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What Happens When Students Do Simulation-role-play in Science?

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Abstract

This article outlines some of the findings based on a study by three teachers and a university academic of role play in the teachers' classes. The study focuses on the results of role plays undertaken with students in mixed ability classes from three high schools in New South Wales. Role plays, where students play parts in scientific phenomena such as the electrons in an electric circuit or molecules from food in digestion, are not new to science education. But, what happens when students participate in role plays in science? In this report it is suggested that simulation-role-play may allow students to demonstrate their understanding, explore their views and develop deeper understanding of phenomena. A strategy for using analogical analysis in simulation-role play is suggested but concerns are raised about the students' capacity to distinguish role play from the subject matter being studied.

Linda, Reg and Stephen were three science teachers studying in an MEd course at the University of Western Sydney Nepean. While doing their course, they negotiated with their science education lecturer, Peter, to work with him as a team to address an issue of concern to them. The three science teachers were dissatisfied to some extent with how and what their students were learning in topics about electricity and gaseous exchange in the lungs, and hence their teaching of these. Linda summed up these teachers' concerns about their students' learning in science, when she voiced her view of her students' learning in the topic of electricity:

> You know they're just crapping on (about electricity). They're reciting - it's just parrot fashion. You say, "Say it again in your own words" and they can't because they don't really understand. They're just telling you what they think you want to hear.

The teachers were concerned that their students could neither express, in their own words, the scientific ideas to which they had been introduced nor apply the scientific ideas to new situations. This indicated to Linda, Reg and Stephen that the students had developed no depth of understanding of the ideas which the teachers had set out to teach. So the teachers were looking for something new to try in their teaching.

Stephen had tried a role play in the past and suggested that the role play had helped students to develop their own ideas and understanding about abstract science concepts. We decided that the teachers would collaborate to try some role plays in their classes. We were curious to see what would happen. Thus we four researchers, that is the three teacher-researchers (Linda, Reg and Stephen) and the university-researcher (Peter) began the study which is reported here. This article has been written by all four researchers, though each was primarily responsible for different sections of this work. The results, discussion and concerns sections, in particular, are a product of our joint analysis and interpretation of the data and our discussions arising from this.

Why Role Play?

The value of role play is that students look at occurrences from a different perspective (Dawson, 1994). They do not just look at what they are being told but are actively involved in reinterpreting information. Ladrousse (1989) has asserted many advantages for doing role plays. These include that role play:

1. encourages students to create their own reality;
2. develops students' ability to interact with other people;
3. does not threaten the students' personality;
4. increases students' motivation;
5. helps build up students' self confidence;
6. allows students to bring their experiences into the classroom;
7. is fun;
8. helps identify misunderstandings; and
9. provides shy students with a mask allowing greater participation.

Role plays have also been recommended as a teaching strategy for their potential to make learning in science more attractive to students who have become disenchanted with school science and female students in particular (Hildebrand, 1989). Thus role play seemed well suited to our desire to improve the teaching and thereby the learning of students in these teachers' classes.

We were not so much interested in role play where students took on the role of another person, for example, a scientist, an environmentalist or a politician in order to better understand the perspective of another human or the dynamics of science in a social context (e.g., Hiotis, 1993). Rather, we wanted to try simulation-role-play in which the students played the part of entities to simulate the processes of natural phenomena and clarify students' interpretation of these phenomena. Employed in this way, role play is used as an analogy to enable students to generate deeper understanding. Duit (1991) has identified five types of analogy: verbal, pictorial, bridging, multiple and personal. The role plays used in this study are personal analogies. Personal analogy may involve students physically "by, for example, (them) being asked to walk around in such a manner that the direction of travel is analogous to the motion of electrons through a wire" (Treagust, 1993a, p. 3). Personal analogy, however, can also refer to drawing on students' personal everyday experiences as analogies for science (Duit, 1991). In this study, the term simulation-role-play is used to distinguish the strategy employed by us from other forms of personal analogy and role plays in which students play the role of people.

