

Essential Skills for Effective 21st Century Engineers and Scientists

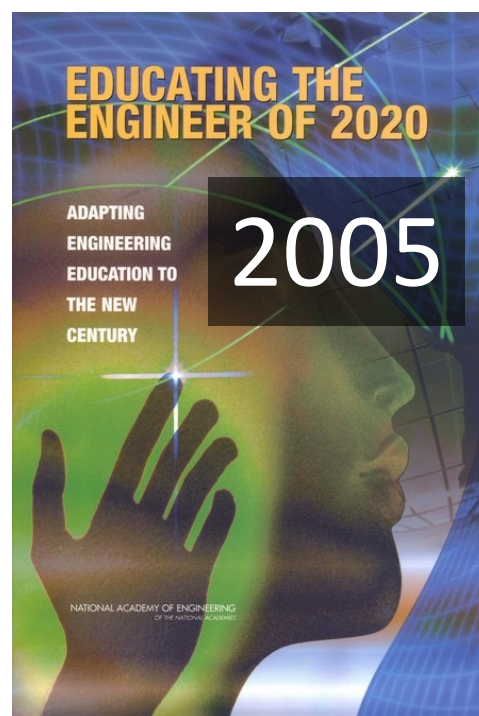
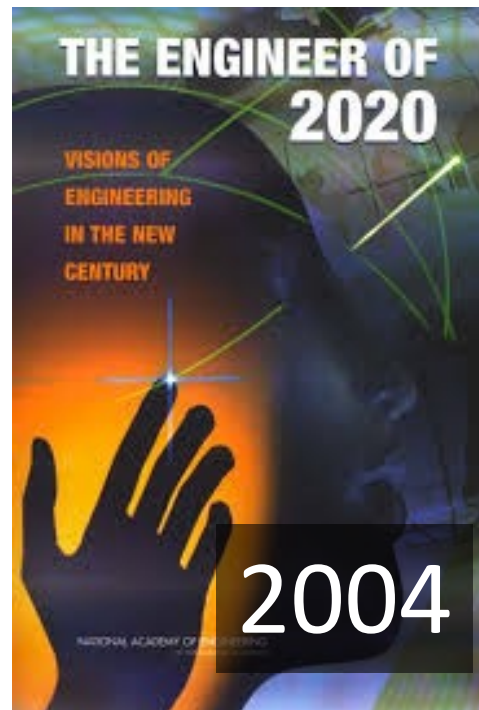


Junaid Qadir

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Information Technology University (ITU), Lahore*

Thinking about Engineering Beyond 2020



Many calls for reform and numerous 21C learning skills lists

- better communication skills*
- more “design”*
- more systems thinking*
- more people skills*

No.	Attribute
A1.	Strong analytical skills
A2.	Practical ingenuity
A3.	Creativity
A4.	Good communication skills
A5.	Lifelong learners
A6.	Dynamic, agile, resilient and flexible characteristics
A7.	High ethical standards
A8.	Leadership skills
A9.	Professionalism
A10.	Business and management skills

Engineering Education, Moving into 2020s: Essential Competencies for Effective 21st Century Electrical & Computer Engineers

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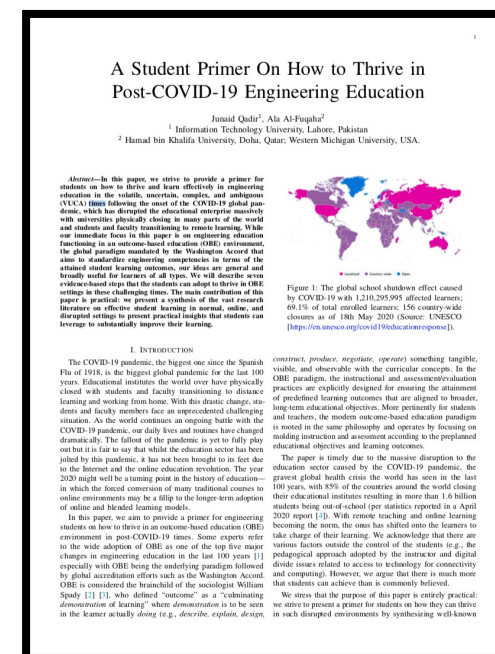
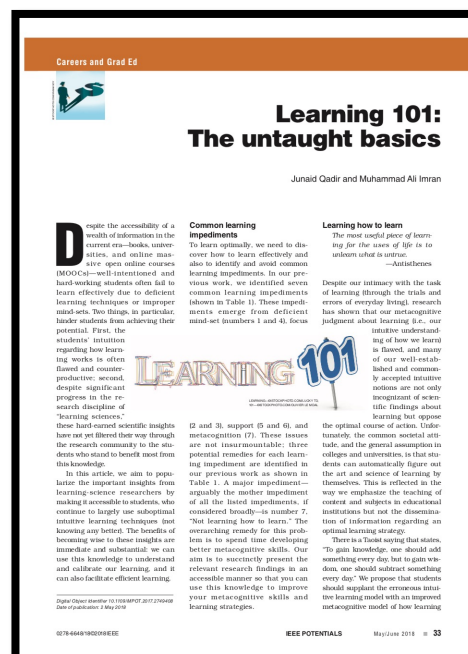
² Sunway University, Malaysia

