Engineering THAILAND

Design of an Engineering Curriculum and 12 STEM modules for the Thai Basic Education (OBEC).

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1   Introduction and context

The Centre for Science Education (CSE), a part of the Sheffield Institute of Education at Sheffield Hallam University was invited by the Ministry of Education (OBEC) in Thailand to review the STEM provision in Thailand with particular reference to the performance of gifted and talented students and to create an Engineering Curriculum and a set of STEM modules which would integrate with existing subjects. This project is part-funded by the Newton Fund in Thailand.

The key outputs of the project are a review of the existing STEM curriculum, the creation of a compatible Engineering subject and the formulation of supplementary courses for 195 Gifted schools which have a focus on STEM. The report would also identify barriers to successful implementation and suggest a monitoring and evaluation approach that would match the initiative's aims.

In August 2016 a team from CSE delivered a three day workshop in Bangkok. The workshop introduced the new Engineering Curriculum and the STEM modules to 50 teachers drawn from the 195 STEM specialist schools. The workshop also provided some professional development input for the teachers about how to create modules in the new Engineering Curriculum and techniques for working with gifted and talented students.

2   Impacts and recommendations

Impacts

Proximal impact

- The project produced a flexible curriculum framework to enable delivery of Engineering across all 195 schools and beyond. This included an assessment strategy which could operate flexibly across Years 7 to 12.
- Approximately 50 teachers were trained in a Workshop in Bangkok allowing them to understand the operation of, and contribute to the ongoing development of, the initiative.
- 12 STEM mini-projects were developed. These were coherent with the demands of the proposed Engineering Curriculum and the demands of the existing Thai curricula for Science, Mathematics and the Design and Technology strand of Occupations and Technology.
- Approximately teachers were also introduced to a number of the issues involved in working with Gifted and Talented students based on research and insight form across the world.
- A document comparing the relevant Thai curricula with those from Singapore lower secondary curriculum for Science and Mathematics; the USA New Generation Science Standards (NGSS); the Computing and Design and Technology Key Stage 3 programmes of study for England (lower secondary curricula); and the GCSE and A level Specifications (AQA Examination board) for Biology, Chemistry, Physics, Mathematics, Design and Technology, ICT and Computer Science.

Distal impact

- Improved understanding and skills in the Thai teacher delegates will improve provision for students across the 195 schools.
- Relationships and network connections established during the Workshop in Bangkok will provide a useful support network for teachers as they implement the initiative in their separate schools.
- Teachers who start to use the existing exemplar resources will be enabled to develop these to fit their particular circumstances more appropriately and develop their own learning resources using the same model.

Insights from the Workshop

- The teachers all worked very hard and produced some interesting and exciting ideas for projects. As the Workshop progressed they increased their knowledge of the Engineering Curriculum model and the opportunities it offers.
- They did not always find it easy and, as science teachers, they did not always identify the Engineering components in projects in sufficient clarity. However, this was expected given their existing experience and knowledge base and it did improve over the course of the three days.
- The Workshop was highly interactive with teachers making a strong contribution throughout the three days. The curriculum was modified slightly following this activity. The recommendations below grew out of conversations with teachers and BC staff at the Workshop and afterwards within the CSE team

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Assets developed as a result of the project

- An Engineering Curriculum for Grades 7 to 12 in Thailand. This include a rationale for inclusion of all components, broad content outlines, level descriptors for assessment and a mechanism for teachers to develop in-school modules to teach the course.
- A set of 12 STEM modules that draw on existing Science, Technology and Mathematics curricula in Thailand and the newly-created Engineering Curriculum.
- A group of teachers who have been trained in the operation of the Engineering Curriculum and STEM modules and who have begun the process of creating their own teaching and learning modules.

Development of the project

- We suggest that the project needs to begin as a pilot or pathfinder project prior to an official launch. This will ensure that when it is rolled out to all schools in the G+T sector the resources and support needed have been tested and shown to be resilient.
- We recommend that the teachers who attended the Bangkok Workshop should form this pilot group with each of their schools. This would provide a team of more than 40 teachers which is large enough to provide useful, reliable development data and small enough to facilitate a shared team approach.
- The teachers should certainly be encouraged to remain in contact with each other to share insights and resources. A shared web platform would be a useful support and would allow external consultants to be involved as appropriate.
- We recommend that the pilot involves a significant evaluation with a clear focus on development.
- We suggest the project sets up a Steering Group (SG) to oversee the pilot and further deployment of the project. The SG should contain personnel from OBEC and BC, representatives from the schools and any external consultants as appropriate. The SG would meet three times in the year - at the beginning of the pilot project, middle and end. The SG's role would be to monitor progress of the pilot to identify and resolve key issues and act as a champion to secure support for the project. They would also have to ensure that a clear implementation framework is available and understood before national roll out.
- We strongly recommend the development of a number of exemplar projects to deliver the Engineering Curriculum. These will need to be carefully researched and developed to ensure that they meet both the demands of the curriculum and match the realities of teachers in schools who sometimes have limited time to develop their own resources.
- We believe that the involvement of engineers at universities and engineering companies is critical. Strong efforts should be made, as soon as possible, to develop the relationships between individual engineers and departments with schools. We believe that both the schools and the universities will benefit from this relationship.

3   The project process

Scoping Meeting

A team of three consultants from the UK attended a three-day Scoping Meeting from 16th to 19th May 2016 in Bangkok. The scoping meeting involved a session with OBEC and visits to a number of schools with particular emphasis on STEM. The outline programme is given below.

Date	Activity
May 16	Meeting with OBEC Visit Samsen Wittayalai School Visit Chonkanyanukoon School
May 17	Visit Suranaree School Nakhon Ratchasima
May 18	Visit Pibulwittayalai School

In addition to the program above Mark Windale from CSE also visited Princess Chulabhorn 's College Phetchaburi on May 19th.

Notes from the Scoping Meeting

We had a meeting with OBEC at the Ministry of Education and visited five schools running the gifted programmes in science. Schools were very similar in their approaches to the STEM part of the gifted programme. We were supported in our visits by staff from OBEC, the British Council and the British Embassy.

The gifted programme

Secondary schools can apply to be part of the gifted programme, which means that they run an enhanced/extension programme for their gifted students. They can choose to focus on: science, mathematics, music, sports or culture.195 schools are currently focussing mainly on science and mathematics, with 24 more to be added soon.

Teachers receive on-the-job training, eg through working with OBEC staff to facilitate student camps.

Students take a test to be identified as gifted students, they need to also have an interest in science/mathematics, this happens at primary age. Teachers and students identify themselves and students can enter the secondary programme at Grade 7 or Grade 10. Students from these programmes do better in national assessments in all subjects.

All schools follow the Thai curriculum, 8 main subjects:

- Thai
- Maths
- Science
- Social studies
- PE
- Arts
- Living and technology
- Foreign language

The gifted programme has five additional elective courses from the normal schools:

- Special project base - heavy focus on this - lots of discussion.
- Extra mathematics.
- An extra foreign language.

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- Research methods.
- Technical hands on skills - e.g. building a kite/aeroplane etc.

There are also six additional areas for these schools:

- Special test for gifted schools - different from other schools.
- Special camp eg for science, mathematics.
- Presentation skills.
- Field trips - eg to industry or to museums, science centres - usually in Thailand.
- University partnered with each school eg to train teachers or for uni lecturers to work in the schools, students may go to the universities to use the facilities and learn about research methods.
- Values and morals course (Thai values).

