

# The Pro's and Con's of Active Learning of Physics

Gareth Jones  
Imperial College London

# The road to becoming a physicist

- Early Years – Big Questions!
  - What is that? → How? → Why? → Why? → Why?
- High School Physics (In the mind of many students)
  - Physics is Boring! Forces, pulleys, electricity, heat
  - Other subjects are more interesting (and easier?) and creative
- But physics is rescued by:
  - Explaining the universe using Big Ideas,
  - Using Mathematics to solve problems
  - Making things, doing things, experiments
  - Radical new ideas which stretch our understanding
- I don't understand! I want to understand!
- What shall I study? What kind of job?

# How do physics students learn physics?

- Learning physics is different because it is the end of the eternal question “Why?” – it is a search for understanding – students are looking for explanations.
- The use of mathematics is a key part of learning physics.
- Ability to solve problems using mathematics and physics principles is the most valued competence of physics graduates
- Physics learning involves doing things, exploring ideas, making connections, examining assumptions, making things.
- So good teaching should make sure students are ACTIVELY doing all of these things and that their MINDS ARE STIMULATED
- It is the student’s mind that should be active.
- Rewards:
  - Inner pleasure of understanding
  - Prospect of getting an interesting (or well paid) job

Active Learning: New Teaching Methods in use  
(Ref: Raphael 1510, Apostolic Palace, Vatican City)



# Competence and Understanding

- **Competence:** Capability to do something but based on knowledge and understanding
  - Emphasis on external effect
  - More cognitive than a skill but depends on skill
- **Understanding:** Ability to explain something to oneself and/or to others
  - Emphasis on internal effect. **An internal Learning Outcome.**
  - Involves making links. Showing how something is a consequence of more basic knowledge → derivation –  $A+B+C \rightarrow X+Y+Z$
  - Ability to explain something to others is a competence that depends on understanding
- Traditional education has emphasised knowledge, understanding and skills but employers emphasise competence and personal qualities.

