Assessments

Assessment tasks complement the teaching and learning resources. Differentiated assessment tasks and questions are adapted to students' different backgrounds, and their differing levels of ability and prior achievement. Any data generated should be sex-disaggregated in order to assess whether the learning needs of girls and boys are being met equally.

6) Interactive teaching resources (optional)

Interactive resources are designed to engage all students in activities related to the modules' content. A range of styles is used across the modules to stimulate the unique interests of girls and boys, and to encourage active interaction and learning. A major advantage of interactive resources is that students can learn on their own and at their own pace. They also facilitate self-reflection and metacognition. Interactive teaching resources can take the form of programmed learning or digital learning.

7) Videos (optional)

Relevant, quality videos have the potential to stimulate interest and engage all students in rigorous discussions. Videos help to link content to context, thus enabling both girls and boys to make connections between the content in the lessons and real-life situations. Additionally, videos can be used as an access point for students to ensure that all have the necessary background knowledge to engage with the content.

8) Pre-tests and Post-tests (optional)

Pre-tests and post-tests are simple assessments of students' understanding of the lessons in each module. They help teachers to track students' progress and the change in students' understanding, and to gauge the module's impact; they also provide input for further improving the modules. All data collected must be disaggregated by sex to ensure that girls' and boys' learning needs are being met equally. In addition to content-specific information in pre- and post-tests, teachers can incorporate questions to assess students' engagement with STEM and self-confidence in the content areas. Refer to Table 5.2 below for examples of questions to identify students' self-perception.

Table 5.2: Student self-concept regarding science abilities

Is learning advanced school science topics easy for you?	1·······2·······3·······4·······5·······6·······7·······8·······9·······10
Can you usually give good answers to test questions on school science topics?	1·······2·······3·······4·······5·······6·······7·······8·······9·······10
Do you learn school science topics quickly?	1·······2·······3·······4·······5·······6·······7·······8·······9·······10
Are school science topics easy for you?	1·······2·······3·······4·······5·······6·······7·······8·······9·······10
When you are being taught school science, do you understand the concepts very well?	1·······2·······3·······4·······5·······6·······7·······8·······9·······10
Do you easily understand new ideas in school science?	1·······2·······3·······4·······5·······6·······7·······8·······9·······10

Source: Adapted from OECD (2015).

Focus of the activity

This activity and the suggested tasks will enable the participants to gain understanding of how to develop or use gender-sensitive STEM resources.

TASK 1: Work in small groups and a plenary discussion

a. Describe the process of developing gender-sensitive STEM resources in your country.

b. Discuss how the process can be improved to make it more effective and efficient.

c. Share your responses in the plenary.

TASK 2: Work in small groups

Prepare a proposal on how to improve the process of developing gender-sensitive STEM resources in your country. Include in this proposal the framework of philosophies/principles/ practices for the content and pedagogy of the proposed teaching and learning resources.

Product

Proposal on how to improve the process of developing gender-sensitive STEM resources

ACTIVITY 5

Digital resources for personalized learning

Personalized learning is based on the strategy of making students accountable and collectively responsible for determining their own learning priorities. The students are given opportunities to access different teaching and learning approaches and resources that meet their needs (Green et al., 2005). Personalized learning challenges teachers and educators to explore innovative resources and make them available to students to support their learning (Bolstad et al., 2012).

The digital age has transformed the way students learn in the twenty-first century. Most students welcome the use of ICT and digital information tools as exciting and interesting alternative resources that help them personalize learning. UNESCO (2012a) outlines the following evidence-based advantages of ICT in learning:

- ICTs can present content in an engaging and attractive form
- ICTs help teachers record and monitor each student's progress regularly
- ICTs allow customized delivery of relevant education material to each individual learner
- ICTs can build virtual social communities among different educational institutions, and teams of students or teachers
- ICTs facilitate learning-to-learn skills
- The latest innovations in ICTs (for instance, mobile tools and cloud solutions) make it possible to implement continuous learning strategies in different learning contexts and to provide on-demand support to students.

Technology in general, and ICT in particular, plays a vital role in the current era of globalization; its contribution to the education system is thus large. Adopting technology can enhance the teaching and learning process by enabling students to access a wider range of content that is engaging and interactive, and to learn at their own pace. Additionally, by actively incorporating technology in the classroom, students who did not have previous exposure or experience with ICT, who are often female, poor and rural, can begin to gain necessary skills (UN, 2012; Antonio and Tuffley, 2014). Technology also broadens study options through an e-learning platform which gives teachers access to both national and international learning resources and communities. A virtual learning environment (VLE) is one example of how technology supports curriculum and assessment. Learning activities and quizzes are uploaded in the cloud system and students are able to access them online. Student performances can also be tracked through online assessment.

There are currently many resources available online that support personalized learning. Teachers can use these resources or adapt them to suit their students' needs. The World Wide Web (WWW) also offers websites that help teachers develop their own resources to suit students' needs. Besides developing a website, teachers can record their lessons and upload videos online on Web 2.0 sites. In the era of Web 2.0, students can play an active role in determining the type of contextual, social and task support they need to set learning goals and create learning environments best suited to meet their learning needs (McLoughlin and Lee, 2009). Whenever they have an internet connection, and with the use of Web 2.0 tools and social networks, students can: access live lessons from almost anywhere, at any time; search for archived lessons; discuss ideas and issues; and, post questions to their teachers, peers or other experts and collaborators beyond their own classrooms. Teachers can use the learning management system (LMS) to automatically assess their students' progress and learning achievements.

Focus of the activity

This activity and the suggested tasks will help participants understand the role of digital resources in promoting personalized learning in gender-responsive STEM education.

TASK 1: Work in small groups

a. Access the resources below and describe how they can be used in your country to promote gender-responsive STEM education.
- 'Tools for Ambitious Science Teaching' (n.d.).
- 'DiscoverE' (2017).

b. What challenges does the use of web-based resources pose for promoting gender-responsive STEM education in your country?

c. What solutions would you recommend for addressing challenges identified in (b)?

Product

Understanding of how to use/incorporate web-based resources in promoting gender-responsive STEM education

TASK 2: Work in pairs

a. Access the resources below and then carry out the tasks that follow in pairs.
- 'Engineering, Go For it! [eGFI]' (2013)
- 'Engineer Your Life' (n.d.)
- 'Alice Project' (2017)
- '1Bestarinet' (2012)
- 'Frog Asia' (2016)

b. Analyse the content in the websites and identify at least three ways in which teachers can use the sites when they prepare and deliver gender-responsive STEM education.

c. Choose one learning area in STEM and prepare a lesson plan using one or more of the websites.

