

*Descriptive Account***Problem-Based Learning: Exploiting Knowledge of how People Learn to Promote Effective Learning**

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Abstract

There is much information from educational psychology studies on how people learn. The thesis of this paper is that we should use this information to guide the ways in which we teach rather than blindly using our traditional methods. In this context, problem-based learning (PBL), as a method of teaching widely used in medical schools but applicable to practically all subjects, embraces the principles of good learning and teaching. It is student-directed, provides incentives and feedback during the learning process, and encourages the experiential development of a number of skills, including team-work, finding and digesting information, peer teaching (explaining to others), reaching conclusions from data, and reflecting on the learning process. Inter alia, it encourages the accumulation of subject knowledge which is perceived to be relevant, and that is digested or compiled and organised.

Introduction

In higher education we teach in various ways – lectures, small groups, laboratory practical classes, and so on – but to what extent do we, the teachers, consider what is known about how people learn? Our teaching methods tend to be traditional, and until recently little attention has been given to training new lecturers and professors in the art of teaching. It was assumed that they knew intrinsically how to teach and they mostly taught as they were taught. We teach, and the students are supposed to learn, but how often do we question whether the methods are appropriate: whether the activities of professor and student are consonant? If we assume that we (as biochemists and molecular biologists, which is my subject area) have a duty to train the next generation, in other words, our replacements in the profession, it is important to consider how we can teach both effectively and efficiently.

As scientific workers, when we carry out scientific work in the laboratory, our *modus operandi* is to look at the published literature to see what is already known and what has already been done, and go on from there. We build on past experience and use established and successful techniques. There is literature on how to teach effectively and there is literature on how people learn (see Handelsman et al., 2004), so why do we not use it? Medical people are now encouraged to carry out “evidence-based medicine”, so why do we not carry out “evidence-based teaching”? I am not going to go into the

reasons here, but instead would like to review briefly the evidence for the effectiveness of some teaching techniques, deal with some ideas about how people learn, based on experience and research, and suggest that problem-based learning (PBL) is an attractive way of encouraging effective learning (Boud & Felletti, 1997). In PBL students have to be active: they have to develop a range of skills including being able to work in teams, formulate a problem, find information, explain new information to others, make decisions and reach conclusions, etc – all quite different from memorising information.