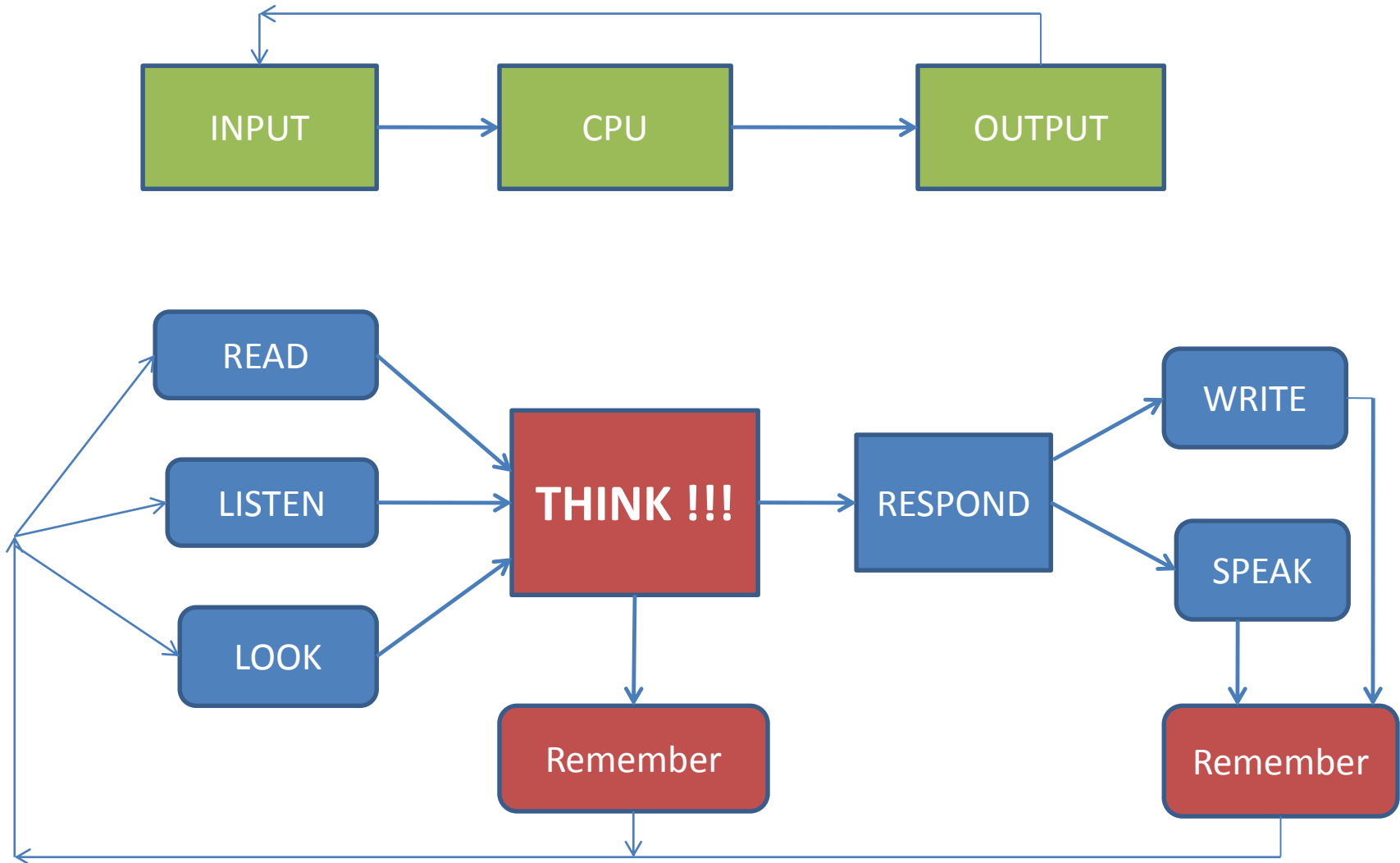
# Internal and External

- Understanding is internal – Competence is external
- Difference between internal and external is important and is basic to:
  - Internal and external learning outcomes
  - The psychology of learning
  - Exams and the assessment of learning: to be assessed, understanding has to be demonstrated – the ability to demonstrate it is a competence (an external effect).
  - Allowing for different medical and psychological conditions of some students, e.g. autism spectrum, sensory and motor problems, personality types → Inclusivity.
  - Team-work, cooperation with others.