Product

Lesson plan using online STEM resources

TASK 3: Individual assignment

a. Read the two articles, 'Why You Should Use a Virtual Learning Environment' (BBC Active 2010) and 'Learn About Virtual Learning Environment/ Course Management System Content' (Oxford University Press, 2016).

b. Access Malaysia's resources, '1Bestarinet' (2012) and 'Frog Asia' (2016) mentioned in Task 2 and explore.

c. Reflect on Malaysia's experience, discuss your schools' readiness to participate in a Virtual Learning Environment (VLE).

d. Prepare a timetable for a one-day capacity-building session for teachers in your school on how to use web-based STEM resources effectively taking into consideration the principals of gender equality.

Product

Timetable for a one-day capacity-building session for teachers on how to use web-based STEM resources effectively, bearing in mind the principles of gender equality

TASK 4: Work in small groups

a. Read the following: 'Personalized Learning Roadmap' (Fulton Country Schools, 2015) 'Three things teachers and leaders do to personalize learning' (Creel, 2016); 'Beyond the Classroom: A New Digital Education for Young Australians in the 21st Century' (Digital Education Advisory Group, n.d.); and 'The Smart School Roadmap 2005-2020: An Educational Odyssey for October 2005: A Consultative Paper on the Expansion of the Smart School Initiative to All Schools In Malaysia' (Multimedia Development Cooperation, 2005).

b. Develop a roadmap to implement personalized learning for girls and boys in your country using digital resources, taking into consideration the availability of funds, infrastructure and government, the community and stakeholders. For more reference and guidance, you can revisit the reading materials above.

Product

Roadmap, using digital resources, on implementing personalized learning for girls and boys

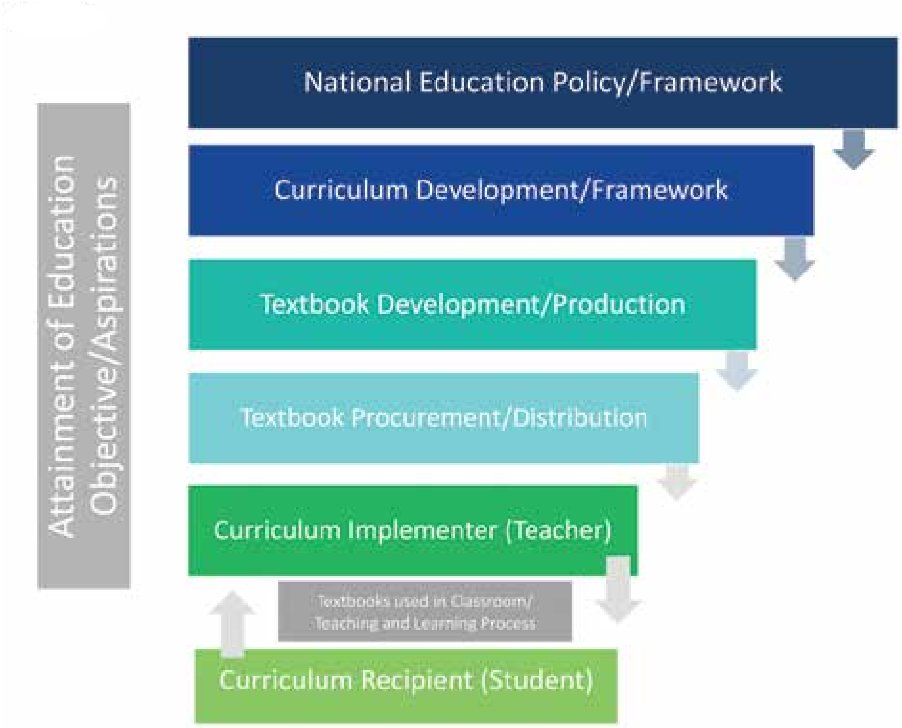
ACTIVITY 6

Developing STEM-related textbooks that reflect the principles of gender equality

Textbooks are one of the physical manifestations of a curriculum to aid students' comprehension of the material. Textbooks also act as tools for teachers to design and guide their lesson plans and classroom activities (Schmidt, McKnight and Raizen, 1997). Abramson (2002; in Cummins-Colburn, 2007) stated that 80% of learning in a classroom derives from textbooks. Recognizing the importance of textbooks, UNESCO has published a guidebook on textbook research and textbook revision (Pingel, 2010) to help those involved in textbook development.

Brugeilles and Cromer (2009) state that textbooks do not only transmit knowledge but also serve as platforms for social change. Children see their surroundings and the world through the lenses of the textbooks. The experience of engaging with textbooks can shape children's views of society and the world, including their views about gender. It is thus important to ensure that textbooks are gender-sensitive and have balanced perspectives on social and cultural values, and on universal values such as gender equality. To ensure that textbooks are gender sensitive, they must be free from gender stereotyping and gender-related bias in all text and illustrations. Figure 5.3 shows how textbooks bridge the relationship among national aspirations, curriculum, teachers and students.

Figure 5.3: Relationship among education policy, curriculum, textbooks and the teaching and learning process



Source: Shaiful H, A.H. (2008).

SEX AND GENDER

As the earlier modules emphasized, it is important to note the difference between sex and gender. UNESCO (n.d.) provides the following definitions:

a. *Sex* describes the *biological differences* between men and women, which are universal and determined at birth

b. *Gender* refers to the roles and responsibilities of men and women that are created in our families, societies and our cultures. The concept of gender also includes the expectations held about the characteristics, aptitudes and likely behaviours of both women and men (that is, about femaleness and maleness). Gender roles and expectations are learned. They can change over time and vary within and between cultures. Gender is not biologically predetermined nor is it fixed permanently but can be changed.

It is the task, not only of textbooks writers, but also those who are involved directly or indirectly in developing and using textbooks, to make sure that textbooks are gender sensitive and adhere to the principles of gender equality.

DEVELOPING GENDER-SENSITIVE TEXTBOOKS

There are various approaches or platforms for developing textbooks for schools, ranging from buying off-the-shelf books to developing them in-house. No matter how textbooks are produced, all textbooks used in schools should be gender sensitive. Guidelines need to be developed to help schools or textbooks evaluators ensure that texts and illustrations in manuscripts or books are gender-sensitive. These evaluations should form the basis of decisions or recommendations about whether or not manuscripts or books are suitable, before they are printed and/or distributed to students. UNESCO has produced comprehensive guidelines and papers on gender bias and stereotyping in textbooks that could be used as a reference by textbooks developers, policy makers, curriculum developers, teacher educators, teachers or any other stakeholders.

