The Pro’s and Con’s of Active Learning of Physics

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The road to becoming a physicist

• Early Years – Big Questions!

• 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?

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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)

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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 → 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.

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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.

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Studying to Learn

- **Think**
- **Context**
- **Long Term Memory**
- **Read**
- **Listen**
- **Look**
- **Respond**
- **Remember**

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Studying without Learning

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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)

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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
• \( mg\Delta h = \int F \cdot ds \) is only true for conservative forces
  – This is the “theory” of ECTS! It is too simplistic!
• Enjoy the view!

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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

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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