Welcome

Wong Khoon Yoong
Mathematics & Mathematics Education
National Institute of Education (NIE), NTU
Email: khoonyoong.wong@nie.edu.sg
Website: http://math.nie.edu.sg/kywong/
Chief Editor, *The Mathematics Educator* (TME)
Web: http://math.nie.edu.sg/ame/

Title

Does Metacognitive Reflection Matter for Secondary and JC Mathematics Students?

Write down your reflection during the talk.

Your Reflection 1

- Write down:

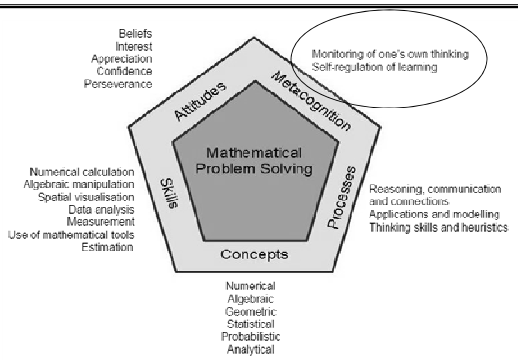
  Now, I think that metacognitive reflection in maths is …

Two Learning Issues

- Help students who are:

1. Poor problem solvers, especially to solve non-familiar problems.
2. Not aware of effective ways to "regulate" their own learning.

Two Aspects in Pentagon



Flavell (1976, p. 232)

- Flavell coined "metacognition":
- one's knowledge concerning one's own cognitive processes and products … active monitoring and consequent regulation and orchestration of these processes in relation to the cognitive objects or data … in the service of some concrete goal or objective.

Other Meanings

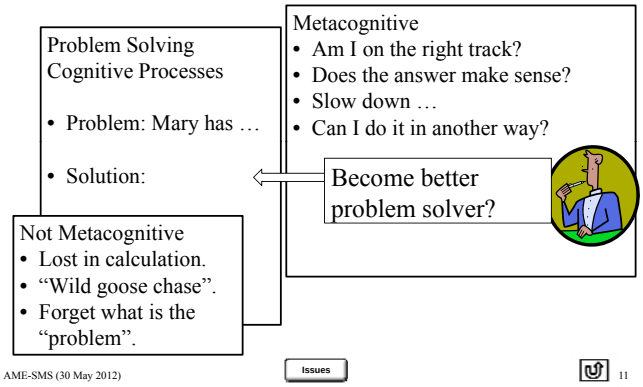
- Schoenfeld (1987): Math; self-awareness, control, belief about one's cognition.
- Fogarty (1994): "metacognitive reflection": planning, monitoring, evaluating.
- Ellis & Denton (2010): "reflective assessments" in math.
- Metacognitive reflection: Elements of metacognition (awareness, regulation) and reflection (look back).

Two Learning Issues

- Help students who are:

1. Poor problem solvers, especially to solve non-familiar problems.
2. Not aware of effective ways to "regulate" their own learning.

Metacognition @ Problem Solving



Ex: Percentages

- O-Level, 2011. In 2009, the population of the United Kingdom was 6.1×10^7. Between 1851 and 2009, the population increased by 173%. Calculate the population in 1851.
- Jot down the main step.
- What metacognition do you expect your students to engage in? Write it down. "Answer" later.

Polya's Model

- Each step requires different types of metacognitive questions.

1. Step 1: Do I understand the key words? What are the conditions?
2. Step 2: Is this similar to …?
3. Step 3: Am I on the right track? Have I used all the conditions?
4. Step 4: Does the answer make sense? Is there a "better" solution?

Studies: 3 Local + 1 Overseas

1. M-ProSE.
2. Problem Solving Wheel.
3. Maths Problem Solving Project.
4. IMPROVE.

M-ProSE (1)

- M-ProSE (Mathematical Problem Solving for Everyone): Toh Tin Lam, Quek Khiok Seng, Tay Eng Guan, Jaguthsing Dindyal.
- http://www.nie.edu.sg/research-projects/m-prose-mathematical-problem-solving-everyone
- Practical worksheet, Polya's steps.
- Ten 1-hour sessions.
- For each problem, score completion of worksheet: Polya's steps (10 marks), evidence of cycling through the steps; heuristics (4 marks); Check and extend (6 marks).

