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ROLE PLAY AS ANALOGICAL MODELLING IN SCIENCE

1. INTRODUCTION

This chapter considers the use of role play as a way to promote learning in science. It is argued that role play can enhance learning when students cooperatively design and develop their own role plays to give expression to their mental models. First a theoretical underpinning of role play as analogical reasoning is outlined. Then, examples are used to illustrate how it has been used effectively in science classes. The aim is to provide a general argument, justifying student generated role play to model ideas in science and to provide guidelines for teachers to promote the more effective use of the strategy. The case that analogical reasoning can be a sophisticated way of thinking and that it is central to understanding and theorising in science has been made (see e.g., Chapter 2). So, the emphasis in this chapter is on the reasons for using and how to use role play as a strategy for analogical modelling in school science.

2. WHY ROLE PLAY IN SCIENCE?

The potential advantages of role play have long been recognised. According to Ladrousse (1989) they encourage students to create their own reality; develop students' ability to interact with other people; increase students' motivation; help build up students' self confidence, allow students to bring their experiences into the classroom; are fun; help to identify misunderstandings; and provide shy students with a mask allowing greater participation. In science education, role plays have also been recommended for their potential to make learning in science more attractive to students (Hildebrand, 1989) and because they allow students to look at occurrences from a different perspective.

Studies of role plays are often associated with research incorporating drama strategies in science (Butler, 1989; McSharry & Jones, 2000). Frequently the role play is used to enable students better to perceive an alternative perspective on a controversial issue in science. They involve the students playing the part of another

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person (either a specific person, generalised or a caricature). The role could be a scientist, a local farmer, an indigenous land owner, an environmentalist or a politician in order to better understand issues or the dynamics of science in a social context (Hiotis, 1993). Less frequently, research on role plays reports teaching and learning where students act out aspects of a scientific model or theory to explain phenomena they are learning about. Sometimes this is called simulation-role-play (Aubusson, Fogwill, Barr & Perkovic, 1997) or analogical modelling role play (Harrison & Treagust, 2000). Typically the role play is designed primarily by the teacher and performed by students (e.g., Mackinnon & Aucoin, 1998). The aim is to provide role played models which most clearly portray the ideas of science. They serve to enable knowledge transfer from the analogy (role play as base domain) to the phenomena being studied (the target domain). Rarely, role plays are designed by the students themselves. Employed in this way, role play is used as an analogy to enable students to generate deeper understanding. They simulate their interpretations of theory. It serves to clarify students views and bring to the fore students' explanations of phenomena. The role plays are socially constructed by students and result from students sharing different views. Students may be physically involved, for example, by "walking around in such a manner that the direction is analogous to the motion of electrons, through a wire" (Treagust, 1993, p.293). These student produced role plays can be classified as personal analogies (Duit, 1991).

An appealing feature of role play lies in its potential to assist students to develop and create their own mental models as, "in trying to understand science students draw on available mental models" (Gardner, 1991, p.157). In science, students' mental models are inferred from observations of phenomena and interpretations of theories. For many years it has be claimed that non-threatening, social and enjoyable opportunities should be provided where students may develop and build on these models (Chester & Fox, 1966; Goodrum, Hackling & Rennie, 2001; Tobin & Fraser, 1988; Yager & Lutz, 1994). Encouraging students to role play and discuss their own mental models can provide such opportunities (Aubusson et al., 1997). Yet student generated models are rarely successful, according to Harrison and Treagust (1999). Nevertheless, though student designed role plays are rarely reported, these reports indicate positive learning outcomes for primary (Cosgrove, 1995) and secondary (Aubusson et al., 1997) science students. Cosgrove showed that, over a series of lessons, primary students could develop a role play, model of electric current, where the electrons-children acted as energy carriers. Aubusson et al. (1997) reported three case studies of student produced simulation role plays developed in three secondary classes in which students designed and performed their own role plays to model electric current (in two classes) and the circulation of blood in a third class. Both studies claimed the role play analogical modelling had been successful, but this begs the question, 'what do we mean by success?' when using modelling as a learning strategy and role play as analogical modelling in particular.

