January 2017

Applying Computational Thinking in STEM Education

CM ASIA LEARNING

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robomatter

Defining…

STEM Education and Computational Thinking

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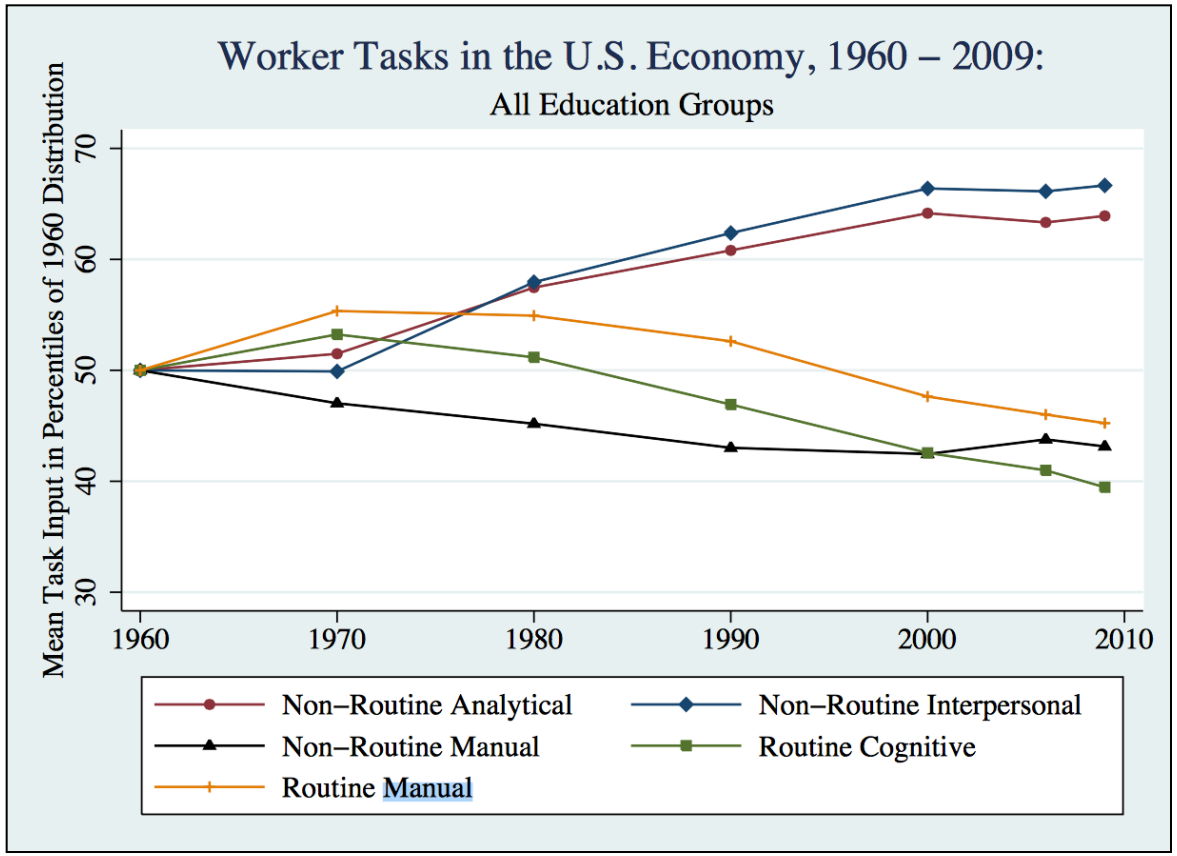
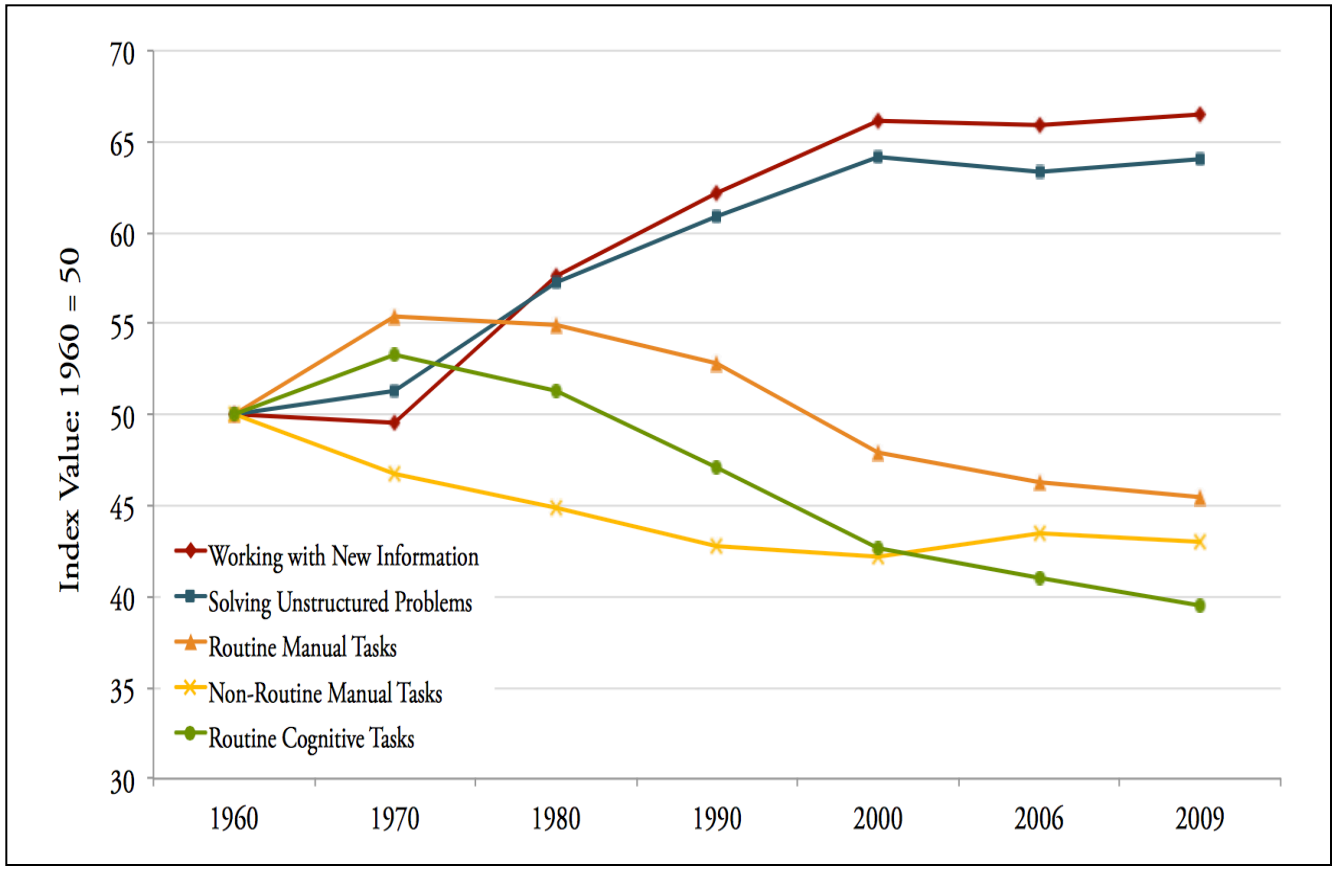
Need for STEM-ready workforce: Changing work tasks



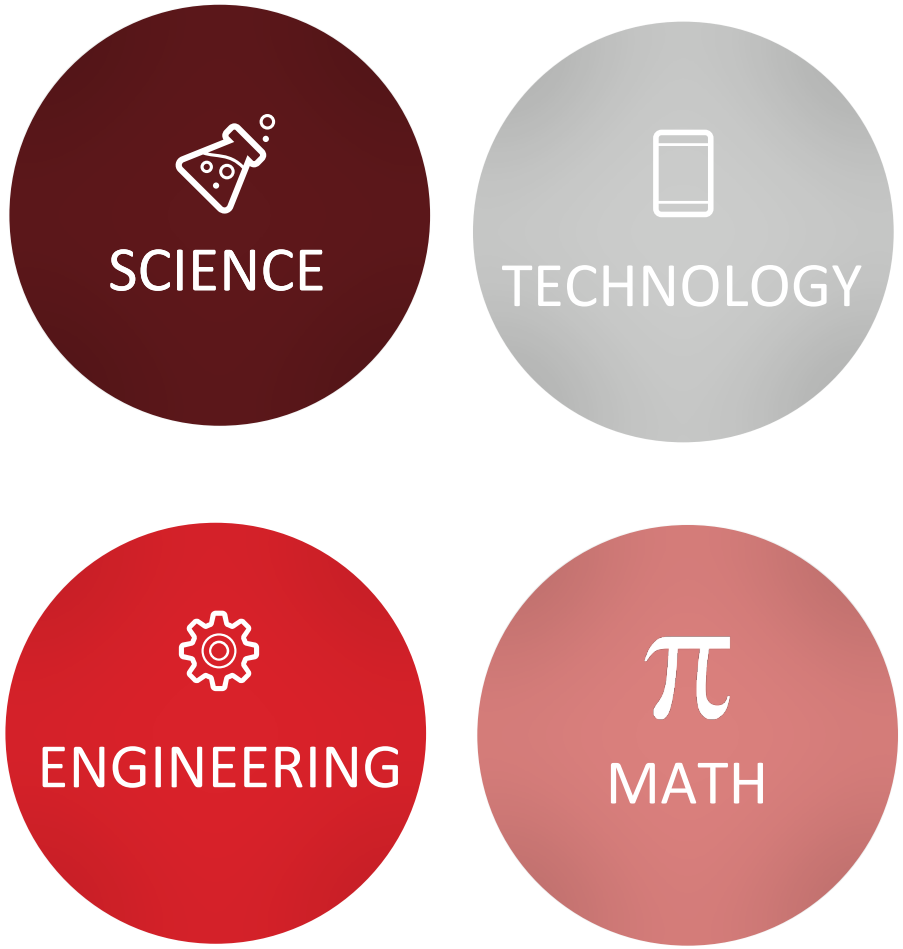
- The skills required of today's workforce are changing dramatically
- Since 1980, there has been a rapid increase in the need for cognitive analytic and interpersonal tasks
- These skills directly correspond to computational thinking skills

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?



