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Science through drama

A multiple case exploration of the characteristics of drama activities used in secondary Science lessons

A context for drama in Science

Cross curricular drama was first cited as a teaching strategy for English students in 1528, according to Richard Courtney (1974: 14). For the next three hundred years, the topics of Religion, Classics, and Elocution were taught through role play in some schools and monasteries in both England and France (pp.14-20). In the modern age, Henry Caldwell Cook's influential book, *The Play Way* (1917) has been credited with stimulating Drama in Education in the UK (Hornbrook 1998). Caldwell Cook was followed by a series of charismatic practitioner-academics, including Dorothy Heathcote, who developed improvisational role-plays in which students were guided by their teacher in-role (Bolton 1985). Such work inspired interest in cross curricular drama across the Humanities, primarily in English, History and Languages, from the 1960s onward.

In the 1980's, inspired by successes within the Humanities, some educators and researchers in the UK began to explore the use of drama in Science (Dorion 2007). The Association for Science Education began to publish guidance and lesson plans such as the Limestone Inquiry -- an extended community debate about the development of a new limestone quarry (SATIS no. 602). At this time too, a seminal study by Robert Metcalfe focussed on the teaching of particle theory through drama, by having students 'act' as atoms within different states of matter (Metcalfe, Abbot, Bray, Exley, and Wisnia 1984).

Drama in Science has since grown in scope and breadth. According to Marianne Odegaard's literature review in 2003, interest has extended internationally, in particular to Norway, North America, and Australia (2003). It has ranged across topics including historical role plays (Solomon 1990), forensic investigations of fictional crimes (Heathcote 1991), the physical modelling of electric circuits (Tvieta 1996) and kidney function (Johnson 1999). The range of drama forms, however, has been relatively consistent: Odegaard observes that the activities tended to be improvisational role plays, rather than scripted performances (2003).

Claims for drama as science pedagogy

It has been claimed that drama, or drama-type activities such as role plays, can support learning of cognitive, affective and technical objectives, especially higher order thinking skills relating to analysis, synthesis, and evaluation (Ellington et al. 1981; Wagner 1998; Harvard-Project-Zero 2001). Some experimental studies have suggested that drama can enable meaningful learning (Metcalfe et al. 1984; Tvieta 1993; Tvieta 1997). A central characteristic of these activities is that they are seen to promote opportunities for 'interactive dialogue' (Wilson and Spink 2005), dialogic teaching (Edmiston and Wilhelm 1998) and student-centred discourse (Somers 1994). Furthermore, the literature consistently highlights findings of high motivation among students, imbued in part by their perceptions of empowerment and ownership during these events (Odegaard 2003).

However, although a pattern of features for learning has emerged, researchers engaged in meta analyses argue that some claims are difficult to substantiate due to ideographic methodologies and incomplete descriptions of the activities (Conard 1998; Harvard-Project-Zero 2001). The confusion over the evidence echoes a similar confusion of definitions across the research disciplines which inform this topic. These include Drama in Education (DIE), Science Education, Games and Simulations, Psychology and Theatre. Each has its own terms of reference and internal disputes regarding the definition of drama (Dorion 2007). For example, authors within Games and Simulations research have argued that although they use similar activities to DIE practitioners, they study role play, not drama (O'Toole 1992). This appears to be an argument over the question of whether pretend play entails the creation of character or the structuring of behaviour according to a set of rules (Jones 1995). One author reflects that this is a case of splitting hairs, and offers a resolution in asserting that an activity is drama or role play depending on the intentions of the instructor (ibid). DIE researchers working within praxial drama have argued that cross curricular drama must attend to the human condition (Somers 1994; Bowell and Heap 2001), as opposed to theatrical forms which explore the representation of non-human concepts through symbolic role play. Science Education researchers have been most consistent in describing their role play strategies as ‘drama’ (Metcalfe et al. 1984; Tvieta 1993; Tvieta 1996; Tvieta 1997; Aubusson and Fogwill 2006).

Defining drama in science

In an effort to draw from research and theory across disciplines, this study aimed for synthesis, and developed a definition which retained a ‘wider lens’ (Stebbins 2001) for exploring drama in the secondary Science classroom. Here, drama could be seen to be the combination of three features: *role play* within an *imagined situation*, and enacted within *the human dimension*. A brief discussion of these features will help to situate the assumptions of the study: The first of these features, role play, has been broken down by McSharry and Jones into *role*, which is to ‘behave in accordance with a specified function’ (2000: 73), and *play*, which is a ‘positive emotional relationship with the learning environment’ (p. 74). While roles and play can occur in non-dramatic activities such as science investigations, they become drama when the students' *specified function* is to behave as if their world is different to reality (Anderson 2004). This pretend world may differ in temporal, geographic, social, corporeal, or dimensional features. Whatever its form, it is superimposed onto the physical limitations of the real world (O'Toole 1992) so that in practice the participant moves through an imagined environment while simultaneously negotiating other students, the chairs and tables etc. A student's mental navigation of these real and imaginary worlds is little understood, but perceived to engender 'metaxis', or a state of 'double consciousness' (Wilhelm and Edmiston 1998: 135) which holds two forms in mind at the same time (Somers 1994). During the process of this internal dialectic, there is also an external, social dialectic, as these activities are primarily collaborative and improvisational. The result is perceived to be a highly dialogic learning environment, which Vygotskian and Bakhtinian researchers suggest helps to develop knowledge development through complex negotiations of meaning (Edmiston and Wilhelm 1998; Lytle 2003).