Gifted programmes have longer hours which can be different for different schools but should be at least 1,200 hours per year. Gifted schools get extra funding from the government for these additional activities, and parents also make a contribution.Gifted programme class sizes - 30-40 students, 1-2 classes per year group in each school.

The Ministry of Education provides platforms for students to share their learning:

- Science communication training - competition for students to present work in English.
- Students are sent to Physics competition - in-country.
- Students selected to do activities with CERN - 4 students and 2 teachers are sent each year.

The Engineering Curriculum

The aim is to design a course for Y9-12 (this later changed after consultation to be Y7-12)which is taught in the gifted programme elective time (and in after school activities). This will be taught as an addition to the five extra strands for gifted students, so part of the 1,200 hours extra for the gifted programme equating to roughly 5-6 hours/week. We can bring in project work similar to what the schools are already doing (design, build, test...) - can use the research model the students are taught.

The expected outcome is to build the basic knowledge, understanding and skills needed in Engineering so that teachers can properly teach through STEM (not just STM)

The assessment methods are open to discussion and development. Other courses use a blend of ongoing assessment (60-70%) and final assessment (40-30%); we could suggest this - or suggest other things. A final written examination is not mandatory.

Normal teachers will teach the course, but there will be training (after the course we write has been reviewed and revised - this might be the case for the STEM supplementary course also).

OBEC may be able to provide small amounts of funding for equipment.

The STEM supplementary modules

The aim here is to design activities for the gifted programme elective time (and in after school activities). They should pull together strands from all STEM including Engineering - to give teachers a way of teaching STEM rather than STM separately.

The modules can be any length but should be large enough for students to demonstrate deep learning and small enough to be manageable in the school context.

The individual/small group projects are already doing a lot of what we might think of providing: students are given a free choice of what they investigate, and then guidance from teacher or university (or hospital) mentor as appropriate. Projects run over a long period of time (more than 1

year), and are assessed through presentations, written report. The projects are of a very high standard. A significant challenge for CSE is that we think teachers are already doing similar work through their existing projects. We need to be careful to avoid generating yet more of what they already have.

Work may need to be done on defining STEM as opposed to STM separately to boost teachers' confidence and to avoid activities degenerating into single-discipline projects.

It would also be interesting to do something to challenge gender stereotypes - although this may not be an issue. Definitely it would be good to use this as an opportunity to suggest other careers beyond medicine.

Project clarification and telephone conferences

Clarification of contract

Following on from the Scoping Meeting in Bangkok 16th to 19th May the outputs for the OBEC project were clarified by agreement as below.

1:     Comparison of the Thailand to other high performing countries

Given the nature of the students at the 195 schools it seems sensible to concentrate our analysis on the demands made on high-performing students in a variety of countries and curricula. This will provide better guidance when developing the Engineering curriculum and the STEM supplementary course regulations. The current suggestion is to look at Science, Mathematics, Design and Technology and IT at Years 9-12 (or equivalent) in:

- The ASEAN basket of curricula using the outputs from the SEAMEO benchmarking project - concentrating particularly on the Higher Order Thinking Skills (HOTS) and advanced content.
- Relevant sections from the NGSS (USA)
- The International Baccalaureate as an example of a well-respected international project.
- iGCSE curricula
- Triple Science and A-level from the UK

The analysis, which will be light touch, will review the:

- coverage of key knowledge with understanding and skills (particularly HOTS)
- specified purpose and rationale for each curriculum and scheme
- expected outputs for students where available to give an idea of standards
- ease of access to national and international careers and progression to higher levels in STEM

2:     Evaluation of national framework

This will further explore any opportunities and tensions revealed by Output 1 and make recommendations for dealing with any perceived problems. We will draw on successful curricula from around the world, including PISA documentation, to inform this evaluation.

3:     (a) Design of Engineering subject and (b) STEM subject supplementary courses which consists of at least content, number of learning period per week, pedagogy, assessment and accountability so that a team of Thai experts will go on to develop learning materials and teacher kit after the courses have been developed by UK consultant.

The CSE team will produce an Engineering curriculum optimised for the 195 schools or other institutions working with students at that level. This will be based on insights from Engineering curricula from around the world up to and including first year foundation engineering courses at SHU.

The team will also produce a brief rationale for STEM and a selection of exemplar modules which will fit in the proposed courses. We will show how these modules support an integrated approach to STEM by drawing together key features from the Thai science, technology, engineering and mathematics curricula.

4:      Assessment and recommendation on the coherence and integration among 4 subjects.

The team will identify any potential disconnects between the four STEM curricula and recommend ways to tackle these with minimum disruption to the existing curriculum documents.

5:      Gap analysis and recommendation for improvement.

This will emerge from the curricular analysis and be informed by our understanding of the success criteria for high-performing countries around the world.

6:      Setting up of monitoring and evaluation system plan, and assessment, assessing the new STEM subjects and engineering subjects being implemented in the 195 gifted schools.

We will develop an evaluation model taking account of assumptions, expected outcomes and impacts over the short, medium and long term. For example, if we assume that offering STEM courses will increase motivation to study STEM (short term), improve learning in STEM (medium term) and lead to an increased likelihood of opting for a STEM-related career (long term) we can devise data-collection techniques to gather evidence about actual outcomes. In this case it may include student attitudes survey (short term), data about improved student achievement in tests (medium term) and a survey of job applications post-graduation (long term.

Telephone conferences

In a telephone conference on 18 July 2016 these were further modified slightly to increase the focus on the Engineering Curriculum and STEM Modules. From the email exchange with the British Council in June:

There has been a change in the emphasis of the project with a much greater importance attached to Outputs 3 (Engineering Course) and Output 4 (STEM modules) and a slight reduction in the significance of the other outputs. SHU will seek to respond to this as flexibly as possible although room to manoeuvre dramatically is somewhat limited given the work already done based on the existing contract and the experience from the Scoping Visit. However, SHU will seek to modify activity going forward as much as possible.

CSE will supply a range of documents in the first week of august for translation into Thai. These documents will be:

- A framework and justification for the Engineering curriculum - this should show the thinking behind it and indicate how the insights can be used to develop learning materials in Thailand.
- A review of broad content outlines for the years and modules - expressed in terms of skills and capabilities rather than a simple list of 'facts' (properties of alloys, strength of welds and bonds etc.)
- A definition of skills and the level descriptors across Grades 7-12
- An explanation of how the strategy can inform development of learning materials
- Outline exemplars of Engineering and STEM modules including suggested activities

CSE will also modify the plans for the Workshop to make it much more focussed on development of materials. The Workshop will build on the initial documents supplied for translation by adding more detail and more examples of possible modules and content.

The Workshop program

This workshop is a three day event delivered in Bangkok, Thailand designed to present the materials developed by SIOE and Leicester CPD+. It involves a presentation on the proposed Engineering curriculum and STEM supplementary courses and a workshop to support teachers in Thailand as they seek to operationalise the initiative.

Saturday 27 August 2016

This day will be devoted to presenting the Engineering Curriculum and the STEM courses and identifying an appropriate evaluation strategy for the project.

Time	Activity	Format
9:00	Welcome and coffee	
9:30	**The Project Context** An introductory talk covering the context in which the initiative was developed (SIOE).	Presentation.
10:00	**The Thailand curriculum landscape** A presentation of our analysis of the Thai National framework and significant other competitors. (MW)	Presentation and discussion
11:00	Coffee	
11:15	**The proposed Engineering Curriculum** A presentation of the proposed Engineering Curriculum (GP + SB)	Presentation and discussion
12:30	Lunch	
1:30	**The proposed STEM courses** A presentation of the proposed STEM courses (GF)	Presentation and discussion
2:45	Tea	
3:00	**An evaluation framework** Introducing the evaluation framework for the project followed by discussion about operationalising this to progress of the project in schools and nationally. (SHU)	Presentation and workshop.
3:45	**Plenary** Drawing together insights from the day.(All)	Plenary.
4:00	**Individual conversations** The SHU team will make themselves available for individual conversations with delegates as appropriate until 5:00.	Informal discussions.