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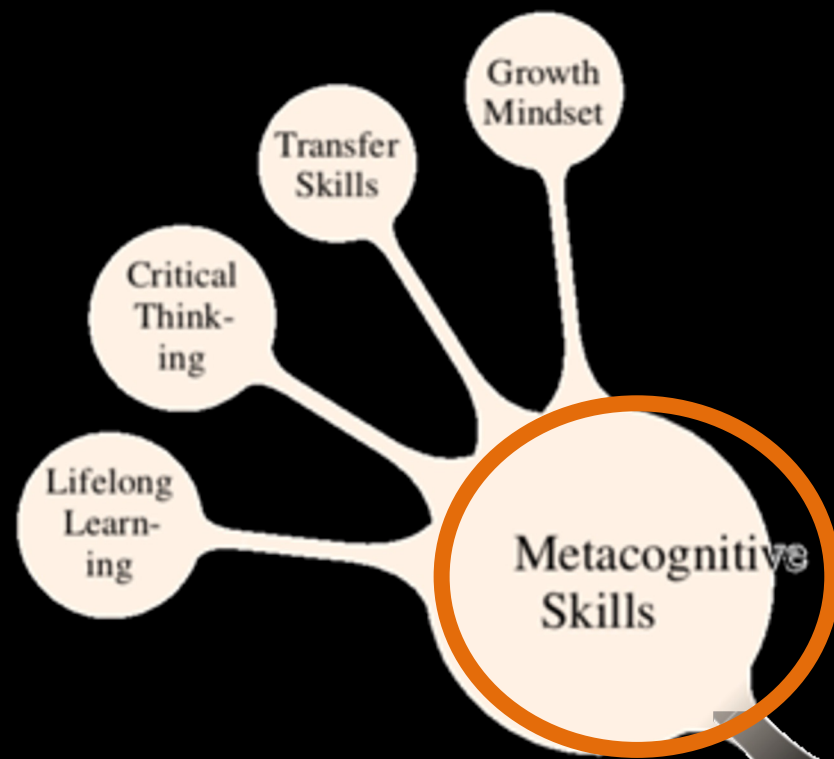
⁴ Hamad bin Khalifa University, Qatar; Western Michigan University, USA



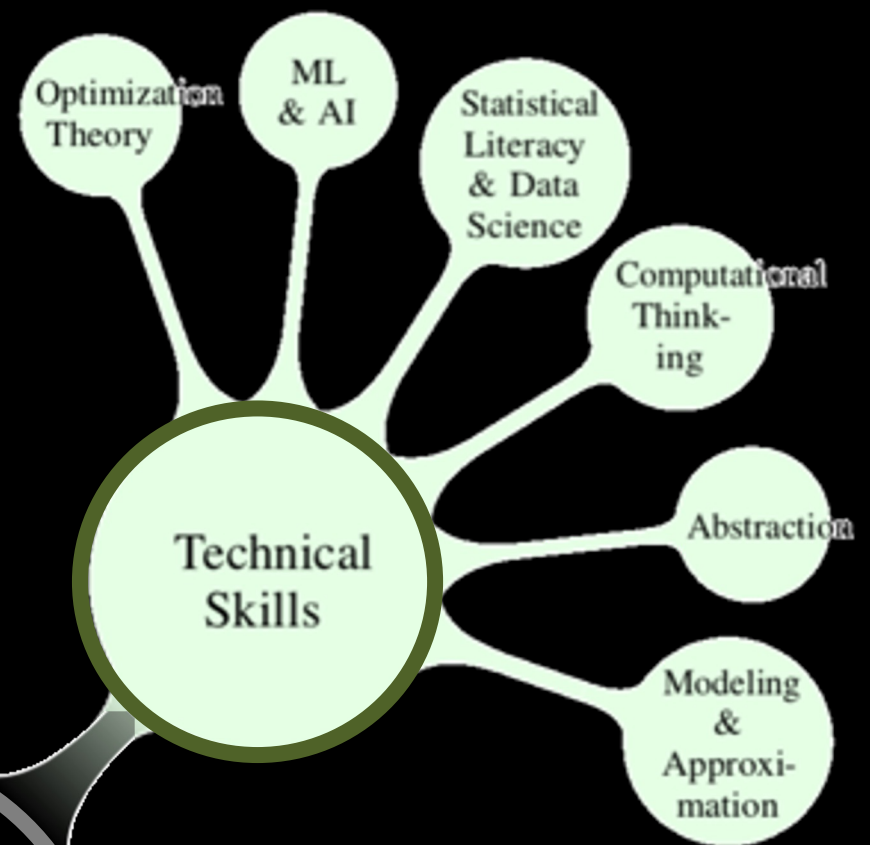
**FRONTIERS IN
EDUCATION 2020**
Education for a Sustainable Future
October 21-24, 2020
Uppsala, Sweden



1



2



3



4





Lifelong learning



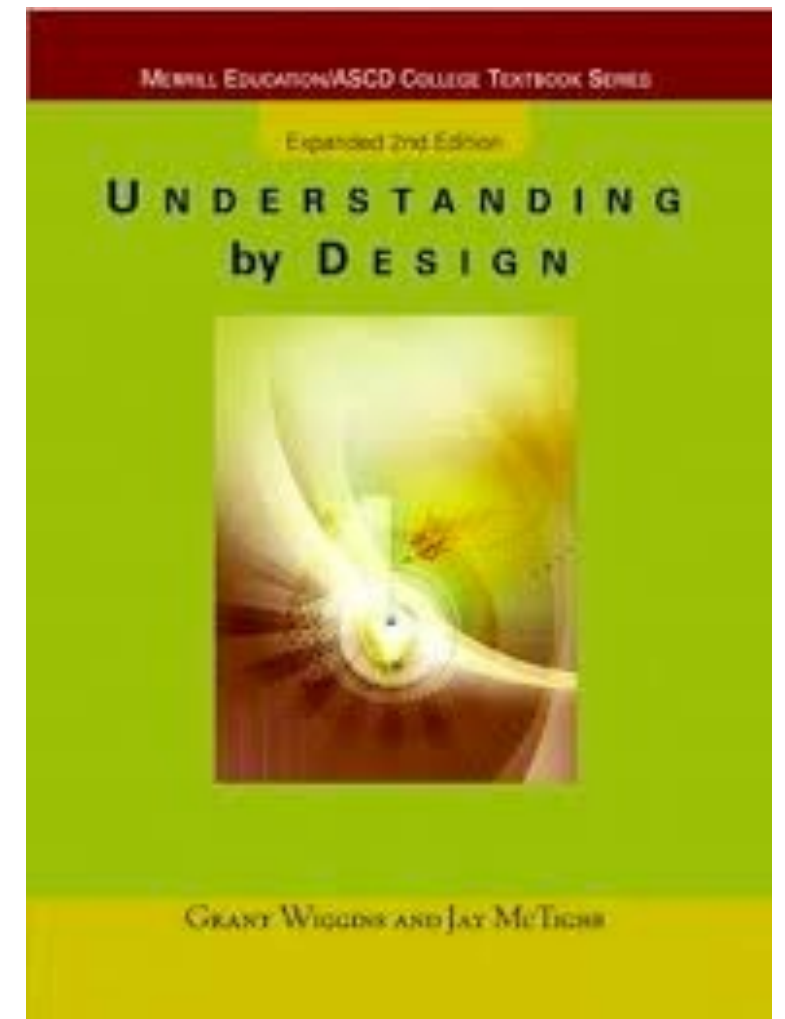
*“Teach a man to fish, and
you feed him for a lifetime.”*