We assert that an analogy is successful not when it most accurately portrays ideas per se but when it promotes conversation, central to producing, evaluating and modifying the analogy, that helps students to clarify and to improve their scientific understanding. All models are flawed and hence all models break down (Maksic, 1990). There is always the danger that students may confuse the model with reality or the classroom analogy with the scientific theory it is designed to emulate (Harrison, 2000). A good analogy of itself does not portend good learning. Indeed there is a danger that efforts could be misplaced in seeking analogical perfection in the expectation that there is 'a holy grail to explain the phenomena' (Heywood, 2002, p.239). The break down of an analogy is not of itself a bad thing as it is, in part, by identifying, analysing and (perhaps) improving the analogy, that learning occurs.

When using models, learning is more likely if the analogies are negotiated (Treagust, Harrison, Venville & Dagher, 1996). Harrison and Treagust (1999) note that this is consistent with science viewed as community seeking consensus but cautions that "classroom negotiation will not construct scientists' knowledge per se" … but "negotiation does help students construct … science understanding" (p.423). Given that students are likely to understand phenomena and scientific theories less well than their science teacher and scientists, their models are more likely to break down. However, they have greater, not less, potential to engage students in analysis of *their* analogy. Comparing attributes of the base and target to determine and analyse the points of agreement, disagreement and ambiguities may lead to extensive consideration of their own thinking, its strengths and weaknesses. Though, there is a risk that students may attend to the extraneous attributes of the model without recognising the significance of critical explanatory attributes (Gilbert, & Boulter, 1989). As a consequence misconceptions may be further entrenched or develop rather than replaced or altered. Nevertheless, their own models provide a way to teach from "where the students are at", to connect with contexts relevant to students and build on or modify students' initial views. The 'success' of student generated analogical role play cannot be judged alone by the degree of perfection of the role play generated independently of the discourse involved in its construction, enactment and review. Sometimes, the role play proceeds through many iterations over many lessons and the 'final' role play may never satisfy all students, particularly those who best recognise its flaws. Nevertheless, students may still exhibit ample evidence that they have developed better scientific understanding of phenomena under investigation. This is well illustrated in the case study of Steve Fogwill's junior secondary class's self constructed role plays of electric circuits, first in small groups and then as a whole class discussing and selecting the best features from each group's role play (see Aubusson et al., 1997). The next section of this chapter reports a recent episode in analogical role play over a series of lessons with a senior chemistry class. This episode is based on guidelines for analogical role play recommended in Aubusson et al. (1997). The final section of the chapter then discusses the effectiveness of the strategy.

3. A THREE LESSON SEQUENCE OF ANALOGICAL ROLE PLAY

First the context in which the role plays arose is described. Then descriptions are used to illustrate significant episodes of the role play process and thinking. Each of these is framed by a short commentary.

3.1 Context

Steve, coauthor of this chapter, is a science teacher in an Australian coeducational senior secondary government school. Peter, also coauthor, is a lecturer in science education. They have worked together on three research projects investigating approaches to teaching in science. One of these studies focussed on role play. Peter was aware that Steve had continued to use role play in his science teaching and invited Steve to collaborate to explore the role plays that were integral to his teaching. Steve later described the process as follows:

> I thought it was a good chance to delve further into what I do with my students. Peter acted very much as the academic and critical friend in talking through the role play processes I use with my students and helped me to decide which examples to report. As it turned out Friday afternoons was a time when it was possible for the two of us to sit together and talk. Peter came to the school approximately every fortnight … During our sessions we discussed and made notes about the various facets of the role play process I encourage my students to use. E-mail communication using editing tools took over (from face to face meetings) as the chapter came together.

Sometimes parts of the chapter were written together at the school. At other times Peter would draft sections based on our conversations and notes. Then these would be passed to and fro electronically as information was checked and ideas developed. The voice of the chapter is now neither Peter's nor Steve's but reflects agreement on ideas and perceptions arising from their interaction.

> To facilitate deeper understanding of the methods we use on a daily bases in our classrooms and encourage the sharing of those methodologies that can enhance learning, I encourage others to work in partnership with similarly motivated academics. (Steve in response to an inquiry from a chapter reviewer about the writing process and voice of 'teacher' and 'academic'.)

