What's the fuss about metacognition in the mathematics classroom?

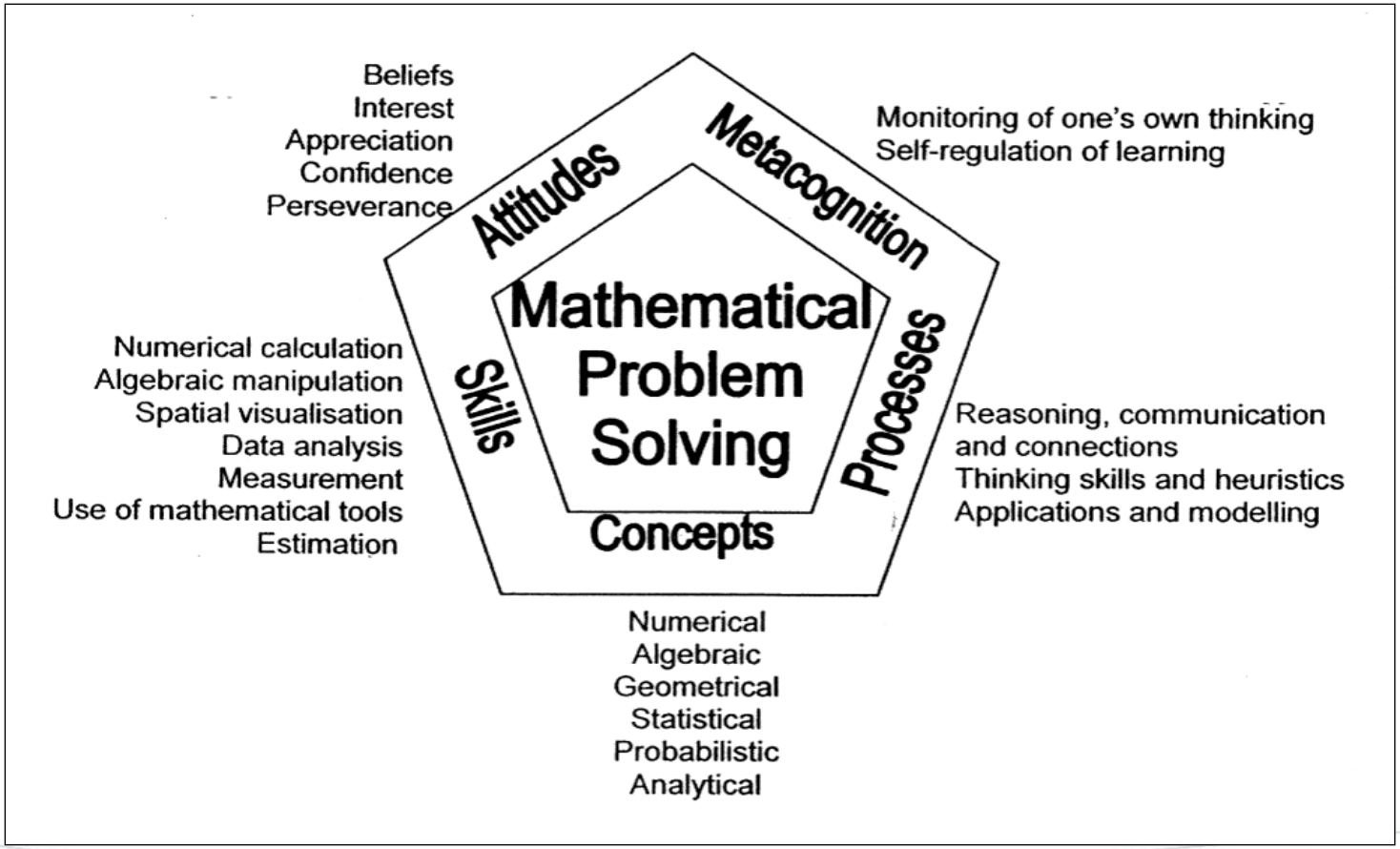
Professor Berinderjeet Kaur
National Institute of Education
Singapore

NIE
NATIONAL INSTITUTE OF EDUCATION
SINGAPORE

1950-2010
NIE, SINGAPORE
Celebrates 60 Years
of Teacher Education

An Institute of
NANYANG TECHNOLOGICAL UNIVERSITY

Framework of the school mathematics curriculum



What is metacognition?