Matthew Effect in Education:

When students acquire meta-skills such as learning how to learn, read, write, they bring this skill to every course and reap its exponential benefits

Develop “Understandings” of “Big Ideas” & Focusing on Transfer of Knowledge

“What we are claiming, based on both common sense and the research in cognition, is that no skill can be integrated into a powerful repertoire unless the learner understands the big ideas related to using the skill wisely.”
—Wiggins and McTighe.





IMPROVING ONE'S METACOGNITIVE SKILLS



VIA NEGATIVA

Avoid common mistakes



VIA POSITIVA

Become more effective

Via Negativa



J. Qadir,

“What every student should know: Seven learning impediments and their remedies,”
IEEE Potentials, vol. 34, no. 3, pp. 30–35, 2015.



Impediment 1) Having a Fixed Mindset

Solution: Conquer your mind to realize your potential.

Impediment 2) the Failure to Engage ‘Yourself’ in Learning

Solution: Knowledge will not give a part of itself until you give to it all of yourself.

Impediment 3) the Failure to Manage Time

Solution: Until we can manage time, we can manage nothing else.

Impediment 4) Failing to Realize that Failing is Key

Solution: Err unabashedly and learn—like a child does.

Impediment 5) Failing to Realize that Learning is Social

Solution: No one can do it for you, but you can’t do it alone.

Impediment 6) Being a Learning Monogamist

Solution: Encourage learning polygamy.

Impediment 7) Not Learning How to Learn

Solution: Don’t be an highly qualified A grade sheep.



J. Qadir and M. A. Imran, “Learning 101: The untaught basics,” IEEE Potentials, vol. 37, no. 3, pp. 33–38, 2018.

Desirable Difficulties:

<i>Effortful learning is better learning</i>	<i>“Practice that’s spaced out, interleaved with other learning, and varied produces better mastery, longer retention, and more versatility. But these benefits come at a price: when the practice is spaced, interleaved, and varied, it requires more effort.”—Brown, Roediger, and McDaniel [11]</i>
<i>To learn, you must forget, then interrupt forgetting</i>	<i>“It is only what breaks that grows.”—Unknown</i>
<i>Disfluency/discomfort can be good for learning</i>	<i>“That which does not kill us makes us stronger.”—Nietzsche</i>

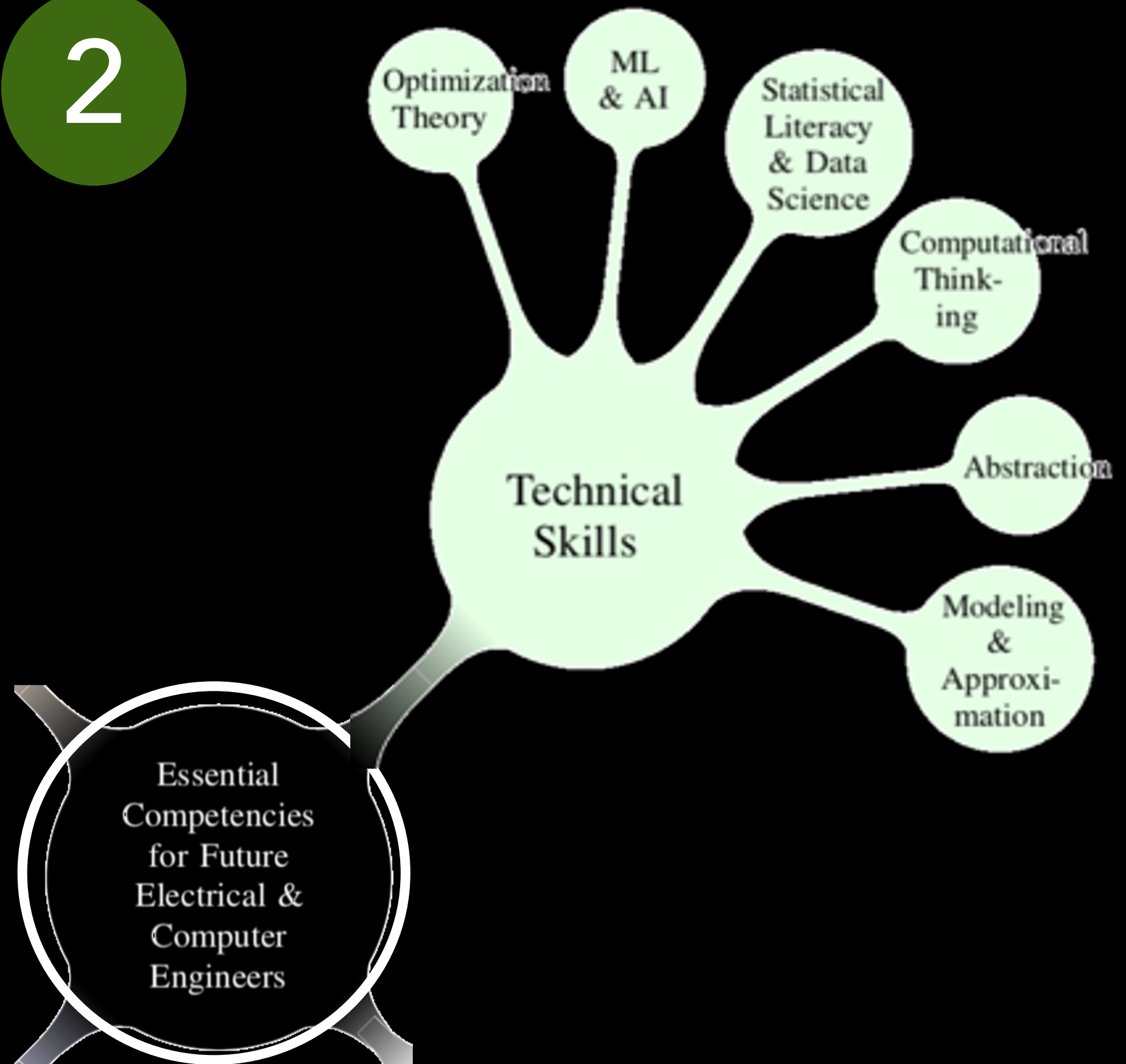
Undesirable fixations:

<i>Fixating on perfection: Why mistakes are required?</i>	<i>“An expert is a man who has made all the mistakes which can be made, in a narrow field.”—Niels Bohr</i>
<i>Fixating on fluency: Why fluency is not sufficient?</i>	<i>“Rising familiarity with a text and fluency in reading it can create an illusion of mastery.”—Brown, Roediger, and McDaniel [11]</i>
<i>Fixating on discipline: The upside of variety</i>	<i>“You don’t understand anything until you learn it more than one way.”—Marvin Minsky</i>

For efficient learning, use optimal learning techniques:

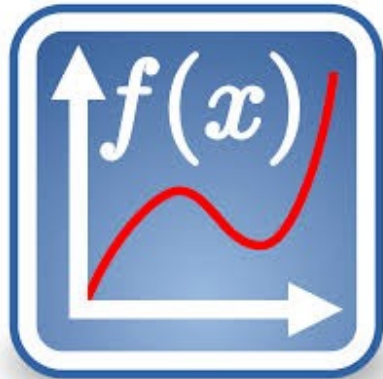
<i>Testing/retrieval as a learning tool</i>	<i>“In virtually all areas of learning, you build better mastery when you use testing as a tool to identify and bring up your areas of weakness.”—Brown, Roediger, and McDaniel [11]</i>
<i>Spaced learning and interleaving</i>	<i>“The truth is, nothing in learning science comes close [to spaced learning] in terms of immediate, significant, and reliable improvements to learning.”—Benedict Carey [12]</i>
<i>Aiming for mastery</i>	<i>“To be a sophisticated learner requires understanding that creating durable and flexible access to to-be-learned information is partly a matter of achieving a meaningful encoding of that information and partly a matter of exercising the retrieval process.”—Bjork, Dunlosky, and Kornell [18]</i>