The key feature of simulation-role-play, which appealed to us, lay 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). Often in science these mental models create a view of a microscopic world which is inferred from observations of, and the applications of, theories to explain phenomena. Many (e.g., Chester & Fox, 1966; Tobin & Fraser, 1988; Yager, 1989; Cobern, 1993; Yager & Lutz, 1994) have recommended that teachers provide non-threatening, social and enjoyable opportunities whereby students can develop their own understandings, especially about the unseeable world. With this recommendation in mind, and given the advantages Ladrousse (1989) identified for role play, we decided to implement role play in Linda's, Reg's and Stephen's science teaching and scrutinise it as a teaching method by considering the learning that occurred. Hence, the main research question became, what happens when these teachers' students do role play? In particular, we were most interested to see how students responded to the role play and what impact it might have on their learning.

Method

Goodson (1994) argues that research in school education needs to sponsor the teachers' voice and ensure that it is heard loudly and often. Taking this advice, we have set out to tell the story of three teachers as they tried role plays with their students. The findings and data interpretation are derived from teachers' knowledge based on their own experience, with their students in their classes; their knowledge of what students do and say and what this behaviour tells them about the learning that happens. In this way this research provides an authentic trial of role play in science classes. We then take these findings and initial interpretations and analyse them further to shed light on the use of analogy in science teaching because it is analogical reasoning that underpins the development of ideas through simulation-role-play.

Rather than set down a specific strategy for the implementation of the role plays, a collaborative approach (as recommended by Cole (1989) and Erickson (1991)) was adopted, whereby each teacher discussed his or her individual plans with the others and a university researcher, all of whom made suggestions as to how the role play might be conducted. We then took the advice of Boomer (1988), Fullan and Stiegelbauer (1991) and Bell (1993) for teachers to explore innovation in their own classes by trying simulation-role-plays with their students. This type of collaboration between university-researchers and teacher-researchers involving trials in authentic classrooms is of value because it provides a shared platform for communication making research into the teachers work inherently more meaningful to them, as opposed to research which may only be meaningful to university academics (Kagan, Freeman, Horton, & Rountree, 1993).

Examples of role plays were described by Peter and Stephen and discussed by the research group. We decided that, rather than simply "do a role play just for the sake of it," that we would plan to implement a role play as it seemed appropriate in a sequence of teaching. We reasoned that if the students were to participate effectively in the role play and, in particular contribute to its design, then they needed to have developed a view of the science phenomena in which their part lay. For Stephen the opportunity was immediately available as his students were discussing electric current and attempting to develop a model to explain their observations of electric circuits. Thus his students were thought to be well placed to contribute to their role play. So it was that Stephen tried role play first and was soon followed by Linda and Reg. Linda and Reg argued that their students needed further experience, in their topics on electricity and circulation respectively, if they were to come to the role play with sufficient knowledge to identify and interpret their roles. Reg soon introduced his role play as part of a planned sequence on the human circulatory system. By contrast, when an opportunity serendipitously presented itself to Linda while teaching her Year 8 class, she spontaneously seized this opportunity to try the planned role play.

The classes in which the role plays were tried were mixed ability science classes in NSW secondary schools, either Linda's year eight, Reg's year nine or Stephen's vertically streamed Year 8/9 class. The teachers had not attempted role plays with these classes previously. Stephen had used role plays with other classes but Linda and Reg had never tried them before. During the role plays the students' actions and conversations were observed. The teachers asked students questions and examined notes the students made in their workbooks. Role plays in Reg's and Stephen's classes were videotaped. During weekly debriefing meetings, the teacher-researchers and the university-researcher viewed the video tapes, discussed what had been observed during the role plays and on tape; what the students and teachers had said and done during the lessons and questioned each other about their experiences with role play. These meetings were audio taped and the discussion analysed to provide further insights into teachers' views about the effects of the role play on the learning in their science classes. Thus there were a variety of sources of data, as recommended by (Lincoln & Guba, 1985) including audio tapes of conversation among university- and teacher-researchers, video tapes of lessons, observation of students and student work samples.

The basic units of data analysis in interpretive studies, such as this one, are also the basic elements of reporting the research (Erickson, 1986). Thus the following elements of analysis and reporting (after Erickson, 1986) were employed by us in this study:

1. empirical assertions which describe generalisations or patterns which emerge from the inspection of the data ;
2. analytical narrative vignettes to give the reader a sense of being there and provide evidence of what actually happened ;
3. quotes from field notes, conversation and artefacts; and
4. interpretive commentary framing description to allow the reader to see the context and assertions of which selected units are an instance and to identify general themes.