Flavell (1979), the founder of research on metacognition, defines it as “thinking about thinking”.

- The two components:

- Knowledge of cognitive processes and products such as
- i) what individuals know about their cognition,
- ii) how to use strategies and other procedures, and
- iii) why and when to use a particular strategy.

- Regulation of cognition typically includes at least three components:

- i) planning,
- ii) monitoring, and
- iii) evaluation.

What does research tell us about intelligence, metacognition and mathematics learning performance?

- **Alexander, Carr and Schwanenflugel (1995)**
- Found that metacognitive knowledge develops along a monotonic incremental line throughout the school years parallel to the development of intellectual ability of students.
- The impact of intelligence neither increases, nor diminishes over the years.
- So, it appears that intelligence only gives students a head start in metacognition, but it does not further affect its developmental course.

- **Veenman (2006)** has shown that among secondary school students although intelligence and metacognitive skills influenced mathematics performance metacognition outweighed intelligence as predictor of mathematics learning performance.

- Therefore we must not discount the role of metacognition in our mathematics lessons.

SOME FINDINGS FROM PISA 2009 STUDY About 15 year olds from SINGAPORE

NIE, SINGAPORE
Celebrates 60 Years
of Teacher Education

PISA: Singapore students achievement in Mathematics

	Rank
PISA 2009	**2**

PISA: Singapore students achievement in Science

	Rank
PISA 2009	**4**

PISA 2006 – Findings about German students

(Schneider & Artelt (2010)

- For the PISA 2003 study mathematics was the major assessment domain.
- Singapore did not participate in PISA 2003.
- In Germany Schneider and Arteit (2010) found that performance in mathematics literacy and metacognitive knowledge were substantially correlated (r = 0.43), indicating that roughly 18% of the variance of mathematics performance in PISA 2003 test for 1433 students (15 year olds) in Germany could be explained by the metacognition indicator.

PISA 2009 – Findings about Singapore students

- The PISA 2009 data includes measures of student proficiency in reading, mathematics and science.
- However, reading was the major domain in PISA 2009.
- 5283 students (15 year olds) from 171 school participated in the study.
- Metacognitive learning strategies and self-regulated learning strategies for reading were measured with the aid of a questionnaire.

Some findings (Kaur & Areepattamannil, 2012)

- Metacognitive learning strategies for reading:
- understanding and remembering
- summarizing

Were found to be statistically significant positive predictors of mathematical literacy for students in Singapore.

This means that students with higher scores for metacognition in reading scored statistically significantly higher in mathematics literacy than their peers who had lower scores for metacognition in reading.

Some findings – contd..(Kaur & Areepattamannil, 2012**)**

- Similarly, one of the self-regulated learning strategies for reading:

- use of control strategies

was found to be a significant predictor of mathematical literacy for students in Singapore.

This means that students who frequently used control strategies in reading scored statistically significantly higher in mathematics literacy than their peers who infrequently used control strategies in reading.

Is there a need for instruction to nurture metacognition?

Veenman, van Hont-Wolters & Afflerbach (2006) affirm that

- Students do pick up metacognitive knowledge from their parents, peers and teachers in informal settings.
- Knowledge acquired from such settings vary substantially.
- To ensure that all students in a class or cohort are given the same opportunities to acquire metacognitive knowledge, instruction of metacognition is essential.

- Research has shown that metacognitive instruction appears to enhance metacognition and learning in a broad range of students. It is of particular relevance to low attainers.

What is the nature of successful metacognitive instruction?

