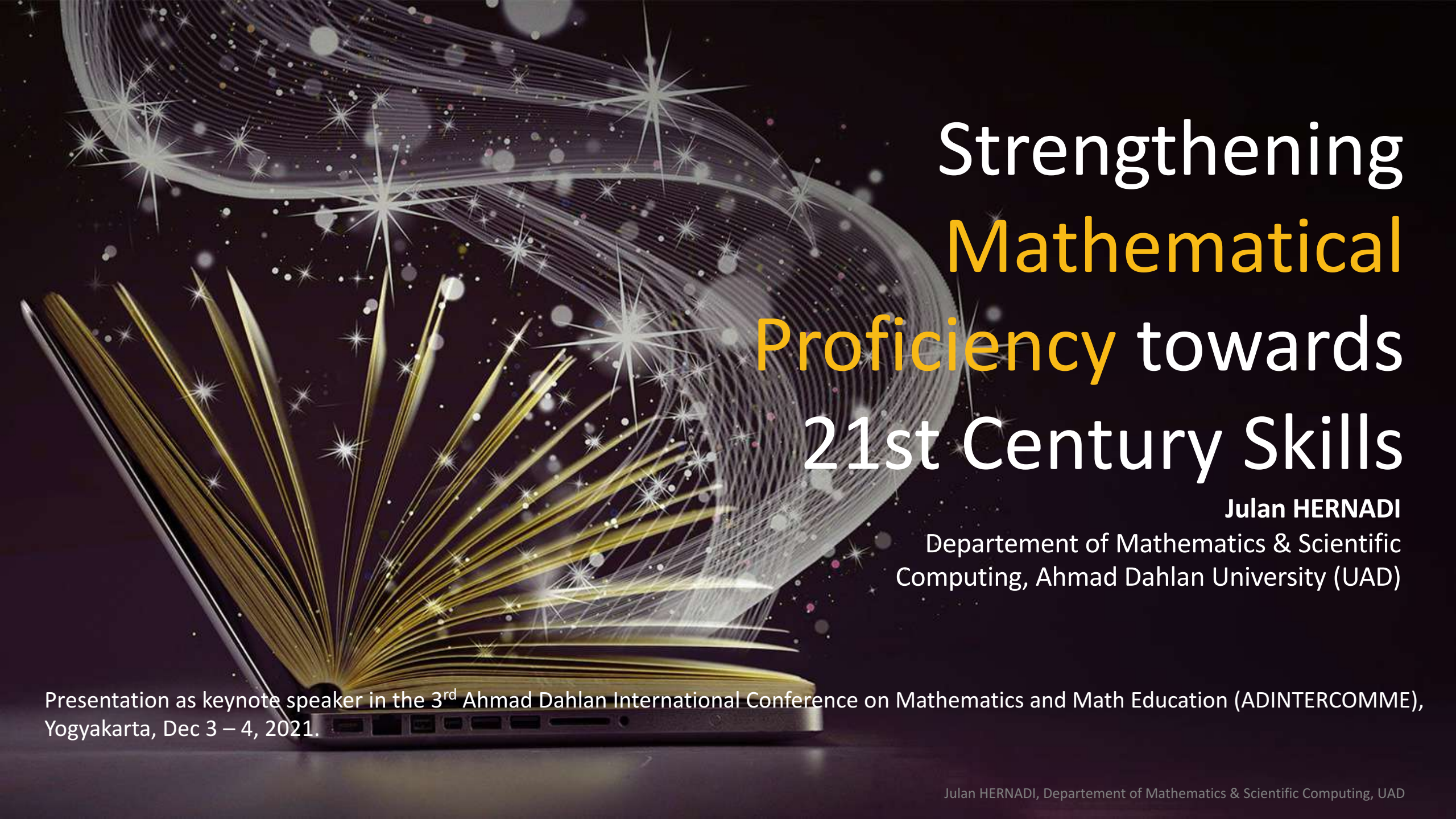


Strengthening Mathematical Proficiency towards 21st Century Skills

Julan HERNADI
Departement of Mathematics & Scientific Computing, Ahmad Dahlan University (UAD)

Presentation as keynote speaker in the 3rd Ahmad Dahlan International Conference on Mathematics and Math Education (ADINTERCOMME), Yogyakarta, Dec 3 – 4, 2021.

Let’s enjoy:
The “entertainment” video clip!

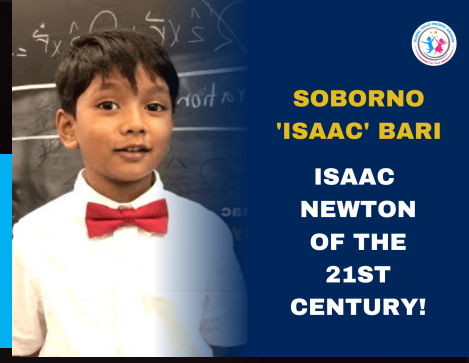
It is suspected that many others students have low math skills like the boy selling the cake.