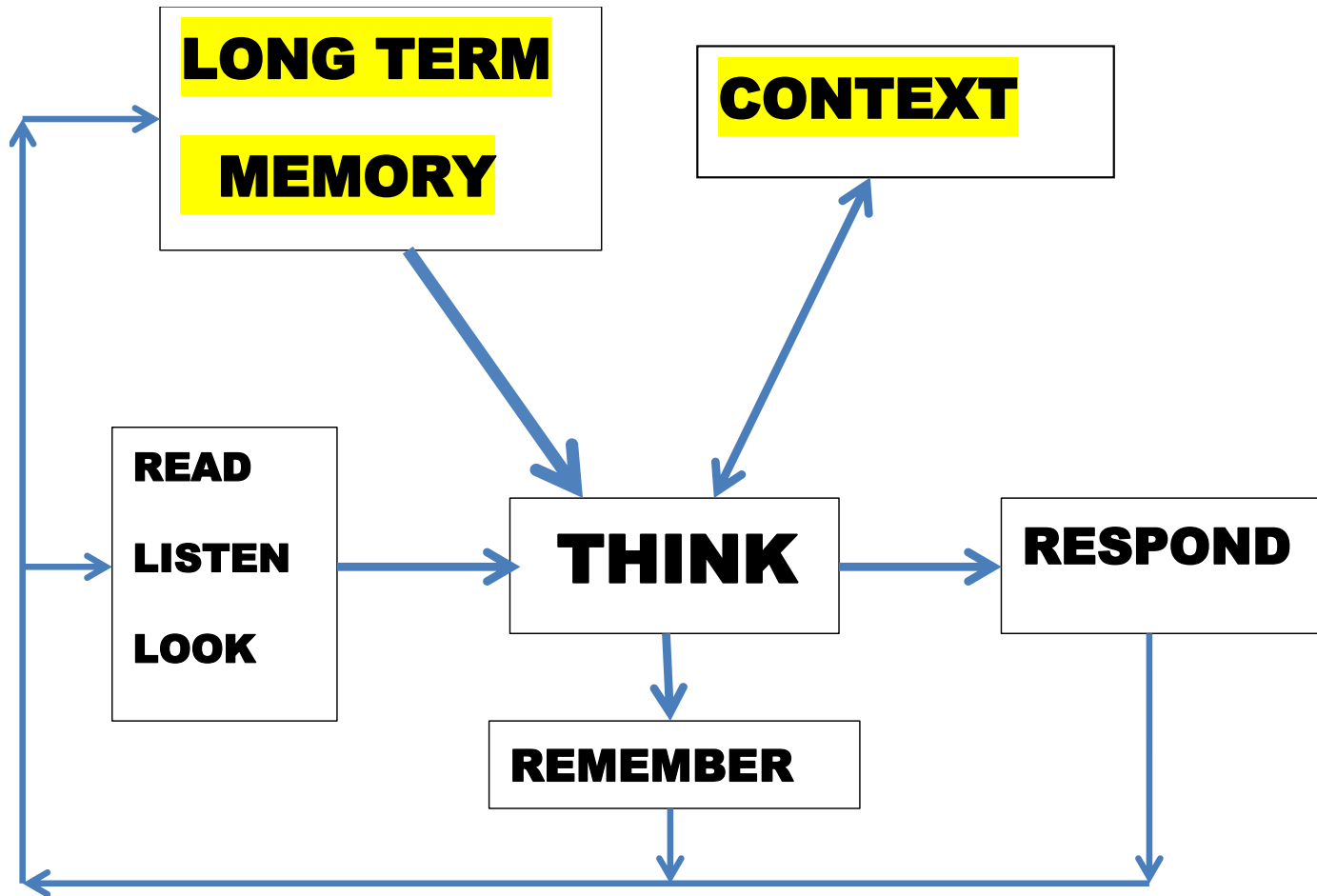


# Metacognition

## Learning Flowchart - Odin's Ravens

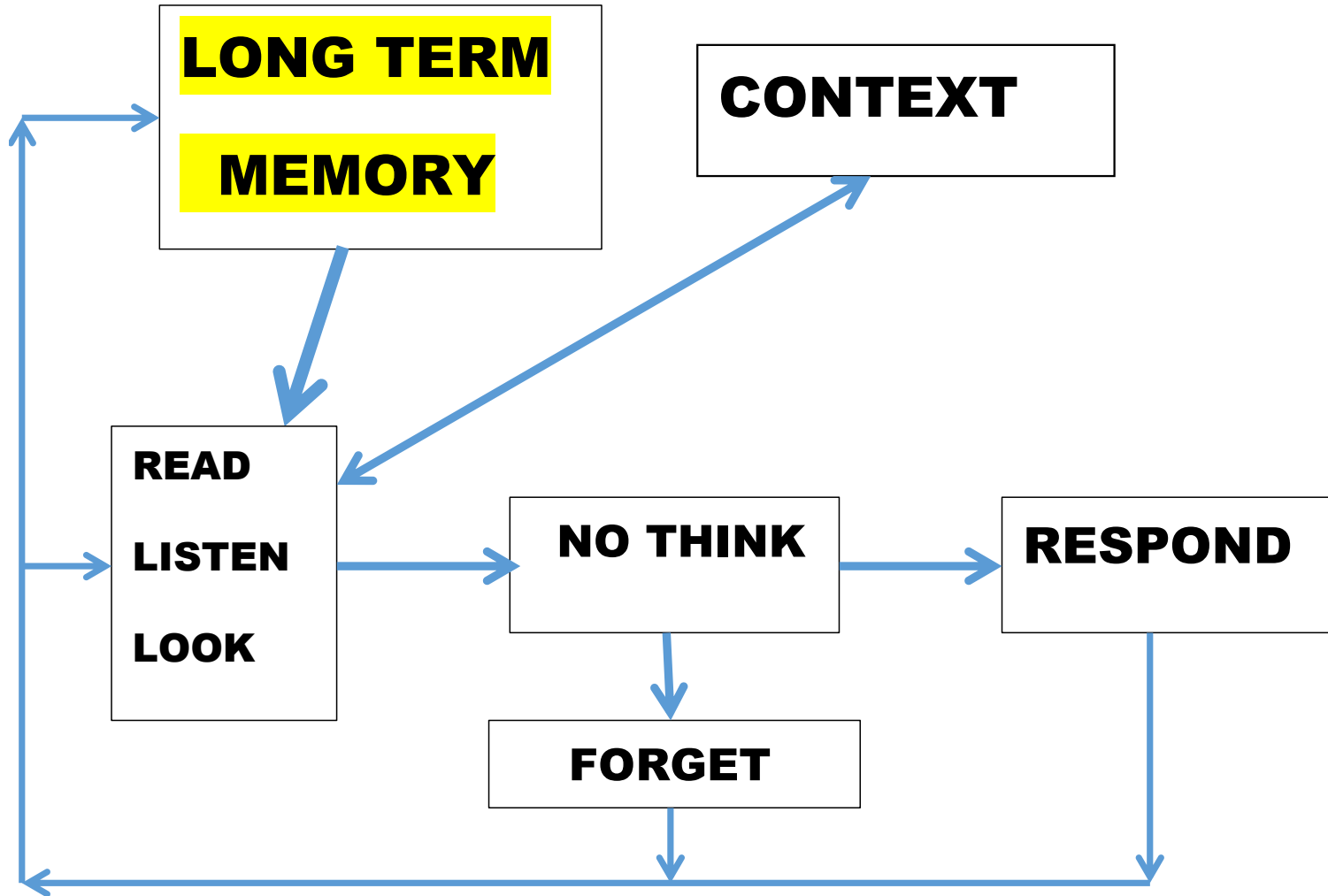


# Studying to Learn





# Studying without Learning



# Learning as a Process of Change

- From the first “How to Study” Guide of Imperial College (1988)
  - Learning is something that **you do**, not something that happens to you
  - Learning is a **process of change** not a product that you produce
  - It is a change in **you**, what you know, what you understand, what you can do
  - Mainly a change in your **brain**. What kind of a change?
- If Science Education is to be universal (like science itself) we should try to base it on **cognitive neuro-science**
  - But the **physical changes** associated with learning are poorly understood!
  - The nature of reasoning/cognition is not properly understood in terms of neural processes.
  - Neuro-physiology is relevant to learning but we don’t know how.
  - Ordered set of graphs of networks (*Ref: Danielle Bassett*)
  - Dynamic Cognitive Maps and network control (*Ref: Danielle Bassett*)

# How Students view Physics

(Courtesy of Mick Storr, CERN)



Gareth Jones, Imperial College London

# Climbing Mount Academic

- Get Fit! Train with the right equipment
- Think about your purpose in climbing this mountain
- Get a good guide
- Choose the best route
- Take care – THINK before moving
- Keep going – don't give up
- $mg\Delta h = \int \underline{F} \cdot \underline{ds}$  is only true for conservative forces
  - This is the “theory” of ECTS! It is too simplistic!
- Enjoy the view!

# Methods of Active Learning

- A long list, each with its own devotees
  - Blended Learning
  - Flipped Classroom plus studio learning
  - Inquiry Based Learning
  - Self-paced Learning
  - Peer Instruction
  - Flexible Learning
  - Guided Discovery Learning