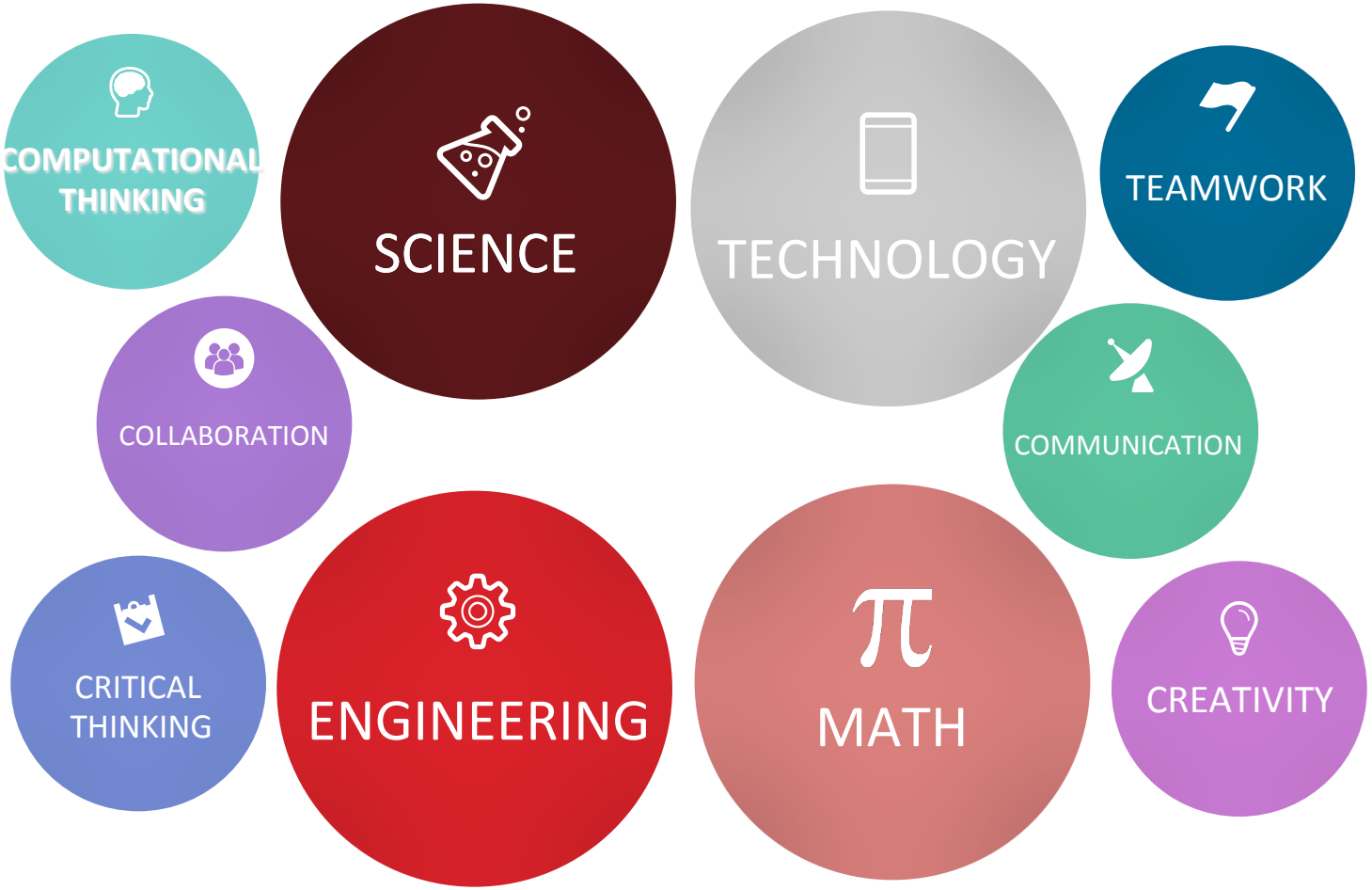
Science, **T**echnology, **E**ngineering, and **M**ath

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."*

The Global STEM Paradox,
The New York Academy of Sciences, 2015

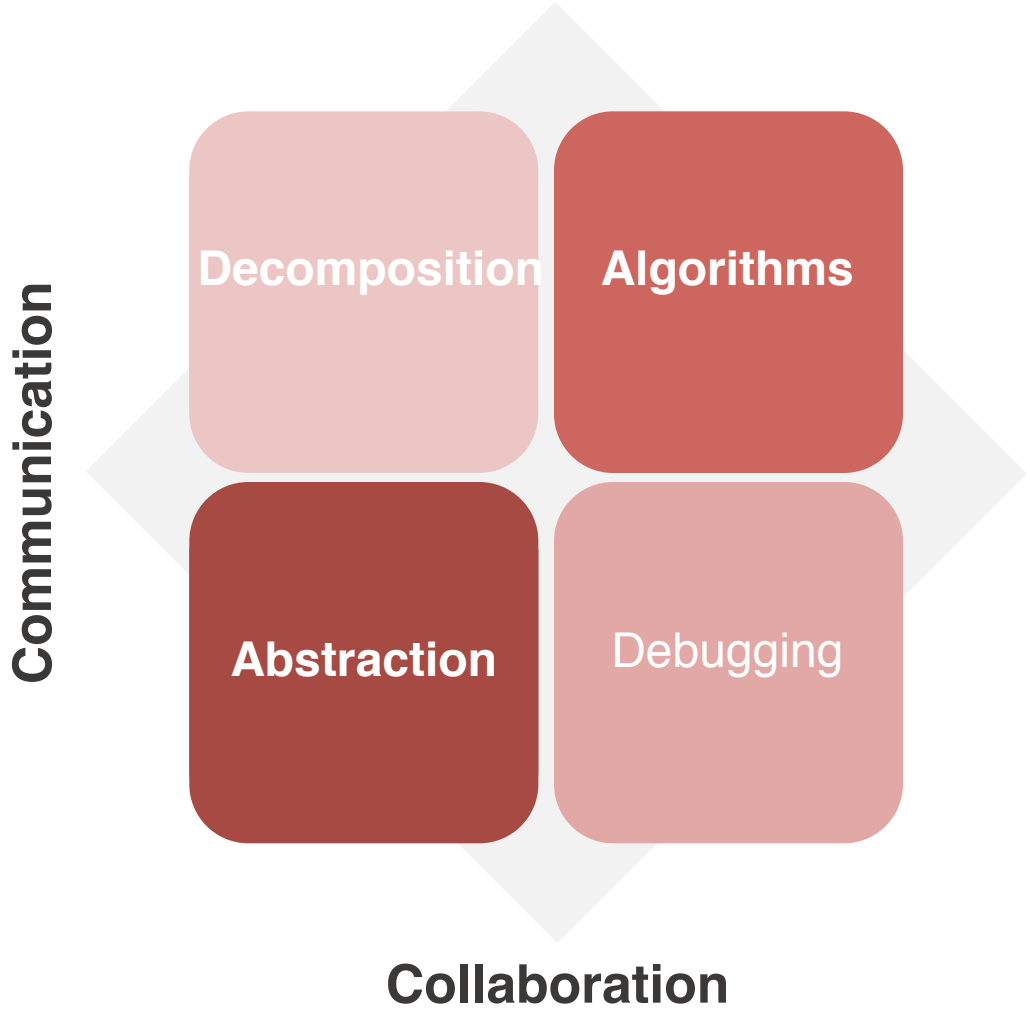
STEM Education



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

UNESCO

Fundamental Computational Thinking Practices



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.

