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# Building a better lecture

Educational research has shown up flaws in the traditional lecture format, but as Keith Taber explains, it has also suggested ways of reshaping lectures that could benefit both students and academics

If you ask physics lecturers what their main job is, they will probably answer "research." But if you ask their students -- or, indeed, most members of the public -- what lecturers do, the answer is likely to be "teaching". The truth is that academics are usually expected to undertake both. However, the training they receive as postgraduates and postdocs is usually heavily skewed towards the research side -- probably because candidates for academic appointments must demonstrate high levels of scholarly ability, while teaching experience is considered less important.

As a result, someone appointed to their first lectureship will often have no experience of teaching large classes, although they may be relatively well-prepared for other aspects of teaching like student supervision and small-group tutorials. To counter this, universities commonly offer professional development courses focused on teaching for new academics. The utility of these courses has sometimes been questioned (see "Cargo-cult training" *Physics World* December 2009 pp16-17), but the need they are trying to address is real. In the modern university it is vital that lecturers understand how they can best support the learning of students.

Luckily, there is now a considerable body of research into teaching and learning that academics can draw upon. Much of this work has been done by cognitive scientists, who are concerned with fundamental learning processes, but educational researchers have also carried out many practical studies of classroom learning. The topics addressed in their work include attention, motivation and group dynamics as well as cognition; all have implications for effective teaching. And -- crucially for aspiring physics lecturers -- there is an extensive programme of research that looks specifically at teaching and learning in science subjects (see box), and that has highlighted common student learning difficulties.

***Insights from research***

One thing that cognition research has taught us is that in any field of study, learning is a "reconstructive" process. In other words, learners cannot generally take in large amounts of abstract material in its original form; rather, they must process it in modest "learning quanta" and then build it up piecemeal into a coherent understanding of the subject.

For example, A-level physics students (and sometimes those in beginning university courses) are commonly asked to derive the relationship between the pressure and volume of an ideal gas, and the speed of its constituent molecules. The derivation involves a series of steps, drawing upon very basic physics, and each step is logically straightforward. Yet for many students, when the derivation is presented in full during a lecture, it overloads their working memory -- the learning quantum is simply too big.

There are ways of getting around difficulties like this. One option is to present the derivation as a group exercise in which students are given the steps of the derivation, but out of order, and must place them in the correct sequence. This allows students to discuss and consider the derivation one step at a time, before they are asked to appreciate the overall argument. But more advanced students might find this approach frustrating, since what counts as an unmanageable learning quantum for one student may be perfectly acceptable for another. Much depends on the individual learner's existing knowledge and understanding. This makes it difficult to plan a lecture that will be challenging yet intelligible for whole classes.

Meanwhile, research on science education -- originally focused on schools, but since much replicated in universities and colleges -- has also revealed that students' existing ideas can interfere with their understanding of science teaching. Students often hold "alternative" ideas relating to key science concepts; many, for example, find Newton's first law counter-intuitive and tend to assume that moving objects will come to a halt unless a force is applied. Such misconceptions, which can survive school and even university teaching, can mean that lectures get misinterpreted, confusing students and increasing their misconceptions still further.

Unfortunately, lecturing is not well designed to address either of these problems. In its most basic form, the university lecture is simply the one-way presentation of prepared notes to students. Certainly, some students *are* able to learn effectively from such lectures; these students may be especially able, or they may have well-developed study skills that help them compensate for deficiencies in the lecture format. Usually, this category of students includes those who eventually obtain posts as academics, and this may be one reason why many academics believe that lecturing is an effective teaching approach ("It worked for me, so it must work for my students"). Yet with the vast expansion of higher education in recent decades, such students are a minority. For *most* students, learning from lectures is, all too often, a "hit-and-miss" affair.

### ***Shaking up the lecture hall***

One solution is to use other approaches, such as projects and problem-based learning, which may suit students who do not learn effectively in lectures. These approaches allow students to have more control over the pace and sequence of learning, and permit considerable discussion between students. Such discussion can be very supportive of learning, because explaining ideas to others helps students to make sense of them. Also, peers are often better placed to spot and question basic misunderstandings than an expert who takes the formal physics meanings for granted.

