Applying Computational Thinking in STEM Education
Defining...

STEM Education and Computational Thinking

SOLUTIONS by iCarnegie Global Learning
Need for STEM-ready workforce: Changing work tasks

- The skills required of today’s workforce are changing dramatically.
- Since 1980, there has been a rapid increase in the need for cognitive analytic and interpersonal tasks.
- These skills directly correspond to computational thinking skills.
Need for STEM-ready workforce: Changing work tasks

- Increasingly, workers are being required to do things like:
  - **Work with new information**
    Acquire and make sense of new information for problem-solving purposes
  - **Solve unstructured problems**
    Solve problems that lack rules-based solutions
What is STEM Education?

Science, Technology, Engineering, and Math

Provides hands-on, relevant learning experiences that teach important 21st century skills and prepare students for the emerging global economy

“...the integration of Science, Technology, Engineering and Math instruction, combined in classroom learning with real-world experiences to provide students with both the technical and personal professional skills they need to succeed.”

“STEM education is the key to innovation and economic growth in this digitally connected world, where we are surrounded by technology and innovations.”

UNESCO
In development since 2008, AP Computer Science Principles (AP) was created with significant support from the National Science Foundation. The Software Research Institute (SRI) additionally began in 2011 development of design patterns that can be used to assess Computational Thinking.

Both AP and SRI recently released documents that identify computational thinking skills and practices.
At its heart lies the notion of computational thinking: a mode of thought that goes well beyond hardware and software, and that provides a framework within which to reason about systems and problems.

Students should be:

- immersed in the problem-solving process, both individually and collaboratively
- learning first how to decompose problems and then apply that to larger tasks
- have opportunities to seek or explore different solutions
- have opportunities to apply CT skills across different disciplines
Empowering ALL with STEM Education (Computational Thinking)

Our vision is that computational thinking is for everyone, not just computer scientists.

*Carnegie Mellon University is the curator of Computational Thinking and this concept is applied in our STEM Programs, which is essential in the ever-changing digital age.*
Approach
Learning-by-doing
Approach in Delivering the Curriculum

Learning by Doing Pedagogical Approach
- Hands-on Activities
- Solving Real-World Problems
- Project-based and Inquiry-based
- Collaborative learning

Integrated Curriculum
- Students develops holistically
- Integrated knowledge
- Help students to apply skills
- Authentic assessment that reflected the curriculum

Learner-Centric/Teacher Empowered
- Facilitated Learning
- Differentiated Instructions & Discovery Learning
- STEM Experts
- Research-Based
- Ongoing PD
Deep Learning in STEM Education

‘Deep learning’… develops the learning, creating and ‘doing’ dispositions that young people need to thrive now and in their futures… Deep learning is more natural to the human condition because it more clearly connects with our core motivations: to directly and deeply engage in learning; and to do things that truly make a difference to our lives and to the world.

The goals of deep learning are that students will gain the competencies and dispositions that will prepare them to be creative, connected, and collaborative life-long problem solvers and to be healthy, holistic human beings who not only contribute to but also create the common good in today’s knowledge-based, creative, interdependent world.

Deep learning through Learning-by-Doing

“For the first time in history, the mark of an educated person is that of a doer (a doing-thinker; a thinker-doer) - They learn to do, and do to learn. They are impatient with lack of action. Doing is not something they decide to do - daily life is doing, and as natural as breathing air.”

How Students Learn Computational Thinking

Abstraction bridges are opportunities for students to write explanations that prompt them to generalize the concepts and skills learned within the course’s activities. In these written assignments, students most often generalize by describing when a concept or skill has been used in other contexts (another class, daily life, etc.).