- Research has also shown that the three fundamental principles for successful metacognitive instruction are:

- Embedding metacognitive instruction in the content matter to ensure connectivity;
- Informing learners about the usefulness of metacognitive activities to make them exert the initial extra effort; and
- Prolonged training to guarantee the smooth and maintained application of metacognitive activity.

{Veenman (1998) refers to the above as the *What to do*, *When*, *Why*, and *How* rule}

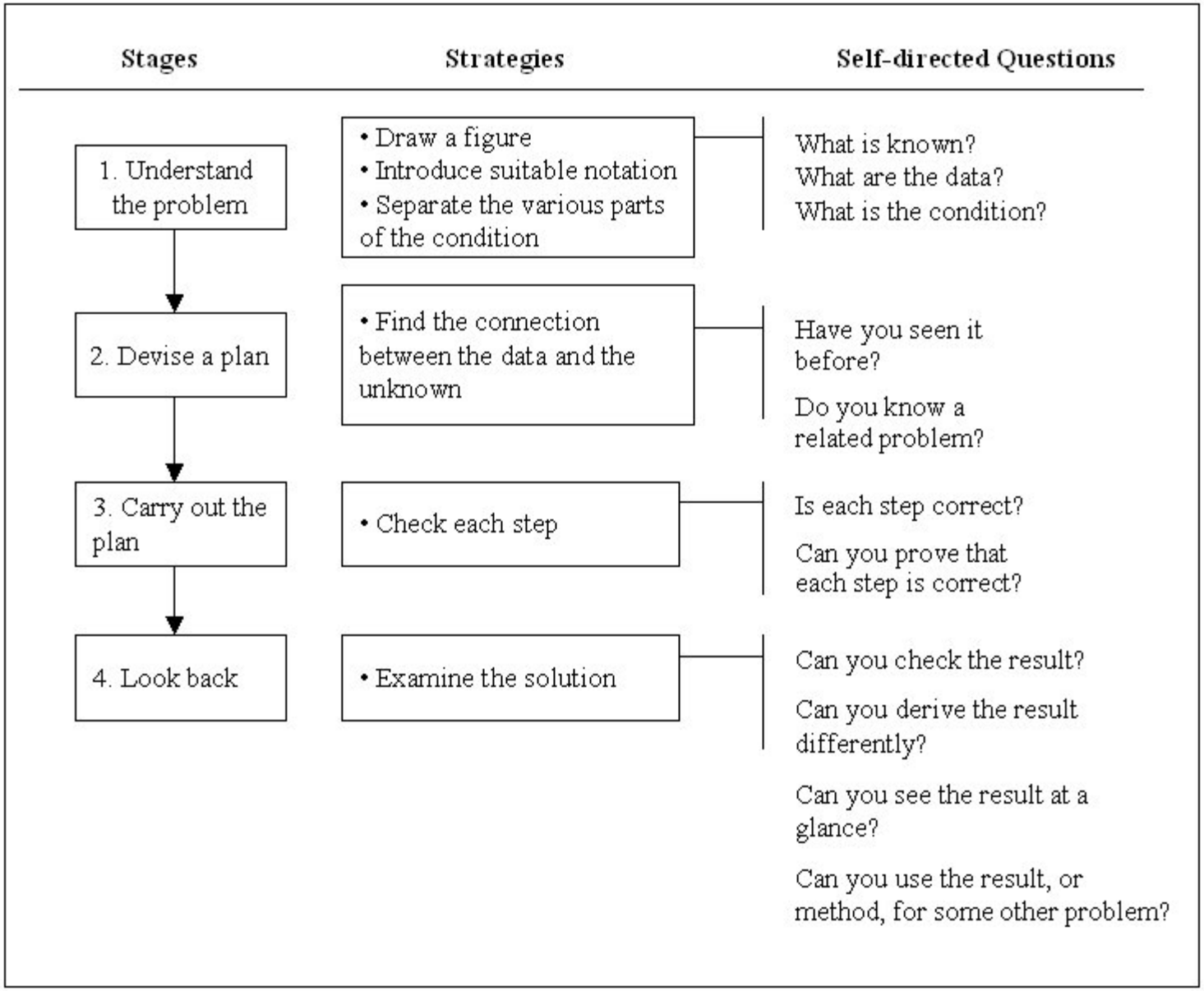
SOME RESEARCH STUDIES on Metacognitive Instruction