Computational Thinking

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

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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

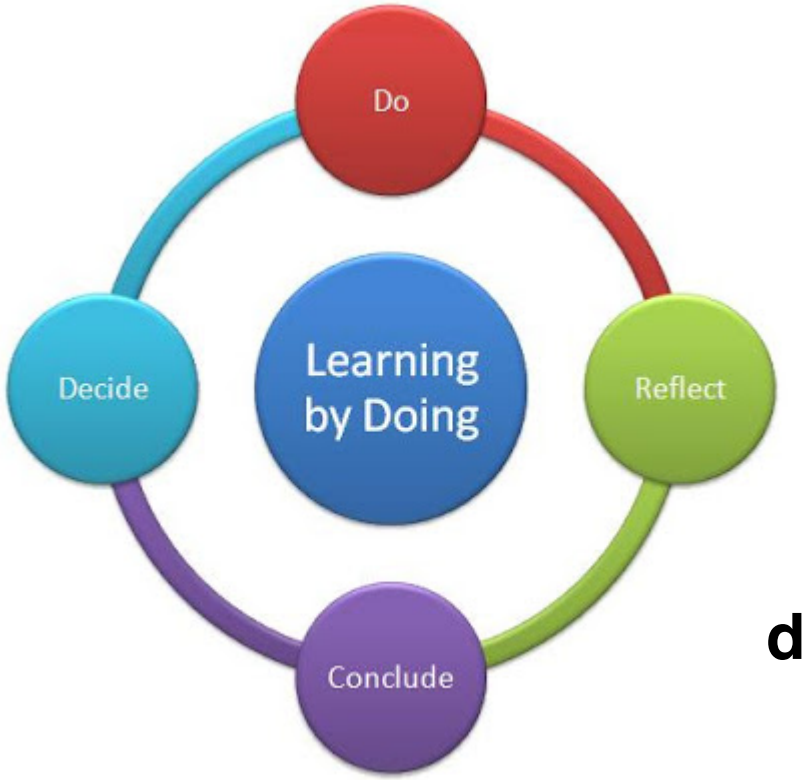
Deep Learning in STEM Education

'**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.

Source: Fullan, M. and Langworthy, M. (2014) A rich seam: How new pedagogies find deep learning

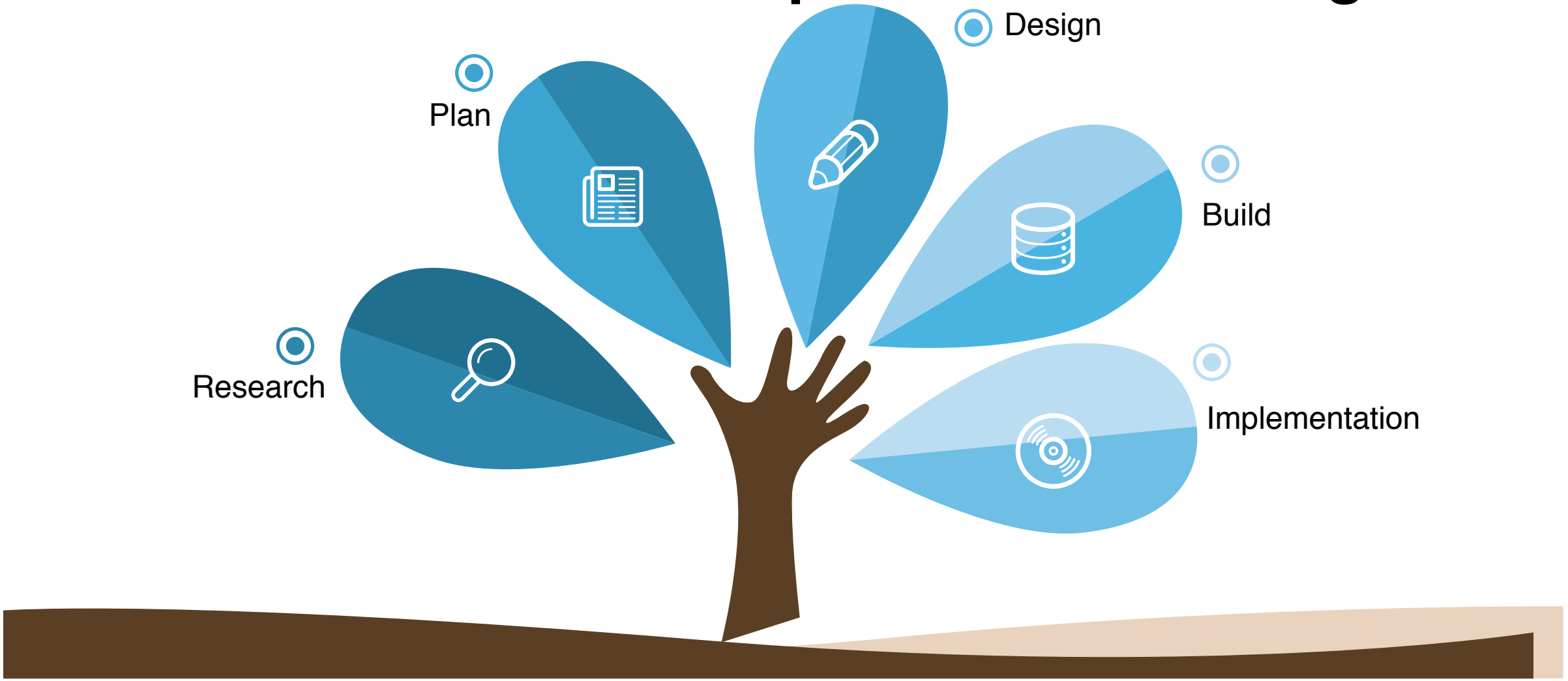
Deep learning through Learning-by-Doing



"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**."

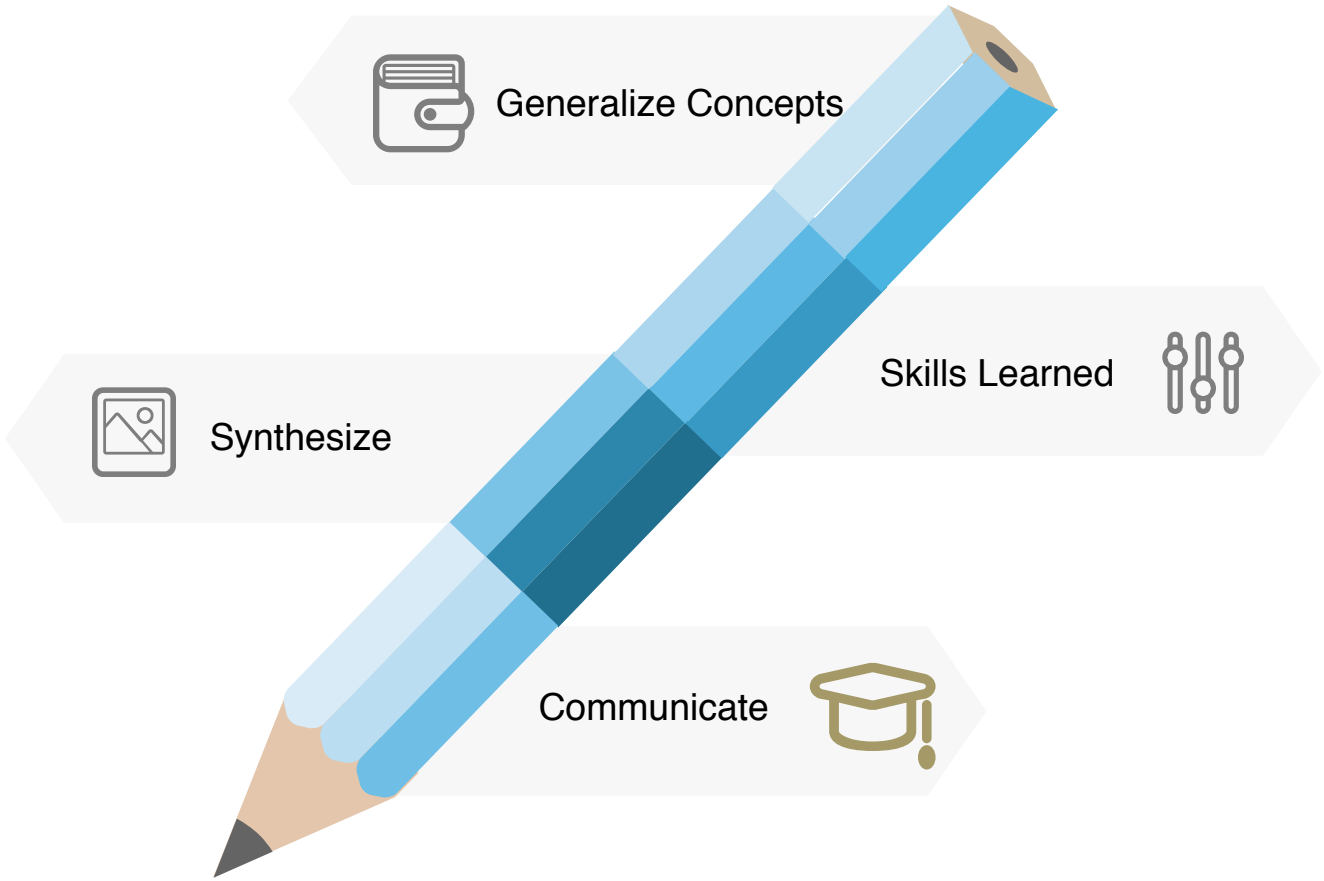
Source: Fullan, M. and Scott, G. (2014) New pedagogies for deep learning: Education plus

How Students Learn Computational Thinking



Kurland, D. M., Pea, R., Clement, C., Mawby, R. (1986) A study of the development of programming ability and thinking skills in high school students, Journal of Educational Computing Research, 2 (4) (1986), pp. 429–458