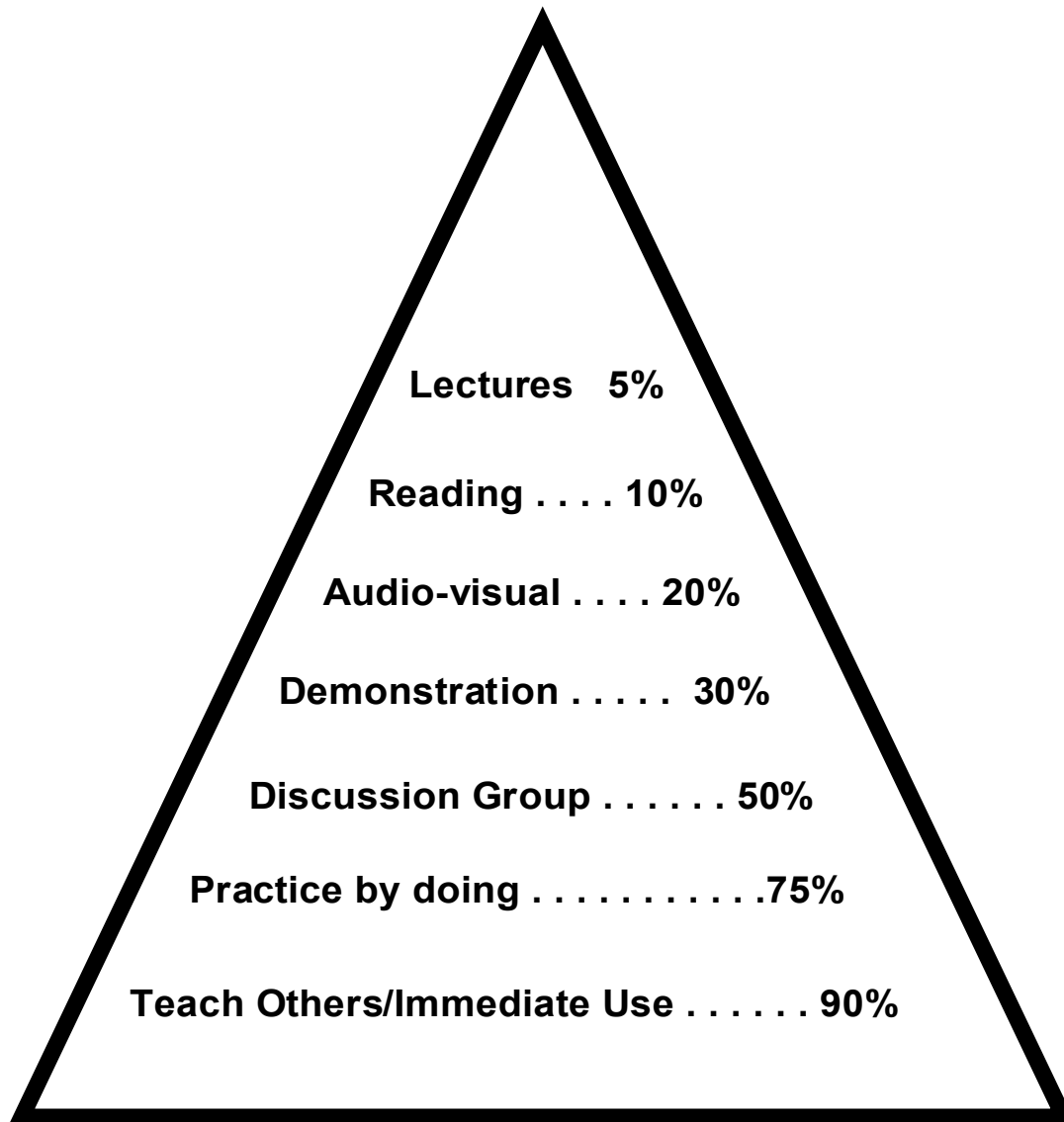
Problem-based learning

The following is a brief description of how a problem-based learning class might operate, although there are many variations to this general scenario. Students in small groups (usually 6–8) are presented with a problem (Smith *et al.*, 1995). In a medical course, the problem will typically be a medical one, possibly some information from which the group is required to reach a diagnosis. The group is 'supervised' by a member of staff, referred to as the 'facilitator', whose function is to guide and advise the group and keep them on the right track, but not to supply information. The group might meet on a Monday and spend several hours discussing the problem, trying to understand it and then re-formulating it in such a way that they can see their way to solving it. Some of the members of the group may have knowledge that can help in formulating or partially solving the problem. At the end of this first session the group decides what information they need to try to solve the problem and they divide the tasks among the members of the group. They then disperse and individually seek information which they will bring back to the group when it convenes again, for example of the following Wednesday. The individuals bringing back the information will be expected to have 'processed' (see below) it such that they can understand it and explain it to the rest of the members. After the presentations have taken place the group discusses whether they are in a position to solve the problem or whether they need further information at this stage. Perhaps a reformulation of the problem needs to take place. There will then be a re-iteration of the process of finding and bringing back information to the group. The group may then meet again on the Friday of the same week and try to reach a conclusion. Other informal meetings may have taken place during the week to clarify the group's aims. A solution may be reached, or the group may perceive that there is more than one solution, or they may be unable to reach a solution with the information that they have. In any case, with the help of the facilitator they reflect on what they did during the week, how they might be more efficient the next time, what things helped and what were a waste of time, and so on. Then the next week a new problem will be presented. Clearly by selecting appropriate problems, those in charge of the curriculum can to a large extent control what topics are covered.

Group dynamics

PBL is conducted in small groups and so it is important for facilitators to know how small groups work in order to achieve the optimal learning experience for all the students in the group (see Newble & Cannon, 1983). For both the facilitator and the students, the skills of listening, speaking, and arguing are key. Thus there needs to be face-to-face contact between all those present