NIE, SINGAPORE
Celebrates 60 Years
of Teacher Education

Polya (1957)

- As early as 1957, Polya suggested training students to activate what we now call meta-cognitive processess.
- 4 step approach

- Comprehend the problem before attempting it
- Plan the solution
- Implement the plan
- Look backward (evaluation)


Stages
Strategies
Self-directed Questions
1. Understand the problem
• Draw a figure
• Introduce suitable notation
• Separate the various parts of the condition
What is known?
What are the data?
What is the condition?
2. Devise a plan
• Find the connection between the data and the unknown
Have you seen it before?
Do you know a related problem?
3. Carry out the plan
• Check each step
Is each step correct?
Can you prove that each step is correct?
4. Look back
• Examine the solution
Can you check the result?
Can you derive the result differently?
Can you see the result at a glance?
Can you use the result, or method, for some other problem?

Schoenfeld (1985)

- Three decades later Schoenfeld videotaped college students solving mathematics problems.
- His observations shaped his thinking about training students to solve problems.
- He trained students to stop periodically during the solution of math problems and ask themselves:

- What am I doing right now?
- Why am I doing it?
- How does it help me?

- Schoenfeld reported that college students who were trained to use these self-addressed questions improved their mathematics achievement.

IMPROVE Project

- Metacognitive instructional method that has yielded positive gains in mathematics achievement of students in Israel.
- The teaching steps of IMPROVE are:

- **I**ntroducing the new concepts,
- **M**etacognitive questioning,
- **P**racticing,
- **R**eviewing,
- **O**btaining mastery,
- **V**erification, and
- **E**nrichment and remedial

Metacognitive questioning

- Students are trained to use a series of self-addressed metacognitive questions.
- Comprehension questions
  - What is the problem all about?
- Connections questions
  - What are the similarities and differences between the given problem and problems you have solved in the past, and why?
- Strategic questions
  - What strategies are appropriate for solving the problem, and why?
- Reflection questions
  - Why am I stuck? What am I doing here? Does the solution makes sense? Can I solve it differently?

Studies based on IMPROVE method of teaching

- Series of studies have been conducted by Mevarech, Kramarski and others in Israel on various measures of mathematics and science achievement.
- A significant and noteworthy finding of their work is that students are able to transfer their knowledge they acquire under metacognitive instruction to new situations.

> "results indicate that the positive effects of IMPROVE were evident on the immediate and delayed examinations"
>
> Mevarech & Kramarski, 2003.

The IMPROVE metacognitive model for teachers

Table 1 The IMPROVE metacognitive self-questioning model for supporting teachers in both perspectives, as a learner and as a teacher

IMPROVE questioning	Learner's perspective	Teacher's perspective
Comprehension questions	What is the problem about?	What is the goal or main idea of the lesson?
Structure of the task	Identify	Demonstrate
	Type of problem	Lesson's topic
	Mathematical terms	Mathematical knowledge
	The givens	Explanations needed in the lesson
	The question	
Connection questions	What is the similarity or the difference between the two problems/explanations?	What is the similarity or the difference between the two lessons/examples?
Focusing on prior knowledge	Why?	Why?
	Write down your reasons	Write down your reasons
Strategic questions	What strategy/tactic/principle can be used and how in order to solve the problem/task?	What strategy/tactic/principle can be used and how in planning/ teaching the lesson?
Declarative (what), procedural (how), conditional (why)	Why?	Why?
	Write down your reasons	Write down your reasons
Reflection questions	Do I understand?	Which difficulties am I expecting in the lesson?
Monitoring and evaluation—during and after the process	Is the solution reasonable?	How can I achieve my goals in the lesson?
	What is a good mathematical argument?	What is a good mathematical argument?
	Can I solve the task differently?	Are the students engaged in the lesson?
		Can I plan the task differently?

