Metacognition in Engineering Education- A Case Study

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Contents

Introduction

Qualities of Experts

- Solve routine problems with the least effort and consciousness.
- Can effectively handle new complex problems
  - Confident to face challenging situations.
  - Follow problem solving framework.
  - Able to analyze problem.
  - Able to analyze solution and reflect on each step.

Characteristics of Real Engineering Problems

- Real engineering/STEM problems are complex.
  - Multidisciplinary.
  - Poorly defined.
  - Conflict requirements.
  - Involve many factors.
  - Etc.

Qualities Needed to Solve Complex Problems

- Creativity.
- Attention to details.
- Mixed methods.
- Thorough understanding.
- Tendency to check on self work and to repeat some steps.

Applies not only to STEM.

Why It is Difficult for Us to Produce Experts?

- Practical limitations.
- Differences in learning styles.
- Engineering programme focuses more on theory.

But we can equip students with skills to become experts in the future.

Introducing Metacognition

What is Metacognition ?

- Definition (Wikipedia)

"Metacognition is thought processes and an understanding of the patterns behind them".

Elements of Metacognition

- Metacognition has two components,
  1. Knowledge about cognition.
  2. Regulation of cognition.

Elements of Metacognition in Teaching and Learning

1. Lecturer's knowledge about student cognition.
2. Lecturer's regulation of student cognition.
3. Student's knowledge about his/her cognition.
4. Student's regulation of his/her cognition.

(3) and (4) are important for OBE and SCL

Related Qualities of Experts

- Automaticity.
- Metacognition.
- Self-efficacy.
- Problem classification.

Metacognition Methods and Strategies

Course in Electromagnetic Theory

Course learning outcomes

1. Solve electrostatic field problems using vector analysis methods.
2. Solve static magnetic field problems using vector analysis methods.
3. Apply the electromagnetic knowledge into the markets/industries via EMC.
4. Explain the market/industrial needs in solving their problem regarding EMC.

Strategies to Apply Metacognition Techniques

- When solving problems
  - Make problem solving a real experience.
  - Apply problem classification.
  - Explore different approaches to solution.
  - Think loudly and encourage students to take part in the discussion.
  - Ok to make mistakes.
  - Reflect on steps.
  - Go back and try other approaches.

Strateg
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Metacc
Technic

fields

uniform non-uniform

fields

time-variant time-invariant

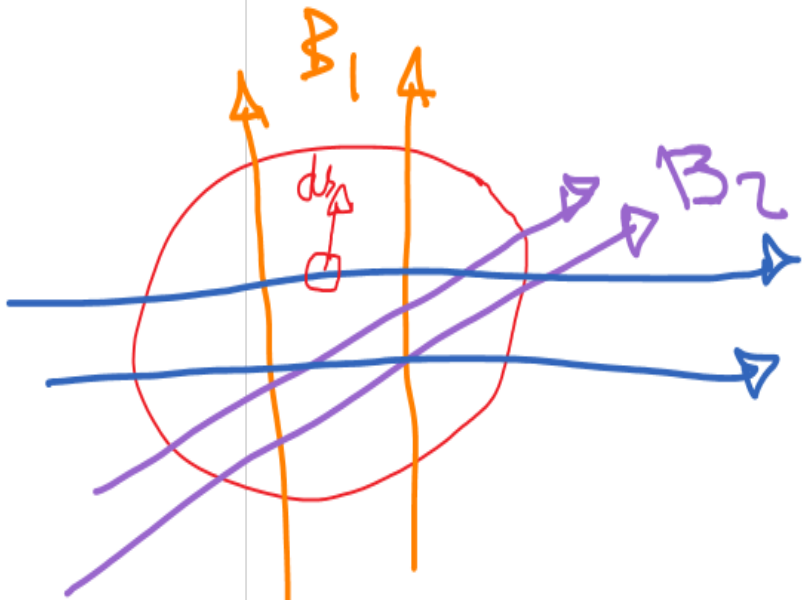
fields

Vector Scalar

Transformer EMF

- If a closed loop with N turns is placed in a region with time-varying magnetic field, an induced emf is generated in the loop given by,

$$V_{emf}^{tr} = -N \int_S \frac{\partial \boldsymbol{B}}{\partial t} . d\boldsymbol{s}$$



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Total Charge if Uniform Distribution

- In uniform distribution, ρ is constant (e.g., not function of position)
- If uniformly distributed, use one of the following simple multiplications.

$$Q = \rho_l \times L$$
$$Q = \rho_s \times S$$
$$Q = \rho_v \times V$$

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Total Charge if non-Uniform Distribution

- In non-uniform distribution, ρ is not constant (e.g., function of position)
- If non-uniformly distributed, must use integration to calculate total charge, Q. One of the following should be used.