This data was analysed jointly by the four members of the research group such that as each offered some interpretation he or she was called upon by the others to support the assertion being made. We have selected three vignettes drawn from our analysis of the data and presented them in detail to illustrate what happened when the three teachers attempted to use simulation-role-play with their science classes but each of the above elements of analysis and reporting is evident in this report.

Results

The three vignettes have been chosen to illustrate different aspects of the lessons in which simulation-role-plays were used. The first, in Reg's class, illustrates how students were involved in the role play design and how they played out their roles. It focuses on how student behaviour in the role play lesson differed from that in other science lessons. The second, in Linda's class, illustrates how role play was used opportunistically and resulted in the promotion of student confidence in dealing with some of their ideas in science. It focuses on classroom atmosphere before and after the role play. The third describes how a series of student designed role plays, together with their analysis and evaluation, resulted in the development of a more comprehensive, if imperfect, understanding of electric circuits. The focus in this vignette is on the process of learning through role play.

Reg's Gas Exchange Role Play

> The role play that I conducted with my Year 9 science class, was about gas exchange in the human lung. I wanted to help students to understand how oxygen enters from the lungs and is carried around the body and, how carbon dioxide is taken from body cells and removed through the lungs.
>
> The class organised the role play themselves first by assigning roles including: lungs, alveoli sacs, red blood cells, plasma and body cells. They used blue balloons to represent oxygen and yellow balloons for carbon dioxide. These balloons were exchanged between the different people as they passed between red blood cells and alveoli, body cells and plasma.

The red-blood-cell-students and plasma-students moved out of the lungs and made their way around the circulatory system to the students playing body cells. Here the red-blood-cell-students exchanged oxygen and carbon dioxide with the body cells. This was played out by red-blood-cell-students handing the body-cell-students the blue balloons (oxygen) and the body-cell-students handing the plasma-students the yellow balloons (carbon dioxide). Now the red-blood-cell and plasma-students moved out of the "body cells" around the "circulatory system" and back up to the lungs. This time the plasma-students handed over the carbon dioxide (yellow balloons) to the alveoli-students completing their gas exchange circuit. This loop was repeated three times as many students held hands with each other and danced around the circulatory system which they had created. Then the role play was stopped to discuss the students' views on gas exchange which they had just simulated in role play.

Some observations on what the science students were doing during the role play were as follows:

1. Students were having fun while learning science. Students without prompting, arranged themselves in pairs and linked arms (red-blood-cell-students with plasma-students). These pairs danced around their circulatory system.
2. The students all had a role to perform in the role play and most students actively participated in the activity without having to be cajoled to do so.
3. Some students helped explain to other pupils what was taking place in the role play. This peer support helped to clear up misunderstandings some students had.
4. The students who, according to Reg, usually had to be pulled up in class for getting out of their seats and walking around the room, were actively on task and seemed to understand science concepts they were being taught.
5. Some students took responsibility for assigning roles to all the students in the activity and decided to organise signs indicating their role, which students wore on the front of their shirts. These students displayed student leadership and took control of this part of the role play enthusiastically.
6. When discussing with the students what they had learnt after participating in the role play, the students were able to describe the function of the lungs using their own words.

After the role play Reg and students discussed what the students thought about the activity. Some of their comments are listed below.

It's fun. We liked it.
The role play helps you to see how the lungs work.
It helps you to understand it (gas exchange), because you can remember what parts your friends played in the role play.
It's better than just drawing diagrams with arrows in it, because you're actually part of it (the role play).
It's more interesting using the role play, instead of writing about it.
Science is boring; this is better.

The response from the class to this role play was positive. The majority of students were able to describe what was happening in the role play and they enjoyed it. Reg explained:

The key to the role play format was that it allows students to experience the science content in a hands-on, kinesthetic way. The teacher can use the role play strategy to assist science students understand concepts that they may have trouble dealing with in a highly visual/auditory lesson such as a didactic presentation with overhead transparencies and listening to the teacher and looking at diagrams in books.