because not only verbal but also non-verbal communication is vital (the chairs should be arranged in a circle – working in a lecture theatre with fixed forward-facing seats is not satisfactory). Clearly we want all the students in the group to participate, and the group needs to be kept engaged in purposeful activity. The facilitator will have to take into account students' behaviour, personalities and difficulties, and adopt an attitude that encourages students to initiate discussion, ask questions, challenge statements and ask for clarification. At least initially, the facilitator may have to work quite hard to manage the group without appearing to be authoritarian, but eventually the group should be able to function effectively in the absence of the facilitator. Tutors (who have mutated into facilitators) will be aware of the various ways in which students can behave in small groups. These behaviours including: *fight* (hostility, aggression, or misplaced humour), *flight* (withdrawal from active participation or attempting to change the direction of the discussion to avoid difficult issues), and *'pairing'* so that there is a conversation between two individuals leaving the rest of the group to feel excluded. There must be a good climate for discussion in the group so that no student feels threatened, that students always come prepared and ready to contribute, and indeed the sessions should become enjoyable for PBL to be effective. This is extremely important in PBL since the group sessions may be the only formal 'teaching' that students receive.



*Figure 1. The Learning Pyramid. The learning pyramid originates from the National Training Laboratories (NTL) for Applied Behavioral Science, 300 N. Lee Street, Suite 300, Alexandria, VA 22314, USA. The percentages represent the average "retention rate" of information following teaching or activities by the method indicated. In fact this diagram was originally developed and used by NTL in the early 1960s at NTL's Bethel, Maine, campus, but the organisation no longer has or can find the original research that supports the numbers given. In 1954 a similar pyramid with slightly different numbers had appeared in a book, *Audio-Visual Methods in Teaching*, published by the Edgar Dale Dryden Press, New York. Bligh (1998) gives some evidence for the effectiveness of different teaching methods.*

Evidence for the relative effectiveness of teaching methods

The general consensus about the effectiveness of various teaching methods is summarised in the “learning pyramid” (Fig. 1) which has appeared in various forms, and this version of the diagram simply deals with how effectively students are thought to retain information.

As can be seen, the lecture is the ‘worst’: on the whole our students cope with this by taking detailed notes, reviewing them (usually) just before the exam and committing the information to their short-term memories for presentation in the exam and then forgetting most of what they had ‘learned’ (or memorised!). This is perhaps a cynical view, but nevertheless we do do a lot of teaching by lecture and students are familiar and comfortable with this way of proceeding! Lectures tend to be regarded as ‘efficient’: one person passing on information to many. As well as giving information of course, we also explain things in lectures, but then we have to ask seriously what is required of the students to pass the assessment. Do we set questions that start “Describe . . .” [memory] or do we set ones that start “Explain . . .” or “Compare and contrast . . .” [using information]. We are usually the ones who set the assessments to check on what the students have learned, but in fact assessments are frequently concerned with checking the extent to which students can remember things. In other words there is a tendency to encourage rote or ‘surface’ learning, especially if multiple choice questions are used. As can be seen from Fig. 1, the teaching methods at the bottom of the pyramid are much more effective in encouraging effective student learning rather than ‘remembering’ (and I will discuss these in the context of theories of how people learn), and that these are the types of activity which have to be engaged in during PBL. These sorts of activities are also ones that encourage intellectual effort at the higher levels of Bloom’s Taxonomy (Bloom, 1956; Fig. 2).

Figure 2. Bloom’s Taxonomy describes the various levels of cognitive domains: knowledge – the ability to remember – is the ‘lowest’ of these. In the second column suggested words are given for outcome levels (Bloom, 1956)

Level	Words
Evaluation	Judge, appraise, evaluate, compare
Synthesis	Design, organise, formulate, propose
Analysis	Distinguish, calculate, test, inspect
Application	Use, demonstrate, illustrate, practice
Comprehension	Describe, explain, discuss, recognize
Knowledge	Define, list, name, recall, record

Active learning

Students learn more effectively (i.e. 'deep learning' rather than 'shallow learning') if they are *active* rather than passive during the learning process. What sorts of things keep students in the active mode – not sitting in a lecture taking notes perhaps? Learning by doing is generally more effective than learning by listening or reading (see Fig. 1) – in other words 'experiential learning' is more effective. And when learning is by doing (i.e. using information to solve a problem), people are more likely to remember what they have learned, and more importantly are more likely to digest or process the information they are receiving and reflect on how they learned, especially if there are incentives for them to do this (see below). Incentives include their being able to see the relevance of what they are learning so that the information is seen in context and is connected. Finally, when students are learning actively they will be learning several skills at once, for example finding and digesting information, as well as being capable of explaining it to others.

