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Computational skills in STEAM Education: a critical overview

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THE CLASSES ON THE MOON

ERASMUS+

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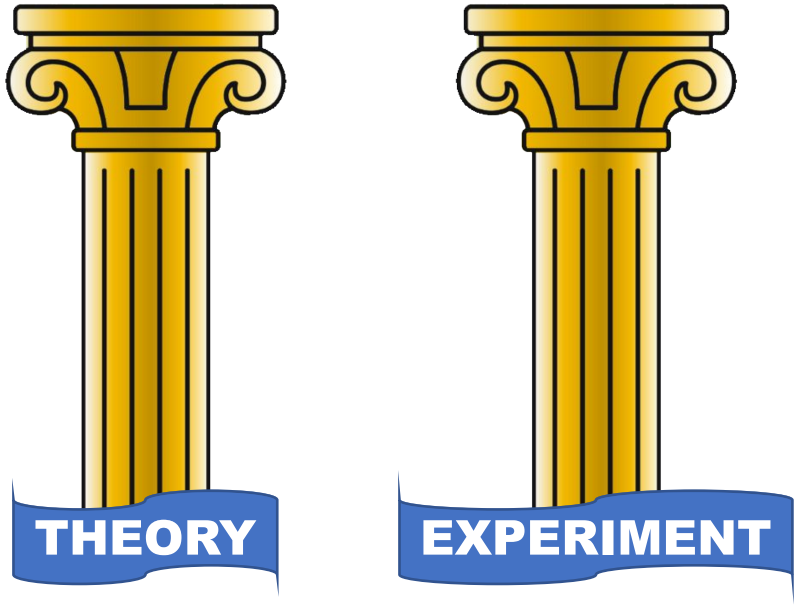
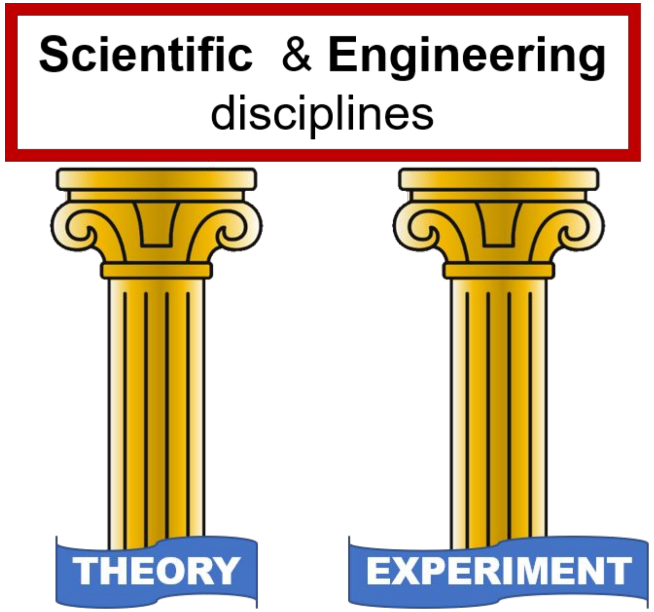
Scientific & **Engineering**
disciplines



