Introduction to STEM-CIP

STEM-CIP

Science, Technology, Engineering, Mathematics-Curriculum Integration Program (STEM-CIP) is an innovative approach to the design of curriculum and instructional materials in which the disciplines of science, technology, engineering and mathematics are taught as one, rather than being distinct and separate as in the past. The natural connections among the four disciplines, which have always been there in the past in research labs and professional work, have not traditionally been emphasised in the design and process of present day education. The (upper primary, middle and high school) modules of the STEM Curriculum Integration Program have been designed to engage students in stimulating, authentic and contemporary problem-based STEM scenarios involving the life, physical, environmental and earth/space sciences, technology and engineering, and mathematics. Drawing from the best in STEM pedagogy, the STEM-CIP modules provide students with the opportunity to learn age appropriate concepts, skills and processes, and to acquire STEM attitudes and "habits of mind".

Curriculum Design Template

All modules within STEM-CIP have been designed using principles of *Understanding by Design* (Wiggins and McTighe, 1998). *Understanding by Design (UbD)* is a well-known curriculum design process used to write units (modules of instruction) in a three-stage process — Desired Results, Assessment Evidence and the Learning Plan. Many departments of education, tertiary institutions and universities, and entire school systems advocate the use of *Understanding by Design* as a contemporary planning process for teaching and assessing applicable standards.

Many authors, among them Reeves (2003), Marzano, Pickering and McTighe (1993) and Lantz (2004) have been proponents of performance-based assessment in which students must demonstrate what they know and can do through the completion of meaningful performance tasks. All modules within STEM-CIP present opportunities for students to engage in performance-based tasks and assessments, along with more traditional forms of assessment, such as selected-response items.

5E Teaching, Learning and Assessing Cycle

A modified 5E teaching, learning and assessing cycle, incorporated into all STEM-CIP modules, is based upon research findings about how students learn science. These findings indicate that students learn best when they have an opportunity to engage in explorations in a hands-on/minds-on environment in which they make and pose explanations for their discoveries. Engagement, Exploration, Explanation, Elaboration and Evaluation are the recursive phases of the 5E teaching, learning and assessing cycle. A brief guide to the 5E model appears next.

The Original 5E Model – At-a-glance Guide (Trowbridge & Bybee, 1996)

Engage
This stage is designed to interest students in the learning, linking it with past learning and common background knowledge. It stimulates curiosity and promotes questioning, while linking the learning to real world experiences. This has a twofold purpose – it interests students in what is coming, while simultaneously showing them the purpose for the learning by situating it in their existing worldview. Teachers can guide this stage by asking specific questions to elicit prior knowledge from students.

Explore
This stage allows students to directly engage with key concepts by inciting them to probe, enquire and question, using their existing knowledge to connect it to new concepts and ideas. These connections may occur rapidly, or may need to be broken down several times before they are clear. The teacher is responsible for directing questioning appropriately and providing probing questions to push children in the right direction.
Explain
In this stage, students begin to logically sequence events and facts from their exploration, with a view to being able to communicate this information to others. The teacher can use this stage to act as a facilitator, offering further explanations and clarifying terms, etc, as necessary. This stage is useful in ascertaining the learner's development and grasp of the key ideas and concepts so far.
Elaborate
This stage allows students to expand what they've learned so far and to connect this directly with their prior knowledge and learning, hopefully reaching understanding. The teacher can therefore verify student understanding fully at this stage.
Evaluate
The process of evaluation should occur throughout the learning experience, allowing the teacher to determine whether the learner has reached the level of understanding needed at every stage. More formal evaluation, however, can now be conducted. If at any point the teacher decides that a student has not reached the desired level, they simply go back to the appropriate stage.

Breakdown of Activities by 5E

TITLE	TOPIC / CONTENT	5E
Module Engagement	Let's Soar: Launch a Rocket and Introduce Module Performance Task	Engage, Evaluate
Activity 1	Dissolving Materials	Explore, Explain, Evaluate
Activity 2	Alka-Seltzer and Water	Explore, Explain, Evaluate
Activity 3	Temperature and Dissolving Time	Explore, Explain, Evaluate
Activity 4	Particle Size and Dissolving Time	Explore, Explain, Evaluate
Activity 5	Different Liquids and Dissolving Time	Explore, Explain, Evaluate
Activity 6	What is Form and Function?	Explore, Explain, Evaluate
Activity 7	Engineering Your Rocket	Elaborate, Evaluate
Activity 8	Engineering Your Rocket: Redesign and Launch Day	Elaborate, Evaluate
Activity 9	What Goes Up Must Come Down	Elaborate, Evaluate
Activity 10	What Might Affect Gravity?	Elaborate, Evaluate
Activity 11	Rhythms of Gravity	Elaborate, Evaluate

Levels of Inquiry

All the example standards (derived from the US National Science Education Standards, the US National Council of Teachers of Mathematics Standards, the US National Education Technology Standards for Students and the Standards for Technological Literacy) utilised in STEM-CIP modules call for teaching, implementing and assessing student understanding of inquiry throughout the curriculum. As a result, four scaffolded levels of inquiry are included in most modules, starting with the most structured form — confirmatory inquiry, moving on to structured inquiry, then to guided inquiry and finally to open inquiry. As students learn the skills and processes, and the content of inquiry, they are challenged by activities that become increasingly more open.

Mathematics in STEM-CIP Modules

One of the goals of STEM-CIP is to develop mathematical power for all students through an integration of science, technology, engineering and mathematics. Exemplary STEM curriculum modules should include performance tasks that engage students and deepen their understandings of mathematics and its applications, and at the same time promote the investigation and growth of mathematical ideas. A key question that is addressed in all STEM-CIP modules is "What enabling mathematical knowledge (facts, concepts and principles) and skills (procedures) will students need to perform effectively and achieve desired results (Stage One of UbD)?"