Sunday 28 August 2016

This day will be devoted to developing and supporting teachers as they investigate ways forward with the proposed Engineering Curriculum initiative.

Time	Activity	Format
9:00	Welcome and coffee	
9:30	**Introduction and audit** A discussion to identify key teacher concerns and requirements from the Workshop. This will inform the following sessions. (Facilitated by SIoE)	Discussion
10:00	**The key themes** Exploring the key themes and how these can be embedded in relevant sectors. Reviewing the factors that produce a compelling and engaging context for pupils. (GP/SB)	Discussions and workshop
11:00	Coffee	
11:15	**Activities and resources** Exploring the range of activities that can support teaching and learning and how these can be supported by targeted classroom resources. (GP/SB)	Discussions and workshop
12:30	Lunch	
1:30	**Assessment for learning** Developing a rigorous and appropriate assessment strategy to track and promote pupil learning during the project. (GP/SB)	Discussions and workshop
2:45	Tea	
3:00	**Review of materials produced** Review of materials produced during the day by delegates to ensure good ideas and approaches are scared by all. (All)	Discussions and workshop
3:45	**Plenary** Drawing together insights from the day.(All)	Plenary.
4:00	**Individual conversations** The SHU team will make themselves available for individual conversations with delegates as appropriate until 5:00. (All)	Informal discussions.

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Monday 29th August 2016

This day will be devoted to developing and supporting teachers as they investigate ways forward with the proposed STEM modules initiative.

Time	Activity	Format
9:00	Welcome and coffee	
9:30	**Introduction and audit** A discussion to identify key teacher concerns and requirements from the Workshop. This will inform the following sessions. (Facilitated by SIoE)	Discussion
10:00	**The modules** A review of the existing modules with suggestions for development as appropriate. (GF)	Discussions and workshop
11:00	Coffee	
11:15	**Activities and resources** Exploring the range of activities in the modules and how these can be supported by targeted classroom resources. (GF)	Discussions and workshop
12:30	Lunch	
1:30	**Assessment for learning** Developing a rigorous and appropriate assessment strategy to track and promote pupil learning during the modules and across the complete course. (GF)	Discussions and workshop
2:45	Tea	
3:00	**Clinic** An opportunity to discuss any issues that have surfaced over the Workshop and develop plans for future developments.(All)	Discussions and workshop
3:45	**Plenary** Drawing together insights from the day.(All)	Plenary.
4:00	**Closing ceremony**	

Personnel

SB Dr. Stuart Bevins, Sheffield Institute of Education.

GF Mr. George Forster, BoostED.

GP Mr. Gareth Price, Sheffield Institute of Education.

MW Mr. Mark Windale, Sheffield Institute of Education.

4   The Engineering Curriculum

The Engineering curriculum: an overview

The Thai Engineering course covers six years (Gr7-12) and is split into three phases (Gr7/8; Gr9/10 and Gr11/12). The whole programme is conceived as a progression across years and phases with a single structure and assessment strategy operating across all grades. The required skills, knowledge and understanding are described through three functional themes and six sector contexts.

The functional themes describe the cognitive experiences that good engineers go through as they do their work. They are:

• **Engineering for everyone**: the importance and impact of engineering on society and individuals.

• **The engineering design process**: from initial idea to prototype and on to a finished product.

• **Manufacturing**: the complexities of shifting from prototypes to mass produced products.

The engineering sectors have been chosen to reflect areas that are important to Thailand as an economy. They are:

• Medical and biotechnology

• Civil engineering and structures

• Agriculture

• Automotive

• Electronics

• Energy

Modules of work combine the themes and sector knowledge to provide students with an authentic experience of engineering. These modules require a minimum of two hours per week of school time although it is assumed that students will commit to an amount of work outside normal curriculum time. The modules are open-ended and the exact content details are flexible to allow them to be optimised for particular school contexts and student and teacher interests. These modules are best regarded as projects that require creativity and commitment from the students but offer an opportunity for significant learning, achievement and personal development.

Assessment is through a mixture of shorter (three weeks), thematic review activities that test student understanding of a particular theme *across* a range of sectors and larger (six or 12 weeks), sector-based projects which require students to apply the all of the thematic material *within* a particular sector. Level descriptors have been provided to allow assessment of projects.

Progression has been ensured by moving from simpler, concrete skills applied in small or local contexts at lower grades to more complex skills with a greater degree of abstraction and a wider applicability at higher grades.

The course also draws on the 'mastery model' of learning. Students are presented with a number of routes to develop their skills and understanding over a number of modules and many opportunities to deepen that understanding in new contexts. Where students fail to achieve the needed understanding in the first instance the course provides new opportunities and experiences, often in a different sector context, to allow student to acquire and develop any missing skills and understanding.

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Engineering as a discipline

The content specified by the Thai Engineering curriculum is designed to emphasise that engineering is a discipline devoted to creative problem-solving embedded in an understanding of the social, economic and environmental context of the engineer and the users of their products. It is a dynamic mindset which responds to challenges both by drawing on existing knowledge and experience but also creates and trials new approaches to ensure a constant increase in the capabilities of individual engineers and the discipline as a whole. To capture this sense of dynamic creativity the curriculum is based around three functional themes that describe the process of engineering and sector contexts which describe the products of engineers.

By working with these themes, students will begin to 'think like engineers'. The addition of manufacturing as a theme emphasises that modern engineering is not just about crafting 'one off' solutions but must recognise the needs of complex, multi-stage manufacturing systems that can produce hundreds of thousands of products to budget, schedule and quality.

The functional themes

Engineering for everyone

This theme explores the place of engineering and engineers within society. It requires students to understand that engineers work on projects that have a significant impact, for better or worse, and that the size of this impact is increasing as our engineering capability increases. Students will be expected to assess the desirability of an engineering project based on its impact on a range of people over extended periods of time and make recommendations for future developments.

• What is the impact of engineering and new technology on people and society?

• What are the advantages and disadvantages of opting for an engineered solution?

• How can we ensure the engineered solution is sustainable over the long term?

• What problems are addressed by engineers and who chooses which developments are funded?

The engineering design process

This theme looks at engineering as a problem-solving process. Students will be expected to recognise and codify problems and develop a range of solutions that are technically, economically and environmentally appropriate. It requires students to construct suitable prototypes, choosing appropriate techniques, tools and materials, and test them. They will also be required to explain how the results of these tests can inform the design and engineering of the final product. They will be expected to choose between a range of possible engineering solutions and give their reasons for selecting a particular approach.

• What is the problem that people are facing?

• What solutions to this problem can engineering offer?

• Which solution is the optimum one and why?

• How will you evaluate the efficacy and impact of the solution?

Manufacturing

This theme looks at the issues associated with large scale manufacture of products. It explores the workings of a modern engineering establishment by looking at relevant legislation, workforce skills and management, supply chain issues and how risk can be minimised and managed. It also emphasises the skills required to move an engineered product from prototype to the marketplace.

• What are the relevant regulations for this area of work (e.g. Health and Safety, consumer protection, environmental regulations)?