… Traditionally are based on two, well distinct, **PILLARS**…

… and so are…

… their respective **teaching and learning processes**



In the last decades, this architecture has profoundly changed …

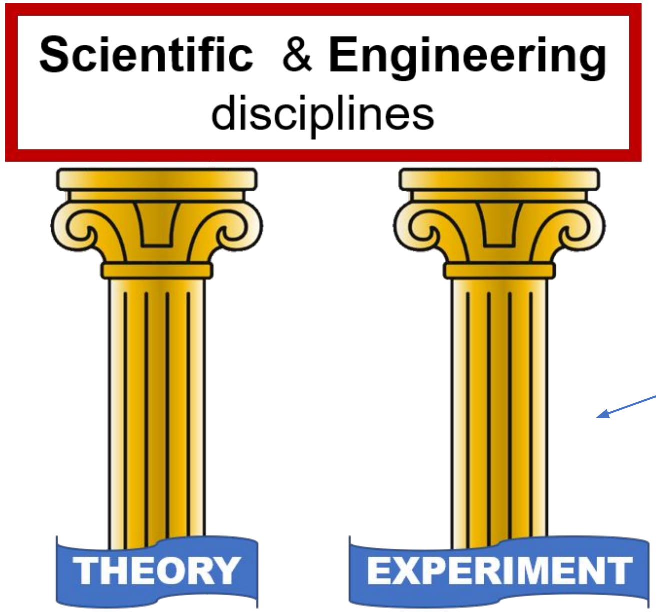
… due to a real…

paradigm shift

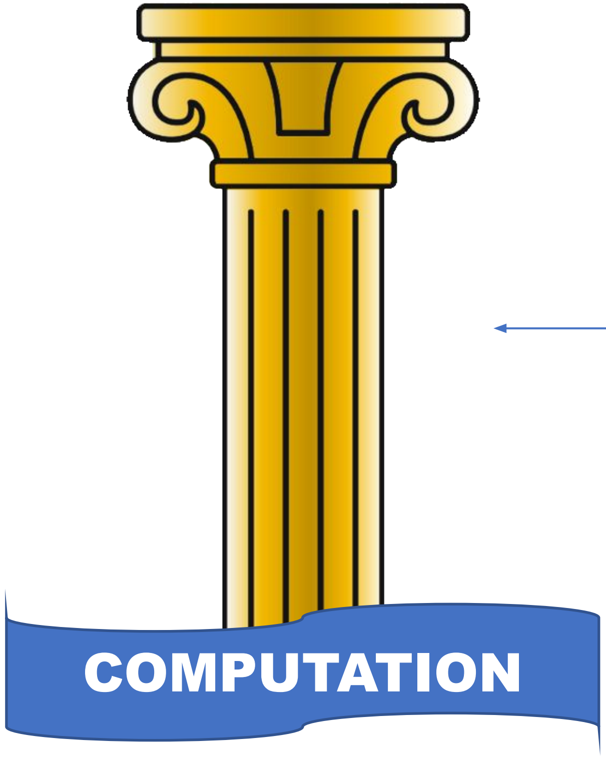
… determined by…

the ubiquity of computers and computational tools

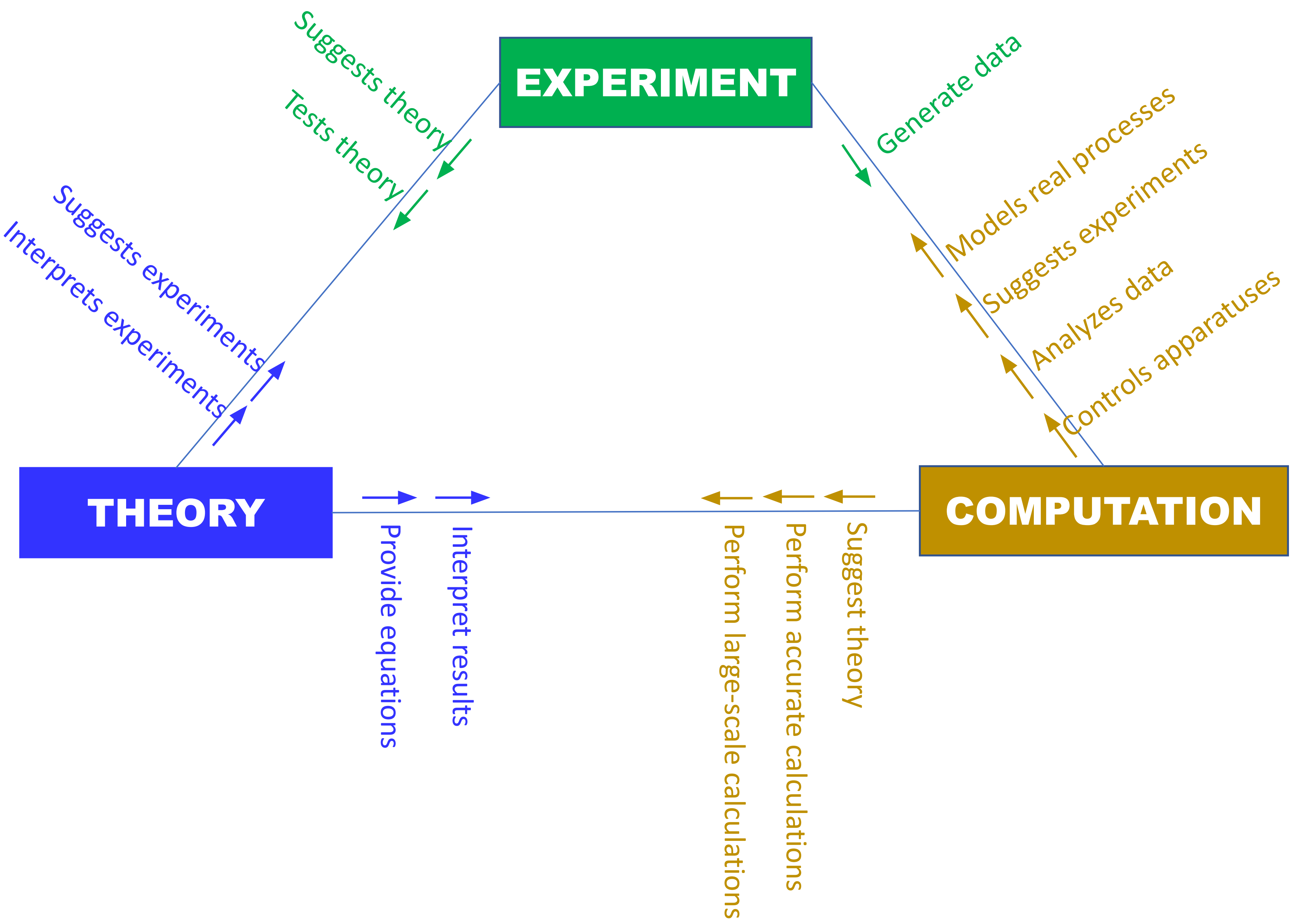
(Chabay and Sherwood, 2008)