Steve often uses role play in his teaching and has a reputation among staff and students for doing so, partly because it is considered an unusual, even odd, teaching practice. The series of role plays reported here was the first occasion that he had used role play with his year 11 (16-17 year olds) chemistry class. They had done a practical investigation: 'The extraction of Copper from Copper Carbonate'. In the investigation, copper carbonate was reacted with dilute sulfuric acid forming copper sulfate. Copper electrodes were placed in the copper sulfate solution and copper was collected at the negative terminal. During this process, the solution stayed blue. This electrolysis was repeated with carbon electrodes and the solution lost its colour. Students enquired about bubbles that formed at the positive terminal and discussion led to the addition of universal indicator showing that an acid was formed as oxygen bubbled off and hydrogen ions went into solution (replacing the copper). After completing the practical, students used molecular model kits to interpret what they had observed and explain what happened to the ions in the chemical reactions. During this modelling process the molecules were constructed. These were then broken up into models of ions. The ions were placed on a table (representing a beaker). Two metre rules, placed on the table, represented the positive and negative electrodes. Students were asked to demonstrate what they thought was happening to the copper ions during the electrolysis phase of the practical activity. This modelling was led by the teacher (Steve) and during the process, their was further discussion about the chemical reactions that had occurred. Students were able to demonstrate that copper ions were attracted to the negative electrode and sulfate ions to the positive electrode.

In the following lesson, the students then were asked to write their response to, “Explain the path of copper in the process” (of extracting copper from copper carbonate). This had been thoroughly outlined in the class discussion when using model kits. Steve explained that, at the time, he “thought this would be the culmination of a series of four, 50 minute lessons. The expectation was that they would have learnt, understood and simply demonstrated this understanding”. Reading the responses to the question revealed a wide range of understanding. Several students either had understood little or simply could not express their understanding. The following student statement was embedded in one of the best responses. “The Cu^{2+} (copper ion) is +2 and because it has two extra protons, it was attracted to the SO_4 which has two extra electrons”. It indicated a possible misunderstanding of how the copper becomes an ion (perhaps gaining protons rather than losing electrons). In a follow up discussion, she explained that she meant that in the copper ion, there were two more protons than electrons. She agreed what she had written could be misinterpreted. This student took a leadership role during the role play construction. Another student’s response was more typical and indicated a lack of attention to ion formation. Something that was an integral part of the learning tasks. “The copper carbonate reacted with the acid and the copper came out. Then the copper atoms went to the electrode”. Discussion with this student revealed that he had not understood the ion formation of copper at all.

3.2 Description Lesson 1

Steve decided to use a role play to help students clarify and develop their ideas because he thought it would help them to visualise the chemical reaction and verbalise their ideas about the chemistry.

The students were asked to assemble as one large group of fifteen to consider the practical they had done; the reaction that had occurred; and to design their own role play to show what they thought was happening to the atoms, ions and molecules in the extraction of copper. The challenge was for them to show what they knew and to enhance their understanding by constructing a role play to represent the culmination of the class's ideas. Part of the requirement was that they talk through what they were representing in each feature of the role play as they developed it. An expectation was that, while they were seeking understanding through role play models, they would eventually need to be able to express their understanding verbally. Hence the role play model needed to generate a clearer understanding that could not only be presented as a role play but also represented orally and later, in writing.