Research findings:

1. It was above 77% of Indonesian students' ability on math were lacking and only about 2% were categorized as good (INAP, 2016).
2. The bottom 10 of 70 countries on reading, math, and science (PISA, 2018). Similar result on TIMSS 2015.
3. The ability of students in solving simple math problems did not differ significantly between graduates of elementary (SD) and secondary school (SMA) (RISE, 2018).
4. More than 70% students of grade 1 Junior high school (SMP) can not performed basic arithmetics calculation (Hernadi at al, 2020).

Country with Mathematical Emergency

Another child in video was: Soborno "Isaac" Bari, a child prodigy (ajaib), it is very rarely, just 1 : 5-10 millions.



"Three things are needed in math & sciences are: Creativity, Observation, and Imagination. But school do not present it that way schools presented so you need one thing, memorization"

"When you are talking mathematics and sciences what happen is you take the school teaches you these equations without any context, then memorize them and then you forget them 5 minutes after your receive your test score"

(Soborno Bari)

21st Century Skills Map

Learning and Innovation Skills (4C's skills)	**Information, Media and Technology Skills**	**Life & Career Skills**
Creativity and Innovation	Information Literacy	Flexibility and Adaptively
Critical Thinking & Problem Solving	Media Literacy	Initiative and Self–Direction
Communication & Collaboration	ICT Literacy	Social and Cross–Cultural Skills
How to fuse mathematical content and mathematical practice to help students fulfill 21st century skills?		Productivity and Accountability
		Leadership

Learning and Innovation Skills

Partnership for 21th century skills

Creativity and Innovation

Students use a wide range of techniques to **create new and worthwhile ideas,** elaborate, refine, and evaluate their own ideas.

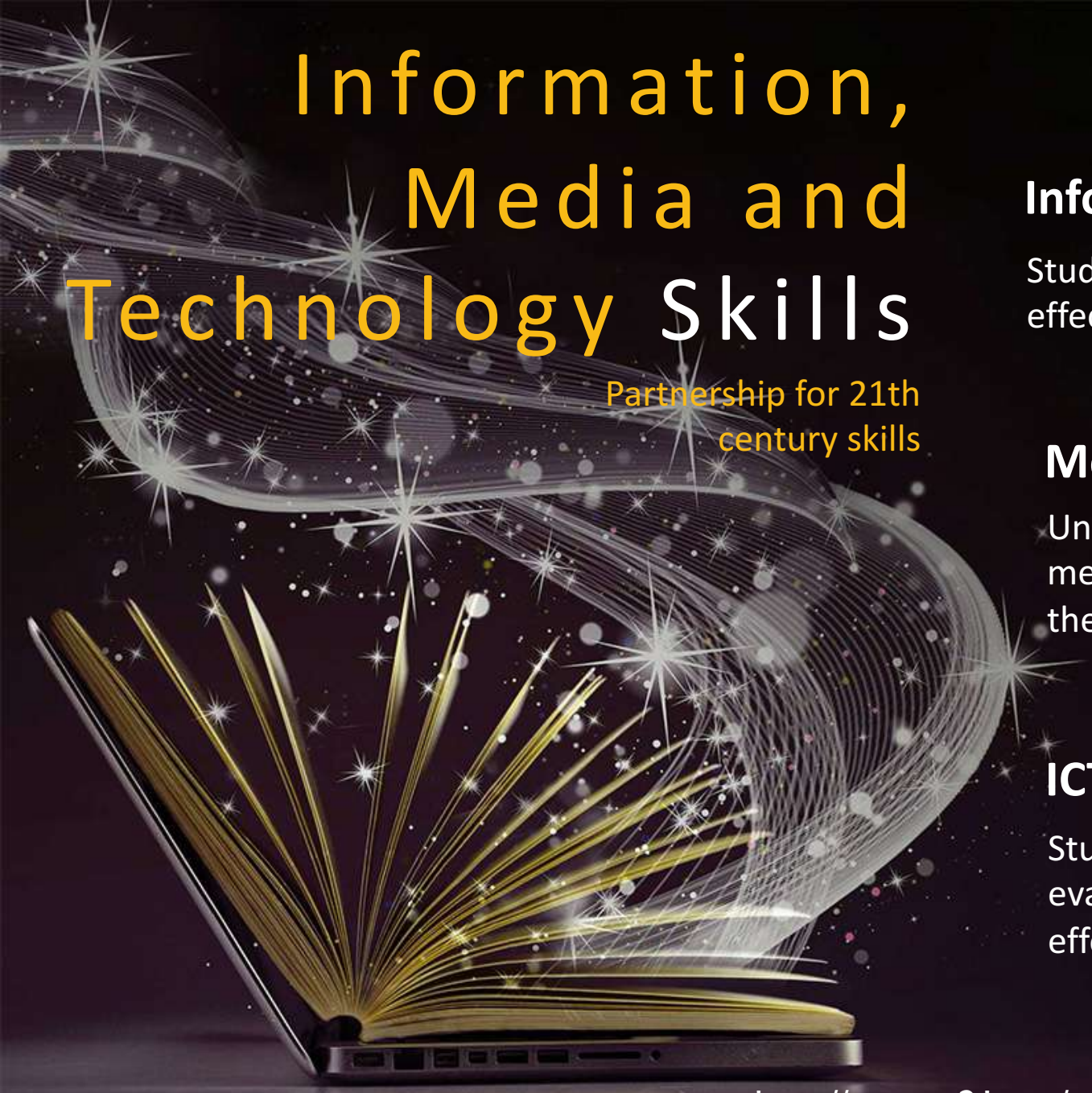
Critical Thinking and Problem Solving

Students **reason effectively**, use **system thinking** and **understand** how parts of a whole interact with each other. They make judgments, decisions and solve problems in innovative ways.

