ThinQ
think • inquire • question

Developing Thinking Abilities Relevant for Engineering Education

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28 April 2020

Overview of the webinar

- Goal of an undergraduate programme in engineering is to empower learners to:
  - function well in their jobs as Engineers
  - function well as educated people in their professional, public, and personal lives.
- *Academic Intelligence* for empowering learners to function as educated people
- Academic intelligence as foundation for developing abilities to think like an engineer

Academic Intelligence: Doubting & Questioning

- Is there air in your room?
  - How do you know?
- Aim of this exercise:
  - Help students learn the norms of *providing rational justification* for the beliefs that are treated as conclusions.
  - Mindset to look for justifications of conclusions that we often take to be true, such as “All living beings evolved from unicellular prokaryotes”, “The earth moves around the sun” etc.
  - Crucial for building knowledge

Academic Intelligence: Identifying Logical Contradictions

- Micro-organisms are organisms that are invisible to the naked eye.
- Fungi are microorganisms, and that mushrooms are fungi.

How do we revise such that the contradiction is resolved?

Academic Intelligence: Abstraction, Deducing logical consequences

- Two definitions of democracy:
  - Democracy is a political system in which citizens have the right to vote to elect their leaders/rulers.
  - Democracy is a system in which those who are affected by a decision have an opportunity to influence the decision.

Which of these definitions would you choose? Why?

- Take the seasonal migration of butterflies and dragonflies in animal behaviour, cell migration in developmental biology, and human migration in the human studies. Suppose we treat all these to be examples of migration. What, then, is 'migration'? How do we define the concept? What is the relation between this concept of migration, and the concepts of migrant and immigrant?

Trans-disciplinary Inquiry Abilities

- *Perceiving, introspecting, conceptualising, imagining, clarifying, classifying, generalising, abstracting, defining, reasoning, detecting contradictions, explaining, proving, and debating.*
- These tools go into both inquiry and critical thinking, and are central to thinking like a mathematician, like a scientist, like a philosopher, like a historian, like an engineer, and so on.

Thinking abilities in Engineering

Scenario 1

- You are reading a book in bed at night. You finish reading, and are ready to go to sleep. You need to get up to switch off the light. This is often a source of frustration, because you have to get out of bed to turn it off.
- Suppose that you report this to an engineer and ask for a solution. The engineer first "formulates" the problem. S/He may formulate it in many ways including the following:
  - How can you switch off the light without getting out of bed?
  - How can you switch off the light **without touching the switch.**
  - How can you switch off **any electrical item** without touching the switch

Thinking abilities in Engineering

Scenario 2

- Suppose there is a gardener in a public park who forgets to close the water valve after watering the plants. As an engineer, what is the problem statement that you will formulate?
  - **How do we make sure that the gardener does not forget to close the water valve?**
  - **How do we make sure that the water valve is closed?**
  - **How do we make sure that water is not wasted?**

Abstraction/generalization – moving from one specific case to a more general case

Thinking abilities in Engineering

Scenario 3

- Consider a scenario where you are designing a child-friendly milk container that reduces milk spillage. Among the many designs, you have two possible ones: a container made of glass or tetra pak carton. Which would you choose?

GLASS CONTAINER	TETRA PAK CARTON	ASSUMPTIONS	CHOICE
not damaged when opening	damaged when opening	Spillage of milk is to be avoided.	GLASS CONTAINER
—	↓ results in spillage of milk.		
breakable	not breakable	Causing harm to the child is undesirable.	TETRA PAK CARTON
↓ can cause harm to the child.	—		

Final choice based on the PRIORITIZING ASSUMPTION:
Milk spillage is more acceptable than harm to the child.
TETRA PAK CARTON

Defeasible reasoning

Thinking abilities in Engineering

- **Scenario 4**

Consider a case where you are trying to decide whether to take a water-can with you when going on a hike in a mountain. Let us say that you can fill in water only at the base where you start. So, you will need to carry enough water that can last until you return to the base. However, you also need to travel light, otherwise you will get tired quickly and will not be able to reach the base on time. Here again, in formulating your problem, you need to prioritize and say:

"Having sufficient water is more important than traveling light"

Thinking abilities in Engineering

Thinking like an engineer involves

- Basic thinking (trans-disciplinary inquiry abilities)
  - Abstraction/generalization
  - Conceptualization
  - Reasoning etc.
- Engineering thinking builds on these to
  - Integrated thinking
  - Making tradeoffs
  - Optimization etc.

Basic thinking feeds into developing engineering thinking

Levels of thinking abilities

- **Level A:** the thinking abilities that we expect of educated people, regardless of their specialization and future careers/professions, regardless of whether they have a BA, BSc, BCom.... BEd degree.
- **Level B:** the thinking abilities that we expect of those who have an X degree (where X can be BA, BSc, BCom, BE, BTech,...)
  - Level B 1: Thinking like a practitioner of profession X (e.g. thinking like a practicing doctor), or
  - Level B 2: Thinking like a researcher in profession X (e.g. thinking like a medical researcher)
- **Level C:** The thinking abilities that we expect of those who major in subject X (subject X = mathematics, astronomy, physics, chemistry, earth sciences, botany, zoology, microbiology, economics, sociology, psychology, history, English Lit, ...)

Thinking abilities in Engineering

Basic thinking feeds into developing engineering thinking for solving real-world problems

Some Book Recommendations

- *Applied Minds: How Engineers Think* by Guru Madhavan. W. W. Norton & Company; 1/e, 2016
- *Engineering Design Process* by Yousef Haik & Tamer M. Shahin. Cengage Learning; 2/e, 2010

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Inquiry & Integration in Education

- Online course for any interested in inquiry, particularly for educators, students & parents
- Aimed at introducing to trans-disciplinary inquiry abilities and helping them to develop them
- More details at http://thinq.education/iie (Application closes on May 01, 2020)

Thank you!

For more details visit
http://thinq.education/iie
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