Linda's Desperate Need Leads to Desperate Measures

> My trial of role play came firstly through sheer desperation at trying to explain abstract concepts to a mixed ability class. The Year 8 co-educational science class had been given a theory based approach to electricity during my 10 day absence from school. Upon my return I wanted to gauge the students level of understanding.
>
> The class sat silently as I fired my initial questions. Students sat with hands under the desk, some twitched nervously, none made eye contact. Bravely, James turned his page and recited the textbook answer as if speaking a foreign language. When asked to explain it in his own words a confused face replied that he could not and silence ruled again. Sarah, on behalf of the class, admitted that they had only copied down the notes but they "didn't really understand" how the circuits worked. Thus we entered into role play.
>
> The room was quickly rearranged, students became electrons. These electron-students walked around as if in a circuit. Chairs (resistors) were then added into the circuit and students had to slow down to climb over them. Therefore, they quickly obtained the image of electric current as moving electrons and resistors as things which slow down the flow of electrons. They then proceeded to act out what happens when the dial on the transformer was turned up. The function of the ammeter was then introduced by having one student take on the role of an ammeter and count the number of electrons (students) that passed a point in a set time.

When students returned to their seats they wrote down some of the key ideas that they had just learnt. All students, regardless of previously demonstrated academic ability, according to Linda, were able to write down ideas in their own words. For example:

> Electricity is the flow of electrons along a path.
> When a resistor is placed into a circuit it is harder for the electrons to pass through that part of the circuit.
> An ammeter is an instrument that measures how many electrons go past a point.

During the last stages of the lesson I asked the same questions that I had at the beginning of the lesson and the results were very different. Students were eager to answer the questions. All students felt that they could contribute something valuable to class discussion.

A positive learning atmosphere had been created. Some students commented at the end of the lesson on how much: fun they had had; clearer the ideas were; easier it would be to remember the concepts in the future; and, they would enjoy doing it again in the near future.

The role play lessons have now passed and I still find that we are going back to the initial role play as the building blocks for future lessons. As a teacher I feel that the role play was a key building block for the unit on electricity.

The role play had allowed an opportunity for the students to visualise important ideas about electric current which had hitherto proved difficult for them to grasp. It also promoted learning in an enjoyable way.

Stephen's Generation and Regeneration of Role Plays

The intended outcome of doing the role plays about electric circuits was that students would form their own mental picture and be able to describe in words a model of electricity that would help them explain some specific observations made while experimenting with simple circuits.

After completing some fairly traditional work on constructing and making measurements from simple series and parallel electric circuits involving globes, switches, ammeters and volt-meters students were given two diagrams; one representing a simple series circuit with two globes and the other, two globes in parallel. Students were asked, for a given voltage, to predict and comment on the brightness of the globes in the two circuits and to explain what was happening in the circuits to cause any differences that they predicted. Many students had difficulty with this task and those who made statements such as, "the voltage is shared" and "the current divided," demonstrated that they did not have a scientifically accepted, mental model for what they were writing. Stephen noted:

> Some discussion followed about what an electric current was and how it could be described as the movement in the wires of negatively charged particles called electrons. I told the students that I was very keen for them to understand what was happening and that if they developed their own mental picture they would have much more success in some of the future activities in the unit in which they would be challenged to design particular circuits.

The students were asked to pretend that they were electrons in a circuit and were organised to walk around a series circuit and then a parallel circuit and recorded the length of time taken to complete each task. Discussion followed about the meanings of the terms series, parallel, current and resistance. This activity introduced students to simulation-role-play in science and helped them to develop some basic ideas that would be called upon later.

In the next lesson, students were asked to set up a circuit including only one light globe, a switch and an ammeter. Observations of what happened in the circuit as the voltage was increased were made and discussed. Three observations were identified as common to all groups: the reading on the ammeter increased; the filament of the globe increased in brightness; there was an increase in the amount of heat given off from the bulb.

I asked them to think about how they could explain these three observations in terms of what the electrons were doing and in small groups to set up their own role play to model what was happening in the circuit.

Students actively worked together at producing their role plays. There was a considerable amount of noise and certainly some laughter. Students were having fun being creative in science. Their conversation was about circuits and they were using appropriate scientific terms in context. For example, I could overhear students talking about more electrons travelling through the ammeter when the voltage was increased.

The students developing their understanding of what happens in electric circuits, was visible. For example, in one group, the two students acting as light globes were progressively raising their arms as more and more of the electron-students passed by them on the chant of two volts, four volts etc., by the transformer-student. Here they were actively demonstrating that the filament of the globe gave off more heat and light as the current through it increased. In another group, one student was acting as an ammeter. His arm was the needle and, when the transformer-student increased the voltage and the rate at which students went past him increased, so his needle-arm moved accordingly. This group were visibly showing their understanding that an increased current meant more electrons were flowing past a given point; and that the increased current resulted from an increase in voltage. A third group used a high five slap to represent the energy of the electrons being transmitted to the filament (a students hand). As the voltage was turned up the four electron-students walked faster and faster around the filament-student and hit his hand harder and harder. At the end (at 12 volts) the filament-student held his two hands together and, noticing that one was decidedly red, exclaimed "Look sir, it's glowing." These students had demonstrated an increased rate of electron flow with increased voltage, an associated increased energy transfer to the filament, and an awareness that the flow electrons was directly responsible for the light produced.