Communication and Collaboration

Students knows how to **articulate thoughts and ideas effectively** using oral, written, and nonverbal communication. They also listen effectively and use communication for a wide range of purposes in **diverse teams and environments.**

http://www.p21.org/tools-and-resources/publications/p21-common-core-toolkit.



Information, Media and Technology Skills

Partnership for 21th century skills

Information Literacy

Students are able to access and evaluate information effectively, use, and manage it purposefully.

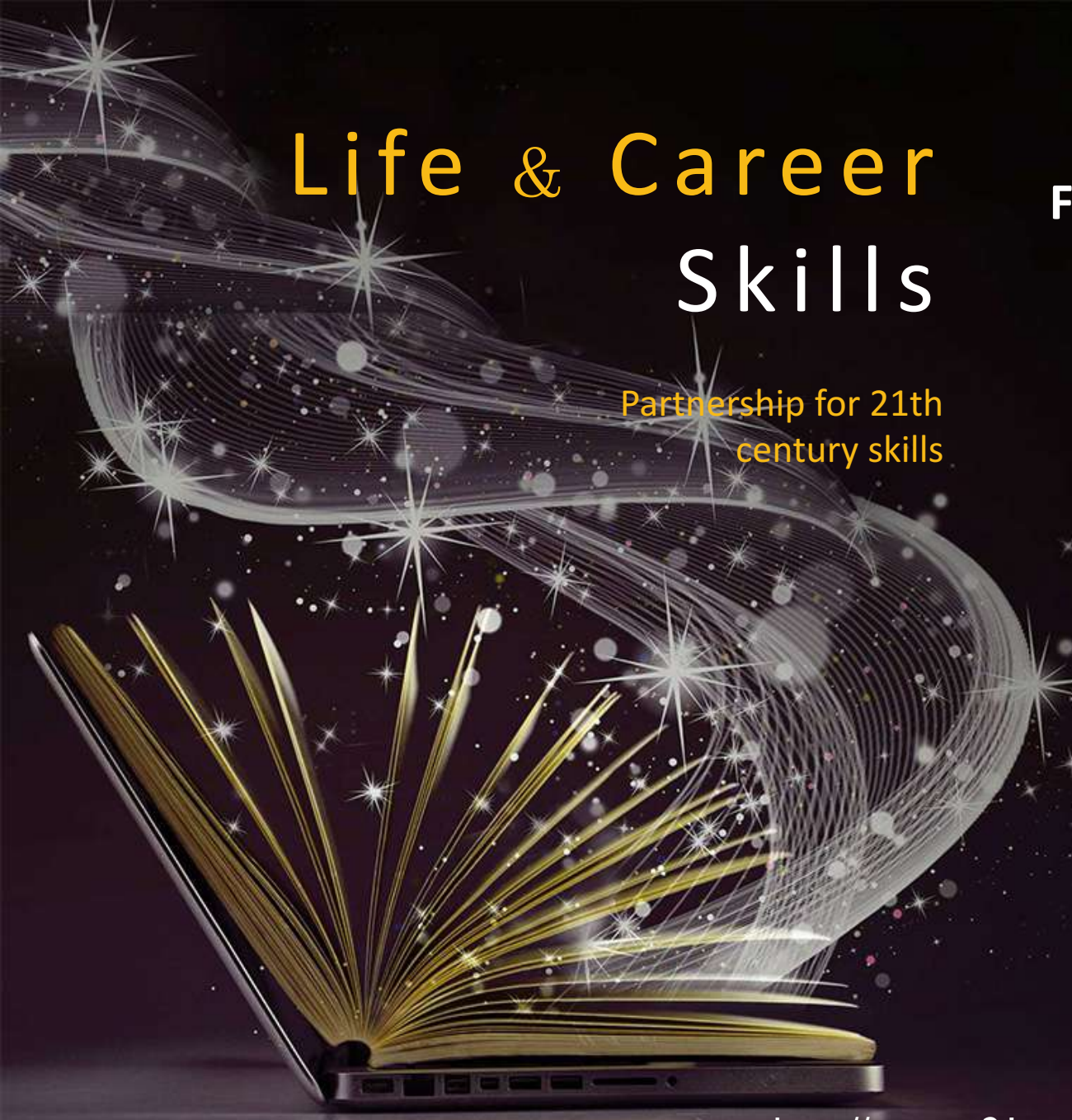
Media Literacy

Understanding how, why, and for what purposes media messages are constructed. Students create media utilizing the most appropriate media creation tools.

