Using role-playing games to teach science

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Introduction

Anybody who has done a course at a corporate training centre will have been struck by the dramatic contrast between their teaching methods, and those generally employed in undergraduate science lectures. In most undergraduate lectures, the teacher stands at the front presenting a stream of information, which the students copy down. Occasional questions are asked, but the students are essentially passive throughout. In corporate training centres, most classroom time is devoted to role-playing simulations, business games and discussion sessions. Students are active throughout, and speak for more of the time than their teachers.

Why do corporations spend big money on such unorthodox teaching methods? Abundant research shows that students taught in conventional lectures, even those who perform very well in conventional assessment, are often quite unable to apply their knowledge effectively in real-world situations (e.g. Ramsden, 1992). Conventionally taught students tend to rote-learn; they fail to integrate their new knowledge into their prior assumptions, and they rarely think through the implications of what they learn (e.g. Mazur, 1997).

In this paper, I describe my attempts to adapt one of these corporate teaching techniques, role-playing exercises, to undergraduate science lectures. These techniques are occasionally used in academic disciplines such as law and environmental management. In a typical exercise, students will play the roles of competing parties in some dispute, and will learn about different points of view and mediation. Role-playing exercises have not previously, however, been widely used to teach mainstream science: it's a bit hard to have competing positions on the solubility of nitrogen, or to mediate between different views on the third law of thermodynamics …

All scientists know that research is an exciting, sociable, chaotic and deeply human enterprise. This is not how our undergraduate students perceive it. Surveys (e.g. Loss and Zadnik, 1994) show that most students think that science consists of endless dull laws and facts, brought down from the mountain on stone tablets for them to memorise in solitude. My goal was to expose students, even in first year, to the real experience of being a research scientist.

Case study: The climate of Venus

Perhaps the easiest way to explain my technique is to give an example. In this section, I will describe how I prepare and run an exercise, designed to teach a class of forty first year Australian National University (ANU) astronomy students about the Greenhouse Effect and how it affects planetary climates.

Pre-lecture preparations
I decide on a scientific problem that I want the students to solve (in this case, the question of why Venus is so much hotter than the Earth). Rather than present the problem and its answer in class, I divide the answer into a number of separate clues. Each clue is written up as a separate briefing paper. I include many red herrings in the briefing papers, to train students in recognising and extracting relevant information.

Lecture preamble

I start the lecture off by explaining the scientific problem to the students. I tell them that Venus should be very similar to the Earth: it has a similar size, orbit and chemical composition. Observations, however, show us that Venus is actually quite different from the Earth: it is bone dry, has a temperature of over 400 degrees Celsius, an incredibly dense atmosphere and clouds of sulfuric acid.

> 'Pretend that this lecture is a research conference, and that you are the world's experts on planetary atmospheres, gathered here together at enormous expense by NASA, to figure out why Venus is so hot. I'd like you to divide yourselves up into groups of three. One person from each group should come down to the front and get one of these briefing papers.'

Groups of three seem to be optimal for these exercises: any larger and the less articulate group members cease to play any effective part. This is smaller than the optimal size for larger scale problem-based learning (e.g. Michaelson, Fink and Black, 1996). Most of my students seem to prefer doing these exercises in small teams to working as individuals.

> 'Each group of you are world experts on some branch of science. Just as in the real world, no single group of you has enough information to crack this difficult mystery alone. You will have to exchange information with the other groups to devise a complete picture. Take a few minutes to read your briefing papers. Come and bug me if you have any questions. A warning: everything in these papers is true, but not all of it is relevant! You should try and pick out the key facts.
>
> Once you've got your briefing paper figured out, you should go out and talk with the other groups. Try and put together the clues to figure out why Venus is so hot. Just as in the real world, you are allowed to lie, cheat, steal and indulge in espionage. But remember: if you do it to them, they'll probably do it to you!
>
> In the real world, whoever was first to figure out a mystery like this would win a Nobel prize, fame, tenure, grants: all the good things in life. We cannot give you that: however, if you get the answer first, you will win one of these glow-in-the-dark stars!
>
> To win the prizes, you must come down to the front and present your complete theory to everyone. Just as in the real world, you don't get the prize by coming up with the correct answer. You just have to come up with an answer that your peers will accept. OK! Get Going!'