Using Abstraction Bridges to Teach Computational Thinking

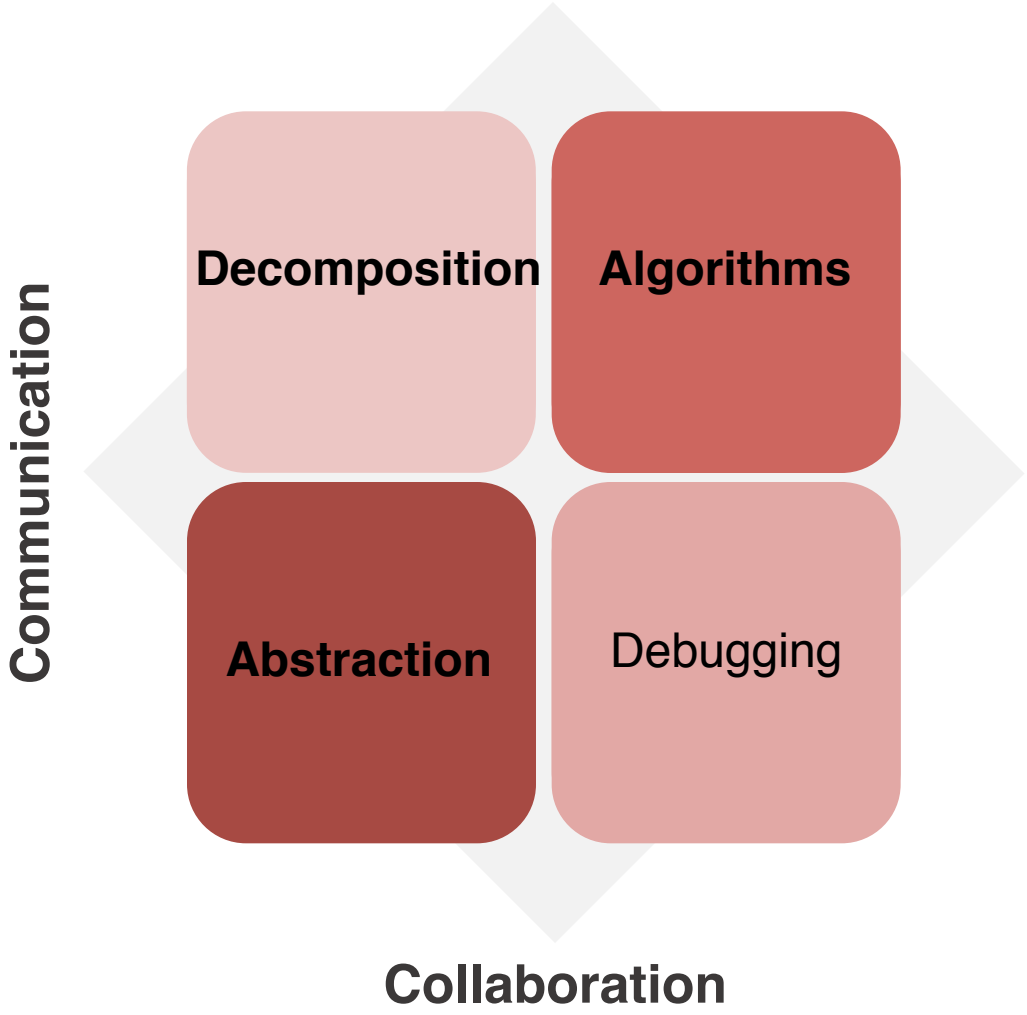


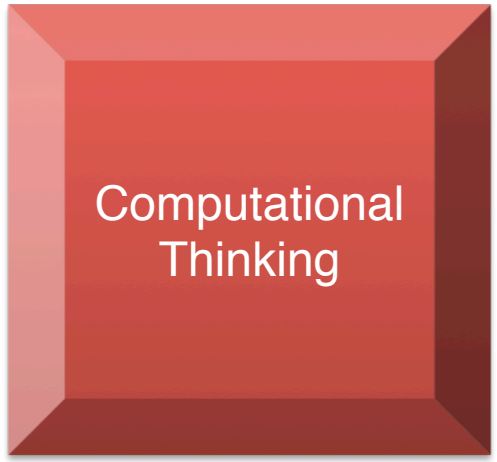
Transfer Their New Understanding

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.).

Brown, D. E. & Clement, J. (1989). Overcoming misconceptions via analogical reasoning: Abstract transfer versus explanatory model construction. Instructional Science, 18, 237-261.

Computational Thinking Concepts





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

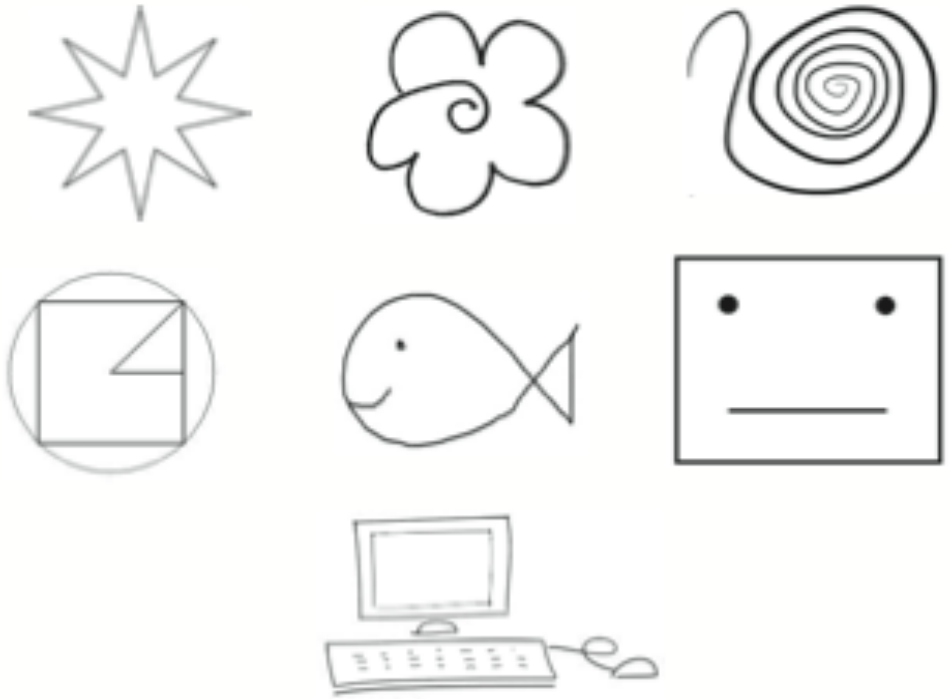
Decomposition

- 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

Unplugged: Draw This!

Now you will write instructions for a friend to draw a new doodle. Remember that you need to be precise. Choose one of these doodles and circle it to remember your choice:



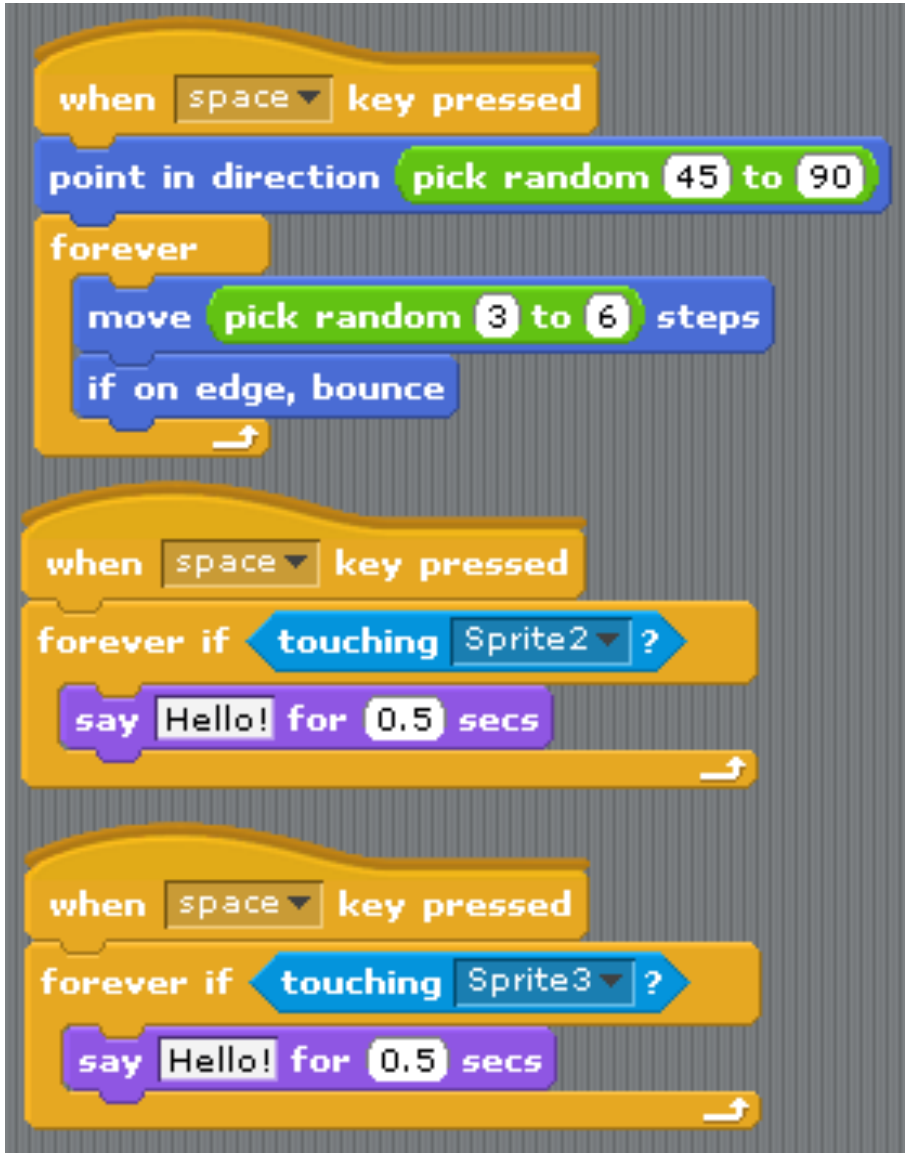
Abstraction

- 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

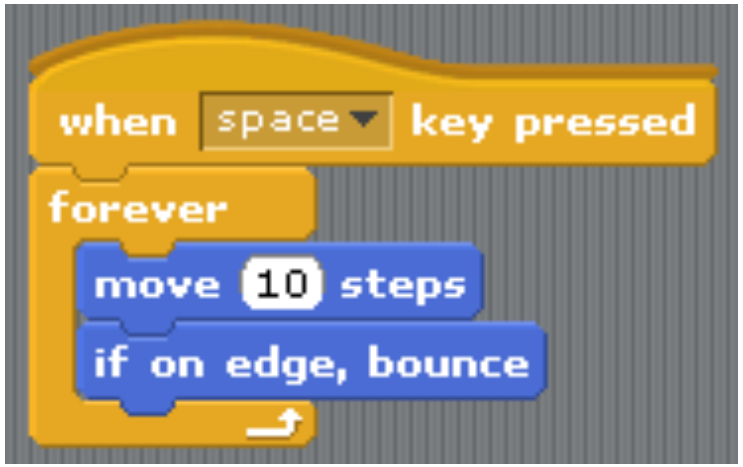
Algorithms

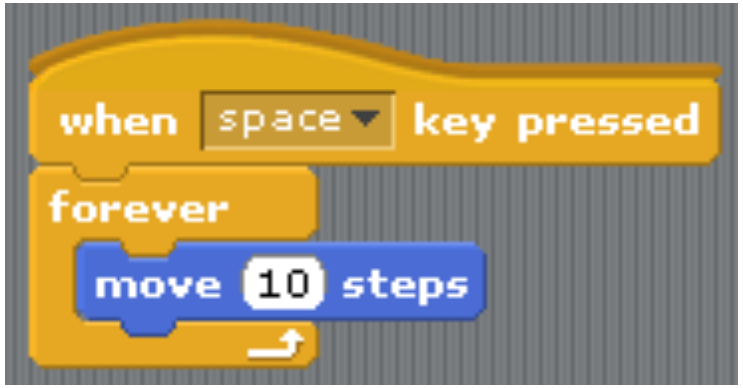
- The ability to develop a **step-by-step strategy** for solving a problem
- It is often based on the **decomposition of a problem** and the **identification of patterns** that help to solve the problem
- In CS, it is often **written abstractly, utilizing variables** in place of specific numbers



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

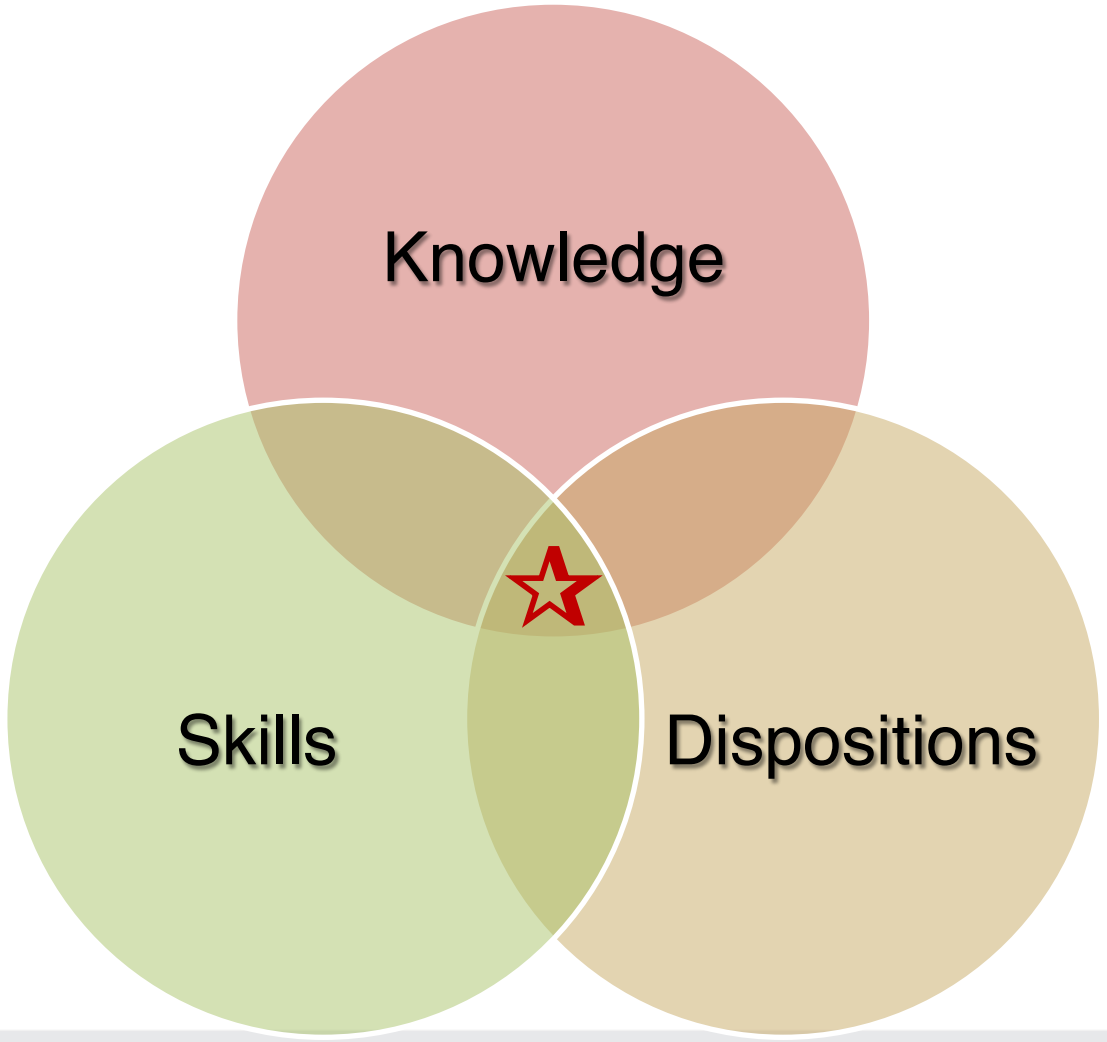
The user wants the sprite to move back and forth, and play a drum after each time that it moves. But, the sprite only moves forward.

#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:

- Katz and Raths (1985). Categories of learning.
- OECD and PISA (2005). Definition and selection of key competencies.
- Council of Chief State School Officers (2013)

STEM Attitudes and Dispositions

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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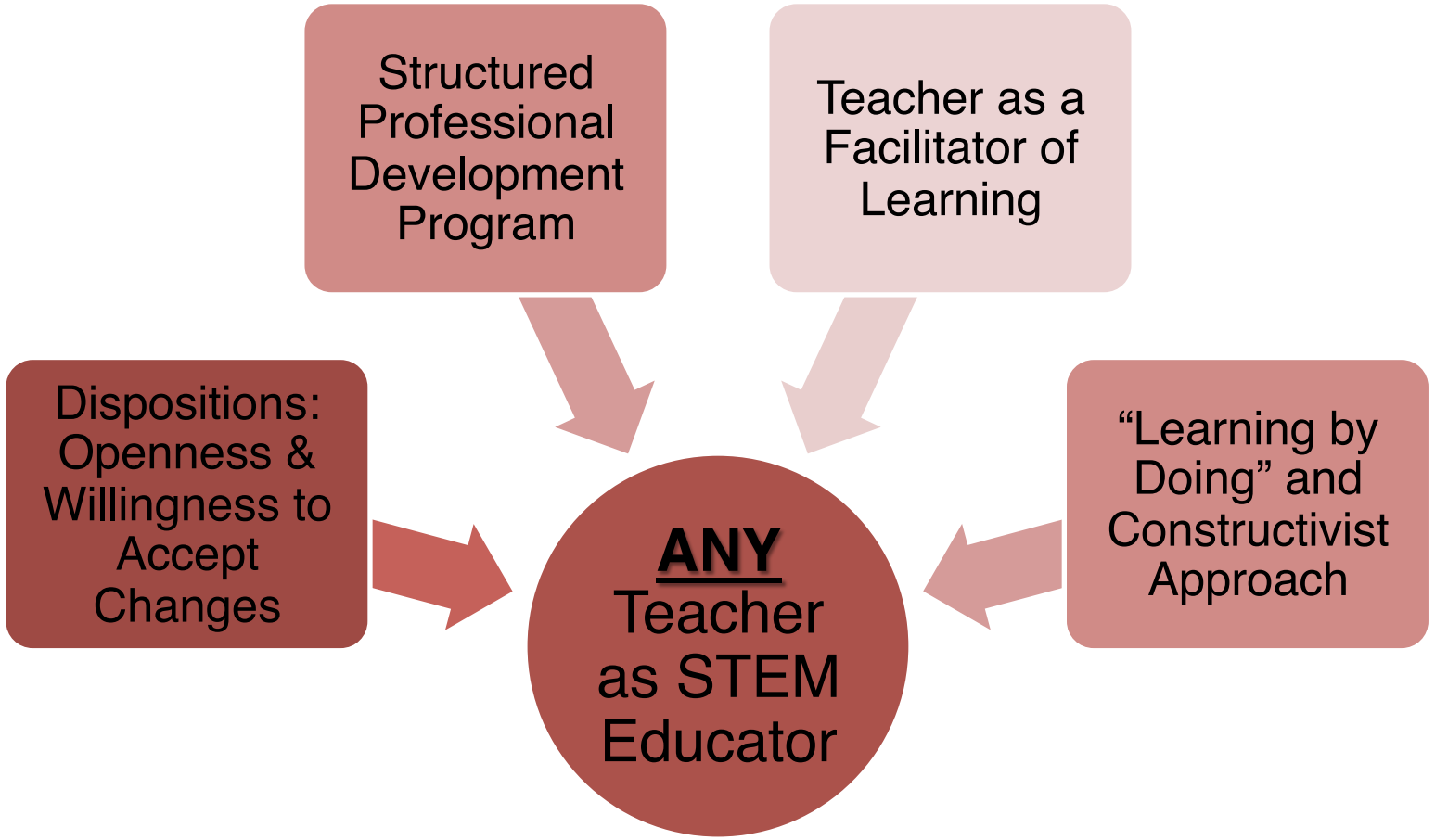
Teachers as STEM Educators