2

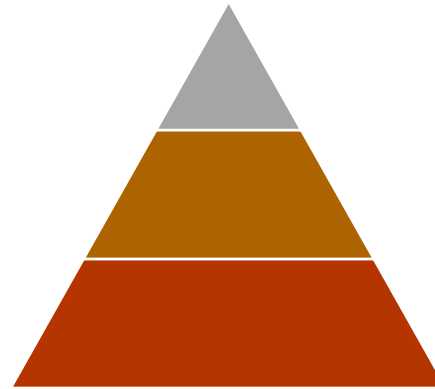


Salient Technical Know-How

Modeling and
Approximation



Abstraction



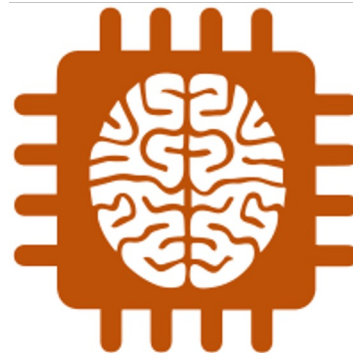
Computational
Thinking/Skills



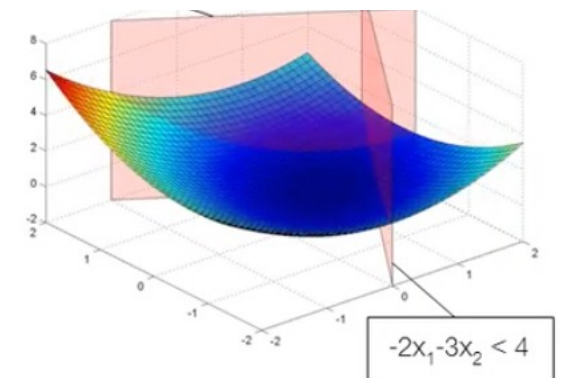
Statistical/Data
Literacy



Machine Learning &
Artificial Intelligence



Optimization
Theory

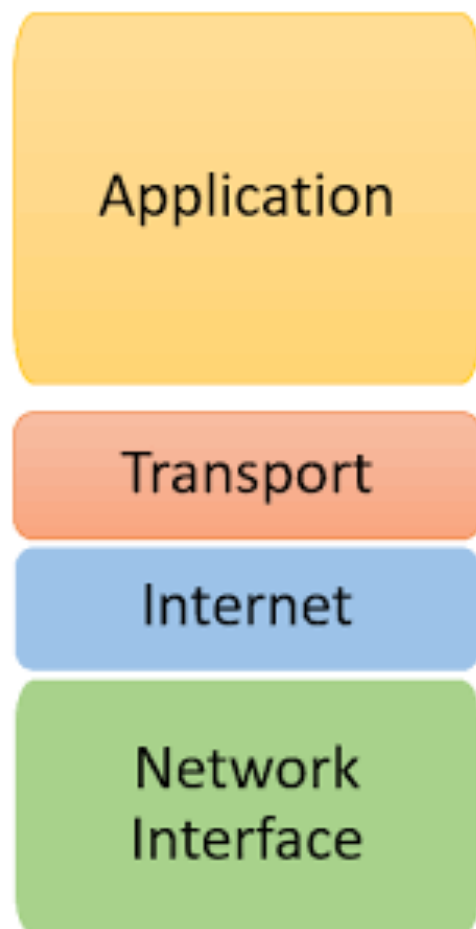
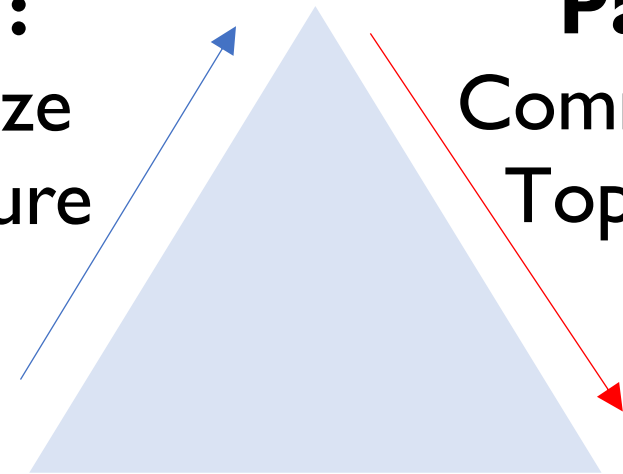


The importance of **Abstraction**

“preserving information that is relevant in a given context, and forgetting information that is irrelevant in that context”

Part 1:
Synthesize
& Structure

Part 2:
Communicate
Top-Down



TCP/IP model

A person playing a computer game uses a series of abstractions—the game is built using a **programming language abstraction**, which depends on an **assembly language abstraction**, which depends on a **microprocessor abstraction**, which depends on a **finite-state machine abstraction**, which depends on a **memory abstraction**, which depends on a **logic gate abstraction**, which depends on a **digital abstraction**, which depends on a **law of physics abstraction**, which aims to model nature.

3

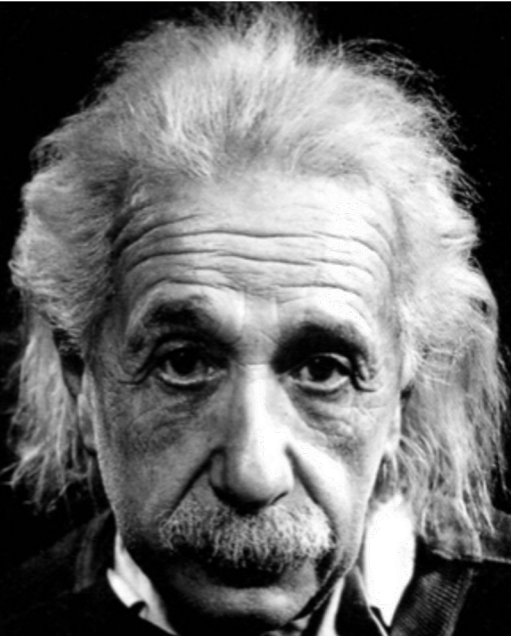
Essential
Competencies
for Future
Electrical &
Computer
Engineers



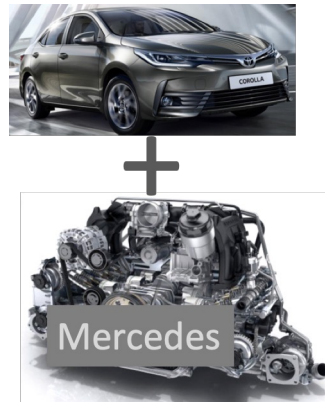
Becoming a Systems Thinker

"The significant problems we face cannot be solved at the same level of thinking we were at when we created them."

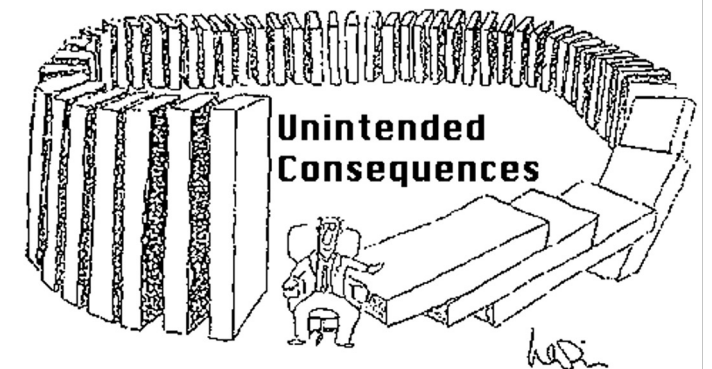
- Albert Einstein



Optimizing the parts rather than the whole

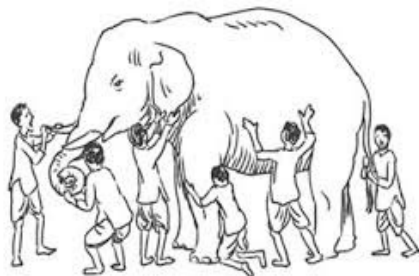


Unintended Consequences



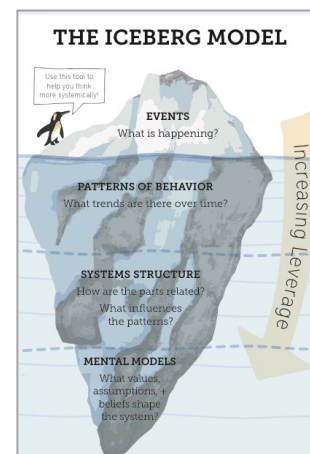
Integrate Mental Models

dictates how we perceive reality based on our values, expectations, & experiences.