• What are the key stages in the manufacture of your product?

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• How will you manage production efficiently to respond to supply/quality/workforce issues?

• How will you minimise and manage risk?

• How will you ensure quality assurance?

The sectors

The sectors used in the course reflect the industrial and engineering landscape in Thailand. We have also sought to take account of gender balance in the selection and include aspects of engineering that will appeal to students in urban and rural areas. The short paragraphs below describe the characteristics and area of activity of each sector.

Medical and biotechnology

Medical engineering produces a wide range of engineered products from simple tablet dispensers and syringes through to replacement body parts and highly technical electronic monitoring equipment. It also includes maintenance of machinery used in medical settings (e.g. X-ray machines, autoclaves). Biotechnology has been included to support the work of tissue culture which underlies a great deal of the extensive Thai orchid industry.

Civil engineering and structures

Civil engineering includes large infrastructure projects like roads, flood defences, bridges and airports. At a smaller scale, structure includes buildings of various sizes and at a smaller scale again items like furniture and packaging.

Agriculture

40% of the Thai people work in the agricultural sector and the country is a major producer of rice and other agricultural products. This sector includes crop and livestock production, protection and processing; farm machinery; water and land management and waste treatment.

Automotive

Thailand is a major exporter of car components and produced over 1.6 million vehicles in 2010. It also has a number of important businesses producing parts for specialist motor vehicles. This sector includes all engineering work involving motor vehicles including mechanical, power transmission, electrical control systems and materials for manufacture.

Electronics

Thailand is a major exporter of electronic components including televisions and hard drives. This sector produces a range of electronic components for a wide range of electrical devices from washing machines and mobile phones to computers and digital cameras.

Energy

Thailand has a significant oil-based energy sector. It also has a large number of rural villages that are off-grid and so need electricity supplies that are locally generated and distributed. This provides a variety of interesting energy projects that could potentially make use of a variety of renewable energy sources, particularly solar and biofuel-driven, which could also become useful export products to other countries who do not have access to large amounts of fossil fuels.

Assessment strategies

Assessment model and objectives

The assessment model, which has both formative and summative aspects, is based around a combination of typically closed, directed mini-projects (three weeks) looking at how the functional themes are addressed across a range of sectors and a number of larger, open projects (up to 12 weeks) where students are granted more autonomy but work within a particular sector to solve an engineering problem. Criteria are provided for the three themes across the phases to allow assessment through these projects. The number of these mandatory assessments is given below. They can be supplemented in schools by any particular in-school assessments (tests, presentations, projects etc.) as desired or required by the individual school. The data generated by these in-school assessments can inform decisions in schools about groups, teaching and progression of students but will not become part of the formal course assessment model.

These assessment opportunities should be used by schools, with guidance from OBEC as appropriate, to develop evidence of progress. In a 38 week academic year we anticipate 12 to 15 weeks will be overtly assessment-focussed leaving 23-26 weeks for development of skills, understanding and attitudes disconnected from the demands of high-stakes assessment. We recommend this balance based on the considerable evidence from global research that assessment can cramp learning as teachers feel compelled to 'teach to the test'.

Year	Miniproject	Large project
7	2 mini projects (3 weeks each)	1 practical project (6 weeks)
8	1 mini project (up to 3 weeks)	1 large project (up to 12 weeks).
9	2 mini projects (up to 3 weeks each).	1 practical project (6 weeks).
10	1 mini project (up to 3 weeks).	1 large project (up to 12 weeks).
11	2 mini projects (up to 3 weeks each) s.	1 practical project (6 weeks)
12	1 mini project (up to 3 weeks).	1 large project (up to 12 weeks).

Roles and responsibilities

Students

Students will also use a variety of techniques to engage in self and peer evaluation. The main component is the logbook in which students record both their activity and their reflections on that activity. This logbook is a valuable source of formative information for the teacher.

Each module will generate a logbook selection that contains data identifying students and team members and the following components:

• A brief description of the project: this is created by the student.

• The Level descriptors being addressed: these to be identified by the teacher and agreed with the student.

• Evidence: this is filled in during the project as students generate evidence of having met the level descriptors. It is validated by the teacher as required.

• Action points: these show areas for future development and are generated by the student or the student and teacher in conversation.

Appendix 3 is an example of a typical module logbook format.

Teachers

Teachers will develop their own approaches to assessment of student progress based on guidance from OBEC and their own in-school policies and practices.

The level descriptors

The level descriptors have been created to describe the skills and understanding students are working towards in each phase. These provide useful formative targets throughout the phase for students and teachers as they work to make progress towards these descriptors. They also form the basis of summative assessment at the end of the phase.

Each level descriptor can generate three levels of achievement: the student is not meeting any substantial asset of the descriptor, the student is often meeting some and occasionally all of the descriptor components and the student confidently and routinely meets every aspect of the descriptor. These three levels of achievement provide a degree of useful granularity and provides guidance for the students.

Engineering for everyone

Theme	Grade 8	Grade 10	Grade 12
Review potential impacts of an engineering project	• List the possible impacts of an engineering project on a number of identified groups.	• Describe the potential impact of an identified engineering project on more than one group showing the advantages and disadvantages for these groups.	• Use evidence to argue the potential impact of an identified engineering project from the perspective of at least three identified groups showing the advantages and disadvantages for each group.
Suggest modifications to minimise impacts	• Suggest simple modifications to reduce negative impacts.	• Make recommendations for the development of an existing project suggesting modifications to reduce negative outcomes for at least two groups.	• Make recommendations for the development of an existing project suggesting modifications to reduce costs and negative outcomes and increase benefits and positive outcomes for a range of groups.
Explore sustainability issues	• List a range of sustainability issues.	• Describe a range of relevant sustainability issues.	• Describe the scale and significance of a range of relevant sustainability issues and recommend ways to minimise future potential impact.

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The engineering design process

Theme	Grade 8	Grade 10	Grade 12
Identify and clarify a problem	• Identify and describe a simple problem in a familiar area.	• Develop a definition of a problem in a familiar area using a range of provided information sources showing some understanding of underlying issues.	• Locate and use a wide range of information sources to produce a clear definition of a problem showing excellent understanding of the social and economic context even when the situation is outside their previous experience.
Explore possible solutions to a problem	• Suggest a possible solution to a defined problem.	• Create a number of possible solutions although these may be simple variations on a theme.	• Create and justify a range of solutions to the problem, some of which are novel or surprising, and choose one to develop further based on available technology, resources and skills, cost and schedule.
Select materials and components to develop a solution	• Select appropriate materials showing an appreciation of their proposed use.	• Identify properties needed by materials, test a range of materials and select appropriate ones providing clear justification for their selection.	• Test the materials and components of the prototype making modifications as required.
Use tools and techniques to develop a solution	• Use simple tools and techniques with some skill to produce a working prototype.	• Use complex tools and techniques with some skill to produce a working prototype.	• Use a range of tools and techniques, including gaining new skills as required, to build a working prototype.
Review outputs from their work	• Test their prototype in some way and use the results to improve their final product.	• Create a plan to evaluate but the data is collected only from the user and there is no reference to social or environmental impact.	• Plan for detailed evaluation of the product in terms of technology, social and environmental impact, and client satisfaction. • Modify the design of the prototype to reflect growing understanding during building.