ICT Literacy

Students use digital technology to manage, integrate, evaluate and create information, and apply technology effectively.

http://www.p21.org/tools-and-resources/publications/p21-common-core-toolkit.



Life & Career Skills

Partnership for 21th century skills

Flexibility and Adaptability

Initiative and Self-Direction

Social and Cross-Cultural Skills

Productivity and Accountability

Leadership

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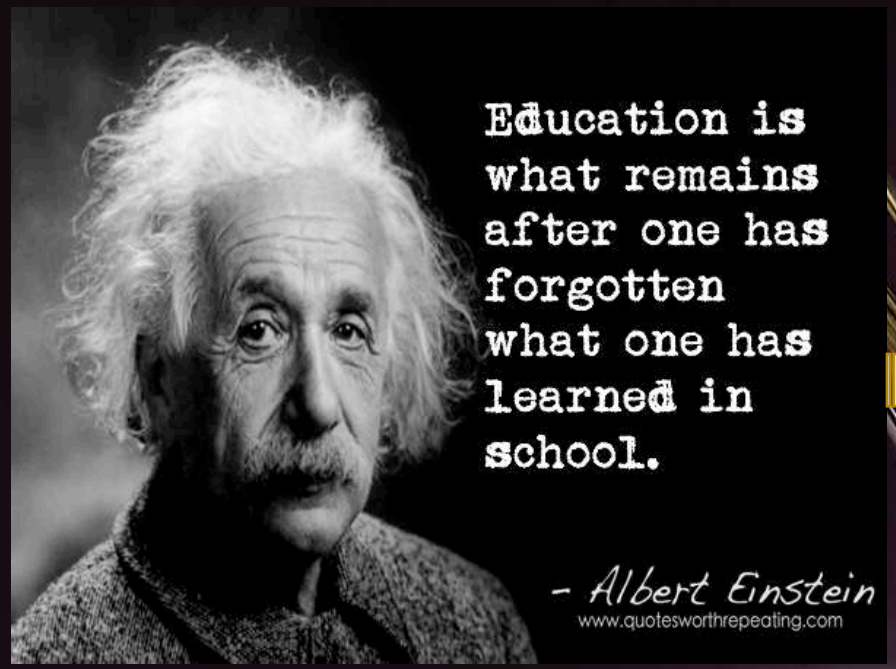
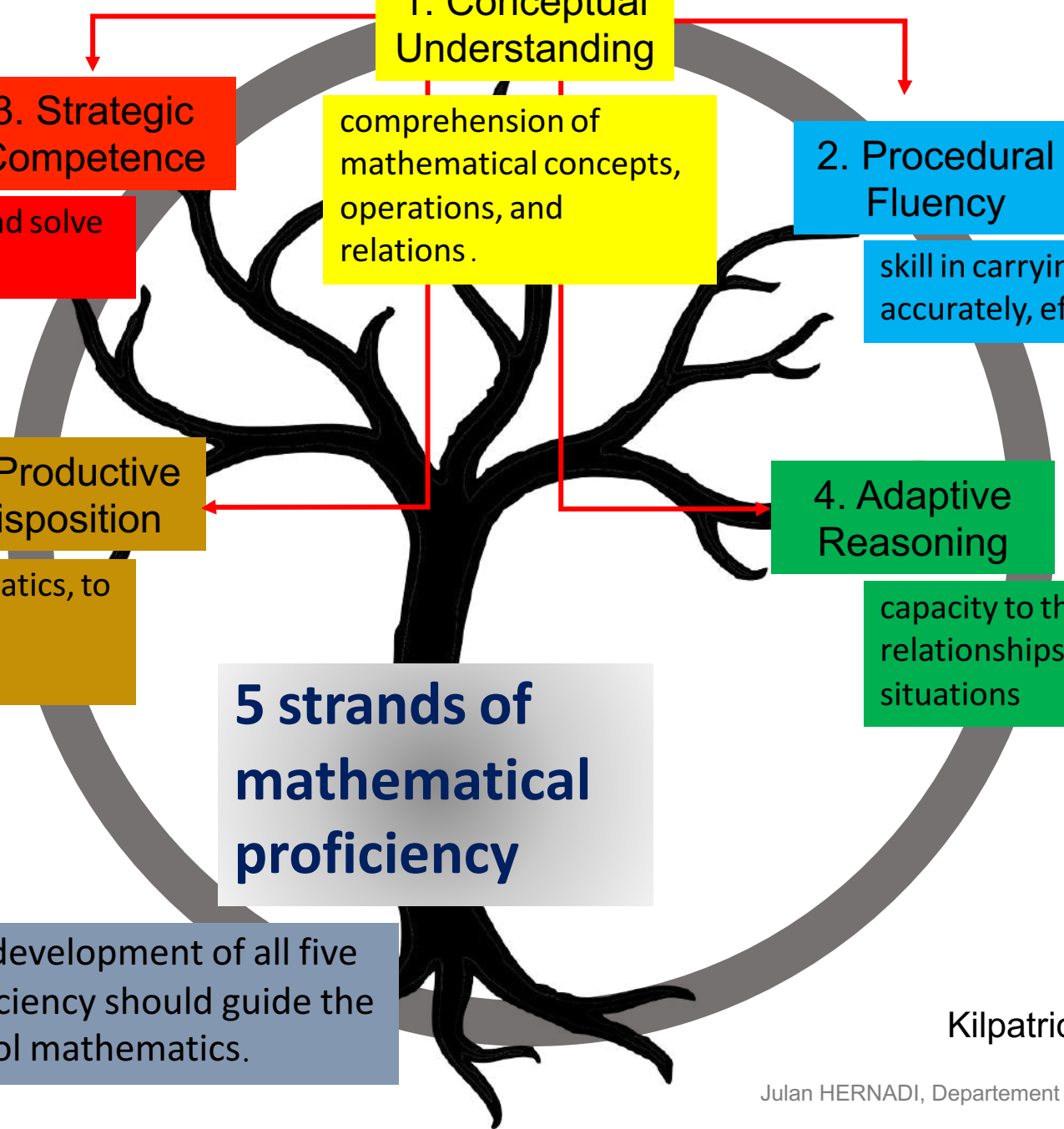