Two strategies for drama in Science

Two strategies for teaching Science through drama in the classroom have emerged within the literature. The first strategy aims to simulate social events, usually of the adult world, which students have not yet experienced. Often employed in the form of extended role plays, these convey topics which relate to affective contexts of social, cultural and intellectual discourse which occur in Science contexts (Odegaard 2003). A second strategy employs mime and role play to convey abstract physical phenomena, which would be otherwise unobservable in the classroom (Odegaard 2003; Aubusson and Fogwill 2006; Dorion 2007).

The first strategy of 'social simulations' has been found to be useful in conveying to students the impact of science and technology on society, with activities that include debates, consensus conferences, and historical role plays (Duveen and Solomon 1994). The structure of these activities is exemplified by Odegaard's description of two historical role plays, in which students are asked to adopt the different points of view associated with a science issue:

> The trial of Galileo and a supposed trial for blasphemy of Charles Darwin are examples of episodes of science which have been developed as roleplays constructed for the science classroom (Duveen & Solomon, 1994; Solomon, 1990). The students play roles of historical characters, which show the range of ideas that were current at the time. They are introduced to the characters by a role-card description, but in the role-play they improvise, and the fictitious context allows the role-play to have no defined ending. Thus this is a semi-structured drama activity, giving the students a story as framework that acts as a scaffold while the students explore these historical science events.
>
> (Odegaard 2003: 86)

A recurrent rationale for introducing such a drama strategy to the Science classroom is its potential for conveying affective knowledge through empathy, i.e. the ability to understand the perspectives and emotions of other people, both individual and collectively. Empathy is described as a potent vehicle for teaching about moral and ethical issues (Duveen and Solomon 1994; Brown 1995; Claxton 1997). It can also focus students on a metacognitive awareness of their own morality, in that they may find out their responses to a given context other than the present situation (Bolton 1980; Heathcote 1991).

Soon after drama began to be considered by Science researchers, Robert Metcalfe proposed a more unorthodox form of empathy: that drama might allow students to 'empathise' with an non human entities, such as atoms:

> However, Drama can be used in an additional way: it can be used to enable the learner to 'take on the role of another', to cast off an egocentric perspective—and the 'other' can equally be an animate or an inanimate object.
>
> (Metcalfe et al. 1984: 78)

Metcalfe's choice of term seems to describe a visceral form of spatial awareness that is now presented as embodied knowledge, consisting of 'force sensations' (Bresler 2004), and other internalised, non propositional features that are claimed to occur in relation to experts' visualisations of abstract concepts in science (Reiner and Gilbert 2000). Metacalfe's 'empathy' is the focus of the second strategy, in which 'physical simulations' are devised with an aim to provide a way for students to experience non-human processes. One example comes from Aubusson et al. in relation to the movement of electrons within a circuit,

> 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.
>
> (1997: 570)

Known variously as drama models (Metcalfe et al. 1984; Aubusson and Fogwill 2006), role play simulations (Aubusson, Fogwill, Barr, and Perkovic 1997), drama machines (Somers 1994), analogy drama (Wilhelm and Edmiston 1998), and metaphorical role play (McSharry and Jones 2000), these employ mime and role play to create three-dimensional models of chemical, physical, or biological processes (Wilhelm and Edmiston 1998). Physical simulations emphasise the use of familiar social metaphors and immediate experience to allow children to explore 'physical systems where the real things are too expensive, complex, dangerous, fast or slow for teaching purposes' (Jaques 2000). They provide a controllable, virtual reality (ibid) through which the participants manipulate the representation of scale, time, and space, and communicate science analogies via different senses (Metcalfe et al. 1984; Kress et al. 2001).

Everyday teachers and drama

To date, the majority of academic studies have tended towards a narrow focus on Arts-based drama strategies, and the promotion of affective learning through social simulations. Odegaard's review of drama in Science revealed that the majority of research had focussed on indicating not what drama *is* in the Science classroom, but what it *could* be (2003). Within this context, a field of research which remains underrepresented is the investigation of everyday teachers in everyday contexts. Academic literature has been slow to record the efforts of Science teachers' use of drama. As a result of this, and a corresponding preference for intervention, the limitations on ecological validity are most evident in relation to the inspiration for teaching objectives, since the activities have been driven by research interests rather than emerging from the contexts of everyday Science. On some rare occasions (Wilhelm and Edmiston 1998; Aubusson and Fogwill 2006) teachers have devised their own activities, but even here the impetus for creating the activities was stimulated by the researchers, rather than coming from the learning context.

The potential for teachers in secondary Science to experience drama as a cross curricular pedagogy has increased in the last ten years (Dorion 2005). In the past, drama was considered something to be contracted out to Science Theatre groups and professionals (ibid). Now, Science teachers encounter drama through a variety of sources: multi-school Science-drama events, the Science Museum outreach programme, drama articles within Science teachers' publications, cross-curricular workshops at Science Learning Centres, and on teacher training courses at some universities (Dorion 2007). Drama in Science has been introduced within the National Science Teacher Association (NSTA) conferences at regional and national level in the United States (Wilhelm and Edmiston 1998), and within the UK role play can now be found within the Department for Education and Schools schemes of work for ages 11-14 (DfES 2006).