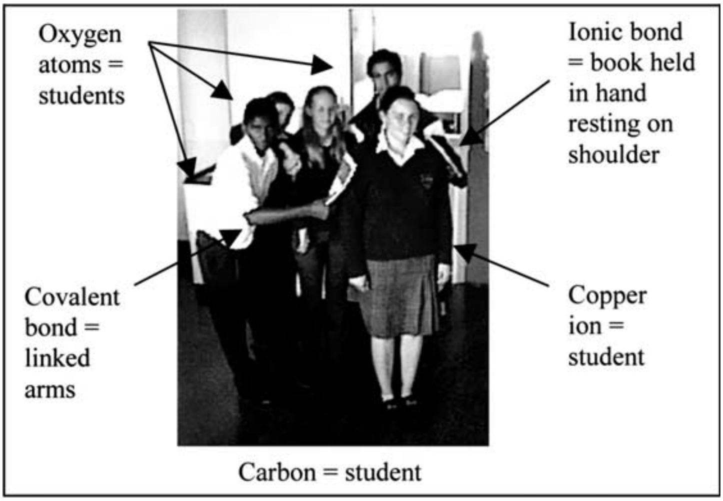

Figure 1. Student generated role play

The students made the copper carbonate molecules with five students (Figure 1). They put labels on themselves, for example, the copper ion students wore a Cu^{2+} label. Four students represented the carbonate ion (CO_3^{2-}), one was carbon and three others were oxygen atoms. They represented the covalent bonds between carbon and oxygen by linking arms. One oxygen student linked both arms with the carbon atom representing a double covalent bond. The other two oxygen students formed a single covalent bond by linking one arm with the carbon student. These two also held a book in their other hand, representing an "extra electron". The students explained that they were trying to show not only that the carbonate group was negative but also the location of the "extra electrons". The students decided to model the copper with a student who held her arms by her sides (representing a lack of valence electrons to share). The two oxygen students with the extra electron (book), held their books (electrons), resting on the shoulders of the copper ion to represent the ionic bonding. Here the students were showing how they thought the copper ion was held in the copper sulfate molecule.

When the clump of students representing the copper carbonate entered the water the carbonate group of four students separated slightly from the copper ion student. The oxygen students in the carbonate group retained the electron books, leaving the ion negative and in solution. The copper student with arms by her sides was now a positive ion in solution. The idea discussed by students, that they wanted to convey in the role play, was that the copper ion was stuck to the carbonate because it (the copper ion) was positive and was attracted to the negative oxygen atoms on the carbonate ion. But, when they were in the water, the water somehow separated them. This was all revealed as they were talking about and designing and modifying their role play.

3.3 Commentary

The role play and associated discussion revealed what was known and unknown. The students knew that water interacted with the copper carbonate but didn't know precisely how. Initially, Steve allowed this to pass at the time of the role play development. The role play and associated discussion had served a diagnostic function and indicated what needed to be considered in future lessons. Later in the lesson Steve raised this problem, "how did water contribute to dissolving ionic substances?"

In this part of the role play event, the students had demonstrated dissolving with copper carbonate separating into its ions. Others in the class had similarly constructed a model of sulfuric acid (an H_2SO_4 molecule) out of people and books. One group of students formed copper carbonate and another sulfuric acid (H_2SO_4). The students used the same principles to model the H_2SO_4 molecule as had been used to model the copper carbonate. They had worked as one team to use themselves to model different aspects of the chemistry. Each had considered and responded to the others' ideas as they were represented in the role play.

3.4 Description Lesson 2

During lesson two of the role play, the two groups of students interacted to show the reaction between copper carbonate and sulfuric acid. It was interesting to watch students construct their ideas about bonding and recombination of atoms and ions. During the formation of carbon dioxide for example, when one student saw the single linking of arms between the two oxygen students and the carbon person she commented, "No, No. You have to hang on with both arms because it's a double bond".

The $CuCO_3$ students dumped themselves into water (the air around them) and dissolved themselves. They showed this by moving apart, leaving a gap between the copper ion person and carbonate group of students. Then the H_2SO_4 group with a similar small gap between the two hydrogen ion students and the sulfate group of students, moved over for the reaction. In the process, the copper joined with the sulfate, standing close to the two sulfate group's oxygen atoms that held spare electrons (books). The oxygen students in the carbonate group kept the electrons (books) when the copper left.

The two hydrogen ion students that left the sulfate group, joined with an oxygen student from the carbonate group forming water. Here there was an interesting moment when the students realised that for the oxygen atom to join with the two hydrogens, the oxygen would need to take both books (electrons). They worked out that this was fortunate for them since it allowed the other oxygen (the one that gave up the book) to form a double bond with the carbon atom.

The students then decided that the carbon dioxide students were "not in it any more". As they were a gas, they bubbled off and were not further involved in the role play. The carbon dioxide students, represented this by standing off to the side.