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Manufacturing

Theme	Grade 8	Grade 10	Grade 12
Creation of a manufacturing plan	• Offer an outline plan for manufacturing of the final product showing limited or no understanding of the difference between manufacture and prototyping.	• Offer a plan for manufacturing of the final product showing some knowledge of how manufacturing techniques impact on this process.	• Offer a detailed plan for manufacturing of the final product showing how insights from the prototype and their knowledge of manufacturing techniques impact on this process.
Develop a manufacturing plan	• Identify possible problems with manufacture.	• Identify risks in the manufacturing plan.	• Identify criticalities and risks in the manufacturing plan and suggest ways that these could be addressed.
Observing relevant legal elements	• List a range of possible relevant legal elements	• Show an understanding of the impact of some regulations on manufacturing.	• Show an understanding of the impact of the relevant regulations on manufacturing. • Demonstrate understanding of the social, economic, technical, environmental and management issues associated with manufacturing.
Developing a QA strategy	List activities that could contribute to a QA plan.	• Identify QA as a process that happens at the end of the manufacturing process rather than at each stage and suggest a possible test.	• Create a clear, reasoned account of how QA will occur and suggest ways the information gathered will inform changes to the manufacturing process.

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The Engineering curriculum: course management

Phases and grades

The course will be divided into three phases. (Gr7+8, Gr9+10, Gr11+12). The earlier parts of the course will concentrate on simpler, concrete skills and local understanding of properties, tools and techniques. The trajectory of the course is towards deeper understanding of the engineering process in more complex technical, social, environmental and commercial terms with a greater emphasis on manufacture and more advanced production systems. The emphasis across the four themes over the years matches this change.

The content used to explore the three themes will be drawn from the six key engineering sectors for Thailand. Students will be expected to encounter content from every sector in each phase but the balance of emphasis can change if local conditions offer a particularly useful connection, e.g. a school near a large concentration of electronics factories might major in the electronics sector whereas a school with a local automotive industry might major in that area. However, all students must be exposed to all sectors in each phase to provide ongoing support for future development, a breadth of learning contexts and accommodate students who may move on other areas of the country during their school careers.

Balance of coverage

Phase	Year	Engineering for everyone: the importance and impact of engineering on society and individuals.	The engineering design process: from initial idea to prototype to finished product.	Manufacture: the complexities of shifting from hand-built prototypes to mass produced products.
1	7	20	60	20
	8	20	60	20
2	9	20	55	25
	10	20	50	30
3	11	20	45	35
	12	25	35	40

Typical phase programmes

The tables below show typical first and second year courses for each phase. The phase always begins with a general introduction to the discipline of engineering and ends with a conference where students share their projects with their peers and invited guests as appropriate.

The sectors can be addressed in any order as decided by the school but the introductory module 'What is engineering?' must be taken at the start of the course. In phases 2 and 3 the nature of the introductory module will change slightly to reflect the greater emphasis on more complex systems and manufacturing as opposed to simple, practical skills and understanding.

Year 1 of phase only: What is engineering? (6 weeks)

This module looks at the societal and technical promise of engineers and how they solve problems by application of the engineering design process in a socially-aware manner. Students will look at

a variety of engineered products they are familiar with and review the advantages and disadvantages of these solutions.

Both years of each phase: Engineering and problem solving mini project (3 weeks)

A review of how an engineered product has reached them showing that the understand why and how decisions are made to create a specified product. They will review the product for a range of simple criteria based on technical excellence, ease of manufacture, societal and environmental impact.

Year 1 of phase only: Large project (6 weeks)

Students choose a project based in a sector they have studied to develop into a detailed case study where they design and build a device arguing for the need for such a device, the benefits of their chosen solution, the technical, societal and environmental aspects they have considered and full justification for decisions made. They would be expected to defend their proposed solution before a jury of their peers.

Both years of each phase: Solving an engineering problem in a sector context (6 weeks)

Schools will look at a particular sector and begin to explore the skills needed to work in them. The students will develop these skills (workshop and analysis) and demonstrate these in work in this sector. The module will be practical but with plenty of opportunity to develop reflection and decision-making skills.

Year 2 of phase only: Large project (12 weeks)

Students choose a project based in a sector they have studied to develop into a detailed case study where they design and build a device arguing for the need for such a device, the benefits of their chosen solution, the technical, societal and environmental aspects they have considered and full justification for decisions made. They would be expected to defend their proposed solution before a jury of their peers. This project may well be a development of the project from the first year of the course as it has more time devoted to it and the students should show greater maturity and deeper knowledge and understanding.

Year 2 of phase only: Course review and conference (3 weeks)

Students present a review of their whole course describing their learning over the two years with examples drawn from their projects as illustrations.

Year 1

Week	Activity
1 - 6	What is engineering?
7- 9	Engineering and problem solving mini project 1
10 - 15	Solving an engineering problem in a sector context 1
16 -21	Solving an engineering problem in a sector context 2
22-27	Solving an engineering problem in a sector context 3
28-30	Engineering and problem solving mini project 2
31-36	Large project

Year 2

Week	Activity
1 - 3	Engineering and problem solving mini project
4- 9	Solving an engineering problem in a sector context 4
10 - 15	Solving an engineering problem in a sector context 5
16 -21	Solving an engineering problem in a sector context 6
22-33	Large project
34-36	Course review and conference

Engineering curriculum: module construction and operation

Teachers construct modules based on the key theme descriptors they wish to cover and the sector in which they are choosing to work. This module construction strategy supports both the development of locally appropriate modules which respond to the skills of the students and locally-available resources (e.g. relevant companies, university links) and builds in a chance to master relevant skills and understanding. If a project is going well, the students will complete it and demonstrate the required skills and knowledge. The teacher can then launch a new project with new descriptors (perhaps revisiting some to deepen students' understanding). If they are finding things difficult or other factors have made it impossible to complete the project successfully the teacher can review the descriptors being targeted and modify as required. Figure 1 shows the general sequence for developing a project.
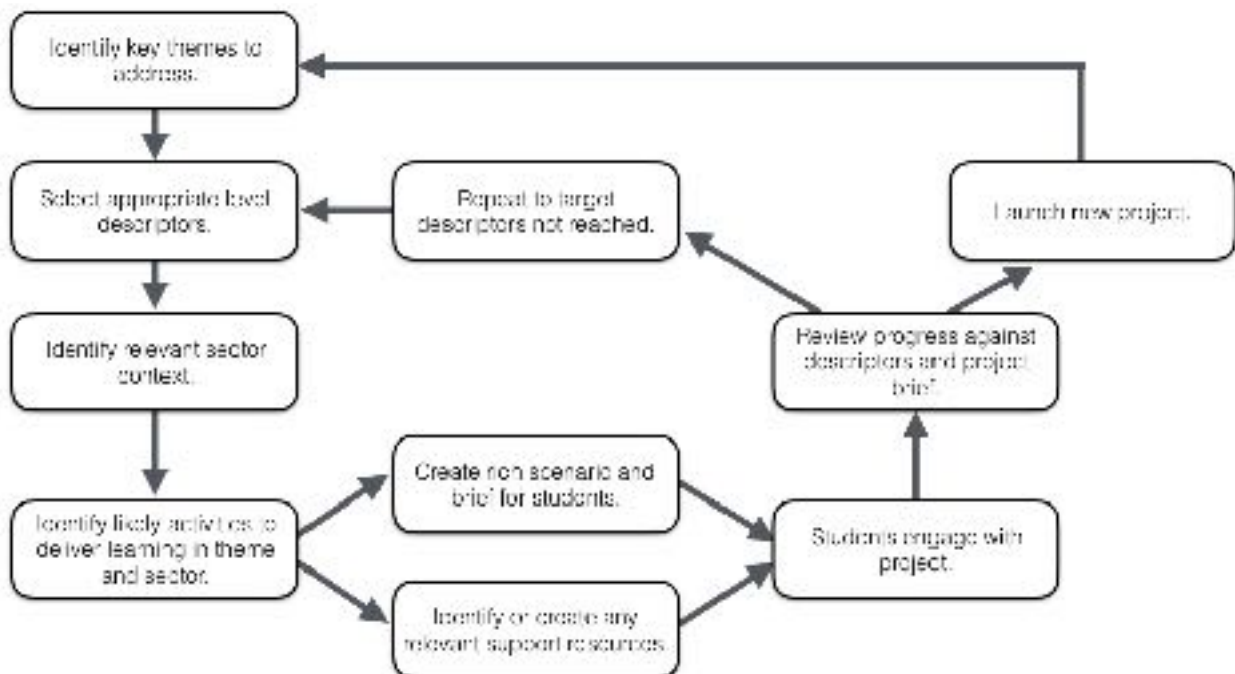

Figure 1: Module construction flowchart

The number of level descriptors for each module will depends:

• students' existing knowledge and understanding,

• the length of the proposed module (6 or 12 weeks).