Working from the assumption that some teachers do use drama in Science, the first two piloted interviews for this study indicated a gap between academic literature and practitioner knowledge. These revealed drama activities not previously published in the literature, such as physical simulations of electromagnetic wave-forms for students aged 16-17, a long-chain molecule, and a description of zeolitic process with students aged 13 to 14. Such immediate originality, when the focus was shifted towards 'real people in real situations' (Cohen, L, Manion, K and Morrison, L. 2000) suggests that there are further activities, topics and objectives that have yet to be recorded in academic research. The study's **research questions** reflected these themes:

What are the characteristics of the drama activities employed in some Secondary Science lessons?

- What types of drama are used?
- What objectives initiate the use of drama?
- What characteristics of these activities are perceived[1] to enable achievement of the teaching objectives?

---

[1] Measured from the perceptions of the participants involved.

Methodology

Developing an ethnographic method

Robert Stebbins has asserted that a field dominated by interventionist approaches should give way to the use of a *wider lens* consisting of inductive, data-rich, case-based exploratory approaches (Stebbins 2001). From this starting-point, the need to gain and retain rich data suggested the Robert Stake's ethnographic approach which advised the use of primary sources of data that foreground 'thick description', 'experiential understanding' and 'multiple realities' (Stake 2006: 43). Particularly appealing was Stake's emphasis on participants' experiences, and their *perceptions and conceptions* of process, which were triangulated with the observations and interpretations of the researcher. Applying Stebbins' metaphor then, this study employed an array of lenses. Following Stake's methodology, the study first aimed to record participants' perspectives within cases, with each case focussing upon the observed lesson in which drama was employed. Analysis was interpretive, but included coding according to a set of themes which had emerged from the pilot interview (see Table 1).

[Insert Table 1 here]

Only after ideographic analyses of all cases was completed was the cross case analysis begun, structured primarily through the coded themes, and then cross referenced with the research questions.

Sampling

In order to focus on everyday teachers and real events, several features were introduced in the design in order to reduce artificiality and bias. First, neither the teachers nor the students were told the agenda for the study. In the piloted pre observation interview, case study[2], and in informal conversations, teachers' responses reflected a stereotypical view of the term 'drama' that could have influenced their responses and teaching approaches in the observed lessons. The study therefore followed a convenience sampling approach, asking initially for Science teachers who believed that they might use 'role play' in their lessons. This term was perceived, from the pilot interview data, as a more acceptable description of drama-like activities for some teachers.

The study took place in English schools. Each case consisted of a Secondary Science lesson, for students aged 12-16, in which drama was employed to convey a science topic. Each lesson was to be taught by the class's specialist teacher in Biology, Chemistry, or Physics; a teacher who had used role play activities regularly in Science lessons. The teachers were asked to invite the researcher in when they next used role play with one of their classes. Only after the fieldwork was complete was the activity vetted as to whether the observed activities adhered to the study's definition of 'drama'. This inductive process led to extra work in one case, as the data for one activity was discarded after preliminary analysis. However, the overall effect was to improve the ecological validity within cases, by following rather than leading the teachers' agendas.

The final sample reflected a variety of school types from Kent, Hertfordshire, and Cambridgeshire (see Table 2).

[2] The potential for the concept of drama to bias Science teachers' responses was evident in the pilot: in the first pilot interview, I had not hidden the fact that I was drama-trained and that I was exploring the use of drama; This seemed to cause the teacher some stress, as evident in her responses.

[Insert Table 2 here]

Interviews

Each case was framed by a pre and post observation interview with the teacher, and post observation interviews for three students from each class. These were chosen through opportunity sampling. The pre-observation interview explored the context for the lesson, the teaching objectives, the teachers' backgrounds, and their perceptions of the students' abilities. The post-observation interviews aimed to, '[focus] on a respondent's subjective responses to a known situation' (Cohen et al. 2000: 273) and included questions that arose in light of data from both the lesson observation and the student interviews that had come before it. All interviews were taped and transcribed.

Show cards

Show cards were employed in an effort to avoid leading questions, while still giving a focus for the discussion. Each card contained nine terms, as this seemed to extend the possibilities for personal response without overwhelming the interviewee with choice. There were two cards: The first show card (Figure 1) briefly named a selection of activities, whereas the second show card (Figure 2) provided a selection of possible learning features; both used terms which had emerged in the literature review. A definition was read out for each. The cards were only presented after the interviewees were offered open questions regarding the activities and learning features, in order to provide scope for more individual responses.

[Insert Figure 1 here]

[Insert Figure 2 here]

Observations and stimulated recall

In keeping with Stake's ethnographic approach, observations were open-ended, providing a descriptive record of significant or intriguing details and events during the lesson. It was an interpretive methodology, useful for exploring the characteristics of an 'innovative resource' (Hargreaves 2006: 2), and allowing one to 'consider the context of behaviours, their sequences, [and] their meanings' (Simpson and Tuson 2003: 45). A video camera provided a further means of triangulation, but more importantly facilitated a stimulated recall methodology in which 'videotaped passages of behaviour [were] replayed to individuals to stimulate recall of their concurrent cognitive activity' (Lyle 2003: 861). Teachers were invited to interpret their perceptions of their role, and their interaction with students during the drama activities. Three extracts from the video of approximately three minutes each were shown to each teacher, who was asked to interpret the participants' behaviour in these episodes. The first extract was shown after the first show card at the beginning of the interview, so that it might also stimulate the teacher's memory of the lesson as a whole.