How people learn

Theories of learning can be divided into two broad camps, the *Behavioralist* school and the *Cognitive* school and these theories have been summarised in a simplified way by Race (2001). Behaviorists believe that people learn on the basis of stimulus~response~reward – a Pavlovian view. The input to the process is the stimulus and the output is the learned behaviour. There are various incentives for learning something (see below) and the reward is for students might be to perceive that what they are learning will be of benefit to them (passing the exam, obtaining a degree or qualification, achieving a profession). The Cognitive school in contrast says that we learn from experience, by doing, and that the learning that comes from the experience is fitted into the framework of our existing knowledge. (Whenever we take on new knowledge we need to incorporate it into our existing knowledge. I have tried to express this as a diagram (Fig. 3) which also attempts to indicate the path of development of a scientist from a consumer of knowledge to a contributing, generator of new knowledge in the science community.). *Doing* involves repeated practice and the use of rewards to encourage perseverance in learning, but a great deal revolves around the word *learn*. Do we want to encourage shallow or surface learning (as when we memorise a telephone number or, in science, the molecular weight of a frequently-used chemical), or do we want to encourage the sort of deep learning which includes processing or digestion of information, so that students gain ownership of it and can apply it in problem solving, for example?

I mentioned above that people tend to teach in the way in which they were taught. This is rather unfair. Many teachers use their own experience: they reflect on how they learn or have learned things, and what they have found to be effective, and they try to apply these principles to how they teach, to help students learn. My aim here is to distil some of the wisdom from the theories and research about how people learn and mix it with some reflections on my own personal experience of how learning takes place, putting this in the context of what is required in PBL.

It helps to reflect on one's own learning style: do you learn things by being taught or trained, by listening to experts, by reading about them? No doubt some things are learned in this way, but often people will say that they learn best by doing, including the process of trial and error, until they get it right. (Incidentally, as Race (2001) points out, our assessment methods do not make much allowance for trial and error, even though this is an important part of the learning process: the general expectation is that you should pass the exam first time!) When we are thinking about *how* we learn, we should also ask about the emotions involved, in other words about the motivation (or lack of it). These emotions might include wanting to learn and feeling good about learning. Learning is also helped by feedback, which encourages through constant checks telling us that we are doing it right, providing input into the trial and error process, reassuring us that we are learning successfully. The motivation – wanting to learn – is not automatic in students. Rather than wanting to learn they may *need* to learn (for example in order to pass the exam): *needing* is similar to *wanting* for the reasons mentioned above.

"Read, learn, and inwardly digest"

In order to make sense of what we have learned, any new information we receive needs to be 'digested', not just memorised. To encourage students to digest new knowledge, the assessment methodology is key. As mentioned above, if it rewards simple memorisation then that is what the students will give us. They try to take the path involving the least work and they also want to please us: to be blunt, they will do surface, actually strategic, learning (and subsequently probably, rapid forgetting). In contrast, if the assessment methods reward the ability to *use* knowledge, for example to solve problems and reach conclusions, then in order to pass the assessment students will *need* to digest the information and prepare themselves to be capable of using it. Digesting or processing information means sorting out what is important, extracting fundamental information and discarding what is not important. It also means checking that the new information fits in with one's existing knowledge and taking ownership of what has been learned, organising it to fit it into one's own conceptual framework (what I have called 'consolidating' in Fig. 3).