In the early stages of the course four or five descriptors is probably suitable but later on in the course the number can increase. The descriptors are summative in nature and describe the capabilities and understanding a student will have at the end of a phase. So, for much the time students will be working towards mastery. Some indicators are also probably more demanding than others.

Module structure

A complete module will contain a number of components each of which has a specific job to do. These are shown in the table below.

Module component	Notes
Theme descriptors	These identify the key skills and understanding the students will be targeting in the project.
Sector context	This describes the sector context in which they will work to develop the skills and understanding identified above.
Project brief	This provides clearer guidance for the students in terms of the concrete project rather than the more abstract themes. The brief should be sufficiently specific to guide and support students but allow them room to develop their own ideas. It should also be very clear about the output of the project, e.g. a presentation should cover x topics and have n slides, a document should contain 500 words and 5 diagrams etc.
Learning resources	These will support the students as they navigate the project. Some will be straightforward instructions (e.g. how to use a particular piece of equipment or produce a convincing presentation), others may require comprehension of particular content (e.g. response curves of solar cells) or be guidance to other useful resources (e.g. textbooks, worksheets, internet references etc.)

Constructing modules

The sequence here is shown as a number of steps. However, it is permissible for teachers to adopt a much more flexible approach perhaps starting from a brief or set of activities rather than the descriptors. Or maybe all of the components are developed in parallel. The exact mode of construction is not important provided that the descriptors are seen as the primary objectives for the module and that other activities are there, and the brief is constructed, to ensure students are provided with learning activities that lead to the development of the skills and understanding identified in the descriptors. The example below illustrates these steps in the construction of a module looking at safe transport of orchid blooms from producer to market.

Step 1: Selecting descriptors

A teacher seeking to develop understanding of problem-solving with engineering at Grades 7 and 8 might select the following descriptors:

• Identify and describe a simple problem in a familiar area.

• Suggest a possible solution to a defined problem.

• Select appropriate materials showing an appreciation of their proposed use.
• Use simple tools and techniques with some skill to produce a working prototype.
• Test their prototype in some way and use the results to improve their final product.

Step 2: Choosing a sector and identifying activities

These descriptors would then be fleshed out with activities that reflect the specific sector. In this exemplar the context involves transport of orchids to warehouses prior to export around the world.

The teacher might want their students to:

• Produce a detailed description of the problem to be addressed (bloom decay and damage) including relevant background information (e.g. effects of temperature, humidity, physical damage, light levels on bloom decay) that could aid understanding of the context. This should involve data gathering from a range of sources (e.g. textbooks, library, internet, interviews with experts).

• Brainstorm a number of possible solutions to the problem and score them for factors such as cost (e.g. is the solution more expensive than living with the problem?), likely impact (e.g. will the solution completely solve the problem or simply reduce its impact?), ease of deployment (e.g. does it require special equipment or expensive infrastructure?), ease of development (does it build on readily available engineering knowledge and skills or is it a long term development project?) and impact on users (e.g. is it hazardous to use?) and others (e.g. will it have an adverse effect on the local environment, economy or culture?)

• Select one or two solutions that offer the optimum combination of benefits and develop this in more detail. Produce fully labelled diagrams to describe what your proposed solution will look like, what materials will be used in its construction and why and how it will work.

• Build a prototype. Keep a log of the work noting down where changes were made to the original plan and justify these changes.

• Test the prototype and identify weak points in the original design and build a specification for the improved solution.

• Generate a report as required by the project brief.

Step 3: Construct the brief

Finally the teacher will create a brief for the students which describes the project they will be working on. This brief can be as detailed or as open as the teacher wishes depending on the skills and maturity of the students.

Step 4: Locate / create resources as necessary

Much of the work in the module will involve students working independently to develop their own approaches and strategies. However, a number of resources may be useful and teachers can help students by locating or creating these resources. The degree of support will depend on the skills and maturity of the students.

Exemplar modules

The following ideas are typical of topics and activities that could be developed into Engineering projects. The grade suggestions are for guidance only - almost all ideas could be developed at any grade depending on the teachers and students.

Grades	Sector	Project ideas
7/8	Medical and biotechnology	• Design, make and test a tablet dispenser for old people who need to take lots of drugs at a variety of times. • Specify the control system for baby incubator - how to ensure temperature, humidity and light levels are appropriate and note movements or distress.
	Civil engineering and structures	• Build and test a low-cost mast for mobile phone transceivers. The project should also identify places to locate the masts to give maximum signal coverage at the lowest possible cost.
	Agriculture including food and rubber.	• Exporting orchids - how to keep orchids safe and fresh on journey from farm to warehouse? Develop a system to preserve these valuable blooms. • Develop a fuel brick using waste material from farming. The brick must have a high calorific value and burn cleanly to leave very little ash.
	Automotive	• Create a mirror adjusting system so the driver in a car can adjust the mirrors on the outside either mechanically or electrically • Create a mechanism for adjusting the beam of a headlight, so that if the vehicle is well loaded, and the front is pointing upwards, the beam can be pointed towards the ground, but can be quickly reset once the vehicle is unloaded.
	Electronics	• Design a scoring system for fencing competitions. It must record the number of times a person has been struck by the foil.
	Energy	• Manufacture of simple cooker for use in the field or at time of natural disaster, e.g. tsunami, earthquake, floods.
9/10	Medical and biotechnology	• Develop a device to measure muscle strength accurately. Explain how this could be useful for a person recovering from a debilitating illness. • Develop a high-efficiency system for composting organic wastes safely and with no unpleasant odours.
	Civil engineering and structures	• Review materials for building a low-cost house for a rural area of Thailand. The building materials must be easy to work with, cheap to manufacture and provide good thermal and noise insulation. It should also be treated to reduce the rate of decay - possibly by use of paints or lacquers. • Develop and test a system to stabilise the banks of rivers and so reduce erosion. Ensure that the system is low-cost and easy to deploy across large areas.

