Less Than Zero: Rethinking STEM Literacy

Charles Van Loan
Professor Emeritus, Computer Science
Cornell University

CAPE Lecture
May 24, 2022
Overview

It is impossible to overstate the importance of having a citizenry that is literate in matters that concern Science, Technology, Engineering, and Mathematics (STEM).

“STEM literacy” has several components.

I will explain this by tracing how my thinking on the topic has developed since joining the faculty in 1975.
Many of Our Big Societal Problems Have a STEM Component
Climate Change

Has a STEM Component
Digital Privacy

Has a STEM Component
Decaying Infrastructure

Has a STEM Component
Redistricting

Has a STEM Component
The Pandemic Has Further Underscored the Importance of Having a STEM-Literate Public

<table>
<thead>
<tr>
<th>Aspect</th>
<th>Issue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science</td>
<td>The biology of infection.</td>
</tr>
<tr>
<td>Technology</td>
<td>The social media spread of (dis)information.</td>
</tr>
<tr>
<td>Engineering</td>
<td>The challenges of vaccine production/distribution.</td>
</tr>
<tr>
<td>Mathematics</td>
<td>The mathematics of transmission.</td>
</tr>
</tbody>
</table>

Keywords: model, data, scientific method, probability, exponential growth, supply chain.
Two Sides of STEM Literacy

There is an Inward-Facing Side

You are able to track STEM issues and are willing to be affected by scientifically supported findings, e.g., you are motivated to recycle plastics because you understand why it is important.

There is an Outward-Facing Side

You are able to track STEM issues and engage with policy makers, e.g., you have ideas about fossil fuel legislation and you write your Senator.
I used to think that Cornell’s “STEM Literacy Mission” was simply to graduate students with these talents.

Not Anymore
Two Big Gaps

1. The shortage of STEM majors who become STEM high school teachers.

2. The underappreciation of non-western mathematics and how it has impacted western culture.
The Talk is Based on Personal Experiences

CS Faculty Member in Computational Mathematics  Emeritus

Teach CS to Non-STEM UGrads

CS DGS (PhD)

CS DUS (Ugrad)

CS Chair

Teach CS to Non-CS STEM UGrads

CS DMS (MEng)

Dean of Faculty


It is NOT some kind of a scholarly analysis.
Important Topics Not Directly Covered

- Attracting Women and Underrepresented Groups to STEM
  There is significant progress but much more to do.

- Degree Requirements for STEM and Non-STEM Majors
  Breadth of education is alive and well—sort of.

- “STEM Sell” Research
  Lots of effective promotions from the professional societies and the NSF etc.
I will now step through my history with the STEM Literacy Issue
What I Learned About STEM Literacy While Teaching...

Programming for Poets
1977-1981
Computer Literacy

Those who fail to understand the computer as a medium for expression will be disadvantaged in the same way as those who cannot read or write.

Importance of History

“The best of all methods for presenting every subject bearing on political and social life is historical” – Andrew D. White
What I Learned About STEM Literacy While Teaching...

Freshman Engineers
The Importance of Intuition

“The intuitive mind is a sacred gift and the rational mind is a faithful servant. We have created a society that honors the servant and has forgotten the gift.”

~Albert Einstein~
The Importance of Intuition

Intuition is a sense of direction, essentially no different from the sense of direction that enables you to find your way around an old childhood neighborhood without a map. The key is that you've been there before.

If intuition is a sense of direction, then computational intuition is a sense of computational direction. Those who have it can find their way around the computational side of engineering and science.
The Importance of Intuition

The perfect foil for a rational STEM expert is the STEM-literate, intuitive nonexpert.
What I Learned About STEM Literacy While Serving as...

CS Director of Undergraduate Studies
A Pair of Advising “Pep Talks”

1. There’s a world shortage of computer scientists who can do one other thing.

2. Choose your electives as if your life depended on it.
What I Learned About STEM Literacy While Serving as...

CS Director of Graduate Studies
A Triplet of Communication Advisories

1. Appreciate that “Dissertation Writing” is Research
   Fallacious “A then B”: I did the research and now I am going to write it up.

2. Be Able to Describe Your Research in One Minute
   It’s “good journalism”

3. Buy Into the NSF’s “Broader Impacts” Idea
   They are a critical component of any research proposal submitted to the NSF. They strengthen the relationship between the science community and society.
What I Learned About STEM Literacy While Serving as...

CS Director of Master of Engineering Studies
Insights from Jay Walker (ILR ’77)

“Great entrepreneurs are able to describe a problem clearly, precisely, and with an economic description that talks about a customer and a price. As an entrepreneur, you need humility to know what you don’t know because customers think differently, often in ways that have nothing to do with science, logic, or evidence.”
What I Learned About STEM Literacy While Serving as...

CS Chair
A Pair of Early Career “Pep Talks”

1. To faculty recruits about to give their “job presentation”:
   Being able to explain your research to a broad audience is as important as the research itself.