[Insert Table 3 here]

Analysis

Analysis was informed by Stake's two-tiered multiple case-study approach, which aimed first to analyse each case as an ideographic event, and only afterwards to employ cross-case comparisons. Individual case study interview transcripts and observations were coded with NVivo, initially according to five themes which had emerged from the pilot interviews. These included descriptions of assessment, drama-type activities, teachers' backgrounds/inspirations, aspects of learning, and practical issues, i.e. health and safety. Following Stake, there was also scope for an interpretation of emergent patterns and differences in relation to the central research questions. After the case studies had been analysed, a separate cross case analysis focussed again on the codings of the five themes. Following Stake, claims with three or more corroborations in the data were considered to have some generalisability beyond the data set (Stake 2006)

Measurement of talk and interaction

Analysis of the initial two case studies indicated the need to explore the styles of dialogue employed within the classroom. The initial assumption of the study had been based on the ubiquitous assertion in the literature that all drama-based activities promote dialogic forms of talk. Dialogism, originally theorised by Mikhail Bahktin, an ongoing dialectic between participants in which no single 'voice' has control over the overall conversation (Bahktin 1984). Translated to the classroom, Mercer has described dialogism as the rejection of 'static, objectified knowledge' and emphasises the role of the teacher as one who guides and models discourse, highlights the metacognitive use of discursive modes, and fosters an inclusive learning environment (Mercer and Littleton 2007: 69).

Such discourse focuses on mediating student talk, in which authoritative answers are not given by the teacher, but rather the students negotiate meaning between each other and the teacher, with reference to the evidence or activity at hand. Scott, Mortimer and Aguiar view dialogic learning environments as a medium for the interanimation of ideas, in which student's ideas about a topic are 'explored and worked on by comparing, contrasting, developing' (2006: 611). Drama environments were assumed to promote this dynamic. However, initial analyses indicated that teachers often seemed to assert a strong degree of direction to student talk which mitigated against true dialogic discourse. This appeared to contrast with the drama literature, and support the assertions of others that in Science lessons there is little dialogic activity (Amettler et al. 2007).

I adopted a measurement approach from Scott et al. (2006) which attempts to delineate dialogic and non dialogic activity in lessons. They have observed that classroom talk can be measured according to whether there is one dominant viewpoint (authoritative), or a range of ideas being considered (dialogic). Scott provides a matrix in which these two attributes are paired categories in which only the teacher speaks (non interactive) and in which the wider class participates (interactive). Scott's table (Table 4) and examples of the pairings in observation follow below (Table 5). According to Scott et al., the measurement scheme has been replicated and been found to be useful according to Gee's 1999 criteria for effective discourse analysis (p629).

[Insert Table 4 here]
[Insert Table 5 here]

Research issues

The two Physics case studies used the same teacher and class. During the first post observation interview, the teacher noted that she would be using an extended role play on car safety features in the coming month. It was an opportunity to explore an A level class using an extended preparation and performance approach, that the teacher had used previously with another class. This did not conflict with the case methodology, which focussed on discrete lessons, not teachers.

FINDINGS

Three central findings emerged from this study:

- There was a greater breadth of variety of drama in Science objectives and topics described and observed than previously recorded
- Teaching and learning was perceived by the participants to be multimodal, with specific modes producing specific visualisations of abstract concepts
- Patterns of didactic, interactive, and dialogic discourse related to objectives concerning teacher control over the transfer of knowledge

Activities

An immediate and striking find was the breadth of topics across age and subjects with which drama had been used by these ‘everyday’ teachers, and which had not been described in academic literature previously. Drama was used or reported for topics across ages 13-18 in Biology, Chemistry and Physics. All observed activities shared the trend for improvisational role plays, rather than scripted work (Odegaard 2003). However, in contrast to the predominant *social* simulation strategies reported in Odegaard’s review, the teachers here tended to choose *physical* simulations strategies, which were developed ad hoc in isolation from drama pedagogy, and were not informed by published work.

[Insert Table 6 here]

[Insert Table 7 here]

The teachers’ backgrounds

The teachers within this case study were subject specialists, with teaching experience that varied from two to twenty-three years. None had received drama training, but all revealed that at some point the use of drama-type activities in Science had been modelled to them. Two of the teachers, a Head of Chemistry and a Chemistry teacher cited inspirational mentors within their first two years of teaching practice. The study's Physics teacher observed that she had been inspired by the memory of acting out an electric circuit as a fourteen year old in class. The Biology teacher claimed that he had been put off role play at school, but that he had begun to explore drama-based activities as a result of a Masters in Education course that he had taken after having taught for some years. These findings suggested that teachers' interest was stimulated by their exposure to positive experiences of drama in Science.

In all cases, teachers cited colleagues within their departments who also used what they termed role play activities, although this had not led to collaborative approaches. At most, the Physics teacher and the Head of Chemistry had *discussed* drama strategies within their departments.

Teaching objectives

Teachers aimed for their students to express science knowledge, to acquire abstract concepts, and to develop technical and procedural skills, within an environment which enhanced affective features for learning. Only once did a teacher emphasise affective learning itself as a primary interest. Rather, teachers aimed to create situations which were atypical to normal Science lessons.