ANALYSING GENDER SENSITIVITY IN TEXTBOOKS

To ensure that textbooks are gender sensitive, various features of the books, including pictures/illustrations, text, and activities/exercises should be evaluated. The evaluation can be carried out in two stages.

The first stage should determine whether females and males are represented equally and with equal frequency in the text and in illustrations. The second stage considers how males and females are portrayed or depicted in the textbook. For example, which jobs are men and women presented as doing? Which activities are shown as relevant to girls' and boys' interests?

The following questions can be a guide to determining the level of gender sensitivity in textbooks.

a. Pictures/Illustrations

- Are there an equal number of boys and girls, men and women, represented in the pictures/illustrations?
- What kinds of tasks are the boys and girls, or men and women, doing in the illustrations?
- How are the boys and girls, or men and women, portrayed?
- Are there any incidences of gender stereotyping?

b. Text

- Are names/pronouns of boys and girls mentioned in the text? What is the percentage for each sex?
- Are there any elements of bias in the text that favour one sex over the other?

c. Activity/Exercise

- Are names/pronouns used in the activity/exercise? What is the relative percentage of references to men and women?
- Are the activities/exercises suitable for both boys and girls?

Focus of the activity

This activity and the suggested tasks will promote better understanding of the principles of developing gender-sensitive STEM teaching and learning resources.

TASK 1: Work in pairs

a. Read the paper 'The invisible obstacle to educational equality: gender bias in textbooks' (Blumberg, 2009), and 'Textbooks pave the way to sustainable development' (UNESCO, 2016).

b. Discuss how gender inequality is constructed and prominent in textbooks and reflect on your countries' textbooks.

TASK 2: Work in small groups

a. Identify some instructional materials, including textbooks in STEM, from your country.

b. Evaluate the pictures/illustrations, text, activities, and exercises contained in these materials to identify any gender stereotyping or gender-related bias.

c. Use the sample evaluation templates in Appendix 5.1 for the evaluation. These templates can be used to summarize the information gathered from this activity.

d. What are the impacts of textbooks, which include gender stereotyping, or gender-related bias?

e. Suggest ways in which any pictures/illustrations, text, activities and exercises can be improved in order to ensure that the resources are gender sensitive and promote gender equality in STEM.

Product

Suggestions on how instructional materials, including textbooks, can be improved to help ensure that all STEM teaching and learning resources are gender sensitive

TASK 3: Individual reflection

Read the following articles, 'UNESCO Guidebook on Textbook Research and Textbook Revision (2nd edition)' (Pingel, 2010); 'Gender in Education Network in Asia-Pacific (GENIA) Toolkit: Promoting Gender Equality in Education' (UNESCO, 2009); and 'Promoting Gender Equality through Textbooks: A Methodological Guide' (Brugeilles and Cromer, 2009).

TASK 4: Work in small groups

Develop a national guideline for producing a textbook in your country by reflecting on the research from previous tasks demonstrating gender stereotyping and bias in textbooks and incorporate the requirements for gender-sensitive STEM resources into this guideline.

Product

National guideline for producing a gender-sensitive textbook

ACTIVITY 7

Setting up a gender-friendly inquiry-based learning space for STEM education

The STEM field comprises evidence-based disciplines that require students to explore and conduct hands-on activities. Successful STEM programmes dedicate space where students can gather to carry out scientific investigation or work on a project, both individually and collaboratively. Teachers also need this learning space to store equipment. Whether a science laboratory, computer laboratory, engineering workshop or technology workshop, the space serves as an icon for STEM learning. More informally, the space may be referred to as a science room, computer room or exploration corner. However designated, these learning spaces can either serve to highlight the importance of STEM and to arouse students' interest and curiosity or they can deter students from participating and further increase feelings of self-consciousness. It is necessary to consider the physical classroom space as another opportunity for promoting gender equality in the classroom.

Blosser's (1990) meta-analysis showed that an effective science classroom is one in which students have opportunities to interact physically with instructional materials and engage in various kinds of activities. For example, the theoretical concepts and relationships introduced in physics lessons describe the general nature and behaviour of phenomena. However, students need to discover them through careful observation and thoughtful analysis by engaging in actual hands-on experiments. In other words, all physical concepts must be verified experimentally if they are to be accepted as representing the laws of nature. This makes a science laboratory an essential part of science teaching and learning.

In STEM learning spaces, the classroom environment, both physical and social, can impact student achievement. However, many schools and governments face financial barriers to implementing structural changes. Within contextual and budget constraints, teachers and school administrators have an opportunity to think critically about classroom design and layout that is cost effective. All students, girls and boys, perform best when the intellectual leaders and scientists visible in the learning space, and when classroom artifacts and decorations, represent classroom demographics. For example, female students in computer science classrooms have been recorded as performing at higher levels when representations of female role models are present in the classroom and the classroom has a gender-sensitive design. Additionally, a survey of nine hundred college students indicated that female students felt most comfortable in classrooms with collaborative working spaces and clustered desks. In this way, the simple use of a new classroom design or layout, without immense budget allocations, can begin to dismantle gender biases and stereotypes regarding the roles of men and women, and can encourage all students to pursue careers in STEM (Cheryan, Ziegler, Plaut and Meltzoff, 2014).

Generally, the goals of STEM laboratories are:

- **a.** To provide a place for students to explore or verify the experimental foundation of theoretical concepts
- **b.** To familiarize students with and engage them in the inductive and deductive process of scientific procedures, experimental apparatus, data collection, and data analysis
- **c.** To expose students to hands-on experimentation and innovation, dealing with experimental uncertainties and with experimental errors
- **d.** To provide students with the knowledge and skills to write technical reports, which communicate scientific information clearly and concisely
- **e.** To provide students with equal opportunities to practice STEM skills (for example, computing skills or engineering skills) in learning spaces that are gender sensitive.

Inherent in these goals is the philosophy that practice is essential to being able to make connections between theory and knowledge. For an inquiry-based learning space to be gender-sensitive, it must be equally accessible, relevant and interesting for both girls and boys.