Groups showed their role plays to the rest of the class and discussion led to a whole class role play which used the "best" features from each group's role play. Students were able to put together this whole class activity with little teacher input. The role plays helped students not only to represent but to develop their own mental models, which, from observations of their activities, comments and writing (see below), has enabled them to more readily understand what they are doing when they construct circuits in the laboratory.

Students' writing

After the role plays, students were given a circuit diagram (Figure 1) and asked to predict what would happen when both switches were closed.

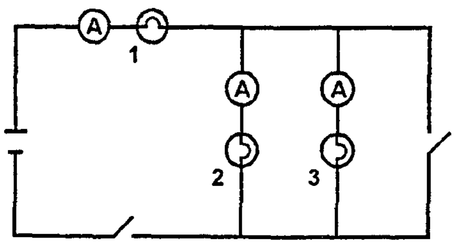

Figure 1. Circuit from which students made predictions.

While several students did not predict that globes two and three would not glow, all were able to make a comment in their own words. For example, Sean wrote, "I predict that most of the electrons will go through the one with no light globe because its easier." In using the term "easier," Sean was relating to experiences in the role play. Mary wrote, "I think the electrons will divide into the three passageways to power each light globe and ammeter." Mary clearly understands the path of electrons around the circuit but has not yet developed a concept of resistance. And Krissy wrote, "I predict that number 1 would be the brightest globe all the time because there would always be electrons going through it. I also think that if the electrons didn't know what they were doing they would probably go through number two because it's the first one in the parallel circuit." Krissy has a good understanding about where electrons will go. However, her view of electrons knowing where to go, as if they have a choice, is an alternative conception product linked specifically with doing the role plays.

The role play helped students verbalised abstract science ideas in terms that they could understand. For example, describing the observed difference between series and parallel circuits containing two globes, Alia wrote:

> When the switch is on, the parallel circuit is the brightest and the series is not as bright because the series is all in one circuit and if there are two lights they have to share the brightness but in the parallel, one light globe gets brightness and in the other circuit it gets the same because they don't have to share the brightness because it's not in series it's in parallel. (Before her initial group role play)

Later, after her group's role play, she wrote:

> The parallel is the easiest to get through because there're two ways for the electrons to get through but the series is hard. It's only one doored so some electrons get through, well all of them, but it takes too much time and the readings for the parallel will be more then the series. The

> parallel is the brightest and has the most readings because electrons go both ways instead of one way.

Alia's group designed their own role play to model the three observations they had made in class of a circuit containing a single light globe and ammeter and then participated as part of a whole class role play. Alia, after the whole class role play, wrote:

> The filament gets hotter and hotter because the more you put the voltage up the faster the electrons go through and they hit harder and the ammeter goes higher too when you put the voltage up and if more electrons go from negative to positive the brighter your lamp will be and you will have more readings.

In Stephen's class the changes students made to their role plays showed that they modified their ideas of electric circuits. In particular, Alia's understanding of and ability to discuss what happens in the circuit had developed.

Discussion

Three main positive outcomes of the simulation-role-plays have been discerned from this research. These are that role play appeared to enhance learning, improve classroom atmosphere and cater for differences among students.

Enhanced Learning

Students took more responsibility and leadership in their learning. "Natalie and Fran assigned students all the roles in our role play, organised the blowing up of balloons and made sure that everyone understood his or her role while I fiddled with the video. Natalie who is normally a very quiet and timid student," according to Reg, "was this time taking control." Here, Ladrousse's (1989) assertions that role play can encourage the participation of shy students and develop students' ability to interact with others has been supported in this research. Thus the role play may have suited students who are disadvantaged when more traditional teaching strategies are employed. In particular, the circulation role play suited kinesthetic learning (Gardner, 1983) as students who, according to Reg, preferred to learn through movement became involved when in other science lessons their tendency to move about was typically discouraged and inhibited.