Computational Thinking Concepts

- Decomposition
- Algorithms
- Abstraction
- Debugging

*An integrated curriculum, with a focus on one of the big areas
Decomposition

• Large task **break into minute details**

• Allow us to **clearly explain a process** to another person or to a computer, or even to just write notes for ourselves
Abstraction

• The ability to **filter out information** that is not necessary to solve a certain type of problem and generalize the information that is necessary

• It allows us to represent an idea or a process in general terms (variables) so that we can use it to **solve other problems** that are similar in nature
Algorithms

• The ability to develop a **step-by-step strategy** for solving a problem
• It is often based on the **decomposition of a problem** and the **identification of patterns** that help to solve the problem
• In CS, it is often **written abstractly**, utilizing **variables** in place of specific numbers
Debugging in Level 1 curriculum

- Make **predictions**
- It helps develop children’s ability to reason logically and to make deductions from the information they have
- Debug – looking carefully at the code and using **logical reasoning to explain** what the program is actually doing are good starting points
Debugging in Level 3 Curriculum

The debugging process and 10 debugging challenges

How can you fix these…?

#3
The user wants the sprite to move back and forth, and play a drum after each time that it moves. But, the sprite only moves forward.

#9
The user wants the sprites to speak to each other face to face. However, they are not facing each other.
Integrated Curriculum for Holistic Learning Experience on STEM Education

Structured and well-designed continuum of curriculum by global STEM Education leaders

Source:
• OECD and PISA (2005). Definition and selection of key competencies.
• Council of Chief State School Officers (2013)
These dispositions and attitudes were outlined by the Computer Science Teachers Association (CSTA).

These dispositions or attitudes include:

• Confidence in dealing with complexity
• Persistence in working with difficult problems
• Tolerance for ambiguity
• The ability to deal with open-ended problems
• The ability to communicate and work with others to achieve a common goal or solution
Preparing the STEM Educators…

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Teachers as STEM Educators

Structured Professional Development Program

Teacher as a Facilitator of Learning

Dispositions: Openness & Willingness to Accept Changes

“Learning by Doing” and Constructivist Approach
Recommendations for pre-requisites of teachers

1. Openness and willingness to accept changes and learn new things
2. Comfortable with computers and technology
3. Willing to troubleshoot their own problems
4. Motivated to teach students
5. Patient with slow learners
6. Willingness and openness to accept changes and learn new things
7. Comfortable with Maths and [Science (Physics) for robotics]*

*need not be Maths and/or Science Teachers, or major in Maths and Science

Note: These recommendations are a guide for the selection of the type of teachers that are suited to teach the STEM with Robotics courses. It is up to the discretion of the individual school to select teachers to teach their courses.
Structured Professional Development Program

Prior to implementation
- Face-to-face training
- Training on the curriculum, technical, pedagogical & assessment
- Teachers’ assessment & certification

Implementation the STEM Program
- Curriculum materials and resources
- Support from school leaders/ministry and trainers
- Community of Practice for a network of support (Vygotsky’s Zonal Proximal Development)

Continuous Professional Development
- Pls see next slide
STEM Educator Training Program

Curriculum

Assessment

Pedagogical

Technical
What will teacher receive from the training?

• Teacher notes
• Teaching slides
• Access to resources in LMS
• Certification from Carnegie Mellon’s Robotic Academy*

*Depending on types of certification that customer chooses
Authentic Assessment and Certification

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### Purpose of Assessment

<table>
<thead>
<tr>
<th>For students</th>
<th>For teachers</th>
<th>For schools</th>
<th>For parents</th>
</tr>
</thead>
</table>
| • Understand teachers’ expectations & standards  
• Use feedback to improve their performance  
• Monitor and assess own progress as they work towards clearly indicated goals  
• Self-reflect strengths and weaknesses, and work on areas for improvement | • Use assessment info to improve teaching & students’ learning  
• Evaluate effectiveness of instructional strategies  
• Motivate students to be more engaged on learning | • Evaluate students’ learning and award certification  
• Evaluate teachers’ effectiveness  
• Hold program accountable | • Inform about the progress of children’s learning  
• Parent-involvement in children’s learning  
• Home-school communication |
Assessment Approach for STEM Education: Authentic Assessment

- Based on performance of the skills
- Variety of data collected in an ongoing basis
- Takes place in a natural learning context
- Shared responsibility & extensive engagement of students