M-ProSE (2)

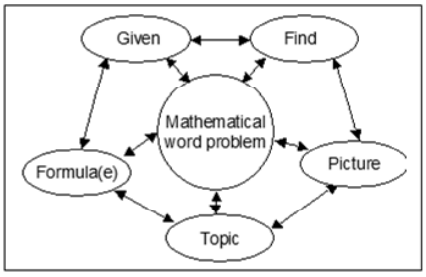
- S3 class. 2009.
- Researcher taught cycle 1; teacher taught cycle 2.
- Later, all S2 classes; $n = 159$.
- End of module problem: *There are two timers: one for 5 minutes and one for 9 minutes. I want to heat up a beaker of water for 11 minutes. How can we do this using only these two timers?*
- 70% scored max in first 3 stages; 75% scored max in use of heuristics; 7.5% scored max in Stage 4 (90% got at least 1 out of 3 marks).
- Can use practical worksheet.

Lee Ngan Hoe: PS Wheel (1)

- Four S1N(A) classes.
- Control-Experiment, pre-post test.
- Metacognitive Instructional Strategies (MIS), 10 sessions:
  - Metacognitive Mathematics log writing.
  - Effective questioning.
  - Identification of structural properties of problems.
  - Pair / group problem-solving.

Lee Ngan Hoe: PS Wheel (2)

- Diagram.



Lee Ngan Hoe: PS Wheel (3)

- Students answered 5 metacognitive questions after each problem.
- E.g.: What are the questions that you asked yourself when you solved the problem?
- Positive changes: Math self-concept, self-efficacy, perseverance, achievement.

MPS Study

- Student Use of Heuristics and Problem Solving Behaviours (2008); http://math.nie.edu.sg/kywong/
- P5 (217) & S1 (143). Solved problems and answered an open-ended questionnaire (9 items) about metacognition; Callahan & Garafalo (1987).
- 1 (a) You have taken the word problem solving exercise. Write down all the things you usually do when you solve these problems.
- (b) Why do you do these things?

MPS: Main Findings

1. General statements, e.g., "trying to understand the problems" (about 2/3).
2. Check their own work: as part of process (about 15%); when asked specifically, about 70% said Yes.
3. Attributed mistakes to carelessness (about 2/3) rather than understanding (about 8%). Carelessness or misconceptions?
4. How to improve? Practice (about 60%), quite general.

- Weak metacognition or cannot describe mental events?

IMPROVE

- Mevarech & Kramarski (2003).
- IMPROVE; M = Metacognitive questioning: comprehension, connection, strategy, reflection questions.
- Control-Expt; 122 Grade 8 Israel students, algebra. Metacognitive vs. Worked Examples, both in cooperative environment.
- M group did better in immediate post-test, delayed post-test (1 year later).

Teaching Metacognition (1)

- Common approach: Give students a checklist of questions.

1. Make sure that the questions in the checklist work for the problems.
   - Vygotsky approach.
   a) I do: Model the use of checklist; talk aloud (scaffolding).
   b) We do: Use Q&A; public talk (fading).
   c) You do: Whisper, private talk (mastery).

Use of Checklist

- Now that you have used the checklist to monitor your thinking (metacognition), reflect on your experience:
  - Which items in the checklist are very helpful?
  - How well can you use those items?
  - How to use other items more effectively?
- If you (teachers) collect these reflection sheets, how would you use them as "assessment *for* learning"?

Teaching Metacognition (2)

2. Teacher thinks aloud and students think along: Solve a novel problem in front of class; show students how to use checklist to be "unstuck".
3. "This *is* the way to …" vs. "This *could be* one way to …"
4. Train students to listen to explanations given by classmates; become more aware of thinking.
5. Teach contents more than metacognitive strategies!

- If problem is routine, metacognition not required?

Ex: Percentages: Ans?

- Cognitive: $(6.1 \times 10^7)/2.73 = 2.23 \times 10^7$
- Metacognitive:
  1. What does "increase by" mean? Same as "increase to"?
  2. Can this "increase by" be greater than 100%?
  3. Is drawing a diagram helpful?
  4. Calculator: 2.234432234. Does this answer make sense?
  5. How can I check my answer?