Many physical science courses already incorporate such non-lecturing components, but the reality is that most individual academics are not a position to transform their assigned lecture courses into something very different. Fortunately, educational research offers a number of ideas for modifying lectures in less fundamental ways. Given the fact that the learning process requires students to construct their own pictures of a subject -- and that their starting point for doing so is strongly influenced by their existing ideas -- in planning lecture courses it is therefore important to have a good idea of what the students already know. It is unwise simply to assume they know what was taught in previous relevant courses.

To gain this information, start with a diagnostic assessment - a test to find out what students already know. Treat it as a quiz rather than a formal exam, and tell students that it is meant to inform teaching, not their grade for the course. The aim is to ensure students have grasped any crucial prerequisite knowledge that will be assumed in the lectures. Any information gleaned from it -- basic deficiencies, common misconceptions and so on -- should be followed up explicitly in the lectures. This could take the form of discussing familiar contexts that can be understood as counter-examples to student misconceptions, or posing thought experiments that lead to clearly non-sensible outcomes when considered from students' alternative perspectives. For example, one of the author's students thought that the force acting from a planet to a moon was qualitatively different from the force acting on the planet due to the moon. In this case, asking what happens as the bodies become increasingly closer in mass can lead to the student recognising a flaw in their thinking.

Once the course is underway, it is important to build interactivity and ongoing informal assessment into lectures. This means regularly inviting questions (not just at the end of a full hour), and stopping after presenting key points to ask questions designed to check students' understanding. This could be in a multiple-choice format, so that students vote for the option they think is correct; or it might mean posing a key question for students to discuss for two minutes in small groups. It is also important to allow plenty of time for students' answers to emerge; lecturers are often tempted to invite responses (or give their own answers) quickly after asking a question, but this tends to prevent students from thinking through their answers properly.

Finally, lecturers must remember to select respondents widely -- not just from the pool of those who volunteer answers -- if they wish to engage all students with the question, and to acquire useful feedback on whether the key points are being understood.  This feedback will help the lecturer to decide whether to move on in the lecture, or to provide further explanation and examples.

***From scaffolding to road maps***

Once lecturers have identified gaps in student understanding, their next task is to fill them.  As the first steps towards learning complex new material are often the most difficult, it is often useful to adopt "scaffolding" techniques that "fade" teacher support as student understanding builds. In other words, the lecturer can begin by reminding learners of the existing knowledge that the course will draw upon (it can be unwise to assume that students will automatically recognize what is and is not relevant). Then, after introducing the new ideas, the students should initially be asked to apply them in carefully designed examples where most of the structure is already "filled-in" for them. Once students have passed this first stage in consolidating new learning, subsequent examples should gradually reduce the level of structure provided, until the students are ready to move from a statement of a problem to a full solution unaided.

It is also helpful to recognize that students do not all learn in the same way.  Some find graphical representations clearer than text; some prefer to see the whole pattern first, then the details; others learn better when the ideas build logically, and so on. These differences suggest that varying teaching methods can be a good way of reaching more students.

Graphical devices such as “concepts maps”, for example, show how the main topics in a subject link together, and can help students develop their own picture of a topic’s structure. The figure shows the basic structure of one student’s concept map for “energy”. Usually the student would be expected to annotate the links or number them and separately explain each connection. Producing such a map as a study or revision aid requires the student to think through the logical connections in a topic (which sometimes become explicit for the first time, leading to new learning), and also allows a lecturer to look for any misconceptions or obvious gaps in understanding.

A short article can only offer a flavour of the range of support that educational research can offer. Thankfully, busy lecturers can draw on support from many useful reviews and digests if they do not have time to study the extensive literature in this field. These resources offer some useful starting points for making teaching more effective -- and so more rewarding for both students and lecturers. Who knows, perhaps more physics lecturers might start to see their main job as teaching, from which other obligations, such as research, become a distraction.