REALITIES:

- Only a small part of mathematical contents applied in daily life.
- Only a few number of graduates using mathematics within their careers.

Mathematics instruction need to be reformed.

Reforming mathematics instruction involves a major cultural shift both in the aims for students learning (i.e. deciding what counts as mathematical proficiency) and in the pedagogical techniques used to teach mathematics (Ortiz, Cristia, Cueto, 2020)



1. Conceptual Understanding

comprehension of mathematical concepts, operations, and relations.

2. Procedural Fluency

skill in carrying out procedures flexibly, accurately, efficiently, and appropriately

3. Strategic Competence

ability to formulate, represent, and solve mathematical problems

4. Adaptive Reasoning

capacity to think logically about the relationships among concepts and situations

5. Productive Disposition

tendency to see sense in mathematics, to perceive it as both useful and worthwhile.

5 strands of mathematical proficiency

The integrated and balanced development of all five strands of mathematical proficiency should guide the teaching and learning of school mathematics.

Kilpatric, Swafford, Findell (2001)

Outcomes for Creativity and Innovation

1. Students compare different ways of approaching problems and find innovative solution.
2. Students listen to and evaluate others' reasoning and offer improvements and correction, with supporting arguments.
3. Students look for patterns then make generalization.
4. By discovering fresh insights and communication them to others, students come to understand that mathematics is a creative endeavor that builds on previous knowledge.

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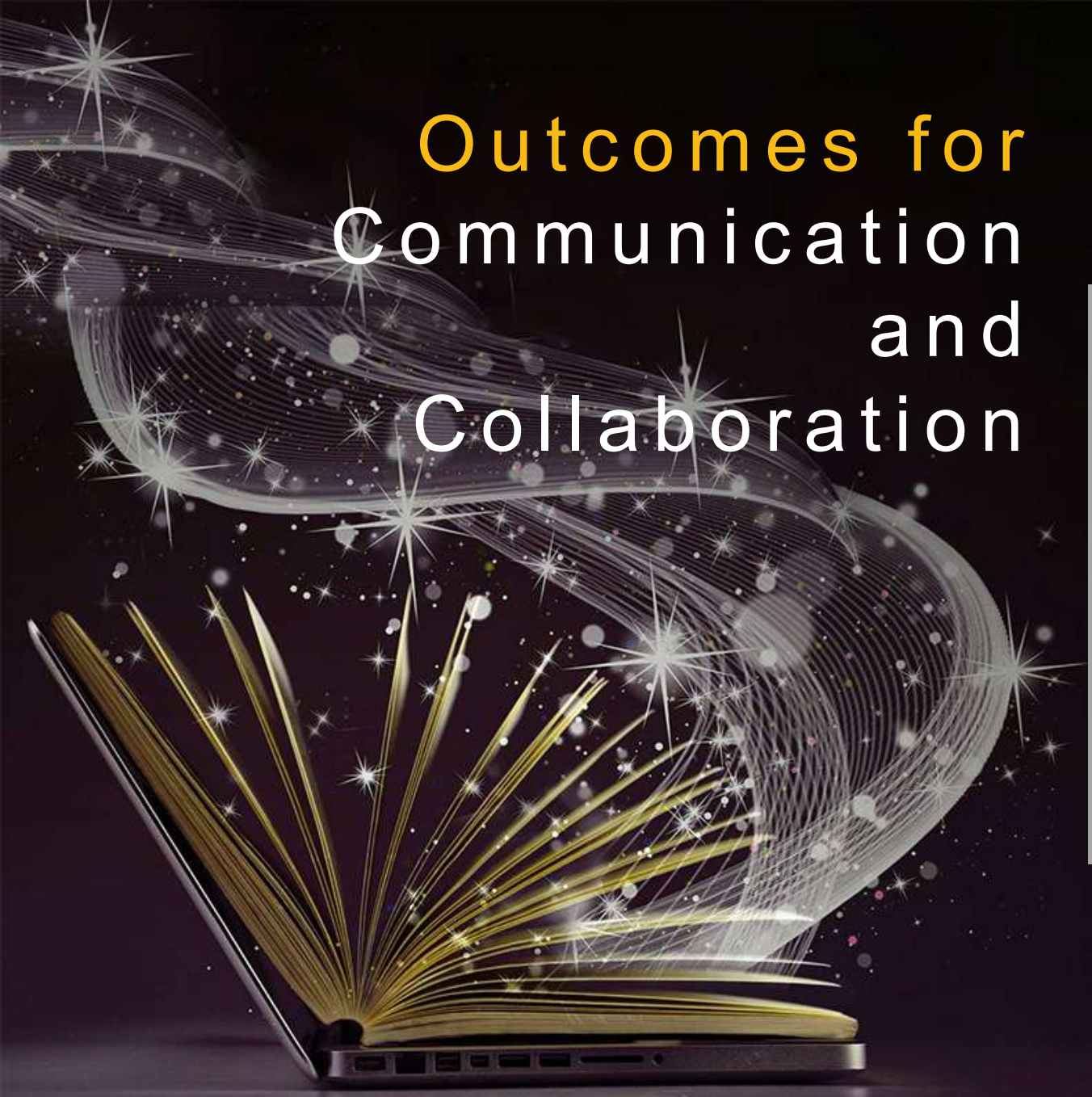