Your Reflection 2

1. Poor problem solvers, especially to solve non-familiar problems.

- Have you "learned" one key idea to deal with issue 1?
- Write it down as Reflection 2 …

Two Learning Issues

- Help students who are:

1. Poor problem solvers, especially to solve non-familiar problems.
2. Not aware of effective ways to "regulate" their own learning.

Self-Regulation of Learning

- Goal: Learn to learn.
- During the lessons, aware that one must:
  - pay attention to teacher explanation;
  - carry out activities such as seatwork practice.
- After lessons, do the following:
  - complete the homework on time;
  - revise for tests;
  - prepare own notes;
  - work with friends or seek help from others;
  - set goals for learning, etc.

Flavell (1976, p. 232)

- Aware: "I notice that I am having more trouble learning *A* than *B*".
- Control: "I should double-check *C* before accepting it as a fact".
- Act: "I had better make a note of *D* because I may forget it … ask someone about *E* to see if I have it right".

Wiliam (2011)

- "[S]tudents can develop sufficient insights into their own learning to improve it" (p. 146).
- Story: I would learn better in math lessons if … (p. 153).
- Write down one "answer" to this reflection.

Wiliam (2011): Story

- S: "if I had a better math teacher".
- T: Not acceptable, try again.
- S: "if I brought the right equipment to school, paid attention in class, and remembered to do my homework".
- T must tell students what is negotiable (under students' control for their learning) and what is not negotiable.

3 Local Studies

1. Study Activities and Student Question Cards.
2. CORE 2: Ridzuan, Hogan & Chan.
3. Metacognition and performance goals: Luo, Paris, Hogan.

EMP: Study Activities

- Enhancing Mathematics Performance (EMP). 2004.
- Self-report of study environment and study activities in math.
- Classes: Teachers nominated a weak class; administered the questionnaire.
- Two reports from http://math.nie.edu.sg/kywong/
- Data for one P4 (36) and one S1N(A) (40) class; Chinese and Malay. *Ways of Studying Mathematics; Chinese & Malay Students; CRPP presentation (2007).*
- Data for P4 (68) and S1N(A) (80), full report: *Enhancing Mathematics Performance of Mathematically Weak Pupils (EMP): Full report (2009).*

Traditional Activities (S1 NA)

- Frequency: 1 = Never; 2 = Occasionally; 3 = Often; 4 = Always
- Helpfulness: 1 =Waste of time; 2= Not so helpful; 3 = Helpful; 4 = Very helpful

	C	M
Q15: Hand in homework on time.	3.05	3.19
(Helpful)	2.86	3.06
Q8: Pay attention to teacher when he or she explains things.	2.90	3.13
(Helpful)	3.35	3.19
Q13: Ask for help when I do not understand.	2.90	2.88
(Helpful)	3.15	3.44

Metacognitive Activities (S1 NA)

- Frequency: 1 = Never; 2 = Occasionally; 3 = Often; 4 = Always
- Helpfulness: 1 =Waste of time; 2= Not so helpful; 3 = Helpful; 4 = Very helpful

	C	M
Q4: Plan my own schedule of studying math.	1.57	1.94
(Helpful)	2.05	2.88
Q5: Make my own notes.	1.76	2.31
(Helpful)	2.50	2.63
Q11: Keep a notebook of my math mistakes and the corrections.	1.71	1.88
(Helpful)	2.10	2.56
Q24: Write reflection about lessons, e.g. in a journal.	1.52	1.69
(Helpful)	1.90	1.81

Ridzuan, Hogan & Chan

- Survey of 1438 S3 students. Core 2, 2009.
- 5-point Likert scale.
- Guess the mean of each item below! (4 items)

1. The teacher teaches us how to identify the best method to solve problems.
2. The teacher asks us to apply what we have learned to practical issues or real life situations.
3. The teacher asks us to check if our answers make sense.
4. The teacher says our arguments must be correct.

Ridzuan, Hogan & Chan: Ans

- Increasing means.

1. The teacher says our arguments must be correct. (3.07).
2. The teacher asks us to apply what we have learned to practical issues or real life situations. (3.15).
3. The teacher teaches us how to identify the best method to solve problems. (3.56).
4. The teacher asks us to check if our answers make sense. (3.57).