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

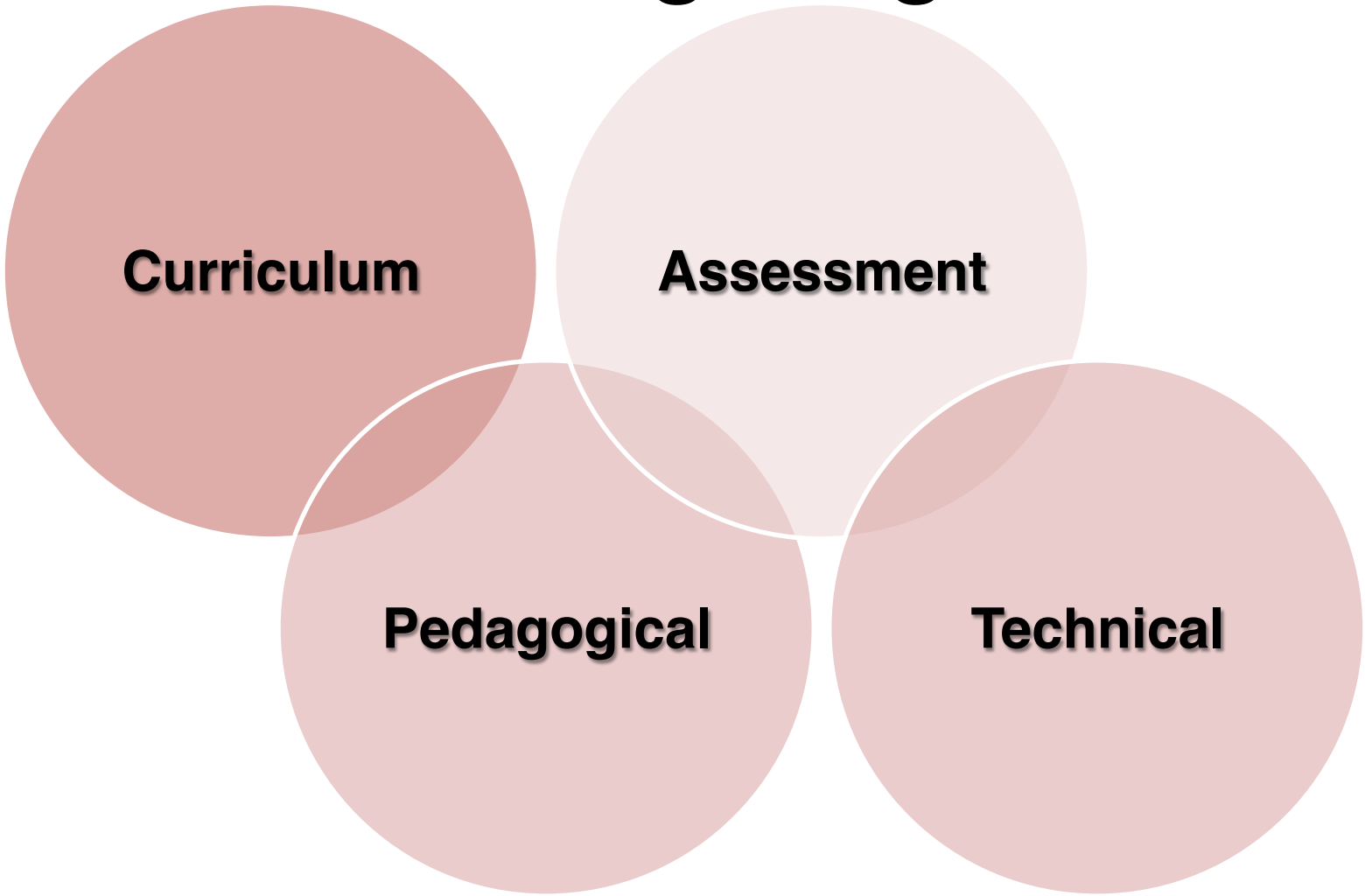
Implementation the STEM Program

- 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



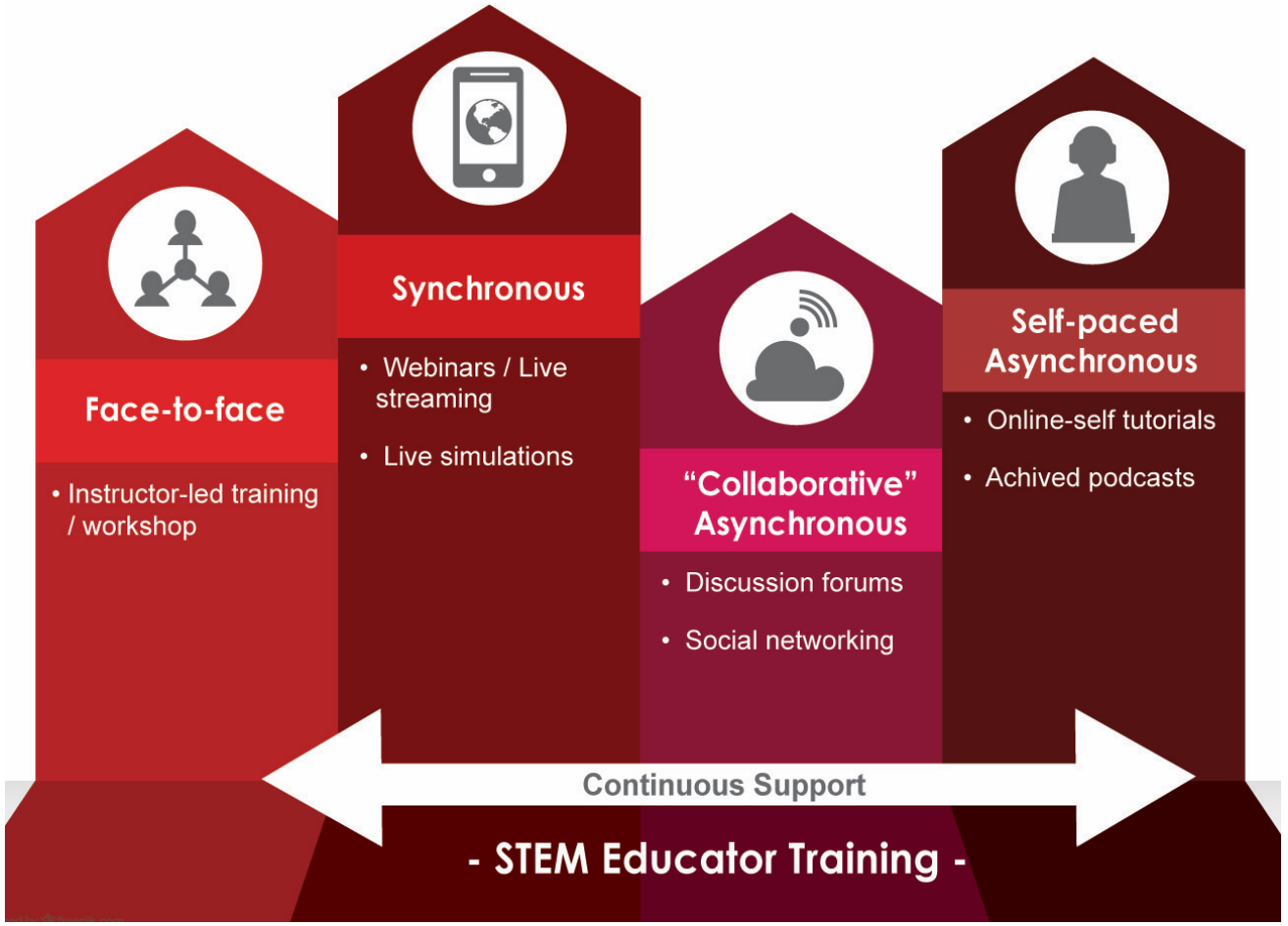
STEM Educator Training

Continuous Support

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

For students

- 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

For teachers

- Use assessment info to improve teaching & students' learning
- Evaluate effectiveness of instructional strategies
- Motivate students to be more engaged on learning