DESIGNING A STEM LEARNING SPACE THAT IS GENDER SENSITIVE

There is no single, uniform design for a STEM laboratory/workshop/room to meet the requirements of a school curriculum. There are, however, several principles that can assist in designing these learning spaces or for improvising existing rooms to be more gender sensitive. These principles are:

- **a.** Functionality
- **b.** Flexibility
- **c.** Safety
- **d.** Sustainability

Since different grades require different rooms and access to different equipment, the needs of the students and the needs of the disciplines/subjects must be considered when designing school science rooms and laboratories. Commonly, the most practical form of school science space is the combined classroom and laboratory, a space where students can receive teacher-led instruction and have hands-on experience. For example, this might be a space where students receive teacher-led instruction while facing a board or elevated table on which the teacher can demonstrate the use of scientific apparatus, and where students can also do hands-on experiments with laboratory equipment located around the sides and at the back of the room. Creating flexible and responsive classrooms and laboratories ensures that all students' needs are considered.

a. Principle 1: Functionality

A STEM learning space can be a simple room or a more structured laboratory. There are several basic features of these learning spaces.

(i) Student work area:

- Adequate lab counters or tables designed for all students to use
- Located in a position that gives the students a good view of the teacher or demonstration area
- Generally equipped with basic laboratory equipment, including electrical fixtures, sinks and storage cabinets
- Movable modular lab counters or tables in case extra free space is needed for other activities. Note that electrical fixtures and sinks will have to be positioned elsewhere

(ii) Teacher work/demonstration area:

- Ample space for the teacher to work
- Positioned so that all students can easily see a demonstration

(iii) Preparation room:

- An area where materials such as specimens, chemicals, tools and equipment will be stored out of reach of students
- Refrigerator and cabinets to store perishable specimens and common equipment
- Preparation workplace/table with sink for teacher/lab assistant to prepare equipment and materials prior to conducting demonstrations or experiments
- Water distiller to collect and supply distilled water for students/teacher experiments/demonstrations

(iv) Storage room

- Located in the preparation area to store chemicals and expensive equipment safely and out of reach of students
- Cabinets to keep dangerous materials separate
- Secure and lockable; note that the key should be kept with the teacher or lab assistant at all times.
- Good ventilation system

b. Principle 2: Flexibility

Traditional science laboratories are built with heavy tables and chairs, and with sinks attached to the tables. In such laboratories, the use of the space becomes very rigid. Modular tables may make the space more useful and flexible in that they can be rearranged easily, thus promoting collaboration and opportunities for all students to share their thinking. Movable sinks can be installed and electrical fixtures can be located on the floor or at the side of the room. A functional STEM learning space allows for individual work as well as collaborative work.

c. Principle 3: Safety

Safety concerns must be paramount when conducting STEM activities. The following safety features need to be part of the plan when designing STEM learning spaces:

(i) Floors: Specialized flooring must meet the standards outlined by government legislation regarding safety and durability

(ii) First aid kit: An essential and legal requirement for all school science labs and rooms

(iii) Labs/rooms where chemistry experiments take place need a shower and eye-wash facility in case of chemical accidents

(iv) Fire Safety

- At least one ABC extinguisher easily accessible to the teacher and students
- A fire alarm outside the lab

(v) Fume extractor: A fume extractor cupboard or system is essential in all labs where chemicals are used

(vi) Emergency exits

- At least two exits: front and back of the room
- Aisles need to remain clear so that there is a clear path out

d. Principle 4: Sustainability

Plans for STEM learning spaces, whether school laboratories or technical workshops, must address issues of long-term educational, environmental and structural (that is, physical) sustainability. STEM learning spaces need to maintain viability for sustained and continual re-use over many years without creating environmental problems or future negative ramifications. In planning for a durable and sustainable learning space, important questions include these:

- Does the learning space support the current needs of STEM education and has it been planned for any possible future needs? (Educational sustainability)
- Does the learning space adhere to environmentally friendly principles, such as the use of natural light, ventilation, management of chemicals, water and waste? (Environmental sustainability)
- Does the learning space comply with legislative requirements in terms of physical/structural viability? (Structural sustainability)
- Has future expansion or renovation been considered? (Structural sustainability)

Focus of the activity

This activity and the suggested tasks will promote better understanding of developing gender-sensitive STEM learning spaces for all students.

TASK 1: Work in small groups

a. Describe the most common features of STEM learning spaces in your country.

b. How do they support or hinder the promotion of gender-responsive STEM education in your country? For example, are they equally accessible, relevant and interesting for both girls and boys?

c. What are some of the strategies that could be used to create effective STEM learning spaces in your country that are cost effective and at the same time promote gender-responsive STEM education?

Product

Strategies to create effective STEM learning spaces that are cost effective and at the same time promote gender-responsive STEM education

TASK 2: Work in small groups

a. Design and draw a plan for a STEM room to suit the needs of the STEM curriculum and the students in your school, bearing in mind the basic features, including those concerned with health and safety, which are considered essential for STEM rooms.

b. Present your proposed science classroom/laboratory to other groups.

c. Mount the plan on the wall for other groups to view.

d. Read the article 'Design physical space that has broad appeal (Case Study 1): Affecting women's entry and persistence in computing through physical space' (Cohoon, 2011).

e. After reading Cohoon (2011), identify useful feedback to improve the room designs of other groups.

f. Take a gallery walk and provide feedback to other groups on their designs.

Product

Plan of a STEM classroom

TASK 3: Individual assignment

Find three designs of STEM laboratories and comment on their suitability for your country.

MODULE 5

TAKE-AWAY POINTS

This module has outlined the importance of developing gender-sensitive resources for use in gender-responsive STEM education. These are two key recommendations:

1. Ensure that all STEM-related resources adhere to the principles of gender equality and do not reinforce or exacerbate existing gender inequalities in STEM-related fields.

2. Ensure that all STEM-related resources are designed to meet the needs and interests of both the girls and the boys who will be using them.