  - Socratic Dialogue
  - Problem Based Learning
  - Team Based Learning
  - Basic Optically Oriented Knowledge Systems
  - .....

# Experience of Socratic Dialogue Method in Tutorials

- Small group Tutorials are devoted to:
  - The tutor asks students questions – making them THINK!
    - First question MUST be apparently easy!
    - Tutor responds: “Yes, but ... there’s more to it than that”
    - Feedback loop → upward spiral
  - Helping students to solve problems
  - Discussing students’ ideas and questions
- Students vary greatly but a good tutor will:
  - Get each individual student to *think*
  - Get students to *explain* their attempts to solve a problem
  - Teach them how to “climb the wall” – which hand-hole to reach for
  - Show them the peaks.

# Learning by Discussions and Q&A

- Students discuss with Students (Peer Learning)
  - Pro: (a) mind is active, (b) to and fro of ideas.
  - Con: (a) can be dominated by over-confident students, (b) very difficult for introverted students, (c) may result in poor explanations and wrong ideas, (d) social dynamics means some students may not engage in discussions.
- Students with Staff (Students ask questions of staff)
  - Pro: Should result in good explanations (authoritative)
  - Con: (a) Students may not ask good questions, tutor may not give good answers, (b) May be dominated by “clever” students, others may be passive.
- Socratic Method (Tutor asks questions of students)
  - Pro: Students minds must be active, upward spiral
  - Con: Students may feel anxious



# Other forms of learning

## (Pro's and Con's for discussion)

- “In text” problems/questions
- Problem sheets (homework)
- Examples classes (structured illustrative applications)
- Laboratory Work
- Project Work
- Team Work
- Studio style after flipped classroom (“Active Learning”)
- Problem based learning
- Flexible Learning