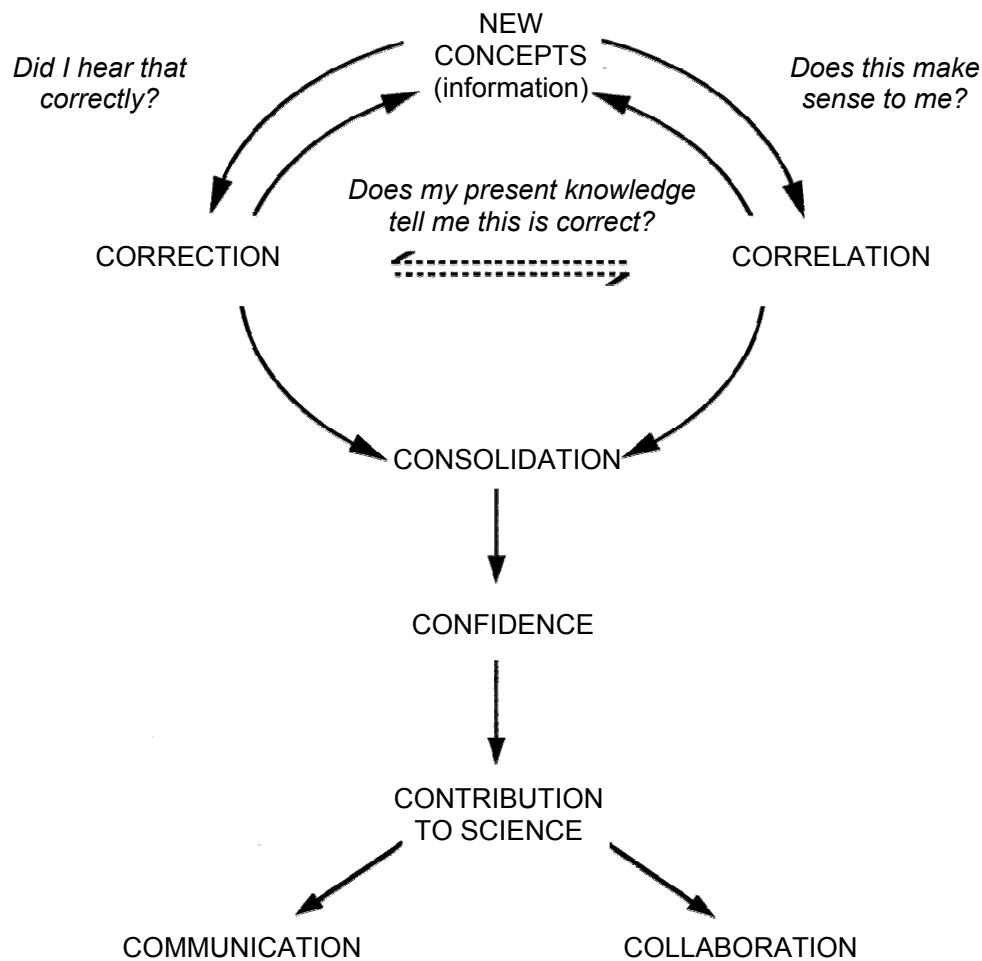


Figure 3. Diagrammatic representation of how learners incorporate new knowledge. First they need to check that what they hear or read is correct and try to incorporate this new information into their existing framework of knowledge (i.e. 'digest' and organise it, a process of consolidation). The more they establish ownership of their new knowledge the more they have confidence about what they know and understand, and can eventually make a contribution to science (i.e. create new knowledge) rather than being mere consumers of information. As practising scientists they will also need to collaborate with others and communicate their data both orally and in written form.

Students may speak of 'getting their heads round something', 'realizing' what it is all about. One of the outcomes of this digestion or 'compiling' of information is that one is then in a much better position to explain it to someone else – another thing that students are required to do in a PBL session. PBL also provides the opportunity to practise this process and so students become better at it. We can regard this practise as trial-and-error, the feedback coming either from the facilitator or by peer pressure from the rest of the group or both. It is not usually penalised in PBL, however.

So, to summarize, the emotions that provide the incentives to learn are *wanting* and *needing*, and these are supported by the processes of *doing* and *digesting* as well as by receiving *feedback*. Although wanting/needing probably provide the initial incentive, the other things do not come in a particular order. Race (2001) summarises this as follows: we need feedback whilst digesting, and we need to be digesting the experience of doing whilst receiving feedback. Doing-plus-feedback produces successful learning, and when there is no wanting, feedback may stimulate it. When we are planning what teaching methods to use we should take these factors into account. When we write the desired outcomes of a course we should ask ourselves whether they generate wanting or need. We should also ask ourselves what we wish students to be able to do at the end of a course or each element of a course?

How effective is PBL?