$$Q = \int_l \rho_l dl$$

$$Q = \int_s \rho_s ds$$

$$Q = \int \rho_v dv$$

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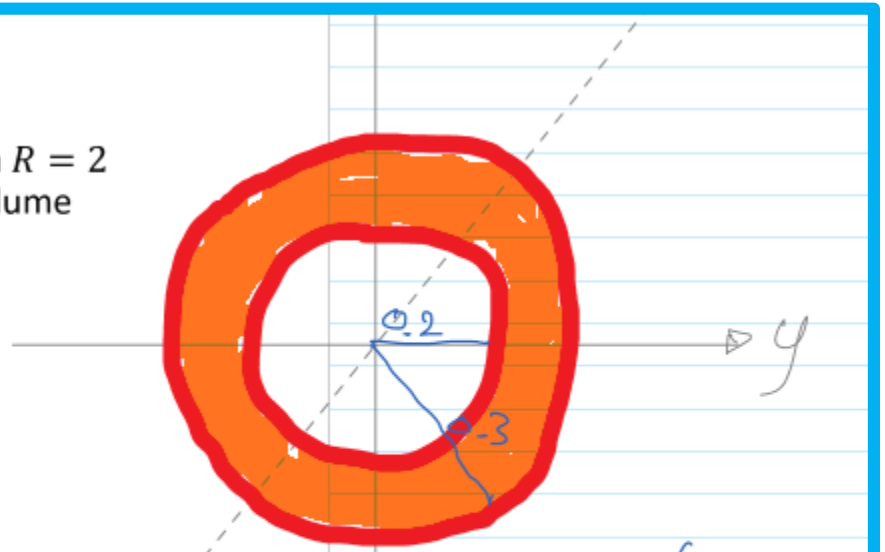
Example

- A thick spherical shell centred at the origin extends between $R = 2$ cm and $R = 3$ cm. Find the total charge in the shell if the volume charge density is,

  a. $\rho_v = 10^4$ C/m^3 uniform

  HW b. $\rho_v = 3R \times 10^4$ C/m^3 non uniform



Method 1

$Q = \rho_v V$

$V = \frac{4}{3}\pi(0.3^3) - \frac{4}{3}\pi(0.2^3)$

$Q = \int \rho_v \, dv$

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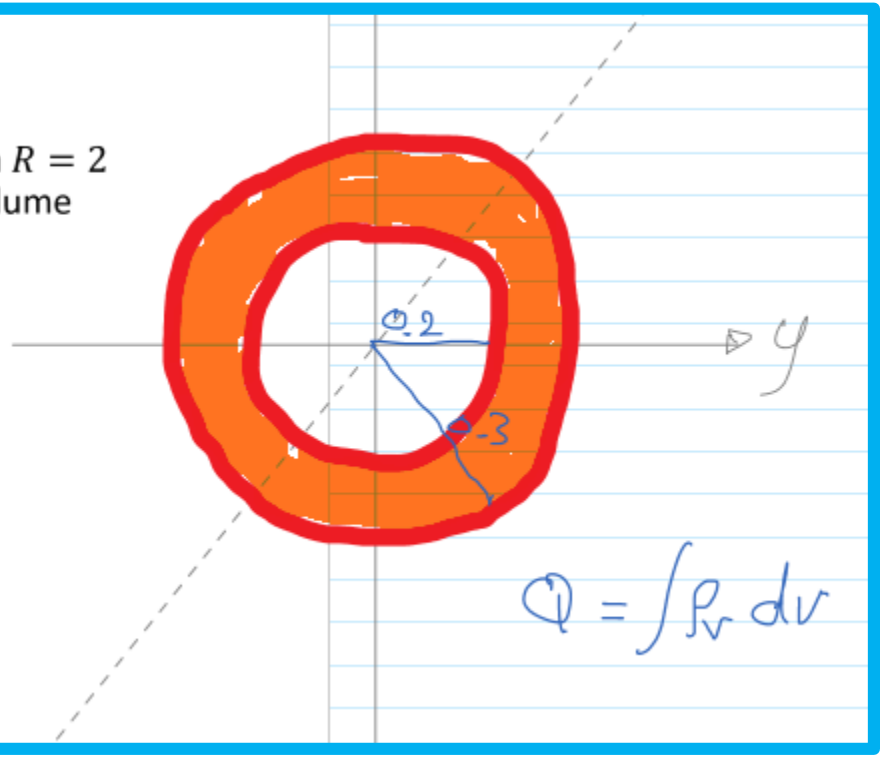

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More Strategies to Apply Metacognition Techniques

- Relate theory to practice.
- Compare newly learned solution methods with earlier learned methods.
- Use active learning techniques.

More Strategies to Apply Metacognition Techniques

The Clamp Meter

- The clamp meter measure the current by measuring the total field around the wire.

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ethods.