READING LIST

- Howard Gardner's Theory of Multiple Intelligences (Northern Illinois University, 2016)
- Debating Learning Styles. Creative Learning System (Prashig, n.d.)
- Learning Styles vs. Multiple Intelligences (MI): Two Concepts for Enhancing Learning and Teaching (Prashnig, 2009)
- Why You Should Use a Virtual Learning Environment (BBC Active, 2010)
- Learn about Virtual Learning Environment/Course Management System content (Oxford University Press, 2016)
- Personalized Learning Roadmap (Fulton Country Schools, 2015)
- Three Things Teachers and Leaders Do to Personalize Learning. Discovery Education (Creel, 2016)
- Beyond the Classroom: A New Digital Education for Young Australians in the 21st century (Digital Education Advisory Group, n.d.)
- The Smart School Roadmap 2005-2020: An Educational Odyssey For October 2005 (Multimedia Development Cooperation, 2005)
- The invisible obstacle to educational equality: gender bias in textbooks (Blumberg, 2009)
- Textbooks pave the way to sustainable development (UNESCO, 2016)
- UNESCO Guidebook on Textbook Research and Textbook Revision, 2nd edn, (Pingel, 2010)
- Gender in Education Network in Asia-Pacific (GENIA) Toolkit: Promoting Gender Equality in Education (UNESCO, 2009)
- Promoting Gender Equality Through Textbooks: A Methodological Guide. (Brugeilles and Cromer, 2009)
- Design physical space that has broad appeal (Case Study 1): Affecting women's entry and persistence in wcomputing through physical space (NCWIT, 2011)

APPENDIX 5.1

Sample Template 1: Analysing Gender Parity Index (GPI)

Textbook Title: ....

Publisher: ....

Page Number	Pictures/ Illustrations		Page Number	Text		Page Number	Activity/Exercise	
	No. Male	No. Female		No. Male	No. Female		No. Male	No. Female
4	1	2						
6	2	0						
12	2	1						
13	0	2						
35	3	0						
121	1	0						
133	1	1						
Total	10	6						
Grand Total	16							
% of Grand Total	62.50%	37.50%						
GPI	0.6							

Sample Template 2: Analysis of pictures/ illustrations suitability

Textbook Title: ....

Publisher: ....

Aspect of Analysis: ....

Page Number	What type of is task assigned to		Is there stereotyping?		Decisions			Notes
	Male	Female	Yes	No	Maintain	Improvise	Change	
4	Supervisor	Housewife cooking	✔			✔		Add female supervisor
6	Doctor	Teacher	✔			✔		Add male teacher
12	Doing experiement	Watching	✔				✔	Picture of boy and girl doing experiment together
13	Cleaning the house	Cleaning the house		✔	✔			

Sample Template 3: Analysis of text suitability

Textbook Title: ....

Publisher: ....

Aspect of Analysis: ....

Page Number	Element of Bias		Decisions			Notes
	Yes	No	Maintain	Improvise	Change	
P8 L12	✔			✔		Add female name
P28 L8	✔				✔	Change text
TOTAL						

Sample Template 4: Activity suitability

Textbook Title: ....

Publisher: ....

Aspect of Analysis: ....

Page Number	Activity No	Suitability of Activity		Decisions			Notes
		Male	Female	Maintain	Improvise	Change	
4	1.2		✔			✔	Change activity
8	2.4	✔	✔	✔			
15	4.3	✔			✔		Add element suitable to female too
56	6.1	✔	✔	✔			
TOTAL	4	3	3	2	1	1	

Sample Template 5: Exercises suitability

Textbook Title: ....

Publisher: ....

Aspect of Analysis: ....

Page Number	Excercice No	Suitability of Exercise		Decisions			Notes
		Male	Female	Maintain	Improvise	Change	
9	3	✔				✔	New questions suitable to female
9	11	✔			✔		Add female name
TOTAL	2	2			1	1	

Source: Huebler (2008) and UNESCO (2012b).

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NOTES

RAISING COMMUNITY AWARENESS AND COMMITMENT TO POLICIES THAT PROMOTE GENDER-RESPONSIVE STEM EDUCATION

MODULE 6

MODULE 6

INTRODUCTION

The objective of this module is to develop educators' capacity to engage the community meaningfully in ensuring that education policies promote developing and implementing gender-responsive STEM education.

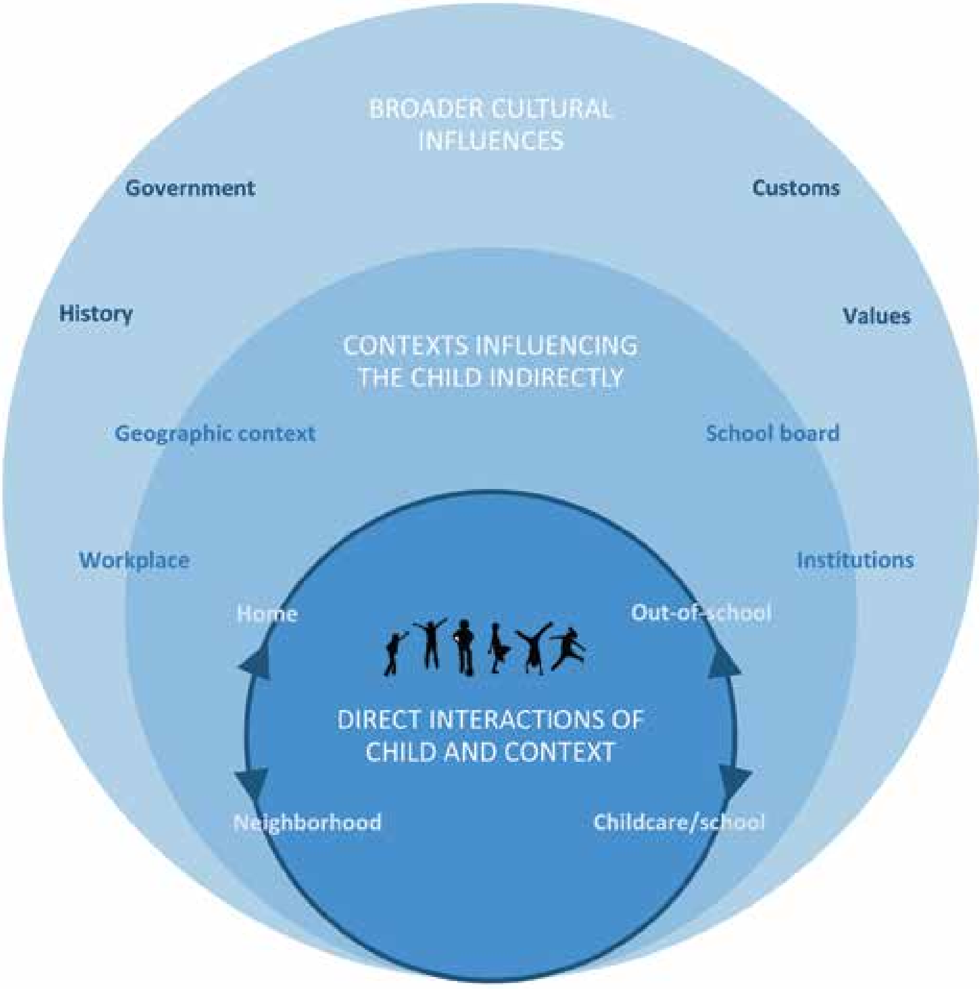
SCHOOLS AND THE COMMUNITY

Many factors influence children's knowledge, values and perspectives. Children's learning begins at birth; much of that learning happens outside the classroom as children interact with their peers, adults and significant people in the community, as Figure 6.1 below illustrates.