In relation to the affective atmosphere, teachers revealed a desire to use drama to provide a sense of *relevance*. The idea of relevance had two meanings: First, in the Physics cases the teacher described an aim for students to realise that what they learned in the classroom could be observed in their own life domains. Second, and more common among teachers, was an aim to convey an image of the Science class as a community in which enjoyment of learning together gave Science a *de facto* relevance.

None of the teachers raised safety or classroom management issues. Only in one case did the teacher take students out of the classroom to do drama. Otherwise, teachers described their classroom layouts, typically of long-fixed tables, as an obstacle but not a barrier to the use of drama. These obstacles appeared to inspire the teachers: The Chemistry and Physics teacher commented that the long spaces at the back of the classroom were conducive to illustrating long chain molecules or electrons in a wire. More constraining was the pressure of time, with teachers specifically citing concerns about upcoming exams.

Characteristics

In all cases, a drama approach was perceived in interviews to incorporate social interaction, humour, and a sense of fun, which students and teachers argued was atypical of their experience of traditional Science pedagogy. A key feature of these activities, identified in the observations, was the degree to which drama enabled teachers to draw students' attention and focus, first to the topic itself, and second, to specific conceptual, affective or procedural features which the teachers wished to emphasise.

Novel imagery

Attention and focus were particularly associated with novel or striking imagery, which was consistently employed by teachers. In analysis, this technique was interpreted with relation to 'eccentric objects and odd experiences' (Loi and Dillon 2006), and theatre director Bertholt Brecht's didactic technique: verfrumdungseffekt (Counsell 2001), the imagery was perceived as a means to develop student attention to the topic itself, and in respect to conceptual learning, also drew students' focus towards the relational features between the base and target aspects of the analogy (Gentner et al. 2001). Novel or striking imagery tended to be the result of odd juxtapositions between image and context. In the Young's Modulus case, for example, the teacher substituted the apparatus for the stretching of a copper wire with a scaled-up and theatrical apparatus for stretching one of the students. The teacher assessed later that the students had a greater understanding of procedural knowledge than through her traditional approach with a previous class.

Humour

These novel and striking images were invariably associated with humour, which was perceived by respondents as an important aspect of the atypical atmosphere, and was observed to enhance student attention. Types of humour identified included, puns, character-based humour, innuendo, self-deprication, sarcasm, religious humour, black humour, and physical humour. Humour created by the teacher was seen to provide an opportunity for drawing students' attention towards a topic, and to drawing their focus towards an image. Humour from the students was observed to allow them to be active participants within discussions and viewed as a way to elicit recognition from other students and the teacher through laughter.

Multimodality

Both verbal and non verbal modes of expression emerged as integral to perceptions of learning by both respondents and researcher. Viewed through a multimodal heuristic, the modes of discourse observed in these activities correlated with Kress and Leeuwen's taxonomy of: external sensation (sight, sound, touch), internal sensation (spatial, affective), imagination, and social interaction (2001). Through observations, corroborated by teachers' stated aims, and students' recall of the central learning features, it appeared that the use of particular modes of communication highlighted particular aspects of knowledge: in the Limestone Inquiry, extended arm gestures revealed either single or double bonds within a group model; in the car crash models the Physics teacher asked students to enact, and so embody, the moment of impact; and the Biology teacher isolated and provoked a feeling of stress in students through a manipulation of time, genre, and character; the Head of Chemistry developed a narrative of himself as a bombastic, personified nucleus, whose bellows to electron suitors, of 'Don't leave me!' highlighted the moments within the reaction when electron transfer occurred, and seemed draw focus to these moments of chemical 'interaction'. Such examples revealed a sort of 'multimodal toolkit', from which teachers chose combinations of modes to focus on particular features of knowledge.

Observations and interviews with students suggested that their conceptualisations differed in relation to the mode through which knowledge was expressed. This was particularly noticeable in the Chemistry demonstrations of atomic and subatomic interactions, where students' responses corroborated observations that suggested a focus on space, movement and interaction. This contrasted with traditional diagrams and models, which produce visualisations that emphasise shape and colour (Theile and Treagust 1994).

Anthropomorphic analogies

The ease of understanding of these physical simulations was noted by all student interviewees. They argued either that it was 'easier', or 'better' than the diagrams on the board. This perception contrasted with the seeming messiness of the analogies, constructed through action within a noisy classroom, and with explicit reference to anthropomorphic analogies. The students' responses in interview appeared to reflect this 'messiness', through the intermingling of anthropomorphic and scientific imagery in their descriptions. However, when probed to explain how they visualised their conceptions, the students showed a metacognitive awareness that the activity represented a model, not reality. This was illustrated by a thirteen year old student after the electronic structure demonstration:

> *Now how does that help you understand what's happening at a microscopic level? Do you picture people at a microscopic level or…?*
> MMm no. No cause like I see it with the people then I like interpretate (sic) it into what it should be and then you can see it easier.
> *Okay. So what should it be?*
> Just small little particles that are represented by the people.
> *Okay. Are you, do you visualise a small particle?*
> Yeah.
> *So what does that look like?*
> Just a round, circle.

Another student stated that he too translated the 'human particles' into those of the formal diagram on the board. The explicitly anthropomorphic nature of the activity seemed to clarify that it was a model. By contrast it is not so clear whether the student understood that that the *diagrams* were models, i.e. representations of reality.