Students developed new understandings of phenomena. This was apparent because students could visualise the unseeable ideas which are interpretations of the phenomena. They frequently used terms such as, "I could see what the electrons were doing." They were also able to relate the ideas learned to everyday life. For example, Sarah after doing the role play exclaimed, "Hey, street lights must be wired in parallel!" This potential for role play to help students visualise the microscopic world, which seems to have been realised, had been one of the main reasons for employing the simulation-role-play.

The role play helped students visualise and verbalise abstract science ideas in terms that they could understand. The chair-resistors, for example, helped students to converse about resistors and their effect on current. In the role plays and through their analyses the students tested and evaluated their role plays by comparing role plays with the phenomena they were being employed to model and interpret. As a consequence of this process, students' ideas about electricity were refined. Thus, as Treagust (1993a) and Duit (1991) suggested, the development of analogies, in this case role plays, allowed students to generate deeper understanding of the phenomena under investigation. There was evidence, however, that in interpreting their role play students may develop or strengthen alternative views of phenomena. For example, the students in Stephen's class simulated increased current by having the individual student-electrons in the circuit move faster and faster. Our concerns about the consequences of the role plays will be discussed in detail in the next section of this article.

Despite this development of some alternative views, the students in Stephens' class, for example, showed that they could use role play to develop a deeper understanding of electric circuits. This is evident in the students' records in their books (see for example the extracts from Alia above). It is also evident (as has previously been described) in the way in which they reviewed and analysed their role plays, which first had been designed and played out by the small groups, to produce a whole class role play . This whole class role play incorporated the best ideas available from each group's previous role play. Thus the value of role play here seems to lie not only in its capacity to allow students to apply and share their ideas, "to demonstrate" phenomena and make phenomena "seeable" as was primarily the case in Linda and Reg's class, though these are important. Rather; the greater value of role plays, as a tool for learning, seems to lie in the opportunity which they provide for students to analyse students' simulation of their own mental models by comparing their model with the models of others, and with observations they make of, for example, electric circuits as was the case in Stephen's class.

Classroom Atmosphere

The role plays provided a non-threatening atmosphere for learning. Kate, according to Linda, rarely volunteers to get up in front of the class because she is scared of being wrong. Yet, during the role play, Kate not only participated as a moving electron but also coordinated the movement of other students. This level of participation was highly unusual for Kate. At the end of the lesson Kate explained simply, "that was really cool, I loved it." Thus, as Ladrousse (1989) claimed, some students felt less threatened by the role play than they did by other science activities which required their participation.

Playing a role, distinct from their own persona, encouraged social interaction among students who normally do not learn from or with each other. Stephen and Reg commented respectively, "I've got these Year 8 kids who don't normally work with Year 9 kids. And they started working together. Some of these kids didn't even know each others names." Similarly Reg explained, "The two people dancing at the front of our role play were academically very different. They don't mix socially inside or outside the classroom yet during this role play they skipped together arm in arm leading the blood around." The role play promoted peer learning/teaching. Some students were unsure of what to do. So other students in Reg's class instructed them, "You're in the lungs now so you get the carbon dioxide and you get the oxygen. You get the blue balloon and you get the yellow one." This peer teaching and learning could be observed in Stephen's class as students described, demonstrated and explained their small group role plays to other members of the class. This further supports the suggestion (Ladrousse, 1989) that role play promotes social interaction among students. It enables students to don a mask thereby reducing personal barriers which inhibit participation.

The role play was an enjoyable and interesting activity and most students willingly participated. There was no shortage of volunteers for the role plays. Students were eager to be involved, even students who are usually "the passengers" in the class. After the role plays had finished, a lot of students declared that the role plays had been fun and asked when they could do it again? Most convincing of all the findings was that the students were motivated during the lessons when they participated in the role plays and thought they were fun activities in which to be involved. This was evident from both the observed enthusiastic behaviour of students and the comments students made about the lessons in which they did role play, thus confirming

Ladrousse's (1989) expectations. What is less clear is the extent to which these observed effects may be due to the novelty of doing role play, as none of the students had previously participated in role plays in science, and/or the opportunity for relaxed social interaction afforded by the role plays.