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Grades	Sector	Project ideas
	Agriculture including food and rubber.	• Develop and test a system to extract oil from plants like oil palms. The device must extract the maximum amount of oil and be easy to use and maintain, cheap to manufacture and operate and produce no hazardous waste. Ideally the residue left should be used as the raw material for another useful product. • Explore the use of cloning for developing plants. Develop an incubator for cloned micro-plants to maximise their growth and protect them from pathogens.
	Automotive	• Develop a door and drivers-seat arrangement so a wheelchair user can get into the car and drive it without assistance. They must be able to load their wheelchair too.
	Electronics	• Develop a system to measure the length of cable that is pulled through it, so that customers can be charged the correct amount for the cable they purchase. (measures up to 100 meters to an accuracy of +/- 1cm) • Develop an emergency lighting system, so that if power to a set of lights fails, another set of lights automatically switches on from battery power.
	Energy	• Explore the calorific value of a range of plant materials to identify possible biofuels. Design, test and optimise a burner to ensure maximum heat output when the chosen biofuel is burnt.
11/12	Medical and biotechnology	• Build and test a variety of artificial limbs. Your designs should review a range of appropriate materials for manufacture and produce an optimum design combining strength, a low weight and comfort for the person using it.
	Civil engineering and structures	• Develop a system to roof for a stadium that shelters the crowd from sun and heavy rain, but does not impede their view. Build a model and identify the issues of scaling it up from a working model to the finished roof.
	Agriculture including food and rubber.	• Water hyacinth is a water plant that grows rapidly and can clog waterways leading to a range of problems. Review the systems for clearing water hyacinth from rivers and develop an improved method.
	Automotive	• Truckmaster - develop and test a system to measure the weight of a loaded truck and signal this to a monitoring station.
	Electronics	• Develop and test a traffic control system for a busy intersection. The system should respond in real time to the flow of traffic and give priority to the busiest roads. • Develop and test a monitoring system for a warehouse. The system should use the minimum of sensors but be able to locate any problems in any part of the warehouse. The data should be available to remote users through a smartphone or tablet app.
	Energy	• Develop, test and optimise a system to harvest and store energy from wave motion, e.g. in the seas around Thailand.

5   The STEM supplementary courses

The nature of STEM

The following document was produced early in the project to inform our thinking about the nature of STEM and how it relates to the separate disciplines and the eventual curriculum units.

STEM is only an acronym that describes a group of disciplines. Our STEM modules should be driven by real problems with real significance rather than an attempt to collect all the disciplines together in a single activity. Students, looking at the problem, should review which methods and approaches would help them to solve it. Carefully picking these would allow students to explore possible solutions that have a flavour of S or T or E or M.

It would be possible, although probably difficult, to create a module that required contributions from each STEM area. The students would collect the different contributions to produce a project. The danger with this approach is that it depends on us directing students to collect the different STEM disciplines. When left to their own devices students, as with almost all practising scientists / technologists/ engineers and mathematicians will tend to operate with the skills and content and approaches they find most convenient, and accessible, for the task they perceive themselves to be facing. It is unlikely that a mathematician or engineer will sample across all four STEM disciplines if they feel they can solve the problem from within 'their' discipline. Multidisciplinary teams often purposely avoid trying to become masters across all disciplines. The wise biologist draws in, and defers to, a good chemist or mathematician when they can see how the problem will be better solved by using in this skills and approaches.

What we cannot do is to insist that *every* problem must contain *all* of the STEM disciplines. That way we construct fake experiences. The argument is analogous to the fight over single, coordinated or integrated science where the identity of the individual sciences can be lost in highly confected themes like 'colour' or 'the very big and the very small'.

We should plan to create STEM modules that will, inevitably, involve aspects of science, technology engineering and mathematics. The exact balance between the components in each module will vary so we may end up with a 'science-rich' module or a largely 'mathematical' module or even a module with added 'technology' flavour. Over the complete package, each STEM discipline will have its day in the spotlight.

So, some rules for our modules:

• The must be built around real problems.

• They must be approachable through a range of disciplines.

• Students must specify, and justify, their chosen approaches by reference to their skill set, knowledge and the characteristics of each STEM discipline.

• The modules must not depend on 'fake' connections to ensure they hit all the STEM buttons.

So, to try to illustrate the way forward. Imagine a module built around the need to increase food production in the southern Sahel region. A biologist might explore suitable crops for the area, an engineer could look at rain capture, storage and irrigation systems, the technologist might look at improved weather forecasting or more efficient storage systems for harvested food (particularly reducing post-harvest losses) while our mathematical friend may look at mathematics of climate change, system costs and whether the local people can afford the crops and maintain the equipment of the irrigation systems. The decision to do this rests with the research team.

Now I may have solved my own problem here by creating a module with a rationale for STEM integration. But, the integration depends on the student perceptions not the enforced teacher direction. We need to devote more than a little effort to developing activities that will force students to consider possible links and possible contributions of the different disciples. And we cannot guarantee that they will opt for our preferred integrated solution if they find an entirely science-based one that they can justify as functional. It is this focus of control that is a concern. If working in a STEM-aware manner offers anything it's this appreciation of the demands and potential of a

range of approaches, under the control of the key researcher or team, rather than a demand that engineers should become biologists or biologist have to be good mathematicians.

Using the modules

Introducing the modules

The modules are designed to be used with Gifted and Talented (G+T) students and cover a wide range of topics in a number of STEM fields. Although they are appropriate for use with grades 7-12, because it is normal for G+T students to work at a variety of levels above their colleagues, the modules are not mandatory specific years. However, the following table gives an indication of the rough grades that could be appropriate for each module.

	Module	Grades
1	School traffic management	7 - 10
2	Rice grain dryer	9 - 12
3	Smart packaging	11/12
4	Tsunami Town	7/8
5	Oil spill	10/11
6	Pack popper	7 - 10
7	Measuring volume	9/10
8	Whitening, pleasant tasting toothpaste	7/8
9	Drone detectives	11/12
10	Mars breakdown	7/8
11	Cleaning up pollution	9 - 12
12	Flood protection	9/10

Teaching the modules

Whilst the modules have been designed to be completed in a minimum of six weeks at two hours' class time a week, it is expected that students and teachers will want to spend considerably longer out-of-class. Indeed, the end production will benefit substantially from the extra time.

The modules are a starting point. Teachers are encouraged to interpret them flexibly and should feel free to change the context to suit local conditions and environment. Contact with local universities or industry may also change the context of the modules.

Gifted and talented students are able to work using their own initiative. The teachers' role is to initiate the module and then support the students without being directive or prescriptive about methods.

The following points provide useful guidance for teacher unfamiliar with these sorts of students.

- Help choice of topic
- Initiate the module – suggest ways of getting started

- Support, do not lead, direct, or prescribe
- Help obtain resources, including access to universities and local industry
- Guide if students are spending too much time on research or a specific stage
- Guide in report or presentation productions and give students confidence to present
- Expand and extend the module topics to stretch the students
- Widen the audience by involving other teachers, parents, local industry other local officials

Each module contains a general teacher guide, which suggests teacher activity at each stage of the module. These suggestions emphasise a 'hands-off' approach which is most appropriate for gifted and talented students.

An assessment guide is also provided. Teachers may decide to choose their own assessment tools, but assessment should be designed to test the characteristics of gifted and talented students. The students' final report or presentation, including prototypes and models, contains the essence of the module and so may form the focus of the assessment as suggested in the module scripts. However, gifted and talented students have many other positive characteristics that can be assessed by other methods including essays, posters, detailed reports with recommendations. Each module includes a question that is designed to demonstrate the student's empathy, the ability to understand and share the feelings of another person, which is well developed in gifted and talented students. There are many other gifted and talented student attributes that can be tested in a similar way.

When the module has been completed, hold a feedback session. How could it be improved? Was the level appropriate? What extra information might have been useful? How could the module be extended? How difficult was it to obtain equipment and facilities? Are there more locally appropriate topics? Can the modules be made easier by local industry and universities? Modules can then be re-written, completing the circle of development.