Outcomes for Communication and Collaboration

1. Students articulate mathematical thoughts and ideas using oral and written communication skills.
2. Students listen effectively to the reasoning of peers.
3. Students work efficiently and respectfully in diverse teams, articulating mathematical thoughts and ideas effectively.

Outcomes for Information Literacy

1. Students identify sources of data, access data, critically evaluate it, and then use it to explore significant questions about our world.
2. Students explore new areas of mathematics and its applications, and share what they have learned with others.
3. Students learn about mathematics from reliable websites and share their knowledge with others.

Outcomes for Media Literacy

1. Students understand how statistics, probabilities, and media messages are constructed for social purposes, how media can influence beliefs and behaviors.
2. Students gain a fundamental understanding of the legal and ethical issues. They recognize the common tendency to treat quantitative data as truth and to infer patterns where none exist.
3. Students present statistical information in ways that support a particular view or help others understand the information.

Big Data

Outcomes for ICT Literacy

1. Students use tools such as graphing calculators, spreadsheets, computer graphing, computer algebra systems, GPS devices, and online resources appropriately and strategically.
2. Students use technology to communicate mathematical insights by constructing appropriate graphical representations of functions and of data.

EXAMPLE (12^{th} Grade):

Outcome: Students compare different ways of approaching traditional mathematical problems and find innovative solutions, using practical examples where appropriate.

Students learn about Hot Potato, a lottery game that was played in Wisconsin, which cost a dollar to play and had payoff probabilities as shown in the table.

1. Students then experiment with different ways to model the game. First they estimate how many people out of 10 win each payoff, how many out of 100, how many out of 1000, and so on. Then they model the problem with a probability distribution.
2. They discover that a key payoff value is missing from the probability table: the expected payoff per game. Students then calculate the missing payoff value and learn that the expected payoff per game is about $0.55.
3. They evaluate the impact of this payoff value from the point of view of the individual player (pemain) as well as the Wisconsin Lottery Commission (bandar).

Payoff	Probability
1	1/9
2	1/13
3	1/43
6	1/94
9	1/150
18	1/300
50	1/2050
100	1/144000
300	1/180000
900	1/270000

Students come to understanding the reason of **gambling prohibition in QS 2: 219:**

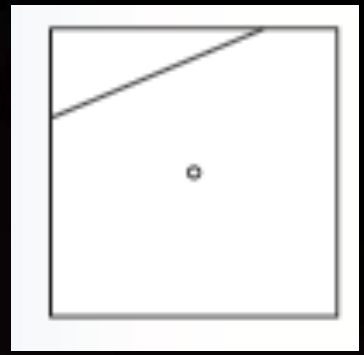
“They ask you about wine and gambling. Say, "In them is great sin and [yet, some] benefit for people. But their sin is greater than their benefit . . .”

EXAMPLE (8^{th} Grade):

Outcome: Students look for patterns that suggest creative shortcuts or simplifying frames of reference. They make generalizations from patterns they observe in repeated calculations.

EXAMPLE: Each student is given a square piece of cardboard with a hole in the middle and a drawn line segment connecting two sides of the square.The line segment may connect any two sides at any point as long as it does not pass through the middle of the square.

1. Students spin the square on the tip of a pencil and
2. Observe the optical illusion of a circle created by the drawn line segment.
3. Students come up with a conjecture to identify where the illusionary "radius" is.
4. Then they translate their square to a Cartesian coordinate plane and discuss the curve tangent to the locus of the line segments as they rotate about the center.



Teachers are highly recommended to demonstrate (animate) using GeoGebra. GeoGebra can make abstract concepts in mathematics to be visible and observable.