Thought experiments

The visualisation process indicated that a physical simulation strategy could enable students to make predictions of how processes and systems might develop, such as when one student gave an unprompted prediction based on her description of ionic structure as consisting of a nucleus (the teacher) and three students (the electrons):

> So ... if we had like 20 more people, he'd have no control over the one that's furthest away.

Although this statement was expressed in the anthropomorphic vernacular which was common in the interviews, it nonetheless suggested that the she had applied her new found visualisation to new applications.

Teachers did not explicitly ask students to apply drama models to new problems. The trend was for expression and illustration. As such, the characteristics of these activities reflected the traits of 'thought simulations' (Georgiou 2005): i.e. visualisation exercises that exist without an explicit hypothesis or answer. Interestingly, however, the teacher's *expected outcome* for the car crash models revealed that the students' expressed models were meant to support thinking akin to a TE in a later, written exam:

> So they're sitting in the exam, and they've got a question saying, you know, 'Why have seat belts? Why do we have airbags? Why do we have crumple zones?' And they can think, 'Right, I'm in the car, I've got my seatbelt, I've got to start over this long distance', and you sort of see it in your head: 'Oh the airbag, right I'm being stopped here where the steering wheel...'

Her response appeared to meet all three of Gilbert's criteria for a TE: that the design must support the attainments of a particular goal; that it must be based on prior experience and concepts; and that it should be internally coherent (Gilbert 2005: 65).

Discourse

As the study progressed, the potential for drama to enable discourse and dialogue within the Science classroom emerged as a central characteristic across all activities. When drama was used, the teachers were drawn towards employing patterns of talk and multimodal discourse which were atypical with the rest of the lesson. During the non-drama tasks in the lesson, the teachers tended to employ traditional didactic approaches of non-interactive/authoritative talk such as lecturing. However, when teacher-led simulation demonstrations were employed, the teachers adopted an authoritative/ interactive approach, marked by leading questions and rephrasing of student responses. This second approach was observed to employ multimodal expression (as opposed to traditional monomodal expression in Science (Heywood 2002)).

In those lessons which included collaborative group work, such as the medical rationing committee, the limestone decomposition activity, or the History of the atom performances, a third, dialogic/interactive form of discourse was evident. According to Kress's list, these activities seemed to increase the degree to which students could choose the modes of discourse. These were the most dialogic episodes across all cases. In group work, students believed that they had been given a high degree of autonomy over their learning. Interviews with Physics students suggested a sense of democratisation within the class, as one student illustrated with the car crash simulation:

> …the teacher might just have one idea but other students might have a different idea which would help you remember.

This comment reflected students' perceptions, in interview, of authority over their learning. This view conflicted, in this instance, with the teacher's perception that she was integral to the learning, because she had moved from group to group and discussed their emerging models. These conflicting responses revealed a dichotomy wherein both teacher and students believed that they were in control of learning;

The importance of performance

In the two activities in which students prepared for performance, the preparation phases were interpreted as dialogic. However, the nature of talk during the resultant performances was most similar to an authoritative/non-interactive category (Scott et al. 2006: 611), i.e. there was little dialogue at all, as students merely delivered their devised narratives. This suggested that the performances provided an impoverished learning environment, in comparison to the highly dialogic preparation phases. The performances, by standards of knowledge transfer, appeared redundant for learning.

Nonetheless, these performances provided a potentially powerful affective effect: the reward of approval from the class was indicated in the applause and laughter. Furthermore, some students had taken a passive role in the preparation stage, whereas they all took an active role in the performances. Therefore, in conjunction, the both preparation and performance were perceived to create a powerful learning environment.

Both the extended role plays and preparation and performance strategies seemed to engender student-centred dialogue, and both created an affective atmosphere which was perceived by respondents to enable learning by, variously, enticing feelings of autonomy, ownership and empowerment. According to the show cards, both strategies engendered perceptions of social interaction, imagination, conceptual development, and fun. Ultimately, the study found that the perception of the quality of learning did not appear to differ between the use of extended role plays and the devised drama activities. Rather, it indicated that the strongest effect on learning was not related to being actively in-role, but rather to the quality of the discourse.

Confined dialogism

Despite the scope for interactive and dialogic teaching encountered in the observations, the beginning and end of the activities consisted of didactic lecturing by the teachers. Even with the most dialogic activities, such as the car crash models, students were debriefed through an authoritative/non interactive format.

Assessment

Assessment within these activities was primarily formative, following Jones and Tanner's description of a functional assessment in which both teachers and students exist in a continuous process of feedback, and modify the activities in which they are engaged (Jones and Tanner 2006). Student self-regulation was a feature of this process. Both observations and interviews revealed that activities which include mime and/or engendered expressive body language provided a medium for non-verbal feedback.

Research model

At the end of the study, an idealised research model (Figure 3) was developed which incorporated three pedagogic routes, identified across the cases, consisting of authoritative monomodal, interactive multimodal, and dialogic multimodal teaching. The model begins with an authoritative frame, moves into interactive, multimodal demonstrations, and progresses towards dialogic, multimodal group work and whole-class forums in which the models are shown and discussed. Dotted lines in the figure below indicate the versatility of this model for adjusting the cycles of devising and sharing, depending on the teaching objectives. The lesson ends with the teacher demonstrating a 'summary' of the students' final models, and then finally relating students' ideas to the consensus, curriculum knowledge in the debriefing.