Catering for Individual Differences

The role plays catered for mixed ability groups because students could work with and or develop their own ideas. Stephen recounted, "No students said, 'I can't do this' and all students seemed to find a part that was suited to their... understanding as they began to design and conduct their role play." Some students were observed to just run around as electrons, or stand as components. Other students created the parts and determined the roles. This is consistent with Ladrousse's (1989) claim that role play enhances self confidence. However it also suggests that students began with and developed different degrees of understanding as they participated in the role plays. Some simply applied their existing understanding taking a principal role in the design of their group role play. Others, like Alia, learnt from the role plays and related discussion to develop a better understanding of circuits, while others simply seemed to play the part they were assigned. These students could then draw on this experience to communicate in conversations and when writing about electric circuits or circulation.

In Reg's class the role plays catered for students who needed to move around or use their hands, in order to learn. Thus role play assisted students who like to learn kinesthetically. Reg opined, "It helps students who want to get up, move around, tap pens, fiddle with things etc. It allows these learners to shine." This is consistent with our earlier suggestion that role play may cater for kinesthetic learning. However, as this finding was evident in Reg's class alone, we recommend that in future studies of role play students who could be referred to as kinesthetic learners should be more accurately identified. Then, the participation of these students in, and the learning outcomes resulting from, simulation-role-play could be more closely examined.

Despite these three positive outcomes, which confirm the claims for role play identified in the literature, some concerns remained for us about the learning which resulted from the role plays. These concerns were due mainly to the observation that some students seemed to have difficulty distinguishing between their role plays (their analogy) and the characteristics of the phenomena under investigation (that is, electric circuits or gas exchange). This problem with simulation-role-play is considered below.

Concerns

Role plays are analogies which help students to understand science concepts being developed. For some students, however, the analogies used become adopted as the children's scientific interpretation, that is, the role play becomes the explanation rather than a means of developing understanding. In describing a circuit one student, after the role plays, wrote, "I think electrons would go to globe two because it is closer to them." Here the student seems to hold the view that electrons have a decision to make as a human might, and has not developed the idea of a general drift of electrons throughout the circuit.

Another student, in describing what happens when the voltage is increased, after the role plays wrote, "So the filament gets hotter because the electrons are hitting harder and faster and the light globe gets brighter with the heat." For this student, the role play has generated the view that electrons are hitting the filament and heating it up to produce light. The hitting analogy used to convey the giving of energy has been accepted as what electrons actually do. Thus, some students may confuse analogy with reality. As people take on the role of electrons so too the characteristics of humans may be transferred to electrons and these electrons are given, in the students' interpretation, the capacity to think, make decisions and choose the path they wish to take. Treagust (1993b) reported a similar problem when using analogies when he noted that students were unable to separate the analogy from the content being learned as some students learned only the analogy and not the science subject matter being studied. Such confusion between reality and analogy is not surprising. Indeed, we usually speak of electricity as if analogies, developed in science to interpret electricity, were indeed real rather than human creations. For example, we speak of electron flow and current, of resistance and flat batteries as if they are real when they are widely accepted, analogical interpretations of phenomena. Thus as a student speaks of electrons "hitting" they are simply doing what we all do when we discuss phenomena, that is, using analogies to describe, interpret and communicate ideas about phenomena.

Other concerns about role play were firstly, that the role plays in the instances reported had great novelty value and may only be suited to particular concepts. If overused students may not respond in such a positive manner as was seen in this study. Further study is needed to determine how the novelty of role play influenced the students in this study and the breadth of phenomena for which role play is a useful tool of interpretation and analysis. Secondly, the teachers were concerned that role plays took a lot of time to prepare, perform, review, evaluate and re-perform. If students are to use role play, which appears to enhance learning, the teacher may then have to teach less in order for students to learn more. Finally, whole class role plays and student designed small group role plays involve considerable movement, need plenty of room and tend to be noisy. Hence, this type of activity needs to be done either outside or in a large space such as a hall. Some students may take advantage of the situation and misbehave. The process requires that the teacher has already developed a good working relationship with the class and sets up clear guidelines for the activity. Without this, lessons involving the whole class actively engaged in role play could well be chaotic.