While the exercise is running

The initial class response is generally stunned silence. Slowly groups read their briefing papers. Many classes need encouragement to start discussing their papers out loud, rather than reading them individually in silence.

I wander around the class, listening in on groups and offering advice, clarification and encouragement. At first, it is often necessary to tell groups that:

> 'You don't know enough to figure this out for yourselves. Go out and talk to some of the other groups, and see if they know anything that helps fill the gaps in your story.'

Once one or two groups start wandering around, accosting other groups and demanding to know what their clues are, the whole class rapidly gets the idea, and breaks up into anarchy. The noise level rises dramatically and animated discussions start throughout the room. When I first ran these exercises, I was afraid that the class might just start gossiping, playing games or otherwise mucking around, but in practice this has never been the case. It may look like anarchy (I once had an ANU

security guard come in to try and break up what he thought was a riot) but if you listen in, you find that the students are actually focussing very strongly on the exercise.

The atmosphere in class is wonderful: lots of excited chatter, students racing around interrogating each other and debating the science. Many of the overheard conversations really sound like academics in discussion:

'So, if the oceans boil, that will release the carbon dioxide. But why should they boil in the first place?'

'But won't it combine with the sulfuric acid first?'

'Those bastards from Caltech won't share their data with us.'

Once the exercise is up and running, I'm almost redundant: the students are answering most of each other's questions. Indeed, it is sometimes difficult to persuade the students to leave at the end of the session.

Ending the exercise

The students seem reluctant to conclude that they have a complete answer (even when they do), and so I normally have to encourage one or two groups to come up to the front and present their theories. In most cases, the first group to come up is confused about some details and is voted down by their peers (though I still give them glow-in-the-dark stars). A good answer is normally obtained by the second or third try.

I will then spend some time debriefing the students: pointing out any subtleties that they missed and expanding on the crucial points. All the briefing papers, and a full explanation of the correct answer, are posted on the Web for them to read.

Evaluation

These role-playing exercises are very much an experiment still in progress. I am therefore concentrating on formative, not summative evaluation. The only summative evaluations carried out are the ANU's standard end-of-course student questionnaires. These tell us that the course (which uses roughly one role-playing exercise per week) is very popular: it regularly receives the highest student ratings yet recorded at the ANU.

Built-in evaluation

When running these exercises, you spend nearly all your time in class listening to students, not talking. This is a form of built-in evaluation, and is one of the greatest benefits of this technique. On several occasions, this has allowed me to pick up and correct major student misconceptions at an early stage: misconceptions I would not otherwise have picked up until marking the examinations.

Listening in revealed a number of pitfalls with this technique:

- Students clearly have an implicit faith that anything their lecturer tells them must be relevant. As a result, they tended to fall for all the red herrings in the briefing papers. Warning them in advance that red herrings are present seems to fix this problem.
- The whole exercise must be completed within a single lecture. If I attempt to spread an exercise over multiple lectures, I find that students lose both the plot and all motivation between sessions. If necessary, the exercise should be simplified until it fits comfortably within a single time slot.
- Many students treat these exercises as 'collect the six pieces of paper' games, unless you forbid groups from showing their briefing papers to other groups: they must verbally describe what they know. This seems to force groups to concentrate on understanding the science, rather than simple paper collection.

Minute papers

In all my classes, I use the well-known evaluation technique of minute papers. At the end of the last lecture of each week, I ask students to scribble on a piece of paper (a) what was the most important thing they learned this week, and (b) what was the most important unanswered question this week left them with. The minute papers were not intended as a method of evaluating the role-playing exercises.

Nevertheless, it turns out that the minute paper responses give very useful information. Normally, most students say that the most important thing they learned that week was some part of the syllabus we'd just covered. In the week when I run the first role-playing exercise, however, around 30% of students give very different responses. Here are some examples of the most important things they thought they had learned:

'The way that as a group of people, we as humans try and answer the way things are using a collection of seemingly unrelated facts.'

'Astronomy isn't all stiff attitudes and boring theories.'