Schools are embedded in broad contexts that are shaped by a community's prevailing sociocultural norms. These norms contribute to shaping ideas, beliefs and practices relating to gender. They also contribute to shaping policies, politics and governance frameworks, and to shaping institutional practices and cultures. Educational environments overlap with the environments of the wider community in which they are located; as a result, gender inequities in the broader society are reflected in the school environment. For example, if a society is struggling with high rates of child marriage or with a pattern of sexual violence, these issues will also manifest in schools. When teachers and school administrators are trained in gender sensitivity and have the competencies to recognize gender inequalities, they are better equipped to play proactive roles in responding to gender-related injustices, and in making schools safe and nurturing for girls and boys alike. In turn, such responses have an effect on the community, where gender inequalities can be challenged and addressed. Thus, schools are important sites for promoting social change.

Communities can play an important role in promoting STEM education for girls and inspiring all children to excel academically. Community involvement and participation is an important element in developing appropriate and effective national and international education policies. Policy makers need to develop and utilize strategies that engage communities in developing and promoting gender equality in STEM education and STEM-related careers. Note that the process of fostering community engagement must also reflect the values and principles of gender equality. Both women and men in the community need to have opportunities to be involved; all voices must be equally valued.

Figure 6.1: Identifying and supporting productive STEM programs outside the school setting



Source: National Research Council (2015).

Awareness of the importance of STEM education for all children – both girls and boys – must be developed within the community, particularly among those in influential positions. such as community leaders or spokespeople. Commitments need to be secured from the community to be actively involved in implementing gender-sensitive policies and to support government initiatives that work towards achieving gender equality in STEM education and STEM-related careers.

Key words

Community awareness, community involvement and participation, community engagement, gender equality, stakeholders, self-confidence

ACTIVITY 1

Stakeholders in the community

The first step in engaging the community is identifying the relevant stakeholders. In this case, stakeholders can be defined as members or sectors of the community who are interested in and capable of playing a role in encouraging and facilitating the involvement of both girls and boys in STEM education. The group of participating stakeholders must itself embody the ideals of gender equality and inclusivity: it should reflect different segments of society, include women and men, and ensure that the voices and opinions of women and men are listened to and considered equally.

The following are some of the sectors/groups:

- **a.** Teachers
- **b.** Parents
- **c.** Policymakers at ministries and education departments
- **d.** Corporate organizations and local businesses
- **e.** Non-governmental organizations (NGOs) and community-based organizations (CBOs)
- **f.** Religious bodies
- **g.** Individuals and leaders who have high credibility among the public
- **h.** Professional bodies, for example, scientists, associations/societies
- **i.** Regional/ local government

Table 6.1 below elaborates on the relevant stakeholders' role and potential impact in promoting gender-responsive STEM education in schools and equal engagement of both girls and boys into STEM fields.

Table 6.1: The role and impact of each stakeholder

STAKEHOLDERS	ROLE	IMPACT
Teachers	• Impart information about gender-responsive STEM education • Act as role models in STEM subjects/ career	Create the first impression/interest in STEM. This could leave a lasting impression on children, either aversion to or inclination towards STEM.
Parents	• Character building • Shape opinion among girls and boys about their ability to do well in STEM and help give them confidence to pursue their interests, including a potential career in STEM	The upbringing of girls and boys, early childhood education and informal education, games; promote aspirations and support for children about their future careers.
Policymakers	• Develop gender-sensitive policies, strategies and modules	The results of the policies and strategies could have an impact on the country over the next 20 years or more. For example, they could translate into an increase or decline in gender equality in STEM-related careers.
Corporations	• Play a role in community development and nation building through making their workforce more gender equitable (for instance, through hiring and promoting more women). • Support activities that encourage and inspire more girls to pursue STEM related study or work, through provi-ding a variety of opportunity such as internships, corporate sponsorships or programmes with schools	Girls, alongside their male peers, will see that career opportunities in the corporate world are available. This, in turn, may raise girls' aspirations and self-belief to pursue STEM-related careers.
Non-governmental organizations (NGOs)/ Community-based organizations (CBOs)	• NGOs/CBOs that are science-based or promote gender equality could work with schools to develop attitudes and practices among staff and children that promote gender equality in STEM subjects; for example, they could raise girls' awareness, interest and involve-ment in STEM education and related careers.	Girls and boys are exposed to STEM subjects and related careers, along with the ideals of gender equality. Listening to different stakeholders exposes children to more information and different approaches, and can help strengthen their interest in STEM.

STAKEHOLDERS	ROLE	IMPACT
Religious bodies	• Religious bodies and leaders often have high levels of credibility among the public and in the community. Religious leaders can play an important role in promoting the importance of gender equality in education and the need for girls and boys to have equal opportunities in all aspects of education and throughout their schooling.	Voices from religious leaders lend support by building confidence among parents and students to actively promote gender equality in education, specifically in fields such as STEM in which women are typically under-represented.
High impact individuals	• Successful scientists or people in other STEM-related careers can play a role in promoting gender equality in STEM education. These professionals can be ambassadors for STEM, and can be role models and mentors for girls and boys. It can be particularly important for girls to see successful female role models, so both men and women scientists and professionals must be engaged with STEM education.	Listening to successful women and men who work in STEM-related jobs can create positive images among girls and boys about their abilities to pursue STEM-related careers.
Professional bodies: Scientific associations / Board of Engineers/ Nursing Associations/ Association of Pharmacists, etc.	• Professional bodies can be engaged to support ministries and departments of education through sharing experiences in STEM education and related careers. They can also play an important role as mentors for students. Schools can create a line of communication between students and professionals.	Experiences beyond the academic circles could be shared with girls and boys to create a powerful impression about STEM and its related careers. Collaboration with STEM-related professional bodies can help create a mentor-mentee relationship between professionals and students.

Focus of the activity

This activity and the suggested tasks will help participants to gain a thorough understanding of how to engage the community in developing gender-responsive STEM education.