The STEM modules were developed by a team led by Dr.George Forster, an expert in teaching Gifted and Talented students. Twelve modules were produced in total and are listed below. The full text for all STEM modules are included in Appendix 2 of this report.

Teaching Gifted and Talented students

Definition

There is no universally accepted definition of what makes a "Gifted and Talented" student. The term "Gifted" may refer solely to academically able students or may include those with certain specific talents such as musical performance, whilst "Talented" may be reserved for high achievers in sports.

In general, the group is taken to be roughly equivalent to the top 10% of students across a wide range of abilities including rapid learning and good problem-solving ability along with high levels of creativity.

Criteria for admission to the group also vary widely around the globe. In some countries access to special programmes is gained strictly by examination results for certain achievement levels in numerical and reasoning tests, whilst at the other extreme it may be by taking part in a creative competition at a national or high level. Most selection systems involve a number of criteria, including a measure of performance as well as teacher recommendation.

Characteristics of G+T students

Attributes usually associated with gifted and talented students:

• Rapid learning

- Extensive vocabulary
- Excellent memory, good reasoning
- Strong curiosity
- Creative thinking, original but possibly 'silly' ideas
- Mature for age
- Good sense of humour
- Keen observation
- Compassion for others
- Vivid imagination
- Long attention span
- Ability with numbers
- Concern for justice and fairness
- Sensitivity
- Wide range of interests
- Ability with puzzles
- High energy level
- Perfectionism
- Perseverance in interests
- Questions authority
- Avid readers
- Prefers older companions

Teaching G+T students

Whilst the possession of such positive characters may make these students rewarding to teach, their seeking of high standards and perfectionism can lead to problems.

Unless they are provided with challenging tasks at an appropriate level they may complete tasks well ahead of others and become frustrated and even disruptive. It is therefore good practice to prepare additional stretching exercises for G+T class members to complete in addition to the normal lesson.

However, gifted and talented students do work well with other G+T students in mixed age groups. Younger students learn quickly and effectively from their colleagues and the older students take on a teaching or supervising role that adds to their own learning experience.

Younger G+T students sometimes have difficulty in understanding that others do not learn as quickly as they do and this can also lead to frustration.

G+T students are often perfectionists and do not see that perfection is often not required and may even be undesirable, in terms of cost or efficiency. For example, they may make overly accurate measurements without considering the accuracy of the overall system or the use they will make of the data.

Failure is an unfamiliar experience for many G+T students. When working in general classes they are always top of the class and, when confronted with others of equal ability or presented with very difficult problems, the lack of automatic success is very difficult to accept. At progression stages, such as entering university, their over-confidence can rapidly change into insecurity as they find themselves amongst many other who are just as able as they are. Teachers must prepare these students to face all challenges even those where success is not guaranteed. In addition to

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discussing how to cope with failure, by turning it into a positive learning experience, they should be set very difficult problems and be provided with substantial support whilst working through them. Despite this, G+T students respond well to high cognitive challenge and teachers should set high expectations of success.

As with all students, every G+T student is different. Their learning styles are different and where possible, personalised learning programmes can be very effective. G+T students are mature learners. They find knowing the context, relevance and purpose of their learning stimulating. They appreciate opportunities to choose how, when and at what speed, they learn.

They are also very good at reflection in order to consolidate concepts. It is useful to discuss the value of reflection and how to structure it to gain maximum benefit. Teachers need to have the confidence to build-in time in programmes for reflection.

6   Monitoring and evaluation

Our evaluation model, adapted from the work of Clarke and Hollingsworth (2002) will focus on four analytic domains which will enable the identification of specific mechanisms of change in one domain that influence change in another. The interconnected and non-linear framework of our evaluation approach will help us identify change sequences and specific stimuli which influence those changes. The four domains are:

External domain - this domain represents the external influence exerted by the intervention

Practice domain - this domain encapsulates the actual practice of teachers and is, therefore, concerned with how teachers manage their classrooms and relative pedagogical aspects

Personal domain - this domain captures the teachers' and students' reflections

Domain of consequences - this domain focuses on the actual outputs and outcomes of engagement with the intervention and is, therefore, concerned with the impact on teachers' practice and motivation.
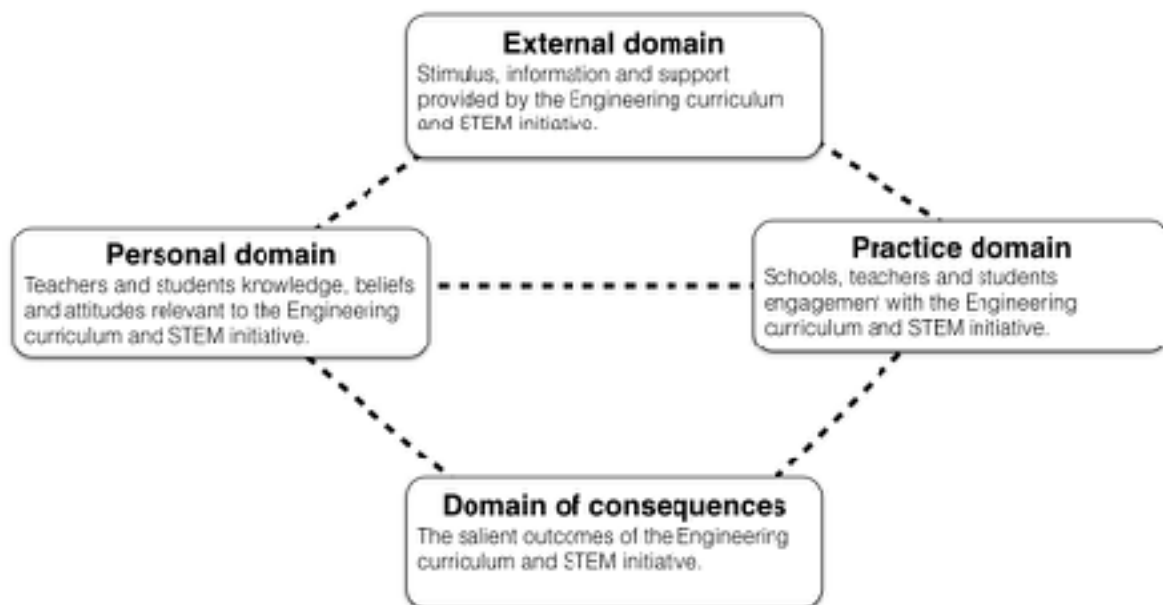
Through the use of an online questionnaire this framework will enable us to identify patterns across the domains and indicate relationships between the domains which are a direct result of teachers' engagement with the intervention.

Again, the detail of the evaluation approach will be agreed with our Thai colleagues, but we provide below our suggested approach which draws on our expertise in and understanding of education research and the evaluation of education interventions.

7   Personnel

OBEC

Dr. Piched Jubjitt, Director, Institute of Science

British Council team

Pijarana Samukkan, Research and Innovation Programme Manager,British Embassy

Chanya Tangsuk Manager of Education, Newton Fund

Uraiwan Samolee – Head of Business Education at the British Council

Sheffield Institute of Education Team

Stuart Bivins

Emily Perry

Gareth Price

Mark Windale

Leicester CPD+ team

George Forster

Tony Daniels

Consultants

Dr. Anne Northcliffe, Sheffield Hallam University

Workshop teachers

Nearly 50 teachers from 195 schools running Gifted and Talented programs across Thailand. The SIOE and Leicester CPD+ teams would like to recognise their contribution to the Workshop and the wider project.