[Insert Figure 3 here]

Discussion

The findings indicate that drama is employed as a classroom resource (Neelands 1984) in some lessons in Chemistry, Biology and Physics, across a variety of schools and within different age groups. The observed drama activities corroborate Odegaard's assertion that educators tend to employ improvisational drama forms rather than use scripts (2003). The study revealed the prevalence of teaching objectives related to affective, cognitive, and technical knowledge. However, in contrast to an emphasis within the literature on affective learning and the use of social simulations (Dorion 2007), this study recorded a predominance of physical simulations amongst its sample. Given that this study was unique in its exploration of teachers' own activities and objectives, this suggests the possibility that the literature is not wholly representative of the activities and teaching objectives of 'everyday' teachers.

The role of role in physical simulation strategies

As the study progressed, the initial emphasis on role as an indicator for learning was re-evaluated. In an analysis of preparation and performance activities which employed physical simulation strategies, the dialogic discourse within the preparation phase and the non interactive authoritative discourse in the performances indicated that the presence of enacted roles did not entail dialogic environments. Within the context of the physical simulations, role seemed to be enacted internally during the preparation phase. Role seemed to be employed to provide a structure for visualisation, much as Einstein proposed that one imagines oneself 'riding on a ray of light' in order to visualise features of relativity (2000: 490). In this respect, physical simulations seemed to employ or adapt visualisation skills which are accepted features for communicating within science, if not the orthodoxy within Science education. As a sort of proposition of perspective, the use of role for learning through thought experiment-type activities in Science has not been the focus of research to date. This study indicates that role could influence the structure of future physical simulation approaches, and aid in students' development of their 'metaphorical imaginations' (Gilbert 2005:134).

Drama as a medium for analogical reasoning

The evidence indicates that physical simulations should be envisaged as supporting learning through complex analogies that are negotiated through a series of focussing activities or images. The complexity of the drama events are evident in observations of continuous combinations of implicit and explicit anthropomorphism, and the description of meaning through gesture, space, movement, voice, artefacts, body language, and rhetoric, between different classroom participants. Furthermore, these modes seemed to elicit meaning based on both their use of science and life-world (Solomon 1983) domain knowledge. Given that these drama activities involve such complexly described analogies, it is interesting to find students' statements of comfort, enjoyment, and self-perceived understanding in relation to these analogies.

Observations of students' ease in employing gesture, body language, movement and space to negotiate expressed models suggests the ease and availability of modes with which students and teacher can describe individual mental models to one another. From an analogical reasoning perspective, drama seemed to support the metacognitive ability of students to focus on key 'relational features' within analogies (Gentner et al. 2001; Goswami 1992), regardless of the seeming complexity of the whole analogy. In this respect, these 'alternative' analogies do not obfuscate meaning, but allow students and teachers to clarify it through dialogue in a shared medium. When words fail, there are other routes for expression of an idea. Juxapositions of certain modes were found to emphasise specific aspects of concepts. Within this context, a *multimodal toolkit* perspective revealed that the teachers would focus the discourse according to child-centred metaphors that could be expansive enough to describe a variety of features within a scientific concept, and that students could be guided to engage in discussions according to their available knowledge. This was especially clear in the teacher's demonstrations, such as the narrative of the nucleus and his electron suitors. The teacher's role, then, became one of mediation, of guiding students towards metacognitive, collaborative group work, in which the students themselves were seen to use drama features as focussing devices.

In an echo of the majority of literature on cross curricular drama, the findings suggest a strong affective benefit to students: in that through describing their own ideas about science, using novel techniques to create personal expressions, they were observed to take a greater degree of ownership over their learning. Students appeared to be empowered in these environments which allowed for personalised expressions, and where successful expressions could include non Science, as well as Science, indicators. This reflects a third important feature: a sense of community which was revealed through students' descriptions of their collaboration, and in particular, observations of humour and laughter, which I interpreted as positive, supportive social interaction which helped to reinforce the identity of the group.

The school context

This study was conducted with a small convenience sample. This leaves open the question of whether the school contexts influenced the chosen modes of interaction. Were these schools particularly conducive to or supportive of drama as a classroom resource in Science? The findings suggest that classroom layouts with limited space, time pressures related to exams, and traditional constructivist teaching perspectives seemed to contribute to school contexts which tended to be more restrictive, rather than conducive to drama methods. Within the sample, departments and colleagues gave passive support, but the impetus for using drama came from the Science teachers themselves.

Rather than school context, teacher interviews suggested that the greatest indicator that drama would be used was related to the teachers' positive personal experience of drama in education in the past. This would seem to indicate the scope for a greater breadth of drama in Science to be discovered through further research. Given the indications in the literature review that more teachers have been exposed to the teaching of Science through drama over the past decade than previously, and given that even the pilot interview revealed previously unrecorded activities, a trend that was corroborated within the study, there seems to be potential for other teachers to be using drama as a classroom resource. Therefore there may potentially be many more drama activities, teaching objectives and drama forms to discover in use within secondary science.