Use of diaries as a self-monitoring tool for self-regulated math learning during homework

- To stimulate students in reflecting about whether it might be helpful to plan their work
- Engage students in sustained practice of reflection
- Schmitz and Perels (2011) found that

- by repeatedly answering questions in a standardized diary students applied more self-regulation strategies
- diaries are one means of support for math learning via procedures supporting metacognition.

Diary (Schmitz & Perels, 2011)

Appendix: part of the diary

Date: _____ **Time:** _____ **Code:** _ _ _ _ _

Right now I'm: **in a good mood** ☺ ○ ○ ☹ **in a bad mood**

At the moment I'm: **awake** ○ ○ ○ ○ **tired**

Do you plan to learn something today (this includes homework)? Yes ○ No ○

If **yes**, how much time are you planning for this altogether? _____ minutes

If you're **not learning** today, please answer the following five statements!
Please also note the corresponding questions on the last page!

Why are you not learning today?	Absolutely fits	Rather fits	Doesn't really fit	Doesn't fit at all
I don't have homework.	□	□	□	□
I have a lot of extracurricular commitments.	□	□	□	□
I don't feel like it.	□	□	□	□
I don't know how to proceed.	□	□	□	□
At the moment, I'm occupied with a problem I have.	□	□	□	□

→ If yes, what kind of problem? _____

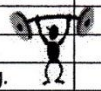
If you're learning today, please answer the following questions!

How are you going to do this today **exactly**?	Absolutely fits	Rather fits	Doesn't really fit	Doesn't fit at all
Today I have a good mind to learn	□	□	□	□
I am sure that I will finish what I have planned to do.	□	□	□	□
At the moment I have a problem that occupies me.	□	□	□	□
→ If yes, what kind of problem? _____				
Before I learn I think about how I will proceed.	□	□	□	□
If I didn't study /do my homework today, it would have unpleasant consequences.	□	□	□	□

After learning:

Answer now the following statements!

	Absolutely fits	Rather fits	Doesn't really fit	Doesn't fit at all
I did look closely at my exercise and thought about how I would proceed.	☐	☐	☐	☐
Before learning I arranged my workplace in a way that I was able to learn undisturbed.	☐	☐	☐	☐
Today, while working, I was concentrated.	☐	☐	☐	☐
Today I put much effort in my work.	☐	☐	☐	☐
I didn't let myself get distracted from studying.	☐	☐	☐	☐
I tried to learn something from my mistakes.	☐	☐	☐	☐
I thought about whether the solution is reasonable.	☐	☐	☐	☐
I thought about whether there are also different ways of solution.	☐	☐	☐	☐
Today I did learn everything I had planned.	☐	☐	☐	☐
I managed to realize my intentions for today!	☐	☐	☐	☐



Today I did use learning strategies.

→ If yes, which ones? _____

→ If no, why not? (Please mark only one statement.)

- ☐ I didn't think of it.
- ☐ To apply them, seemed too much work to me.
- ☐ I don't know any suitable strategies for learning.

Compared to today, what will you be doing different or better the next time you learn?

For example, set yourself specific goals?

Or are there any strategies, which you want to apply the next time?

I will _____

Right now I'm: **in a good mood** ☺ ○ ○ ☹ **in a bad mood**

At the moment I'm: **awake** ○ ○ ○ ○ **tired**

Metacognitive monitoring and mathematics achievement

- Cohors-Fresenborg and colleagues (2010) have shown that metacognitive monitoring improves mathematics achievement.