- Mathematics data on student performance from STEM-CIP modules provide mathematics teachers and curriculum designers with a way to sequence mathematics standards and indicators, and to plan instructional strategies. The disaggregated mathematics data from STEM-CIP provide answers to the sequence of mathematical units and also generate questions about a maths curriculum.

Questions that may need to be addressed are:

- How do we sequence our mathematics curriculum when our mathematics text was not written in the same order?
- What are the strengths and weaknesses of our mathematics students?
- Although prior knowledge and skills were taught, some students have not demonstrated proficiency. Why?
- What type of remediation model was used?
- What type of enrichment model was used?
- What types of professional development needs were identified?
- How does STEM-CIP mathematics data compare with wider milestone/benchmark data?
- What other resources are needed to "enable" our students?

Assessment of Student Work

Formative and summative performance-based assessments have been thoughtfully sequenced and scaffolded to provide ample opportunities for students, teachers, parents and others to assess student progress. An end of module summative assessment contains selected- and constructed-response items.

Extensive rubrics are provided for open-ended, performance-based questions and other performances that cannot be scored using typical right or wrong multiple-choice items. In addition, most activities within STEM-CIP contain an end-of-activity evaluation called "Check Your Understanding" which consists of selected-response items that lend themselves to the use of Student Response Systems for ease of scoring and immediate feedback on student understanding. Each activity within the modules is accompanied by scoring tools, including a variety of field-tested and US National Science Teachers Association (NSTA) endorsed performance list, holistic and analytical rubrics.

Teacher's Guide (TG)

The Teacher's Guide (TG) provides much detail about implementing the module. A matrix of example standards, consisting of the US National Science Education Standards, the US National Council of Teachers of Mathematics

Algebraic Expressions

Evaluate formulas and algebraic expressions given the value of the variables.

33. What is the value of the expression x + 32, when x = 18?

    D. 50

34. What is the value of the expression 2L + 2W when L = 16 and W = 12?

    C. 56

35. A car travelled at 35 kph for 3 ½ hours. What is the distance the car travelled? Use the formula d = r · t. Round your answer to the nearest whole number.

    D. 123 kilometres

Patterns and Functions

Solve problems involving patterns and functions using a calculator when appropriate.

36. What are the values for "x" and "y"?

Hours Worked (h)	1	2	3	4	80	y
Toys Produced (p)	4	8	12	16	x	400

D. x = 320 y = 100

37. What are the values for "a" and "b"?

Days (d)	1	2	3	4	5	6	7
Total Spiders (t)	14	28	56	112	224	a	b

D. a = 448 b = 896

38. How many dots are needed for drawing m and n?

1 2 3 4 6 8

C. m = 36 n = 64

Functional Relationship

Given a functional relationship, describe how a change in one variable results in a change in the other.

39. Which answer describes how a change in "x" results in a change in "y"?

x	2	4	6	8	10
y	10	20	30	40	50

A. as "x" increases by 2, "y" increases by 10

Activity 9: What Goes Up Must Come Down

Activity Description

Activity 9 is a post-launch, structured inquiry. It reinforces and extends the students' understanding of the force of gravity which they have been experiencing and are beginning to build an understanding of throughout Activities 7 and 8.

WHERETO Elements

E — How will we EQUIP students to EXPLORE and EXPERIENCE the expected performances?

T — How will we TAILOR learning to the varied needs, interests and learning styles of different students?

Materials Needed

- Tennis ball
- Cricket ball
- Ping pong ball
- Pencil
- Ruler

Background Information

Gravity is a force of attraction that exists between any two objects. There is a force of gravity between the sun and the Earth, between the Earth and us, and even between two marbles. Projectiles, satellites, planets, galaxies and clusters of galaxies are all influenced by gravity.

Gravity is the weakest of the four known forces of nature, yet it is the most dominant force. Even though it's the weakest force, gravity holds entire solar systems and galaxies together. The law of universal gravitation says that every object attracts every other object with a force that, for any two objects, is directly proportional to the mass of each object and inversely proportional to the square of the distance between the two objects.

There is a popular story that Newton was sitting under an apple tree when an apple fell on his head, and he suddenly thought of the Universal Law of Gravitation. As in all such legends, this is almost certainly not true in its details, but the story contains elements of what actually happened.

What really happened with the apple? Probably the more correct version of the story is that Newton, upon observing an apple fall from a tree, began to think along the following lines: The apple is accelerated, since its velocity changes from zero as it is hanging on the tree and moves toward the ground. Thus, by Newton's 2nd Law there must be a force that acts on the apple to cause this acceleration. Let's call this force "gravity" and the associated acceleration the "acceleration due to gravity". Then imagine the apple tree is twice as high. Again, we expect the apple to be accelerated toward the ground, so this suggests that this force that we call gravity reaches to the top of the tallest apple tree.

Now comes Newton's truly brilliant insight — if the force of gravity reaches to the top of the highest tree, might it not reach even further — might it not reach all the way to the orbit of the Moon? If so, the orbit of the Moon about the Earth could be a consequence of the gravitational force, because the acceleration due to gravity could change the velocity of the Moon in just such a way that it followed an orbit around the earth.

Galileo was probably the first to look closely at the way objects fell down to Earth. Legend has it that he climbed to the top of the leaning Tower of Pisa and from there dropped simultaneously heavy and light balls, noting that they hit the ground at the same time. He thus demonstrated, contrary to some an-