The theory / experiment dichotomy has been significantly altered by the irruption on the scene of a real third pillar…

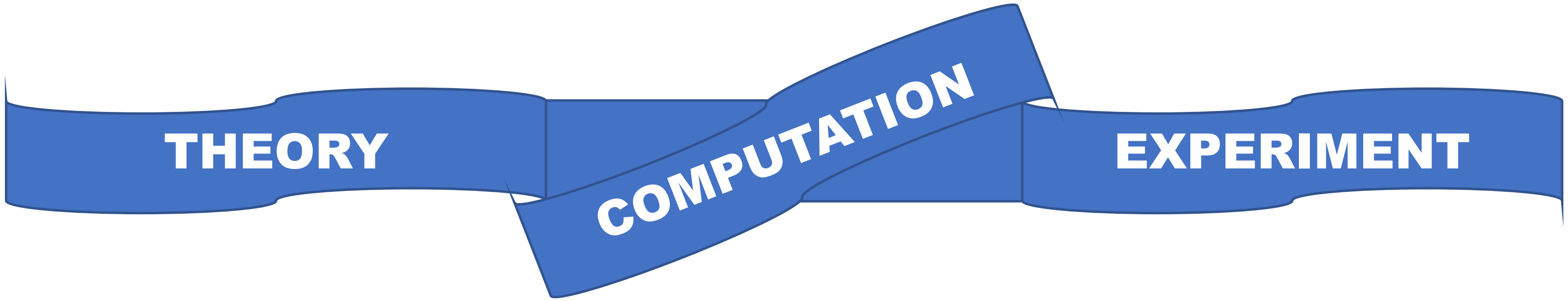


(Chabay and Sherwood, 2008)



(Sluşanschi E., CERN 2019)

COMPUTATION has blurred the distinction between theory and experiment



e.g.:

Numerical ‘experiments’ allow «experimentally» exploring physical systems

What we need to fully integrate computation in

the didactics of the STEAM disciplines?