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More Strategies to Apply Metacognitio Techniques

Example

A digital transmission system is operated at 400 kbps. The double-sided noise power spectral density of the system is $\frac{N_0}{2} = 2 \times 10^{-10}$ W/Hz. Calculate system BER for the following line coding,

1. Binary unipolar signalling with amplitude $A = 100$ mV.
2. Binary polar signalling with amplitude $A = 70$ mV.

What can we conclude from comparing answers.

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Even More Strategies to Apply Metacognition Techniques

- Create positive experiences and avoid negative ones.
- Course should progress from easy to difficult.
- Avoid using speed as a grading factor.
- Challenge negative believes.
- Show other (non-engineering) aspects of the theories.

Strategies to Try

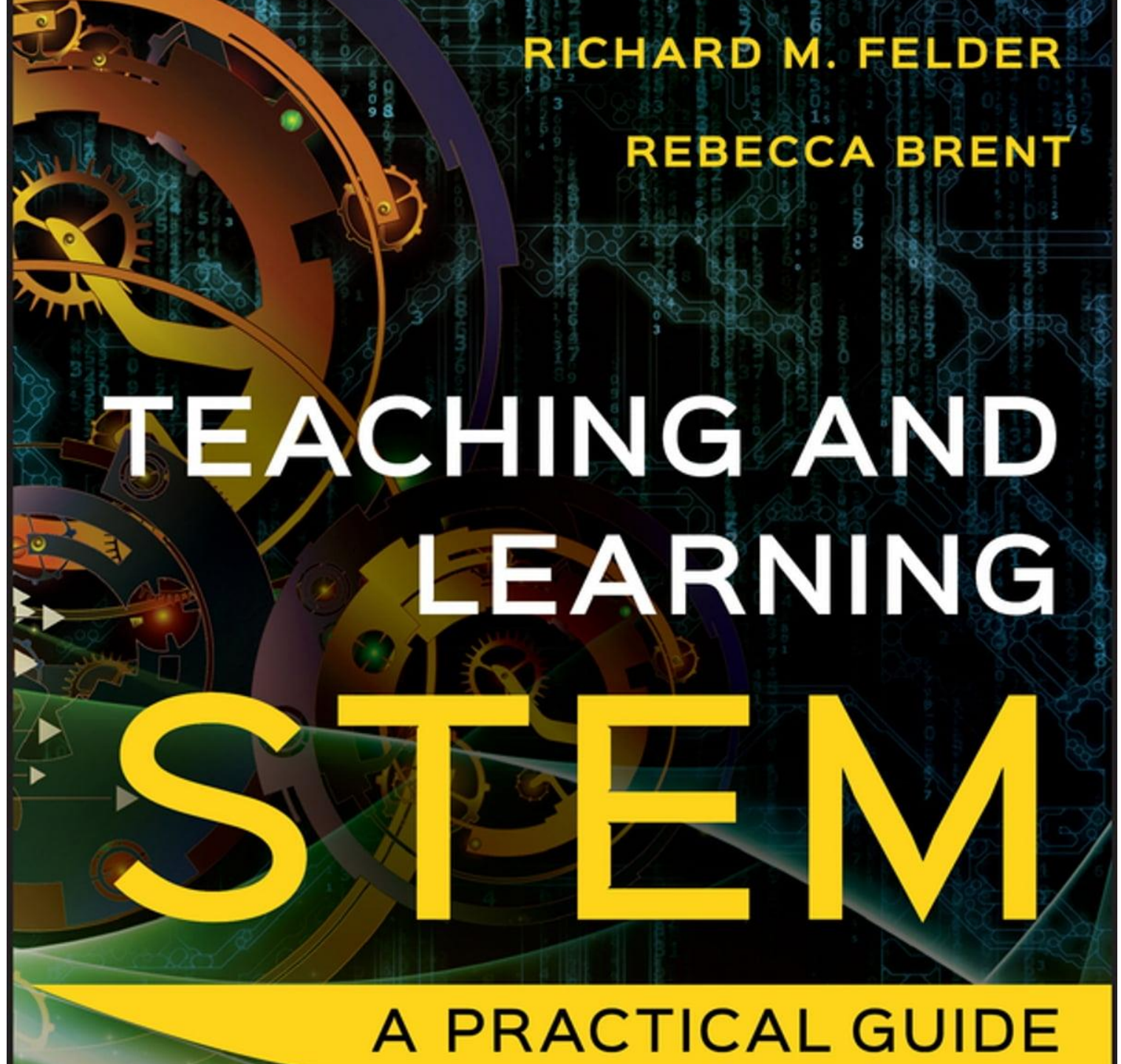
- Exam wrapper and post-test questionnaire.
- Problem-based learning.
- Teach about general problem solving techniques.

Challenges

- Cultural barriers.
- Students are diverse.
- Allocation of resources (time management)

Conclusions

1. The learning experience should consider both short and long term objectives.
2. Metacognition plays an important role in achieving course learning objective.
3. Various approaches can be followed to utilize metacognition.
4. Lecturers need to be creative is devising good metacognition strategies.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Questions