Symptom Treatment

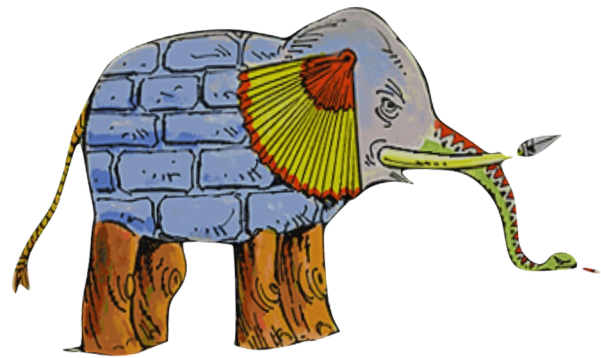
"There's always an easy solution to every problem that is neat, and plausible, but wrong." — H. L. Mencken



Policy Resistance

measures taken to improve a situation can directly make it worse due to policy resistance arising from people adapting

Multidisciplinary Holistic Learning



A latticework of models [from different fields] helps remove blind spots to better make sense of the complex world through multidisciplinary thinking.

No one model alone is entirely perfect.

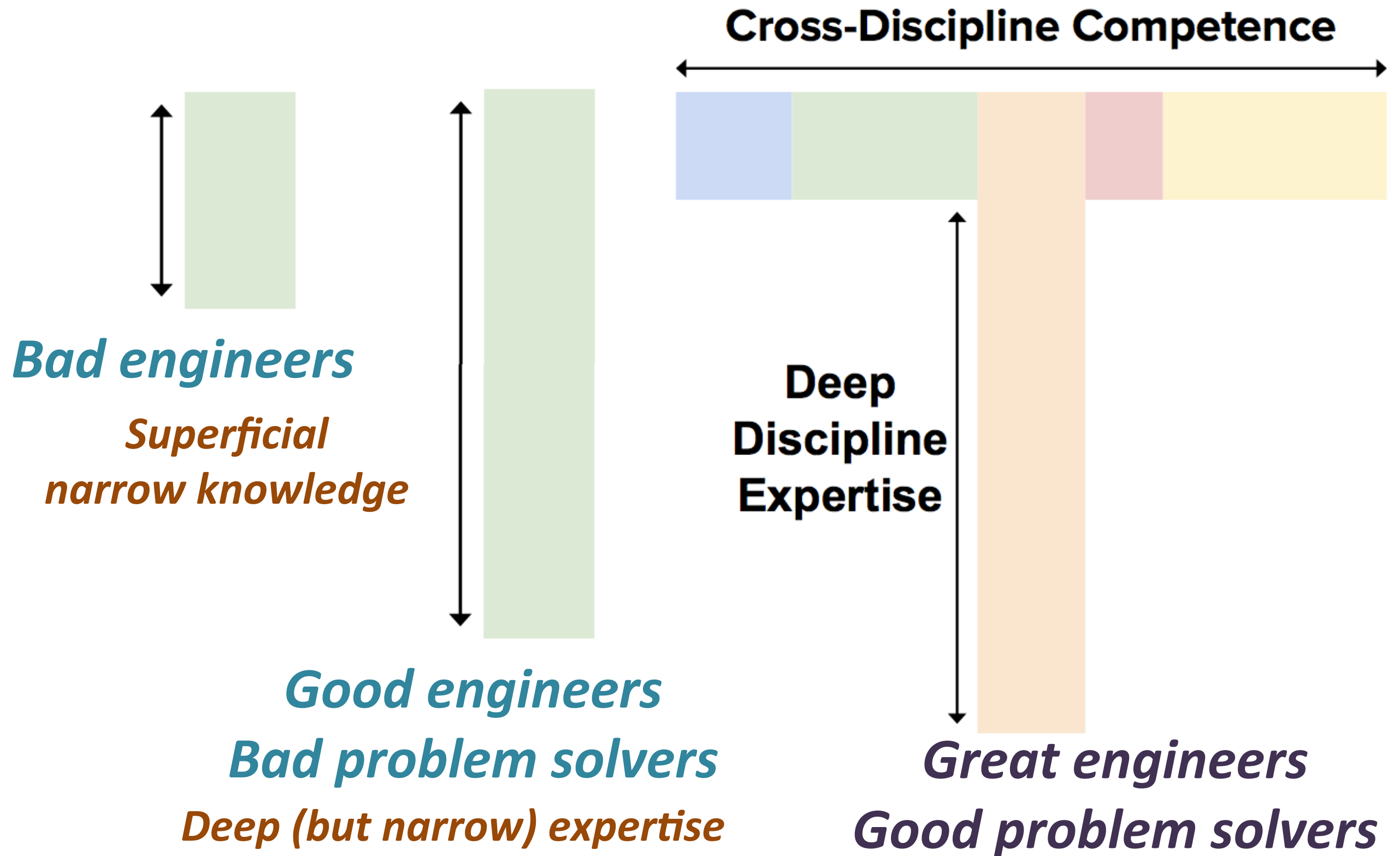
*If a hammer is all you have,
everything appears like a nail*



*Combine the arts and the sciences
(e.g., for visualizing and generating ideas).*

Breath Not At The Cost of Depth

(i shaped vs. I-shaped vs. T-shaped)