3.5 Commentary

When modelling the reactions, the covalent and ionic bonding posed some problems for the students. The students were not sure how to represent water using the models that they had developed for the oxygen and hydrogen when they were part of copper sulfate and sulfuric acid. In particular, the so named “oxygen girl”, who formed the water, took both the electrons (books) with her when she went over to form the water with the two hydrogens. When the hydrogen and oxygen students came together, they couldn’t decide what to do with the electron books that she held. They tried the oxygen touching them on the hydrogen but rejected this, one saying, “No. That’s an ionic bond. That’s not a covalent bond.” The alternative was for the oxygen and hydrogen to link arms mimicking the covalent bond formed previously but they were dissatisfied. They still said, “What do we do with the books (electrons)?” They were having fun, were amused and laughing but trying to think through the problem. They were genuinely trying to work out and represent what happens but also were aware that at some time in the future they could be expected to write about the reaction.

One of the key benefits of the role play was that it promoted student conversation and the use of language associated with the chemistry. Students said what they thought about the reaction and clarified their understandings. As part of this process the students got feedback, both from the model and each other’s responses to their ideas. There was a little confusion about how to “turn an ionic bond (which seemed to be forming in the role play) into the covalent bond” (which they knew was formed). There was difficulty adapting one model to work effectively in the other. For example, in solving the issue in organising the hydrogen and oxygen electrons (books) in the formation of water, the books (electrons) were put aside and students simply linked arms to represent a covalent bond, as they had done before.

Such imperfection in the role play was no disadvantage. It was useful as it helped identify things to be considered and clarified. Identifying the imperfections seemed to reinforce the notion that the role play model was not real but a representation of views. The identification of mismatches between the role play and what is known or observed also encouraged students to improve the role play to better represent and review their ideas. Often the students were dealing with the implicit question, “how could they alter the model to show more clearly what they thought was happening?” It is also apparent that the process did not merely involve presenting their initial ideas about the reaction in a better way but rather the modelling helped them to generate deeper understanding of the chemistry and to represent this understanding both verbally and as a model.

3.6 Description Lesson 3

The students moved on to role play the next part of the reaction, where the copper sulfate was electrolised, forming copper at the negative electrode. They decided they had to have water taking an active role. They realised that water played an important part in the reaction (see above) in the first role play but seemed unsure how it contributed to dissolving. As they did not have enough students to play the role of water in lesson one, they had ignored the matter for the time being. To them, at the time of lesson 1, it was not crucial to thinking through the reactions because water was not a reactant. They had compromised by having the air as the water but were not now satisfied with this solution. In lesson 3, they extended the role play to account for the formation of copper at the negative electrode. They wanted to use a water molecule to take the copper ion to the negative electrode that they represented with a chair. They had a sulfate ion made of five students, the same copper student and three students who had made the water molecule. All these had been modelled in the earlier role play (see above). By this time they discarded the books and used linked arms to represent bonds. The sulfate students went to the positive electrode. The oxygen end of the water molecule 'pushed' the copper to the negative electrode, a seat with two books (electrons) on it. Then the copper student picked up the books and happily (now being "a complete atom" according to the student) sat down on the electrode seat. The SO_4^{2-} was just hanging about and they were not sure what to do with it. They commented that they had seen bubbles in the experiment and that they expected the sulfate ions went to the positive electrode. They speculated that this may have had something to do with the bubbles. While this was not role played it was discussed. They were not sure what was happening and therefore could not construct a model. Steve reminded them of the indicator test performed during the experiment, explaining that when oxygen was produced an acid was formed and this had turned the universal indicator red. They went on to further consider this matter in later lessons.

3.7 Commentary

In the role play, the students decided what was important to model in order to explain the observations they had made and to represent the knowledge they brought to bear on the problem. There were limitations to their understanding. There were some observations they were not yet able to explain or ready to model. More importantly, through the process both students and teacher became aware of where the edges of their understanding lay, where to go next and suggested how to build on the ideas that had already developed.