TASK 1: Work in small groups

a. Read the papers 'Communities, gender and education: evidence from sub-Saharan Africa' (Rose, 2003) and 'Parent, Family, Community Involvement in Education' (Roekel, 2008).
b. Identify key capable stakeholders in relevant communities in your country.
c. Describe strategies that can be used to engage stakeholders in developing and implementing gender-responsive STEM education policies.
d. What challenges do you envision in engaging each of the stakeholders identified, and how could you overcome such challenges?

TASK 2: Plenary discussion

a. Discuss ways in which members of the community might reflect or counter gender disparities in STEM in your country.
b. Discuss strategies that can be used in sensitizing the community, with the goal of creating gender-responsive STEM education.

Product

Challenges in stakeholders' engagement in promoting gender-responsive STEM education and the prevailing strategies used to overcome these challenges

ACTIVITY 2

Strategies to promote gender-responsive STEM education

TEACHERS AND OTHER SCHOOL PERSONNEL

Teachers and other school personnel working at all levels of education, both women and men, must promote and nurture the values of gender equality among all children, both girls and boys. This must include active commitments to promoting gender equality and preventing forms of gender-based discrimination in STEM teaching and learning. Teachers play a central role in building character and confidence, along with imparting academic knowledge and encouraging academic excellence among students.

In many countries, the ratio of female teachers to male teachers is high, particularly at lower levels of education. If teachers themselves have anxiety or low self-confidence regarding STEM subjects, students' attitudes and achievement may be impacted. According to Beilock, Gunderson, Ramirez and Levine (2009), female teachers make up over 90% of elementary teachers in the United States and 'the more anxious teachers were about math, the more likely girls (but not boys) were to endorse the commonly held stereotype that 'boys are good at math, and girls are good at reading' and lower these girls' math achievement' (p. 1860). Since girls and women are currently under-represented in STEM education and related careers, female teachers in STEM can act as important role models and/or mentors for girls. All teachers, however, should adhere to the principles of gender equality in their teaching. This requires that all teachers be trained in gender sensitivity in order to build knowledge, confidence, and strong ambitions and aspirations among all students, and to support all children who are interested in pursuing careers in STEM-related fields.

In order to promote gender-responsive STEM education, strong community support is needed. The community must help in developing, or lobbying for the development of, policies that encourage the recruitment and employment of both female and male STEM teachers. This should include trainings for teachers in gender sensitivity and gender-responsive pedagogy.

GENDER-SENSITIVE SCHOOL RESOURCES

Textbooks and other learning materials convey messages about gender through texts and illustrations. In order to ensure that all school resources are promoting gender equality and other values relating to inclusivity, developers (including authors and publishers) and users of these resources must be gender sensitive and ensure that gender equality, as a central concern, is embodied in all school materials and in the ways they are used. For example, both women and men need to be portrayed in a variety of STEM-related professions, such as scientists, engineers or pilots, to promote girls' and boys' understanding that they are both equally capable of entering these fields.

Communities and parents need to be aware of and support the development and use of gender-sensitive resources both in schools and outside, whether during lessons, homework or extra-curricular activities. Members of the local community must be well informed about their local schools' values and practices regarding gender equality. Members of the broader community who have expertise in STEM and/or gender equality can contribute to developing gender-sensitive learning and teaching materials.

SUPPORTING A GENDER-SENSITIVE SCHOOL ENVIRONMENT

Communities can provide important support for schools to develop a gender-sensitive learning and teaching environment in which all children are able to thrive, where girls and boys have equal opportunities to participate in lessons and other school-related activities, and where their different interests and achievements are celebrated and supported. Community members, in their role as parents, members of school committees and civic administrators, can ensure that schools have high expectations for learning and behaviour for boys and girls; that all students have equal opportunities to pursue STEM-related subjects; that extra-curricular STEM-related activities offered by the school are inclusive for all children; and, that a good mix of boys and girls in all activities is not only valued but actively encouraged.

Women and men who are working in the community in STEM-related fields should be encouraged to come into schools to talk about their jobs, to share their experiences and knowledge, and to actively promote the importance of STEM education for all children, along with the importance of gender equality in STEM-related careers. Such visits and support can help counter stereotyped expectations and understandings about women's and men's capabilities or suitability for STEM-related careers.

PARENTAL SUPPORT AND SUPPORTING PARENTS FOR GENDER EQUALITY IN STEM EDUCATION

Parents and children's caregivers can help to sustain and promote gender equality and the ethos of achievement in schools. This can include knowing how to use the school's grievance procedure, should their child experience any form of gender-based discrimination.

Concurrently, schools need to play a role in promoting awareness among parents/caregivers of the importance of STEM education for all children, both girls and boys. Schools support parents/caregivers in fostering their children's learning through offering information and through social gatherings with parents and caregivers.

ENGAGEMENT OF THE COMMUNITY MEMBERS: CREATING STEM AMBASSADORS

Community members can be mobilized to act as mentors or STEM ambassadors, promoting the importance of STEM education and STEM-related careers among girls and boys. Local experts – women and men who work as doctors, engineers, farmers, geologists, architects and pharmacists, for example – can come into schools, explain their jobs and share their knowledge and skills with students and teachers, to enhance STEM teaching and to develop students' interest and enthusiasm about STEM-related careers.

COMMUNITY-BASED ACTIVITIES TO ENCOURAGE GIRLS' AND BOYS' INVOVLEMENT IN STEM

A wide range of activities can be organized as part of a STEM campaign. Competitions, debates, public speaking, poster presentations and interest surveys can help to create awareness among girls and boys about STEM and about the variety of STEM-related careers that are possible.

The Malaysian Biotechnology Information Centre (MABIC), for example, organizes science carnivals for students to promote science awareness and understanding (MABIC, 2017). In Cambodia, the Science Engineering Festival, a national initiative, is organized annually to inspire Cambodian youth with interest in STEM education or a career. The Festival is organized with the whole-hearted collaboration of various stakeholders, including the Ministry of Education, Youth and Sport (MoEYS), local and international academic institutions, private companies and non-governmental organizations (NGOs) (CSEF, 2016). FameLab, which originated in the UK, is one of the world's biggest science communication competitions where contenders explain science concepts in simple language to a non-technical audience. The student version of this competition is called School Lab (Cheltenham Festival, 2017).

Opening such activities to the general public can raise awareness among communities about the importance of gender equality in STEM-related fields. This awareness could help encourage policies that support girls' and boys' involvement in STEM. In addition, such activities could help in promoting informal learning, which can also have an important impact.