Procedural Fluency versus Conceptual Understanding

saving method:

$$\begin{array}{r} {\scriptstyle +1} \\ 47 \\ +\ 34 \\ \hline 81 \end{array}$$

using place value dan basic properties

$$\begin{aligned} 47 + 34 &= (40 + 7) + (30 + 4) \\ &= (40 + 30) + (7 + 4) \\ &= 70 + 11 \\ &= 81 \end{aligned}$$

borrowing method:

$$\begin{array}{r} {\scriptstyle -1} \\ 41 \\ -\ 23 \\ \hline 18 \end{array}$$

$$\begin{aligned} 41-23 &= 30 + 11 - (20+3) \\ &= (30 - 20) + 11 - 3 \\ &= 10 + 8 \\ &= 18 \end{aligned}$$

Cuisenaire rods vs fingers

3 = 1 + 1 + 1

3 = 1 + 2

3 = 2 + 1

Sense number approach

1 + 1 = ?, 1 + 1 + 1 = ?

1 + 2 = ?

2 + 1 = ?

Counting approach

Julan HERNADI, Departement of Mathematics & Scientific Computing, UAD

Understanding = Ability to Change Perspective

$\frac{4}{3} = 1.3333333333\cdots$ (base 10)

$\frac{4}{3} = 1.0101010101\cdots$ (base 2)

$\frac{4}{3} = 1.1000000000\cdots$ (base 3)

$\frac{4}{3} = 1.1111111111\cdots$ (base 4)

$\frac{4}{3} = 1.1313131313\cdots$ (base 5)

$\frac{4}{3} = 1.2000000000\cdots$ (base 6)

$\frac{4}{3} = 1.2222222222\cdots$ (base 7)

$\frac{4}{3} = 1.2525252525\cdots$ (base 8)

$\frac{4}{3} = 1.3000000000\cdots$ (base 9)

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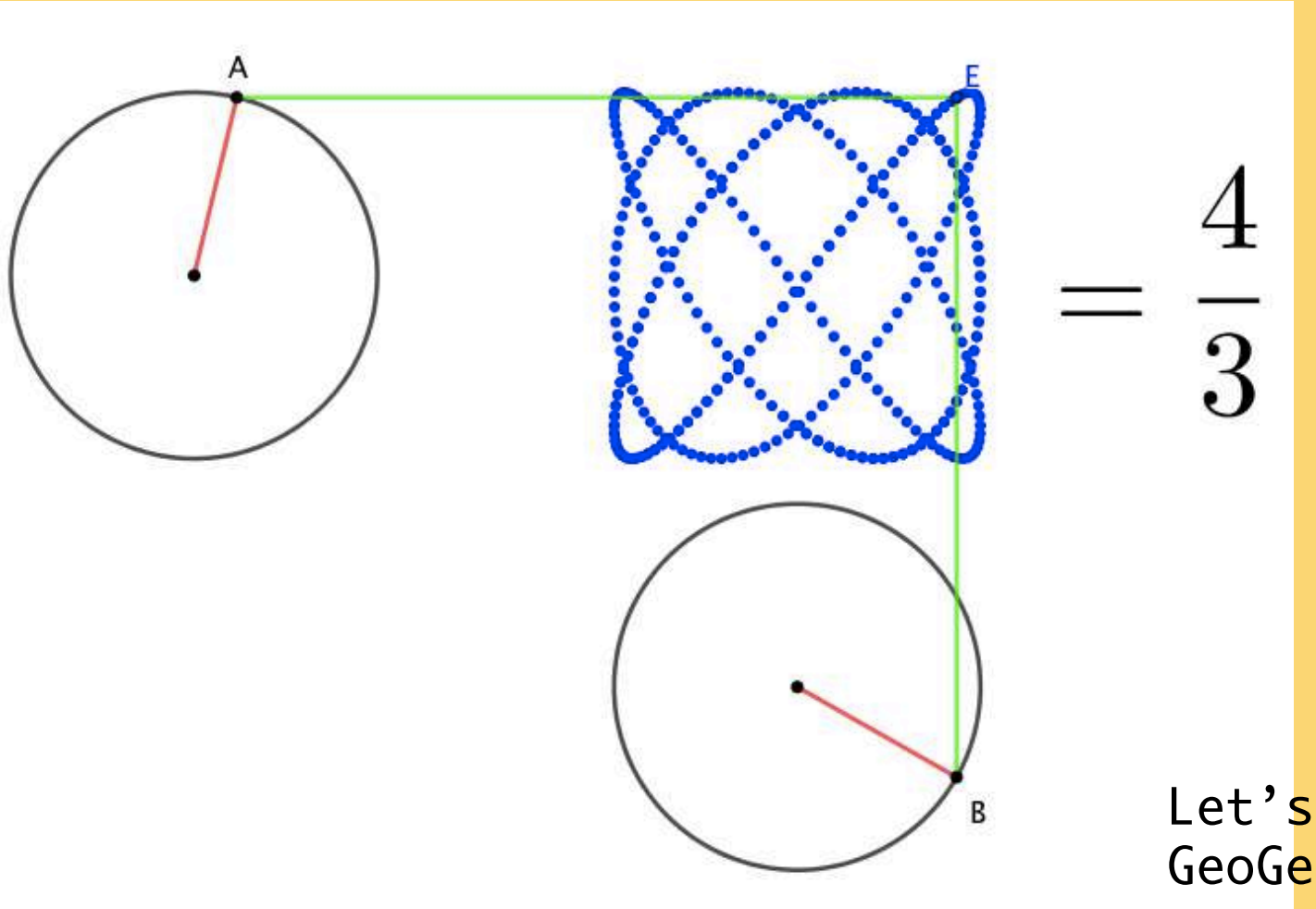
Perspective of $\frac{4}{3}$ in art



Let's go to
GeoGebra Demo

What is Mathematics, Really?