4. DISCUSSION

Some students were initially reluctant to be involved in role plays but once they tried it they admitted that it helped them to understand the reactions. Experience has shown Steve that, getting students to try role play as modelling for the first time, requires him to be enthusiastic and encouraging to convince them that it is a worthwhile learning experience. In this senior chemistry class, only one student needed additional encouragement to be involved. Developing a classroom atmosphere where students can do and say things without fear of failure, to be able to express ideas and hypothesise with confidence helps to create a classroom environment where role play models work well. Student generated role play, in turn, promotes such a classroom environment.

The role play provided physical, concrete models to represent different ideas about chemical reactions. Interaction between students ideas and representations in the role play was moderated by their discourse; they expressed their views and evaluated the merit of both their views and the ways in which their views were represented. They subjected their ideas to scrutiny, as well as sensitising the way in which the ideas were portrayed by their role play. The role play enabled their ideas to be viewed and subjected to scrutiny – tested against other ideas, observation and evidence derived from the modelling. They built their role play on their initial understandings but also clarified and developed better understandings. Critical to this seems to be keeping the role play dynamic and evolving. By this we do not mean that it merely involves people moving but rather that the role play should not be a fixed rendition of a set of ideas, proposition or theory. Rather it should be flexible and progressively modified contributing to ideas and modified as the new ideas develop. In this way, ideas can be represented and visualised more easily, manipulated, scrutinised and developed.

The role play is always an imperfect representation of that which it attempts to model. There is a danger that it may mislead. However, we contend that students are often aware of the shortcomings of their models, as was the case in the role play described here. They chose to focus on some salient aspects of their models and ignore others. There is a risk in analogy that students may attend to trivial or inappropriate aspects of an analog and ignore the critical or relational features. A role of the teacher is to help students to focus on critical evidence, observations and understandings related to the phenomena as well as critical attributes of the model. Students often fail to see what the teacher knows to be important and this problem is not limited to science. For example, an English teacher was having trouble explaining to her class what a moral was in a story. Being a good teacher she illustrated the point with an example, one of Aesop's fables. She told the story of a dying man who told his children that he had buried his fortune in the orchard. After his death the children dug throughout the orchard looking for the buried treasure. In time the orchard blossomed and bore fruit. Fruit was taken to market and sold. Unwittingly the children's hard work had made them wealthy, while they ever cursed their father. Having completed the story, the teacher asked her students what the moral or main message of the story was. A student raised her hand, shaking it, demanding the chance to answer the question. When asked, the student responded with certainty, “Never trust your father!” There is little doubt that analogy, fables and parables have been part of human learning since humans first began to share ideas in speech but they are open to misunderstanding, particularly when the trivial attributes are mistakenly appropriated and transferred.

One of the advantages of using students' self designed analogies is that the students themselves not only determine but also make explicit which aspects of the analog and target are important, which parts have explanatory value and attempt to model these. Hence, their thinking is revealed to both teachers and peers. Both teacher and peers engage in conversation to clarify the explanation, the model and purposefully explore the attributes which are salient to understanding the phenomenon. The presentation of the role play model is crucial to learning through analogy. It provides a concrete representation but the explanation (the story) that students provide with their role play gives the representation meaning. A student going to a chair, picking up some books and sitting down has no intrinsic meaning in chemistry. The associated explanation, however, where the girl is the copper ion, the books are electrons and the chair the electrode does have meaning. This representation provides a shared basis for conversation about the phenomena under study. We argue that much of the learning that occurs is brought about by the discourse associated with the analogical reasoning rather than by the role play per se.

5. CONCLUSION

The evidence that analogical role play provides a motivating, interesting and enjoyable way to sustain student engagement with ideas may be reason enough to include the strategy in the teaching repertoire. But analogical role play provides much more than affective gains. Role plays can be used to portray ideas and promote discussion. As the role plays evolve in response to this discussion they provide a powerful way to encourage students to think scientifically through analogical reasoning. The dialogue used and developed in the process of producing and analysing the role plays contributes to a successful learning experience. It not only helps to enhance understanding of the concepts being studied at the time but fosters learning during discussions in subsequent lessons.

It is tempting to avoid analogical role play, particularly where the students construct their own model, because the model must by its very nature be incorrect. Yet in classes such as Steve's, the thinking and learning which occur are difficult to deny.

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