Given the advantages of role play identified in this study and by others (e.g., Ladrousse, 1989; Hilderbrand, 1989) the concern that students may confuse the roles simulated in the role play with reality needs further consideration here. Such confusion is a consequence of rendering the interpretation and analysis of scientific phenomena accessible to students through analogies. Analogies are valuable tools for advancing thinking because they give concrete expression to otherwise abstract ideas (Badcock, 1995). In science analogical thinking is normal practice (Eisenberg, 1992). Consider for example light "waves," gene "shears," "bendy" space, electron "affinities," "donating" electrons and basalt "dykes." Such analogies are so common place and used so freely that it is easy to forget that they are analogies, human creations to interpret and describe of phenomena. Novel ways of representing ideas can bring radical advances in thinking and, according to Holyoak and Thagard (1995), the use of analogy in such novel thinking has conveyed evolutionary advantage to humans. Thus the use of analogy in human thinking and communication is natural and of selective advantage to our species.

Analogies can be mapped against the phenomena they are used to describe to identify similarities, differences and grey areas where the correspondence between analogy and phenomena is unclear (Gick & Holyoak, 1983). This mapping can lead to knowledge generation as the familiar analogy informs our view of the unfamiliar phenomenon under investigation (Holyoak & Thagard, 1995). Being analogies, simulation-role-plays provide a thinking tool through which students can work with their abstract ideas and render features of their interpretations of phenomena explicit, observable and accessible. In Linda's and Reg's class, the students showed how role play could make scientific interpretations more comprehensible through the concrete representation of scientific explanations of gas exchange, and electric current. In Stephen's class, students analysed and compared different role plays with each other and with the phenomena they were intended to represent. Thus a deeper understanding might be generated when students not only use role play to model phenomena but analyse and evaluate their role play against phenomena to identify similarities, differences and grey areas in order to reconstruct new role plays ever more consistent with the phenomena they set out to understand. A one-off role play may provide a valuable tool for recall and allow students to better access scientific explanation and enable student expression of views. Analytical mapping where students compare student constructed role plays, which represent their views of with phenomena, with those of other students and the reconstruction of new role plays may provide a mechanism for students to generate deeper understanding in science. A systematic, six step approach to this type of analysis has been suggested by Harrison and Treagust (1994, p. 21):

1. introduce the target concept;
2. cue students memory to the analogy;
3. identify the relevant features of the analogy;
4. map the similarities between the analogy and the target (science subject matter);
5. indicate where the analogy breaks down; and
6. draw conclusions about the target concept.

Based on this research we recommend two changes to this six step strategy. First, we recommend that students concentrate not only on areas of disagreement between the analogy and phenomena, as much learning might result from a consideration of the grey areas where the correspondence between the analogy and phenomenon is unclear. Second, we recommend that students use their analysis to generate new role plays to represent new and emerging ideas. In this strategy the six step process becomes a circle as simulation-role-plays are "generated, tested and regenerated," a heuristic by which, according to Plotkin (1994), all knowledge develops.

Conclusion

The students in all classes seemed to benefit from the simulation-role-plays but students who had shown little interest in school science and those who preferred a kinesthetic approach to learning found the role plays a particularly attractive and productive way to learn their science. Students operated in three ways in the role plays as the role plays allowed students with different understanding and different aptitudes to learn in different ways. Firstly, for some students role play was a way of demonstrating understanding they already had about science phenomena. These students, for example, already understood the electric circuit or gaseous exchange and they could apply this understanding in a role play. Secondly, it was mechanism students could use to construct an understanding about scientific phenomena. The students discussed and refined their ideas as they developed better role plays. These students, for example, used ideas from different groups to produce a class role play. And thirdly, it provided experience which modelled a scientific phenomena initially not understood, which became the building block for understanding in later discussions. These students mimicked others. They could play their part but could not relate the part to electricity or gaseous exchange at the time. In later discussions students were able to remember their part and it provided a link for their developing of ideas.

Irrespective of the way in which students operated, through the role plays they were able to form a picture in their mind of the scientific phenomena; something most students were less able to do previously. We have argued that simulation-role-plays, like other analogies, may be valuable tools for knowledge generation. Yet, operational guidelines for the use of this thinking tool in science teaching is not clear. We have hypothesised that the use of simulation-role-play might be optimised if students create their own role play, analyse role plays by comparing them with phenomena, compare the role plays created by other students and recreate role plays in the light of this analysis. Further research with other phenomena and other classes is needed to determine the efficacy of analogical mapping with simulation-role-play. Furthermore the apparent development of student understanding, enjoyment of learning and capacity to recall science subject matter reported in this study is indicative that simulation-role-play enhanced learning but further research of role play should incorporate strategies to systematically examine knowledge development which may result from role plays and their analysis.

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