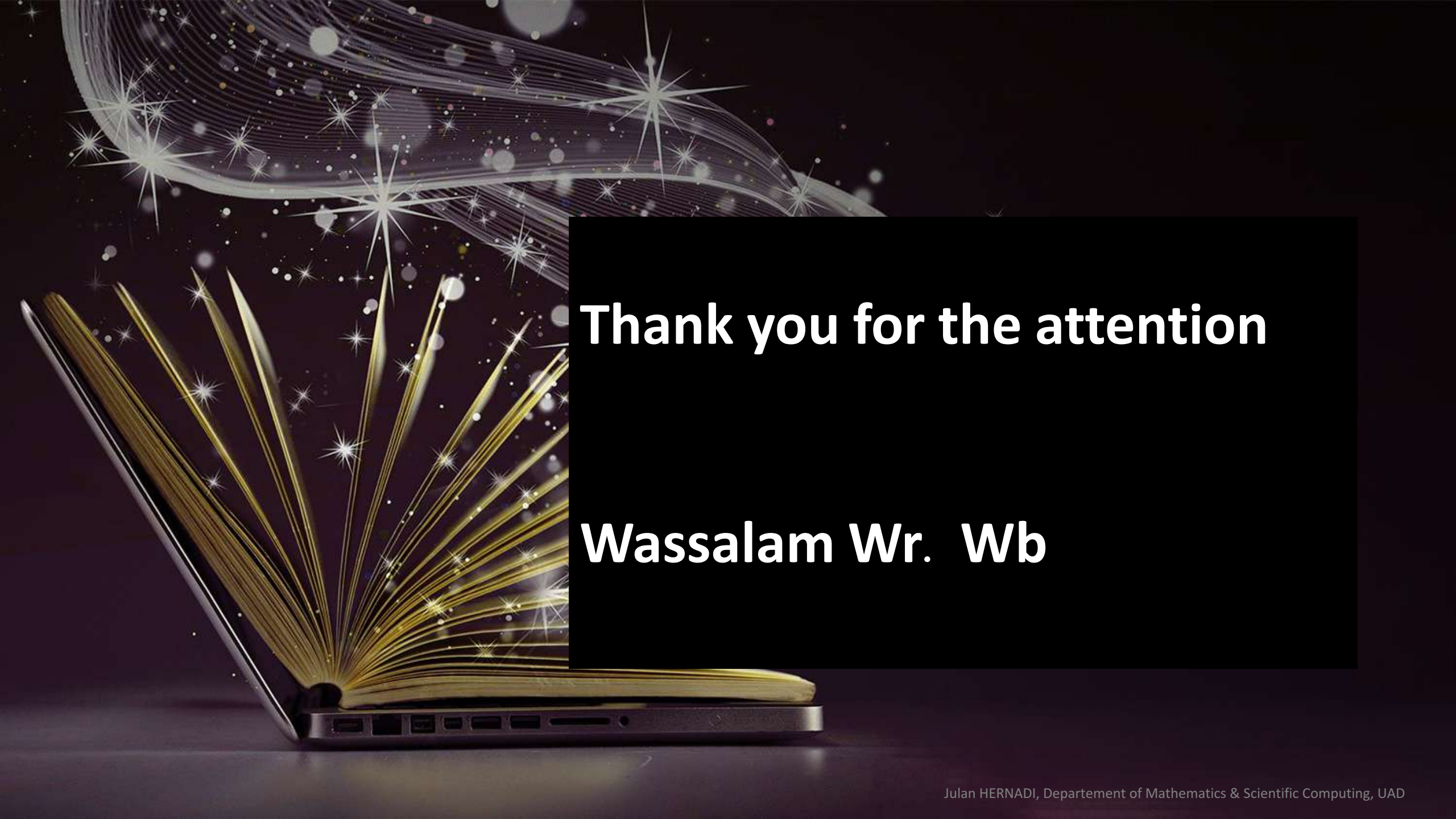
From the view of philosophy,
mathematics must be understood as a human activity,
a social phenomenon, part of human culture, historically evolved, and intelligible only in the social context .
(Rubens Hersh, 1997)

Humanism of Mathematics

Dilemma in Teaching Mathematics

Deep learning but narrow coverage
versus
Broad coverage but shallow learning

Uniform contents for students of different passion and interest.


Thank you for the attention
Wassalam Wr. Wb