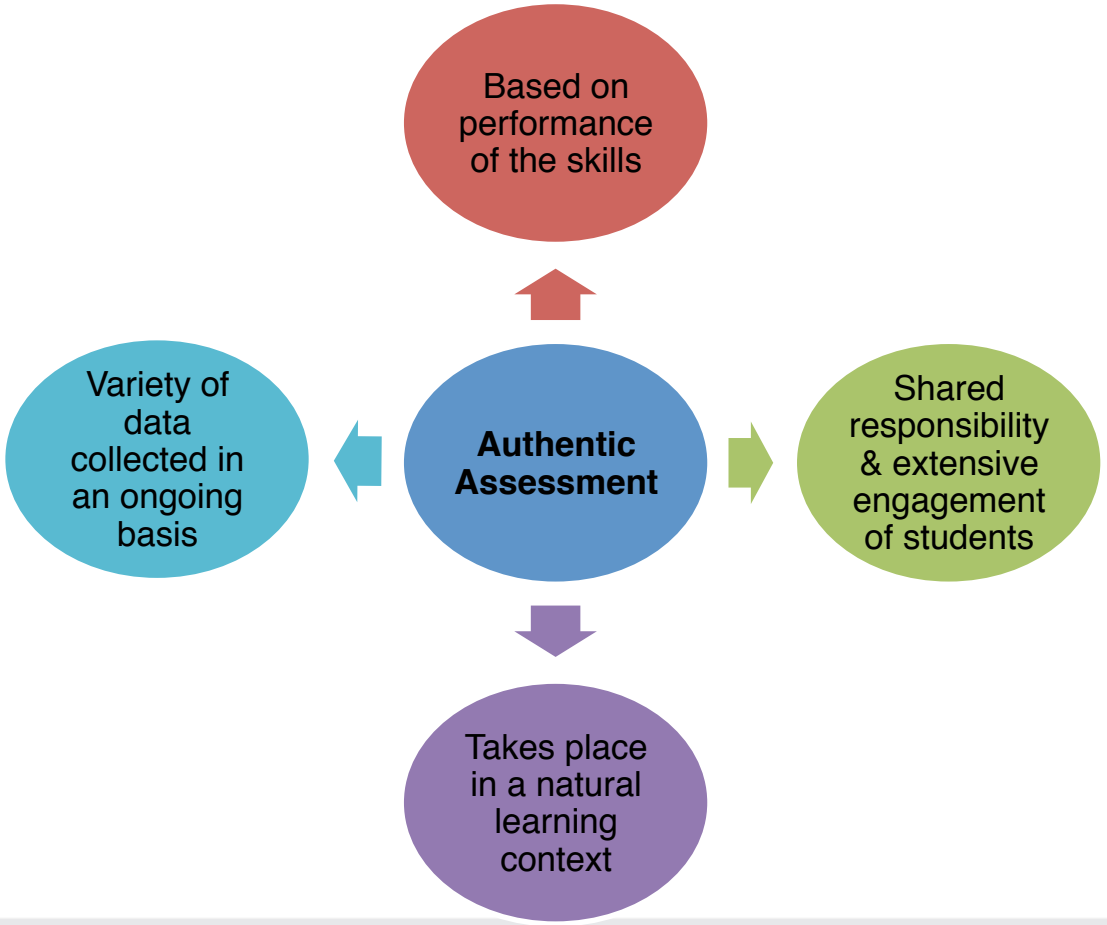
For schools

- Evaluate students' learning and award certification
- Evaluate teachers' effectiveness
- Hold program accountable

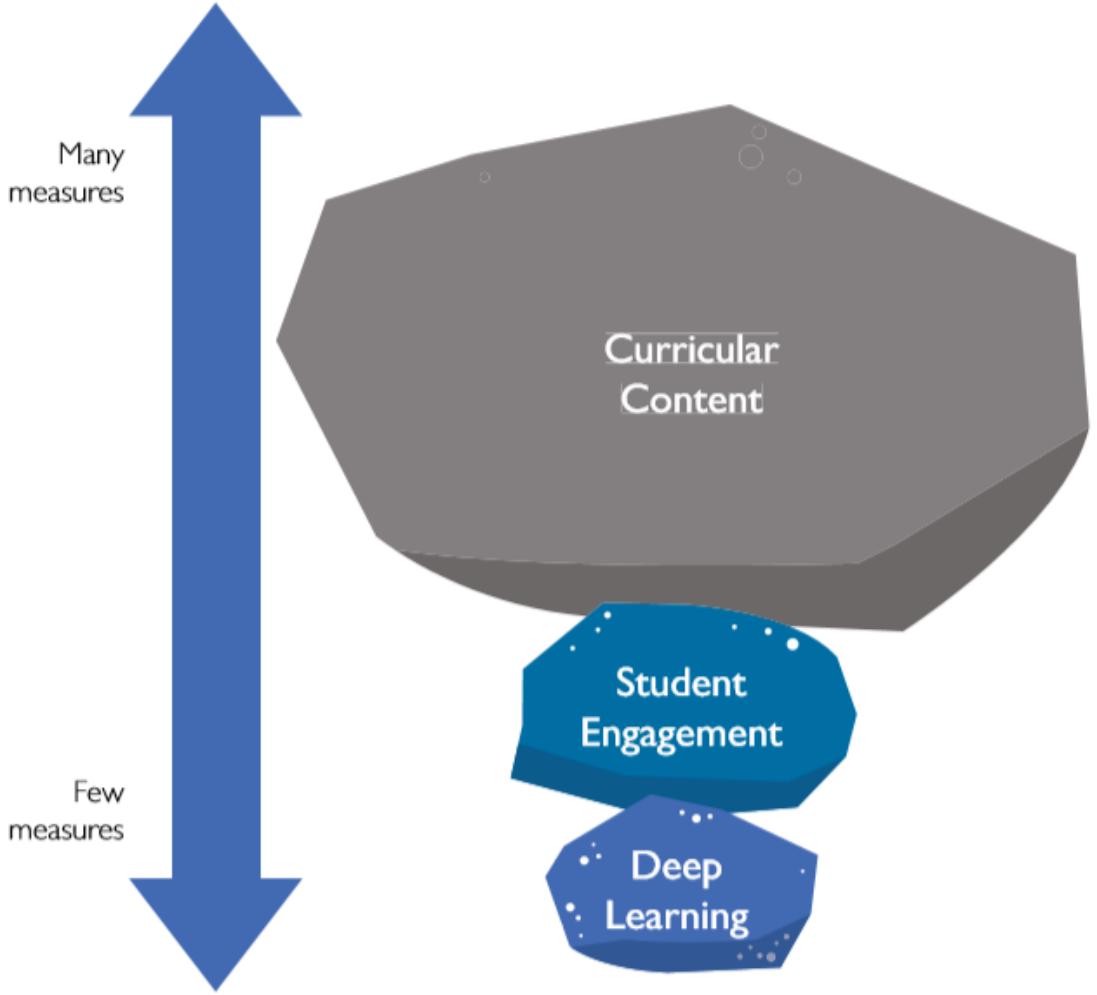
For parents

- Inform about the progress of children's learning
- Parent-involvement in children's learning
- Home-school communication