'The best way to learn is to ask questions. Never accept an answer or a theory without thinking it through, and if you disagree, without argument.'

'There are no right answers, only theories based on observations.'

I conclude from these responses that these exercises are indeed changing the attitudes towards science of at least some of the students.

Focus groups and open-ended questionnaires

On many occasions, the students were asked to fill out open-ended questionnaires. These gave them the chance to say what they found good and bad about the role-playing exercises.

I was worried that there might be a disaffected minority of less articulate students, who found the exercises intimidating but whose discontent had been missed by the other forms of assessment. I therefore asked Dr Chris Trevitt, from the ANU's Centre for Educational Development and Academic Methods (CEDAM), to conduct focus groups with my students. These focus group discussions were held during tutorials. They were not announced in advance, to prevent self selection of those participating. Chris was given instructions to search for a disaffected minority, as well as probing the good and bad points of the role-playing exercises. He took notes on a white-board, and with the permission of the students, taped the whole discussion. The tapes were only released to me after the end of semester, when all student marks had been finalised. The tapes turned out to be far more useful than the notes taken. I feel that this is inevitable: only the person responsible for the experiments, and who has agonised about the details of how they are run can pick out from the vast mass of discussion the most relevant points.

No sign of any disaffected minority was uncovered. The focus group discussions, however, combined with the open-ended questionnaires, provided a great deal of information about why the students thought that the role-playing exercises were an effective technique. I will let the students speak for themselves:

'You weren't just receiving the information, we were sitting down and working it out for ourselves.'

'It was personalised, it was your own ideas rather than dictating somebody.'

'Rather than rote-learning facts, we got to see the processes unfold and evolve (which makes them easier to remember in the long run).'

'You had your own sorts of breakthroughs when you found out another piece of information and it was like Oh Wow! This fits in with this, and now we know this, and … You actually felt quite intelligent.'

'We enjoyed these tasks more because it gives us the sense that we're the first ones to discover these things, and it gives us a sense of pride in what we were doing, whereas if we read it out of a book we wouldn't get the same sense of pride.'

'It really helped to expand our own ideas.'

'It compressed an awful lot of information into a single exercise.'

Students repeatedly emphasised two themes that surprised me:

- Many mentioned that they liked the role-playing exercises because it 'made them feel intelligent'. People were forced to come to them for information and they got to play the role of the expert. This seems to be a new and very fulfilling experience for them. This suggests to me that lack of student self esteem is a big problem in these classes, and is not addressed well by conventional teaching techniques.
- They really appreciated the prizes (glow-in-the-dark stars, or lollies). They acknowledge that the prizes were a joke, but still – they really liked them. I'm not sure that I understand the psychology behind this.

Other users' experience

I publish all my exercises on the Web (Francis, 2002), and they have now been used in around 20 universities, science centres and high schools around Australia, in the USA and the UK. They have been used in classes as large as 150 and as small as 10. Different exercises have been used at every level from Year 10 to postgraduate.

Almost all users report similar experiences to those that I have presented here. These exercises do seem to work well for a wide range of student types. There are two reported exceptions:

- One lecturer at a prestigious west coast US university reported that her students became very political and combative while running one exercise, so much so that the science was almost forgotten. This has not been my experience, or that of other US lecturers.
- At the ANU, we find that third year undergraduates find it harder at first to get into these exercises than first years. We hypothesise that they are simply more used to traditional teaching techniques.

Conclusions

These role-playing exercises are still an experimental technique, but one which, I feel, shows promise. You can find other descriptions of these exercises in Francis and Byrne (1999), Francis (1999) and full copies of them all on the Web (Francis, 2002).

When I first published this technique, I was expecting that people would borrow my basic idea, learn from my experience, but that they would write their own exercises, better suited to the courses they teach. I do not find these exercises hard to write; the preparation time is little greater than for a conventional lecture. Instead, most people use my exercises unmodified. I am only aware of one person who has written his own role-playing exercises. I'm not sure why people are doing this: I'd be interested in any suggestions. There may be some way to make these things easier to write. Alternatively, it may be necessary to publish books of them suitable for different disciplines.

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