Educational advances by physicists for physics students

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My mongrel intellectual history

- Went to Sussex University to study English Lit.
- Restarted, doing Physics. And finished.
- MSc in computer science
- D.Phil in Artificial Intelligence: topic of visual perception
- Switched fields to Human Computer Interaction
- Much later, joined a project on using ICT in (higher) education
- Now focus on Education, theory and practice

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Part 1: Catalytic assessment

"Catalytic assessment" is a catch phrase for questions that may look like tests, but whose important mathemagenic (learning generating) effect is hidden in the learner.

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Hake

Hake (1991): "The results [course feedback] showed quite clearly that my brilliant lectures and exciting demonstrations on Newtonian mechanics had passed through the students' minds leaving no measurable trace. To make matters worse, in a student evaluation given shortly after the exam, some students rated me as among the worst instructors they had ever experienced at our university. Knowing something of the teaching effectiveness of my colleagues, I was severely shaken."

So he went looking for better ways to teach physics …..

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Hake's survey

Hake (1998) published a survey of 62 courses (6,542 students) all studying the same subject, all using the same standardised test, and using it both pre- and post-.

He graphed the mean gain on each course against whether or not it had used the method of "Interactive engagement".

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Hake's results

See fig. 1 in:

Hake,R.R. (1998) Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses Am.J.Physics 66(1), 64-74

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Mazur

Crouch & Mazur (2001) published an analysis of 10 years of Mazur's MIT course.

Again, the standardised pre- and post-test.

He concludes he has doubled the amount of learning, but the graph suggests that really, he tripled it.

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See fig.2 in:

Crouch, C.H. and Mazur, E. (2001), "Peer Instruction: Ten years of experience and results" American Journal of Physics 69, 970-977

Mazur's gains

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Questions:

So more effective teaching can be achieved.

"Interactive engagement" and "peer instruction" revolve around asking students questions. These may be presented using Electronic Voting Systems (EVS).

But what kind of questions?

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Questions about reasons

The night sky is dark because:

A. The Universe is infinite in size

B. The Universe is expanding

C. The Universe is made up of, mostly, Dark matter

D. The Universe only existed for a finite amount of time

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Asking about confidence

Hunt (1982) (in an artificial experiment) showed that participants who first chose an answer and then had to indicate a confidence level learned about 20% faster than those who just chose an answer.

(This general issue is sometimes called "metacognition": when the learner isn't just a recorder of information but reflects on their learning and may modify their learning activity because of this.)

Gardner-Medwin's CBM (confidence based marking) is a direct application of this.

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Mazur's peer instruction

Mazur's peer instruction is a method of teaching that may (but need not) use EVS;

Is grounded in a psychology of how peers aid learning

Is addressed at a long researched principal weakness of his course's particular subject matter (mechanics)

It revolves around a particular type of question that Mazur calls "ConcepTests": basically brain teasers.

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Brain teaser questions

The point is to provoke debate, internal and between peers.
Cf. Socratic questioning, and "catalytic assessment"

Remember the old logo or advert for Levi's jeans that showed a pair of jeans being pulled apart by two teams of mules pulling in opposite directions. If one of the mule teams was sent away, and their leg of the jeans tied to a big tree instead, would the force (tension) in the jeans be:

- half
- the same
- or twice what it was with two mule teams?

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Peer Instruction: Mazur Sequence

1. Concept question posed (brain teaser)
2. *Individual Thinking*: students given time to think individually (1-2 minutes)
3. Students provide individual responses
4. Students receive feedback – poll of responses presented as histogram display
5. *Peer Discussion*: students instructed to convince their neighbours that they have the right answer.
6. Retesting of same concept
7. Students provide individual responses (revised answer)
8. Students receive feedback – poll of responses presented as histogram display
9. Lecturer summarises and explains 'correct' response

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Miyake and "constructive interaction"

We can understand Hake's and Mazur's demonstrated practical educational successes in terms of the theory developed in developmental psychology of how peer interaction promotes individual's conceptual advances.

Miyake (1986) got researchers round her lab to discuss their understanding of sewing machines.

Detailed analysis of the conversations showed that this was NOT teaching, yet both did advance their conceptions.

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Christine Howe's work (1)

Long series of studies on peer interaction causing conceptual development.

Good selected paper:
Howe, C.J., Tolmie, A, and Rogers,C. (1992)

To get the effect, you need to work on the setup:

Peers with different prior beliefs
Elicit commitment to their personal view in advance e.g. write their view, then show peers this opinion.

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Christine Howe's work (2)

- Benefit is delayed (e.g. 4 weeks)
- Final conceptions are different in solo than group interviews
- More advanced child ALSO advances still further
  I.e. it is NOT information transmission
- "not agreement but private conflict resolution"

⇒ Mechanism is metacognition
(Howe, McWilliam, Cross 2005)

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Getting students to design the questions

This is another powerful teaching tactic ("learner authored questions"). Perhaps more suitable for levels 3,4?

Basic idea:
Students have to design a test MCQ (best in a small group) complete with reasons why each response option is right or wrong.

Have to aim for questions that discriminate (splits class).