Need of a theory of COMPUTATIONAL LEARNING in STEAM

In order to…

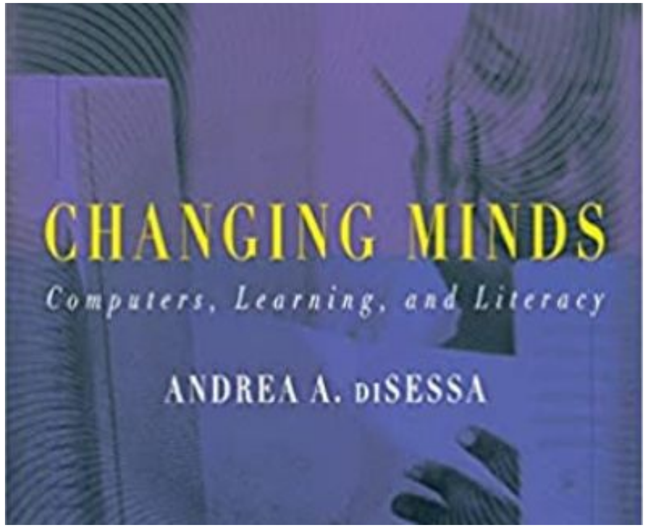
Address the challenges and affordances that computation brings to the table

Help guide the implementation of computation across courses and curricula

Some attempt for developing such a theory has been done for Physics learning (*Odden et al., 2019*)

Based on a theory of COMPUTATIONAL LITERACY

(*Di Sessa, 2000; Di Sessa, 2018*) – The only so far proposed… to the best of my knowledge…



diSessa A. A. (2000),
Changing Minds: Computers, Learning, and Literacy

"Computation is rapidly becoming a new literacy, at the same level of importance as mathematics, reading, and writing."

… statement dating back two decades ago!

Theory of COMPUTATIONAL LITERACY

IN FACT…

… it is becoming increasingly common and necessary for everyday life and professional practice,

… so that…

… it makes possible a *new set of skills and ways of thinking* *(Wing,2006; Vee, 2017; Blikstein, 2018; Odden, 2019)*.

"Computation is rapidly becoming a new literacy, at the same level of importance as mathematics, reading, and writing."

The ways we use computation are structurally similar to the ways we use write/print and mathematics