2. To assistant professors about to teach their first (big) service course:
   This is an occasion to refine your expository skills, something that will multiply the impact of your research.
What I Learned About STEM Literacy While...

Working on the Tenure Track Project
The Importance of Ugrad Teaching to the Case

Paying attention to Ugrad teaching is the right thing to do because most of our salary comes from Ugrad tuition.

Paying attention to Ugrad teaching is the smart thing to do because that’s the best way to refine our expository skills and the long term well being of the profession depends on how we communicate our work to the public.
What I Learned About STEM Literacy While... 

Serving on President Pollack’s Inauguration Program Committee
I became concerned that Cornell may not be adequately clearing a path for STEM majors to become high school STEM teachers.
Six of Our Presidents Have U Michigan Origins

The program committee’s idea was to impart a historical perspective through readings taken from earlier “UoM” inaugural addresses.
“It is our duty always to remember that the gold of the Indies cannot make a great and successful university unless there are good preparatory schools for the supply of well-trained students.”

“Coupled with this is the further truth that there cannot be well trained pupils without carefully trained teachers.”
Charles Kendall Adams (1885-1892)

“It is our duty always to remember that the gold of the Indies cannot make a great and successful university unless there are good preparatory schools for the supply of well-trained students.”

“Coupled with this is the further truth that there cannot be well trained pupils without carefully trained teachers.”

Full Inaugural Address
The US is in Dire Need of STEM Teachers

Physics Today
March 2022
It Matters How Faculty See “the Pyramid”

Promotes Indifference.

Promotes Responsibility.
Cornell Used to Support Teacher Certification

From the 2001 Courses of Study:

Science and Mathematics. Students completing the registered program in science and mathematics may pursue secondary teaching credentials in biology, chemistry, earth science, general science, mathematics, and physics. Students can begin the program as Cornell juniors or seniors by completing an undergraduate major in a scientific field and up to five courses in education. Students from all Cornell colleges may apply. In a year of graduate study, students take additional math and/or science courses and a supervised student-teaching experience.

The program was discontinued in 2010. Much student unhappiness.
But now there is an Education Minor

The *minor* is open to all Cornell Ugrads.

Special agreement with Ithaca College for grad study and certification:

The agreement is based on a mutual commitment by Cornell University and Ithaca College to support the preparation of outstanding, academically talented teachers for today’s schools.
Our Peers

Some have graduate schools of education:

 Penn, Columbia, Harvard, Stanford

MIT doesn’t but still paves the way for in-house teacher certification for its undergraduates:

Scheller Teacher Education Program
What I Learned About STEM Literacy While...

Working on Various Antiracism Initiatives During 2020-21
A great deal of thought went into how we might adjust our courses so that the student acquires a racially honest and historically accurate presentation of the subject matter.

Not hard to imagine this for the social sciences and the humanities. But what about STEM areas?
Realizations

We have a very Euro-Centric view of mathematics (algebra, calculus, geometry).

And a very Anglo-Centric view of computing (ENIAC, IBM, Turing, etc).
Great Gifts

“Life as we know it” would be very different without the invention of zero, the positional system of notation, and the idea of algorithm.

These are Hindu/Arabic gifts to Western culture.
Zero: A Symbol for Nothing

Inventor of Zero

Approximation of π by Aryabhata

"Add four to 100, multiply by eight, and then add 62,000. By this rule the circumference of a circle with a diameter of 20,000 can be approached."

Father of Astronomy

Aryabhata

Major works: Aryabhatiya, Arya-siddhanta

Notable ideas:
- Explanation of Lunar eclipse and Solar eclipse,
- Rotation of earth on its axis,
- Reflection of light by moon,
- Sineoidal functions,
- Solution of single variable quadratic equation,
- Value of π correct to 4 decimal places,
- Circumference of Earth to 98.8% accuracy,
- Calculation of the length of Sidereal year

Invention of Zero

- Popularizing Zero:
    - First in what is now Iraq to use zero.
- Indian ideals spread to China, along with zero.
  - Chu Shih-Chieh's Mathematical treatise in ten sections.
  - Zhu Shijie's Jade mirror of four elements.
- Fibonacci is credited for bringing Indian ideals to Europe, but only treated it as a sign, not a number necessarily.
The Positional System

\[ 1,000,000 + 1,000,000 + 100,000 + 100,000 + 100,000 + 100 + 10 + 10 + 1 + 1 + 1 = 2,300,123 \]
Algorithms
“Life as we know it” would be very different without the invention of zero, the positional system of notation, and the idea of algorithm.

These are Hindu/Arabic gifts to Western culture.

Failure to appreciate this is perhaps the most consequential form of STEM illiteracy.
Summary
STEM Achievements Define a Great Skyline
STEM Literacy Is the Infrastructure that Makes it Possible

But it is “under the street” and harder to brag about. Do something about it!