Why is this effective? Same underlying reason as Mazur: the factual question requires them to generate reasons ….

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First rest stop

The above all revolve around questions that aren't measures of student knowledge, but stimuli for thought / metacognitive prompts / or if you see it as linked to designing tests, then "catalytic assessment".

Here endeth that lesson. It is an abbreviated tour of an in-press paper: Eric has copies (I'm not supposed to put in on my website).

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Part 2: Experiments for learner self-investigation

Part 1 was based on some of the most impressive empirical results in HE teaching and learning (established by physicists, for physics students).

Part 2 has no direct empirical support (beyond a few pilot tests). However it may appeal because it seeks to apply the idea of controlled experiment to helping students improve their learning.

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Athletics as controlled <u>and</u> experiential experiments

The last 2,500 years of athletics competitions could be seen as prototypical (actually, very advanced prototypes) of controlled experiments.

They additionally have the feature, lost by big science, of being as directly perceptible to the objects of study (the athletes) as to observers. An athlete <u>sees</u> how well they perform, without needing others' judgement.

I will argue that Students have to self-regulate crucial aspects of their learning
Are we providing the measurement opportunities to support this?
Could we?

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The alternative interpretations of a failure

1. Technical knowledge or method: I didn't use the best information or method for the task
2. Effort insufficient
3. Method of learning about the task
4. Ability, trait, aptitude.
5. Random event
6. The judgment process was wrong, I was right.

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Corresponding self-regulatory actions

1. Work out the appropriate improvements to my knowledge and skill, and adopt them as permanent parts of my future practice.
2. Increase or decrease the time and effort allocated
3. Seek out new ideas on study methods.
   Find better information on the true task criteria
4. Change the course I'm taking.
5. Persist: try, try, try again
6. Get a second (and third and fourth) opinion.

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The loops, the experiments

Each of the 6 items above can be thought of as separate variables, requiring separate regulation based on feedback.

A first thought is are we asking for data on each so tutors can comment? And are we giving feedback on each?

A second thought is: can we organise micro-experiments where students can self-test each variable separately?

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Effort

xxxx

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Aptitude: and choosing courses [4]

Universities require students to choose between courses.

What information is provided on which to base their choice?

One fantasy is that all students pick only on personal taste; but in fact HEIs impose pre-requisites based on student performance.

So are you standardising level 1 exams between departments to provide the evidence for level 2 course choice?

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Learning skills [loop 3]

Interviews suggested to me that most of our students left the part 1 finals thinking about changes to their revision methods, and exam techniques. Is this the only occasion where they can draw any such conclusions.

A project student of mine ran an experiment where participants had 30 mins of revision from a new lecture to a test, and in successive weeks, used 2 different revision methods.

I've also piloted a few workshops based on "micro-tasks", where 5 min. versions of exam related tasks are performed, marked, retried.

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Learning skills [loop 3] *(2)*

To practise for 1 hour exam essays, break it down into subtasks and practise (and mark and discuss) these separately. E.g.

- (1 min) Read all 6 questions, choose one.
- (1 min) Brain dump everything you might use in the essay
- (1 min) Go over the list, delete everything not strictly relevant to qu.
- (5 mins) Write an essay plan
- (50 mins) Write the essay

This is the part-whole training approach: should we be using this much more in HE? Improving each part separately is much more effective because the feedback is unambiguous.

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Learning skills [loop 3] *(3)*

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What might an equivalent for physics exam problem-solving be?

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Second rest stop

That's the general idea about asking if we are supporting student learning by separating out the variables they are necessarily trying to control. Without that, how can they interpret their experience and improve?

The conceptual idea is that students have multiple variables to self-regulate.

The applied idea is that of experimental structures where the participant directly sees/ experiences their own performance. (Within-subjects expt. design).

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Post script

I have materials on EVS use at: http://www.psy.gla.ac.uk/~steve/evs/

If you are interested in physics teaching, you might want to contact Alistair Bruce (recently retired Edinburgh prof.) and ask for his report on this (if you can get hold of him).

You might want to invite, or visit, Prof. Simon Bates at Edinburgh. He has introduced many promising teaching improvements in physics there.

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How to use the University's NEW EVS

Book *through Central Room Booking website*
& Collect

CRB site
→ **Room & equipment details**
→ **Classroom Voting System**

Or

http://www.gla.ac.uk/services/learningteaching/learningtools/classroomvotingsystem/

Two different types of hand sets

~200 housed @ the Kelvin building

housed @ Maths & James Watt South

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A place to stop

For the slides, references etc. see:

http://www.psy.gla.ac.uk/~steve/talks/physics.html

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handout

Hakes' graph
Ref for Hake
For Mazur
CAA ptr URL

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Questions about reasons

Trivia quiz questions will only elicit learning random facts, not reasons. So a good first step is to ask directly about reasons
(I learned this from Chris Parkes). E.g.:

In an atom, electrons do not spiral into the nucleus despite the strong electrostatic attraction. Is this due to?:

1. The Pauli exclusion principle
2. Heisenberg's uncertainty principle
3. Planck quantization
4. de Broglie's wave-particle relation

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