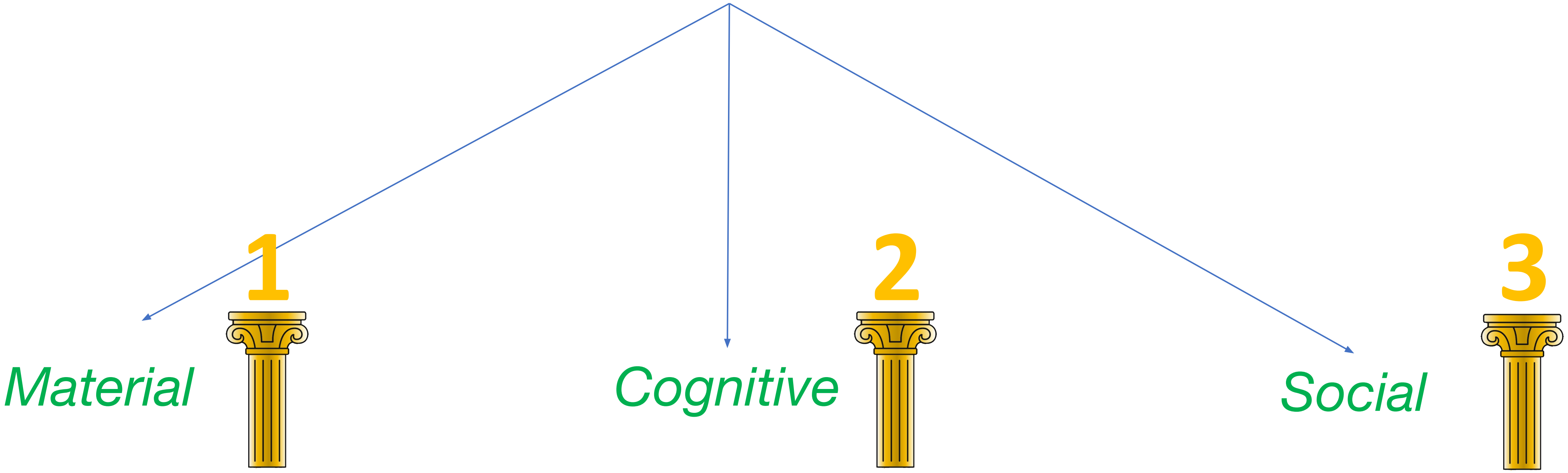
LITERACIES

set of skills	write/print	mathematics	computation
… based on a specific: **representational system**	writing	numbers	code
… that have certain: **rules for use**	grammar	algebra	syntax
… and aim to: **dedicated intellectual purposes**	communication	calculation	programming

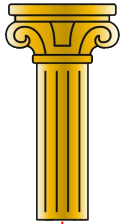
COMPUTATIONAL LITERACY

… is based on…

Three pillars



1



Material pillar of… COMPUTATIONAL LITERACY

familiarity and fluency with the basic representational system underlying all programming → **computer code**

a necessary condition for computational literacy… … in the same way that one must be familiar with

letters and sentences — OR — numbers and mathematical symbols

… to be…

print — OR — mathematically → **literate**

1

Material pillar of... COMPUTATIONAL LITERACY

To attain...

familiarity and fluency with the basic representational system underlying all programming

→ **STUDENTS SHOULD**

learn to program, at least at a basic level, including operations like:

- assigning variables
- defining functions
- running simple scripts

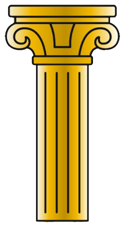
be familiar with at least some of the structural components of code such as:

- Syntax
- Objects
- Libraries

know tools necessary to program such as:

- integrated development environments (IDE)

2



Cognitive pillar of... **COMPUTATIONAL LITERACY**

The ways the material basis is used to improve:

- our ways of thinking and
- our understanding of the world.

In order to

- expand the space of tractable problems and,
- broaden ways in which we acquire new knowledge.

this pillar is "cognitive" in that

- It extends our cognition,

  allowing us to think about and

- understand the world in new ways.

Acquiring cognitive computational literacy…

… involves learning a new set of skills, beyond the fundamentals of programming,

… namely, the ways in which computation can be applied to tasks!

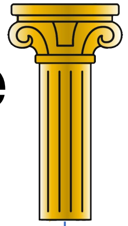
Examples from other literacies

One might learn different

- writing styles (argumentative essays, news reports, technical summaries)
- applications of mathematics (measuring quantities, solving equations, statistical analysis)

In the same way, in computational literacy one must learn ways to apply the fundamental tools of computation to real-world problems and situations.

3

What about the  of **COMPUTATIONAL LITERACY** ?

… namely the:

Social pillar ?

Let's start with a consideration

Computation is never done alone…

…one is always programming with others;

… for example through:

- collaboration on projects,
- consulting documentation,
- building on others’ code

Just as... Reading/writing and mathematics are used to communicate with others…

... analogously … computation will always have an inherent social dimension that must be taken into account in any robust theory of computational learning.

The social dimension…

concerns...

… the ways in which we communicate with and about computation to other people

- the communication practices within project teams.
- how one structures one's code to make it more readable.
  - commenting code,
  - explaining the meaning of one's code to others,
  - writing simple reports on computational projects.

Conclusions

- The wide and simple availability of computational tools has produced a true paradigm shift in the way science and technology work: A third pillar, **computation**, appeared alongside the two traditional ones: **theory** and **experiment**.
- To fully and fruitfully incorporate computation in the teachin/learning process of STEM disciplines we need a **theory of computational learning**.
- A fundamental step towards formulating such a theory is the recognition of a **trifold dimension** underlying computational literacy, namely: **material**, **cognitive** and **social** dimensions.
- Building on such premises, a lot of work is underway to provide a solid **theoretical basis for the didactic use of computation**.

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