- Tasks of the type “what’s wrong?” helps in focusing students on thinking through the steps of their solutions.

$$
\begin{aligned}
& (-a-b)(-a+b) \\
=\ & -(a+b)(-a+b) && \text{correct } \circ \quad \text{incorrect } \circ \\
=\ & -(a+b)(b-a) && \text{correct } \circ \quad \text{incorrect } \circ \\
=\ & -(a^2-b^2) && \text{correct } \circ \quad \text{incorrect } \circ \\
=\ & -a^2-b^2 && \text{correct } \circ \quad \text{incorrect } \circ
\end{aligned}
$$

- Self-assessment prompts also help students monitor their performance
-

1. I am sure about my answers.
   (1: very unsure, 5: very sure)
   1 o 2 o 3 o 4 o 5 o
2. I have read everything thoroughly.
   (1: not very thoroughly at all, 5: very thoroughly)
   1 o 2 o 3 o 4 o 5 o
3. I have carefully considered possible sources of mistakes.
   (1: not at all, 5: very carefully)
   1 o 2 o 3 o 4 o 5 o
4. I have checked my answers well/ thoroughly.
   (1: not at all, 5: very well/ thoroughly)
   1 o 2 o 3 o 4 o 5 o
5. I have imaginated I would have to justify my answer.
   (1: never, 5: often)
   1 o 2 o 3 o 4 o 5 o

Journal writing as a tool for the development of metacognition

Clarke, Waywood, and Stephens (1993) studied the use of journal writing in mathematics to foster the development of metacognitive processes. A major finding of their long-term journal writing study was that students convincingly explained why they used journal writing:

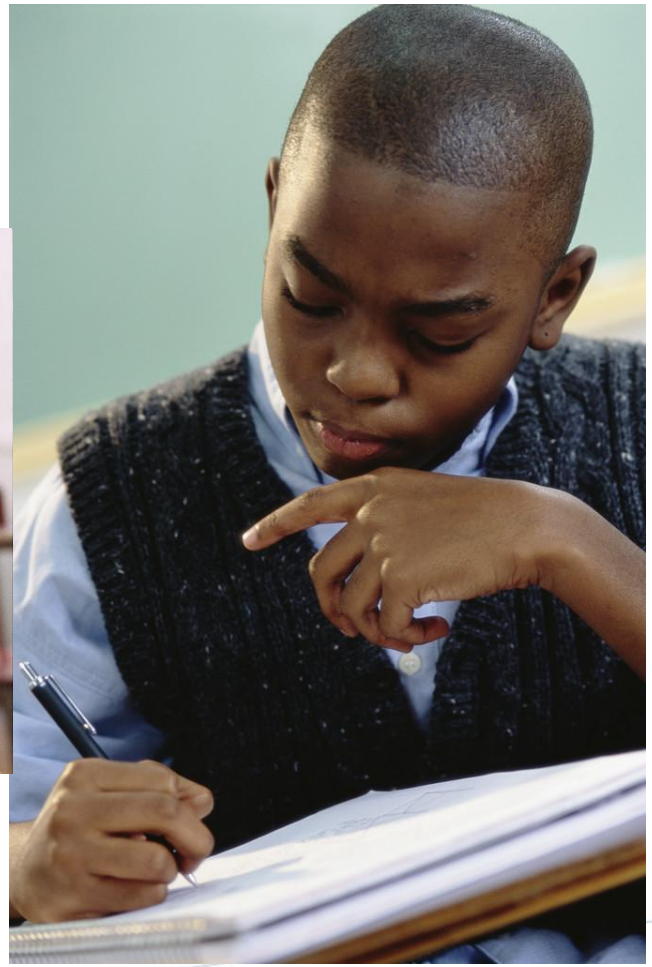
Sixty percent of the students gave as the main reason for writing in their journal, *because it helps me* (…), the most popular justification for journal use was *To help me learn* (…). Half of the student sample reported that the most important thing learned from journal completion was *To be able to explain what I think.* (p. 241)

What is reflection?

- *What is the difference between reflection and metacognition?*
- According to the Oxford dictionary to reflect means:

- to go back in thought,
- to consult with oneself,
- remind oneself or consider (that, how, etc…)
- So it appears that *metacognition is a reflective review of one's work by oneself.*

Learning by Reflecting



THANK YOU

NIE, SINGAPORE
Celebrates 60 Years
of Teacher Education