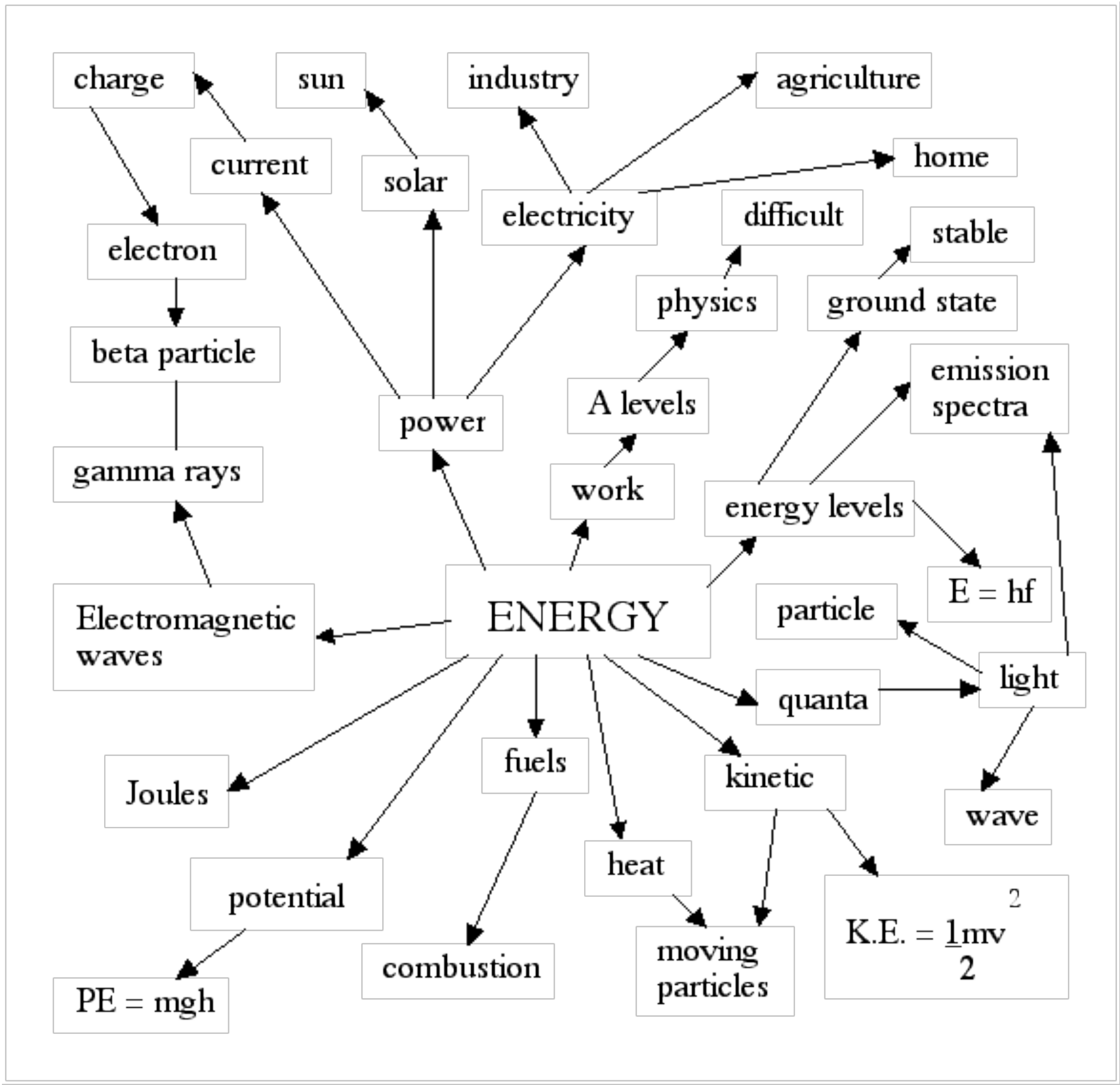


Figure: A concept map (redrawn) produced by a student preparing for university entrance examinations showing associations for the concept of energy [a different version of this figure was used in Taber, K. S. (1994). Student reaction on being introduced to concept mapping. *Physics Education, 29*(5), 276-281.]