Essential Competencies for Future Electrical & Computer Engineers

4

Inter/Intra-personal Skills

Focus on Wisdom and Ethics

Entrepreneurship

Creativity & Innovation

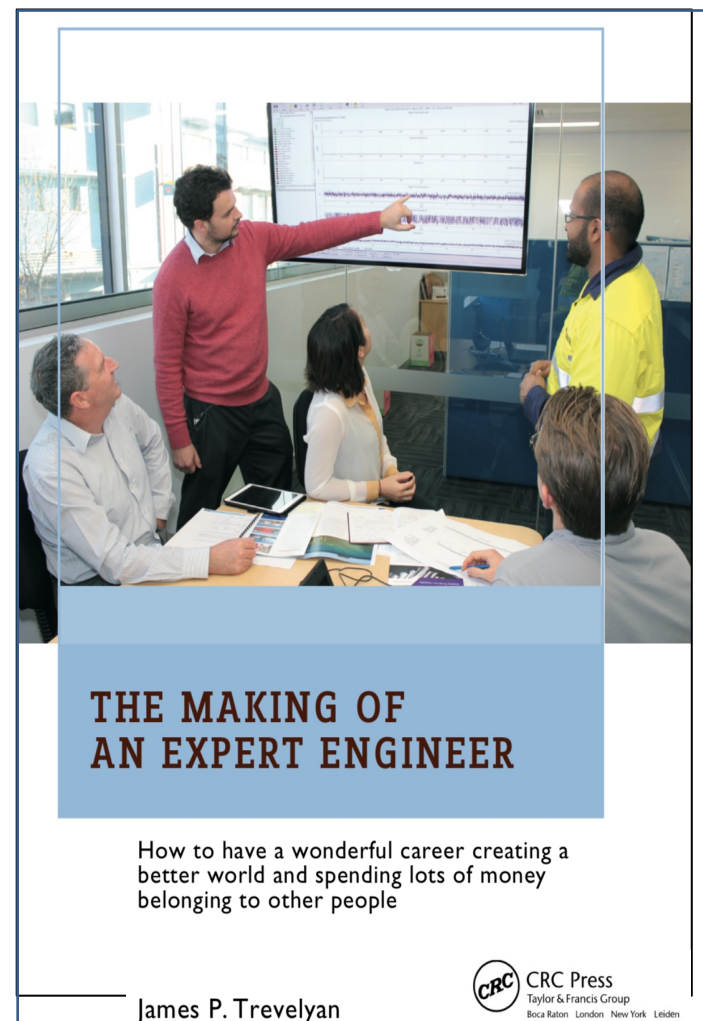
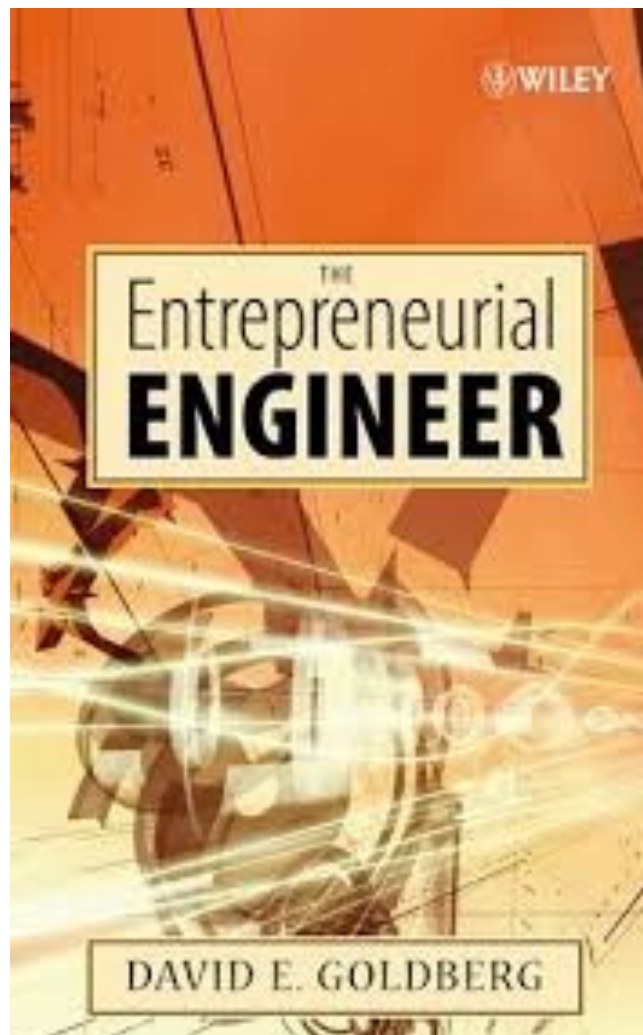
Teamwork Collaboration, and Global Competence

Comm Skills

Entrepreneurship

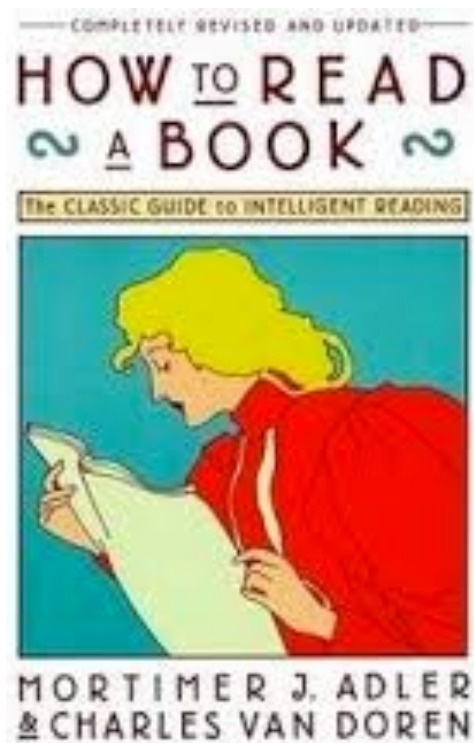
4C Skills for the 21C.

Critical thinking; Communication; Collaboration; and Creativity.