Focus of the activity

This activity and the suggested tasks help participants to deepen their understanding of effective strategies for promoting gender-responsive STEM education with community engagement.

TASK 1: Work in small groups

a. Read the article 'The Do-It-Yourself Guide to STEM Community Engagement: How to Build Sustainable Education Innovation in Your Community' from page 8 to 9 (Carraway, Rectanus and Ezzell, 2012) and the issues paper, 'Access and Participation of Women and Girls in Education, Training and Science and Technology, Including for the Promotion of Women's Equal Access to Full Employment and Decent Work', from page 2 to 4 (UN Women, 2014).

b. Which strategies or activities do these readings introduce to encourage community involvement in promoting gender-responsive STEM education? Why do you think they are useful?

c. Which other activities would you consider useful in promoting gender-responsive STEM education? Why?

TASK 2: Individual assignment

Prepare a proposal on how your country can engage the community, using the strategies above, to promote gender-responsive STEM education.

Product

Proposal on how to engage the community to promote gender-responsive STEM education

ACTIVITY 3

Community engagement in developing gender-sensitive policies on STEM

When developing STEM policies, consultations should be conducted with all stakeholders. The responsibilities of all stakeholders, including parents, should be clearly laid out in the policies (see Table 6.1) in order to help mobilize community support and involvement.

STEM policies for gender equality in STEM should:

a. Enhance self-confidence among girls and boys to pursue and excel in STEM
b. Increase interest among girls and boys to engage with STEM subjects
c. Ensure that girls' and boys' confidence and interest translates into high achievement in STEM subjects
d. Create a positive image about STEM subjects and careers
e. Enable girls to make informed decisions about their future field of study
f. Support girls in making informed decisions on their careers
g. Raise public/community awareness in promoting girls' and boys' participation in STEM fields

CREATING A LINK BETWEEN STEM AND THE EVERYDAY LIVES OF COMMUNITY MEMBERS

Sociocultural norms and expectations about the role of women and men in society affect girls' educational opportunities and their future career choices. As noted, girls and women are particularly under-represented in STEM-related study and work. In order to encourage more girls to pursue STEM education and STEM-related careers, and to enable them to succeed in their chosen fields, community members need to demonstrate positive and active support. STEM has direct relevance to all people's lives; community members must understand, develop and promote the awareness that STEM knowledge is both important and relevant to the everyday lives of girls and boys alike. Ensuring that girls and boys all develop better knowledge and skills in STEM is important for children and young people as individuals; it will also benefit their future families (for instance, with better knowledge of healthy lifestyle choices) and the communities and societies where they live. In addition, more girls and women in STEM-related fields of study and work will increase the potential talent pool in STEM significantly, affording the world a better chance of addressing some of its most pressing problems.

ENGAGING THE LOCAL COMMUNITY IN DEVELOPING AND IMPLEMENTING GENDER-RESPONSIVE STEM POLICY

It is vital that awareness on gender equality in STEM be promoted among various groups in the community, and that the community be engaged in developing and implementing policy, as the following value chain illustrates.

Figure 6.2: Process of community engagement in developing and implementing policy

A traditional African proverb says, 'It takes a whole village to raise a child'. This idea can be applied to helping all children – girls and boys – to excel in STEM. Communities form the informal network that helps to shape ideas, opinions and practices relating to gender; these attitudes and practices have an impact on girls' and boys' education and future careers. Thus, all the various groups identified in this module should be engaged actively and have responsibility for increasing gender equality in STEM, and for girls' and boys' performance in STEM-related fields of study.

Activities and strategies may vary from country to country to suit local culture, sensitivities, infrastructure, STEM ecosystem and limitations.

Focus of the activity

This activity and the suggested tasks seek to enhance participants' knowledge and skills on how to engage the community effectively in developing gender-responsive STEM education.

TASK 1: Individual reflection

Read the paper 'Implementation of STEM education policy: challenges, progress, and lessons Learned' (Johnson, 2012).

TASK 2: Work in small groups

a. Write a letter to the editor of a national newspaper in your country on the topic of 'The Role of the Community in Enhancing Gender Equality in STEM Education'.

b. Prepare a poster that captures the essence of gender-responsive STEM education.

TASK 3: Individual assignment

Prepare a list of five priority areas that require community engagement in promoting gender-responsive STEM education in your country.

Product

List of five priority areas that require community engagement in promoting gender-responsive STEM education

MODULE 6

TAKE-AWAY POINTS

This module has outlined the importance of engaging the local community in developing and supporting measures that promote gender-responsive STEM education. These are three key recommendations:

1. Develop awareness within the local community on the relevance of STEM to the everyday lives of girls, boys, women and men, in order to garner support for promoting greater participation of the community's girls and young women in STEM-related study and work.

2. Foster links between schools and key women and men in the local community who work in STEM-related fields, and businesses working in STEM-related fields, in order to promote interest among both girls and boys in STEM.

3. Engage the local community in developing and implementing gender-responsive STEM policies so as to realize gender-responsive STEM education with collective support.

READING LIST

- Communities, gender and education: evidence from sub-Saharan Africa (Rose, 2003)
- Parent, Family, Community Involvement in Education (Roekel, 2008)
- The Do-It-Yourself Guide to STEM Community Engagement: How to Build Sustainable Education Innovation in Your Community (Carraway, Rectanus and Ezzell, 2012)
- Access and Participation of Women and Girls in Education, Training and Science and Technology, Including for the Promotion of Women's Equal Access to Full Employment and Decent Work (UN Women, 2014)
- Implementation of STEM education policy: challenges, progress, and lessons learned (Johnson, 2012)

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NOTES

NOTES

ANNEX 1

COMPREHENSIVE LIST OF ACTIVITIES AND TASKS

MODULE 5

The IBE-UNESCO series of *Training Tools for Curriculum Development* is designed to support Member States with regard to education and curriculum reforms and development processes. The overarching objective of 'A Resource Pack for Gender-Responsive STEM Education' is to share a broader understanding of the theory and practice of gender-responsive STEM education, in order to support its effective development at the policy, school, classroom and community levels. The Resource Pack provides comprehensive guidance for national policymakers, curriculum specialists and developers, teacher educators, teachers, school leaders and district level administrators.

INTERNATIONAL BUREAU OF EDUCATION

Training Tools for Curriculum Development:
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United Nations Educational, Scientific and Cultural Organization

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