Assessment Approach for STEM Education: Authentic Assessment

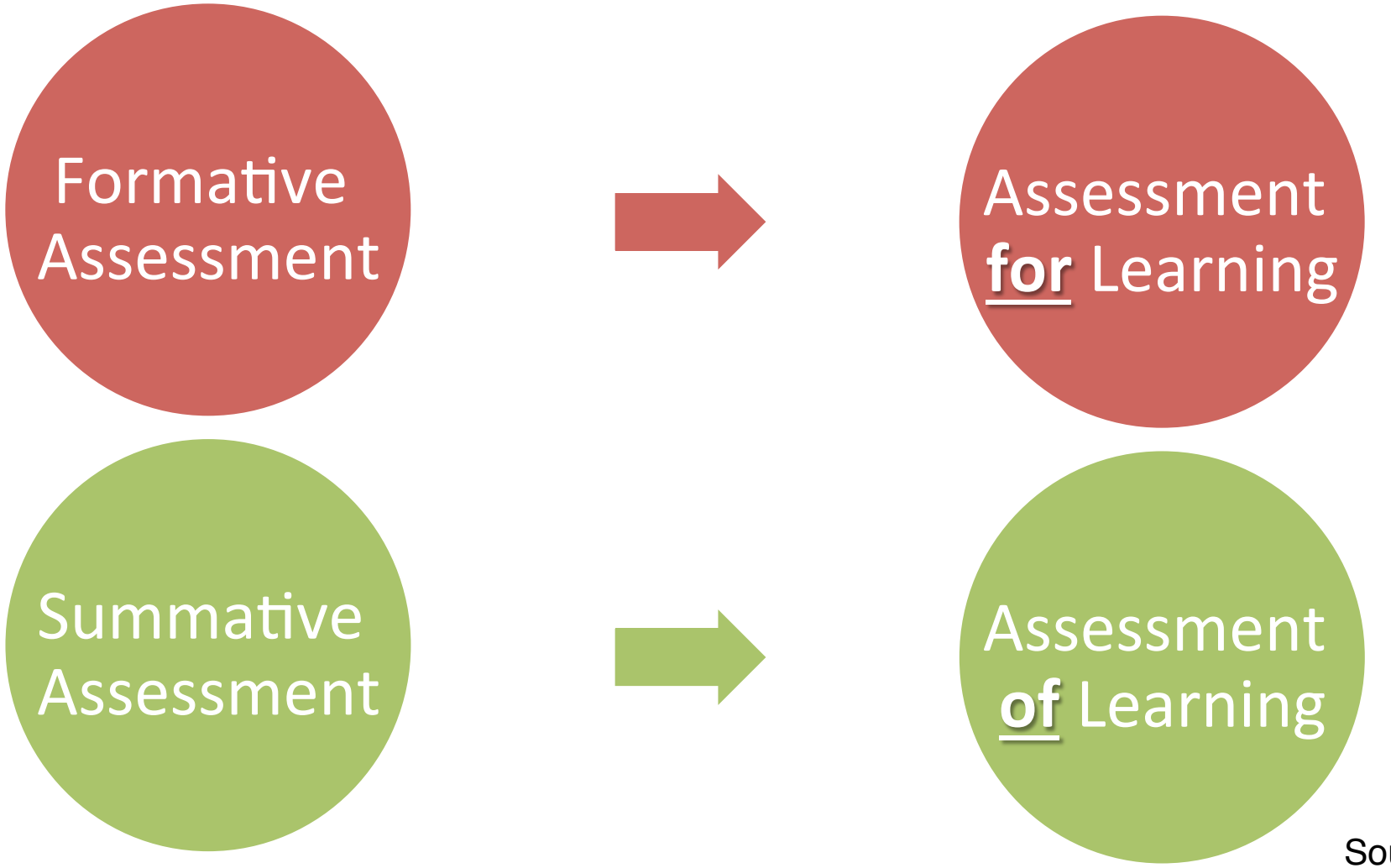


Availability of Student Assessments



Source: Fullan, M. and Langworthy, M. (2014) A rich seam: How new pedagogies find deep learning

Formative and Summative Assessment



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.

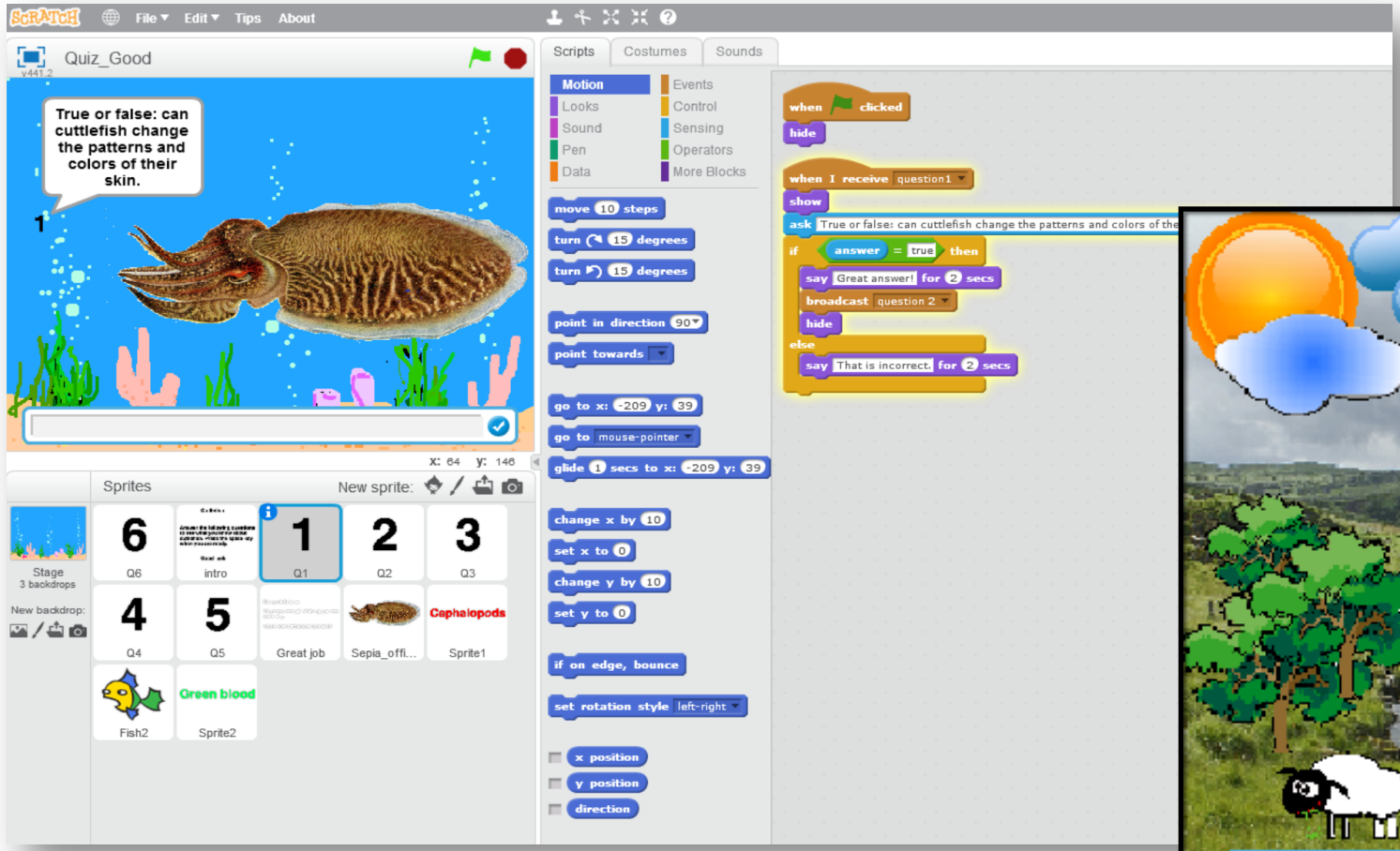
Sample of Collaboration Rubric

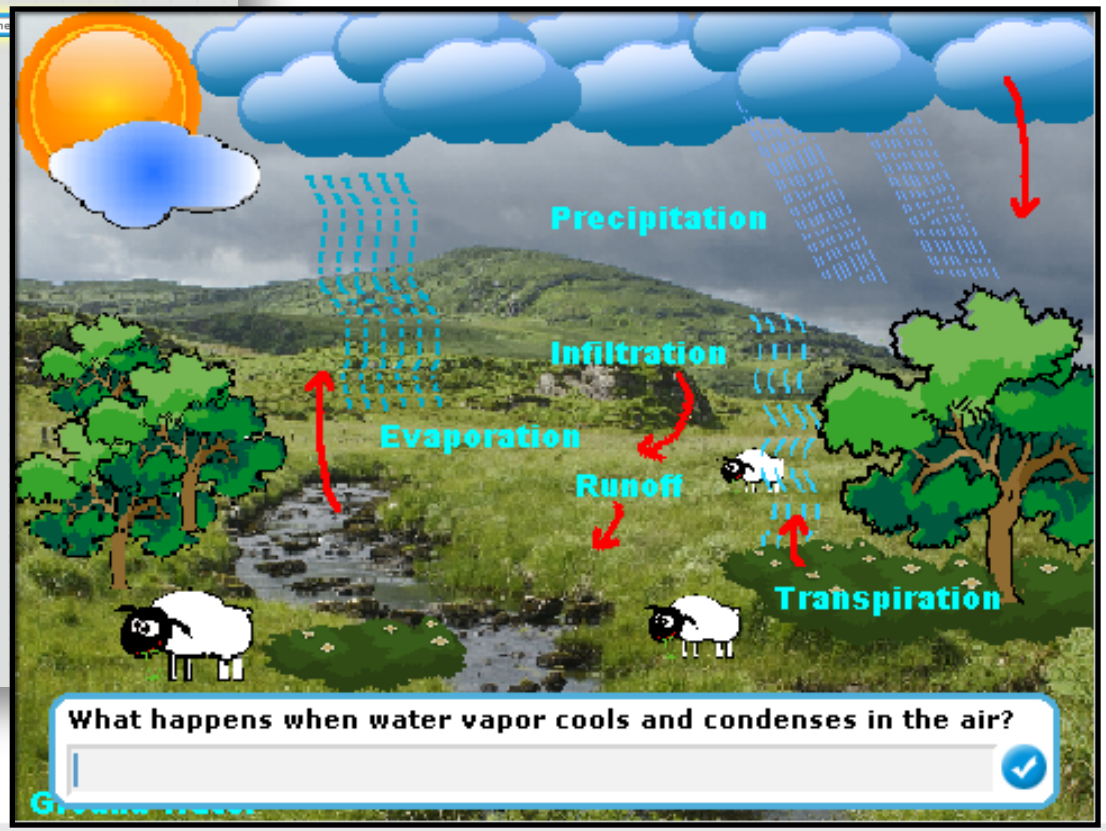
	Description	Ideal	Approaching	Developing
Working with Others	• Listens to others. • Shares with… • …	• • • All 3 bullets are true.	• • One bullet is missing.	• One or no bullet is true.
Focus on the task	• Stays focused on the project. • Can identify… • …	• • • All 3 bullets are true.	• • One bullet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

Sample of Project Rubric

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

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

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