Now we can try to put this into the context of how people learn. First, the incentive: this translates as *wanting* or *needing* to solve the problem that has been set to the group. In order to progress on the course students need to solve the problem. In the context of becoming a doctor, for example, the problem is relevant: in their working lives doctors have to solve problems, many of which they have not encountered before. Therefore they will *want* to learn how to solve problems and become skilled at it, accumulating digested information on the way. Because PBL is done in small groups students have a strong incentive to be active and also to become skilled at working in teams, setting the group task, being relied on, relying on others, and so on. This is to some extent *doing*, but also setting the group task is important: they (collectively) need to understand the problem and to formulate it so that they can see a way to obtaining a solution. This involves making decisions on how to solve the problem (again *doing*) and about what information is needed in order to do this. This will subsequently need the skills of finding information (*doing*), and when this information is obtained it will need to be *digested* so that it can be explained to others and ultimately used by the team to solve the problem. During the process there will be *feedback* from others in the group (or perhaps the facilitator) to ask whether the team is on the right track or whether further questions need to be asked. Finally, a conclusion needs to be reached and here students may need to deal with the problem of not being able to find the right information, or more often, of the available information being incomplete or imprecise – but still having to try to reach a conclusion, nonetheless. For a doctor this might be to reach a diagnosis and initiate treatment on the best information available – not a trivial matter.

The last part of the PBL process, but not the least important, is the *reflection*. This will involve *feedback* from the other members of the group and the facilitator, as well as one's self, about how successfully the problem was tackled and solved, and how effective the various learning processes were.

Having put in place a PBL course in Clinical Biochemistry in the University of Otago, New Zealand, Schwartz (1997) reported "The results have been amazing. Students and faculty were delighted with the method and student performance on assessment improved immediately . . . compared to the old

course we have observed more positive attitudes towards clinical biochemistry, more enthusiasm among the students, and more co-operation among students and between staff and students." However, it is more difficult to evaluate whether students do indeed learn more deeply in PBL courses. Assessment is a problem – what sort of assessment is appropriate? Not tests of recall of information surely, yet many schools use the same sorts of assessment as with traditionally taught courses. So, enthusiasm is one thing, the evaluation of whether students in PBL courses undertake deep learning is another. This is discussed briefly by Coles (1997). Others have been disillusioned with PBL, but this may have more to do with failure to properly implement the system than a fundamental fault of PBL (Glew, 2003). Nevertheless, Barrows reported that in PBL medical students learn as much science, perform better clinically, and continue to educate themselves more effectively in the years after graduation (Barrows, 2003, and references cited therein).

Conclusion

PBL embraces the principles of good learning and teaching. It is student-directed (which encourages self-sufficiency and is a preparation for life-long learning), and promotes active and deep learning. It often includes or requires peer teaching, which encourages students to digest information so that they can present it to the group with some degree of authority. But also it taps into existing knowledge, and this again has to be digested knowledge so that it can be explained and used confidently. Re-using knowledge reinforces the processes of remembering and digesting. There are many learning skills to be accumulated on the way, and these are learned in context and indeed the whole process, from the functioning of the group to solving the problem, will not work unless these skills are mastered. And in the end, PBL encourages, and indeed requires, reflection on the learning process: how did it go this time, and next time will the team do it more efficiently and more effectively?

Acknowledgments

The author acknowledges considerable debt to the ideas propounded by Phil Race in the first chapter of his book (Race, 2001). Many references to supporting work will be found in that chapter.

References

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Smith CA, Powell SC & Wood EJ (1995) Problem-based learning and problem-solving skills. *Biochemical Education* **23**, 149–152.

Web Resources

There are now a number of UK-based web sites that deal with problem-based learning, offer advice on how to do it and give trigger problems, in a number of areas besides medicine. They also offer links to other sites around the world.

<http://www.hss.coventry.ac.uk/pbl/>

<http://interact.bton.ac.uk/pbl/index.php>

<http://www.aspire.supanet.com/~aspire/pbl/into.html>

There is an ESRC funded TLRP Project on the effectiveness of PBL:

<http://www.hebes.mdx.ac.uk/teaching/Research/PEPBL/index.htm>

and this is linked to two UK-based PBL e-mail discussion groups and there is an LTSN Generic Centre initiative on PBL

Other resources

The journal *Biochemistry and Molecular Biology Education* ("BAMBEd", bi-monthly) runs a standard feature on PBL in each issue. Some recent papers, in addition to the ones cited in this article, include:

Rangachari PK (2003) Poised between the pedantic and puerile, *BAMBEd* **31**, 192–194.

White HB (2003) Wrap-up assignments for problem-based learning problems. *BAMBEd* **31**, 260-261.

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