Authentic Assessment
Availability of Student Assessments

Formative and Summative Assessment

Formative Assessment → Assessment for Learning

Summative Assessment → Assessment of Learning

Source: Ainsworth and Viegut (2006)
Types of Assessment Tools

- Comprehension checks
- Assessing processes
- **Performance tasks**
- Pre- and post-tests
- Assessing prior knowledge
- Reflection assignment
- Etc.
## Sample of Collaboration Rubric

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
<th>Ideal</th>
<th>Approaching</th>
<th>Developing</th>
</tr>
</thead>
</table>
| **Working with Others**  | • Listens to others.  
• Shares with…  
• …                      | •       | •           | •          |
|                          |             | •     | One bullet is missing. | One or no bullet is true. |
|                          |             | All 3 bullets are true. | One bullet is missing. |
| **Focus on the task**    | • Stays focused on the project.  
• Can identify…  
• …                      | •       | •           | •          |
|                          |             | •     | One bullet is missing. | One or no bullet is true. |
|                          |             | All 3 bullets are true. | One bullet is missing. |
| **Contributions**        | • Provides useful ideas during discussions  
• Can lead…  
• …                      | •       | •           | •          |
|                          |             | •     | One bullet is missing. | One or no bullet is true. |
|                          |             | All 3 bullets are true. | One bullet is missing. |
| **Time-Management**      | • Has all materials needed for class that day.  
• Has been able to…     | •       | •           | •          |
|                          |             | •     | One bullet is not true. | No bullet is true. |
|                          |             | Both bullets are true. | One bullet is not true. |
| **Communication**        | • Expresses thoughts clearly using oral, written and/or nonverbal communication skills.  
• Communicates respectfully. | •       | •           | •          |
|                          |             | •     | One bullet is not true. | No bullet is true. |
|                          |             | Both bullets are true. | One bullet is not true. |
## Sample of Project Rubric

<table>
<thead>
<tr>
<th>Description</th>
<th>Ideal</th>
<th>Approaching</th>
<th>Developing</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Designing &amp; Planning</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• The project achieved its intention as stated in the objectives</td>
<td>•</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>• The user is able to...</td>
<td>•</td>
<td>• One bullet is missing.</td>
<td>One or no bullet is true.</td>
</tr>
<tr>
<td>• ...</td>
<td>All 3 bullets are true.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Programming</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• The requirements are all completed correctly</td>
<td>•</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>• The program shows...</td>
<td>•</td>
<td>One bullet is true.</td>
<td>No bullet is true.</td>
</tr>
<tr>
<td><strong>Application of New Knowledge</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• The project includes new programming blocks or skills taught in recent class</td>
<td>•</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>• Those blocks...</td>
<td>•</td>
<td>One bullet is true.</td>
<td>No bullet is true.</td>
</tr>
<tr>
<td>• Those blocks...</td>
<td>Both bullets are true.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Content Organization</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• The animation connects topics in clear ways</td>
<td>•</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>• The organization of topics...</td>
<td>•</td>
<td>One bullet is true.</td>
<td>No bullet is true.</td>
</tr>
<tr>
<td>• Those blocks...</td>
<td>Both bullets are true.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Testing</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• The project does not have any bugs...</td>
<td>•</td>
<td>Project has two or less bugs.</td>
<td></td>
</tr>
<tr>
<td>• The bullet is true.</td>
<td>The bullet is true.</td>
<td>Project has more than two bugs.</td>
<td></td>
</tr>
<tr>
<td>• Those blocks...</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Ideal**: All 3 bullets are true.
- **Approaching**: One bullet is missing.
- **Developing**: One or no bullet is true.
Artefacts: Students Created Own Quizzes
Summary

- Offers age appropriate and multi-levels of quality structured content
- Hands-on, Learning by Doing
- Guided instructions
- Teaching and learning resources
- Embeds authentic assessment (Quiz, Rubrics)
- Unique software that comes at no additional costs with the curriculum, such as Sandbloqs
- Activities promotes collaboration and other 21st Century Skills
Thank You!

MAKE MY DAY.

Ask me Questions!

ps.ng@cmasialearning.com
enquiry@cmasialearning.com
www.cmasialearning.com