- Metacognitive (3.59) > Procedural (3.48) > Epistemic (3.36) > Conceptual (3.25). Our teachers had taught S3 students to be metacognitive.

Luo, Paris, Hogan, Luo (2011) #1

- 1697 S3 students from 39 schools.
- Metacognitive self-regulation scale (4 items, 5 point). Sample items:
  - I ask myself questions to make sure I understand what I study in my math class.
  - When I study math, I try to determine which ideas I don't understand well.
- Guess overall mean!
- Overall mean: 3.47.

Luo, Paris, Hogan, Luo (2011) #2

- Online MCQ test (28 items); topics?; mean 13.21 (≈ 47%, weak?).
- Mean PSLE math grade 5.25 (1 to 7).
- Correlation of Metacognition with Math (.11), PSLE (.06); moderate correlations (≈ .5) with mastery goals, self-efficacy, and engagement.
- Highest predictor of current math score: PSLE math (.53).

Teach Self-Regulation: Aware

- Story: Writing down blood pressure readings can lead to lower blood pressure?
- Raise awareness with checklist, e.g., doctors, pilots, etc.
- Produce a form about homework: Topics, when to submit, teacher comments, what had I (student) done?
- Paste at front page of file or exercise book.

Teach Self-Regulation: Debate

- Aware of alternative learning activities.
- Bell @ Shell Centre. Mini-debate about learning math.
- Ex: You learn more from tackling one hard problem than ten easy ones.
- 3 groups: pro, con, judge.
- Groups present arguments.
- Group 3 asks questions and votes.
- My experience.

Teach Self-Regulation: SQC

- Ask questions. SQC (Wong & Quek), train students to ask math questions in lessons.

Meaning
M1: What do you mean by ...,
M2: What is the difference between ..., and ....
M3: Can you use a diagram to show ....
M4: (Your own question)

Method
Md1: Can you show us how to do this problem in another way?
Md2: Can you explain/show us this step (....) again?
Md3: What will you do next?
Md4: (Your own question)

Reasoning
R1: Why do you do that ....?
R2: What happens if you change ..., to ....?
R3: (Your own question)

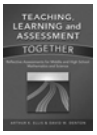
Application
A1: Why do we study this topic (....)?
A2: How do we use this (....) in everyday life?
A3: (Your own question)

Teach Self-Regulation: MOE

- MOE (2013):
- Summarising their learning using concept maps, writing journals to reflect on their learning and making connections between mathematical ideas and between mathematics and other subjects should be encouraged.
- Sharing such reflections through blogs makes learning social.

Teach Self-Regulation: Exit

- Ellis & Denton (2010). Exit card/slip. Students complete one at end of lesson.
  - Convergent: Write down the steps to find turning points.
  - Divergent: Write down two statements about turning points.
- Teacher's exit thought! One crucial issue to discuss in next lesson.



Your Reflection 3

2. Not aware of effective ways to "regulate" their own learning.

- Have you "learned" one key idea to deal with issue 2?
- Write it down as Reflection 3 …

Be Reflective Yourself

- You need to experience metacognitive reflection yourself before you can guide your students.
- No need to start from scratch! Pick one idea from the literature or workshop and try it for at least one term.

Partial Answer

- Only partial answer to question:
- Does Metacognitive Reflection Matter for Secondary and JC Mathematics Students?
- Find your own answer from your practices; a true professional.
- A word of encouragement.

Journey Ahead

With passion

you get on the metacognitive reflection journey

To educate your students to be reflective

To become reflective yourself

These are bumpy journeys ahead

But invigorating, exciting…

Abstract

Metacognition is one of the five major components in the Singapore mathematics curriculum considered as important to facilitate students' ability to successfully solve mathematics problems. It is one form of reflection that students are asked to engage in, usually at the end of a lesson or a topic. In this lecture, I will discuss theoretical underpinnings of metacognitive reflection, cite some evidence of its impacts, and discuss techniques that teachers might trial in their mathematics lessons. Teachers are urged to find out for themselves, rather than rely on others, which techniques "work" for their students to help them become more effective mathematics learners, thus achieving better learning outcomes in the cognitive, affective, and social domains.