Communication Skills

“It is nearly impossible to overstate the benefits of being able to write well. The importance of the written word in storing, sharing, and communicating ideas at all levels of all organizations makes a poor facility with the mechanics of writing a severely career-limiting fault.”, John E. West, *The Only Trait of a Leader: A Field Guide to Success for New Engineers, Scientists, and Technologists*, 2008



On Writing Well

6 Tips on Bringing Clarity to Writing

1. Top-Down (Big Picture)
2. Flow (Connected)
3. Coherence (United)
4. Empathy (Reader Focus)
5. Design (Consistency)
6. Style (Flair)



JUNAID QADIR

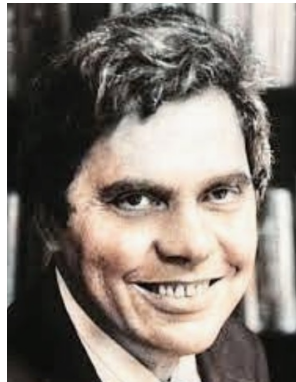
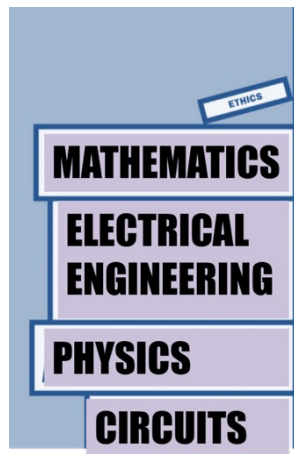


Writing Course - June 2020

 Technical Writing Short Course 6 Tips on Bringing Clarity

<https://www.youtube.com/junaidq>

Ability To Act Ethically and With Wisdom



Neil Postman

"Every technology is both a burden and a blessing; not either-or, but this-and-that."

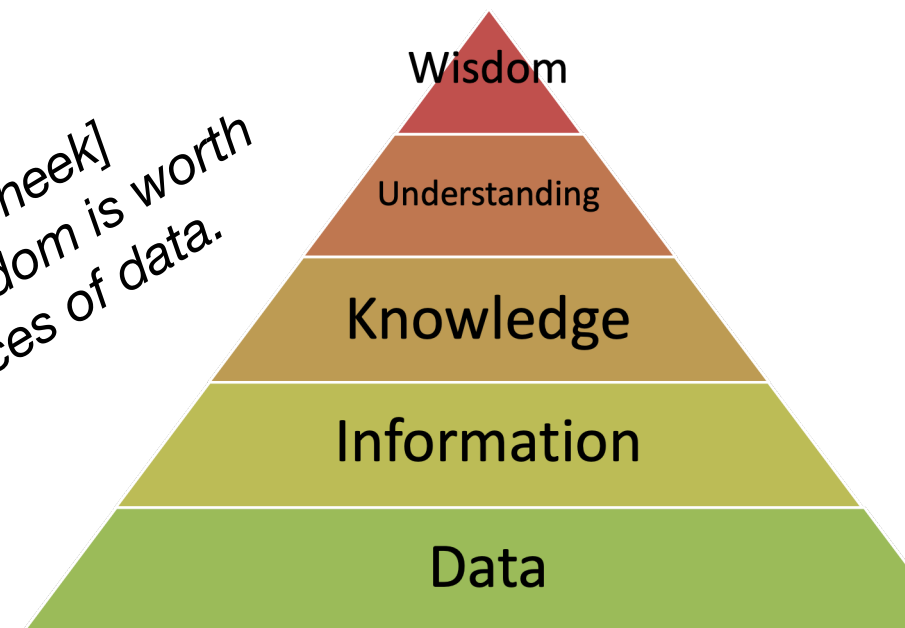
*An ounce of information is worth a pound of data.
An ounce of knowledge is worth a pound of information.
An ounce of understanding is worth a pound of knowledge.
An ounce of wisdom is worth a pound of understanding.*



IHSAN for Muslim Professionals - A Short Course

<https://www.youtube.com/junaidq>

*[Tongue-in-cheek]
An ounce of wisdom is worth
65,536 ounces of data.*



Washington Accord/ Pakistan Engineering Council (PEC)'s Recommended Graduate Attributes

12 Program Learning Outcomes (PLOs)

*What the graduates are
expected to know and able to
perform or attain by the time of
graduation (skills, knowledge
and behavior/attitude)*

**ELECTRICAL ENGINEERING
DEPARTMENT**

BS ELECTRICAL ENGINEERING

Program Learning Outcomes (PLOs)

Engineering Knowledge Ability to apply knowledge of Mathematics, Science, Engineering fundamentals & specialization to the solution of complex engineering problems.	Design/Development of Solutions Ability to design solutions for complex engineering problems and design systems, components or processes that meet specified needs with appropriate consideration for public health and safety, cultural, societal, and environmental considerations.
Professional Ethics Apply ethical principles and commit to professional ethics, responsibilities and norms of engineering practice.	Project Management Ability to demonstrate management skills and apply engineering principles to act as a member and/or leader in a team, to manage projects in a multidisciplinary environment.
Investigation Ability to investigate complex engineering problems in a methodical way including literature survey, design and conduct of experiments, analysis and interpretation of experimental data, and synthesis of information to derive valid conclusions.	Problem Analysis Ability to identify, formulate, research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences and engineering sciences.
Lifelong Learning Ability to recognize importance of, & pursue lifelong learning in broader context of innovation & technological developments.	Environment & Sustainability Ability to understand the impact of professional engineering solutions in societal & environmental contexts and demonstrate knowledge of and need for sustainable development.
Individual & Team Work Ability to work effectively, as an individual or in a team, on multifaceted and/or multidisciplinary settings.	Communication Ability to communicate effectively, orally as well as in writing, on complex engineering activities with the engineering community & with society at large, such as being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
The Engineer and Society Ability to apply reasoning informed by contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to professional engineering practice and solution to complex engineering problems.	Modern Tool Usage Ability to create, select and apply appropriate techniques, resources, & modern engineering & IT tools, including prediction and modelling to complex engineering activities, with an understanding of the limitations.

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Concluding remarks

Gaining knowledge is a lifelong project.

With the diminishing half-lives of engineering knowledge, it is futile to cover everything during engineering education.

Learning is a lifelong engagement. Learning how to learn is and having broad knowledge in many fields is becoming increasingly important.

Beyond 2020 skills are timeless skills and are “anti-fragile” (thus suitable for volatile, uncertain, complex, and ambiguous [VUCA] times).

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