Conclusion

The emergence of discourse and visualisation as key features in drama in Science provides a focus for future research to explore the scope for different discursive and modal combinations within the classroom. In a subject in which there tends to be little dialogic discourse (Scott et al. 2006), drama may provide interventions to promote dialogic learning in relation to Science-specific objectives. Drama's multimodal characteristics highlight imagination and embodied knowledge, the latter of which has gained in significance as education moves from primarily visual towards more 'virtual' worlds of learning (Kress et al. 2001; Ihde 2002; Bresler 2004). The drama activities in this study indicate that more use can be made of non visual sensations in order to promote cognitive learning. Research in this direction might explore the use of soundscapes to describe the there-and-not-there quality of electrons within a cloud model of the atom, or the devising of role plays of human behaviour that reflect aspects of non-human phenomena (Wilhelm and Edmiston 1998). In this context, this study supports an assertion that analogies, models and metaphors in Science should be judged according to the richness of their metaphors, and the extent to which they can be shaped to facilitate discourse between students and teacher (Heywood 2002; Aubusson and Fogwill 2006; Ametller et al. 2007). As such, drama-based approaches may be viewed as a potentially rich classroom resource for interactive and imaginative learning.

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FIGURES

Debates	Simulations	Socratic questioning
Teacher-in-role	Students-in-role	Scripted skits/plays
Writing-in-role (Diary)	Hotseating students-in-role	Comparing inanimate objects to people

Figure 1 'Drama activities' show card

Social Interaction	Motivation	Kinaesthetic
Mnemonic	Imagination	Fun
Conceptual Development	Student-centred	Focused Work

Figure 2 'Characteristics' show card

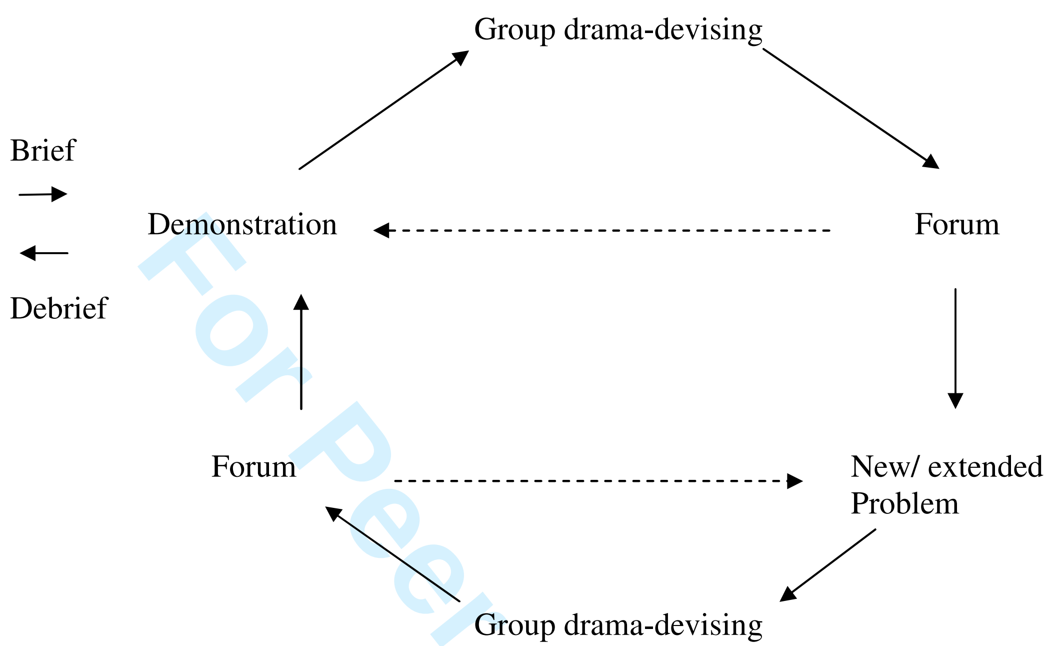

Figure 3 An idealised model of a physical simulations strategy

Tables

Themes	*Relating to*
Assessment	Teachers' assessment of student learning
	Students' assessment of peers' learning
Activity	Descriptions of drama forms and techniques, frequency of use, and topics for which they were used
Background/Inspiration	Descriptions of past lessons, teaching objectives and perceptions of teaching and learning in general
Aspects of Learning	Perceptions of the learning which occurred during the drama activities
Practical Features	Issues of classroom management and classroom layout

Table 1 Case and cross case analysis themes

Date	County	School	Subject	Year	Class size
16/05/2006	Hertfordshire	Comprehensive state school	Chemistry	10	26
24/05/2006	Kent	Selective state school	Chemistry	9	26
13/11/2006	Cambridge	Boy's selective independent school	Biology	10	24
20/11/2006	Cambridge	Comprehensive state for ages 15-18	Physics	12	20
13/12/2006	Cambridge	Comprehensive state for ages 15-18	Physics	12	18

Table 2 Schools and classes within the study sample

	Stage 1	Stage 2	Stage 3	Stage 4
Method	Teacher pre-observation interview (45 min.)	Lesson observation (1hr 20min- 1hr 40min)	Teacher post observation interview (45 min.)	Student post observation interview (20 min.)
Structure	Semi-structured	Open-ended and unstructured	Focused and semi-structured	Semi-structured
Rationale	Provides context for student learning and knowledge	Interpretive; highlights important moments during the intervention triangulation with teacher and student perceptions	Utilises experiential knowledge of the teachers; narrow focus on case activity; triangulation	Triangulation with teacher interviews, and observations
Specific Resources	Show cards	Video	Stimulated recall with video for teachers	Show cards

Table 3 Fieldwork stages

	Interactive	Non Interactive
Dialogic	Interactive/ Dialogic	Non-interactive/ Dialogic
Authoritative	Interactive/ Authoritative	Non-interactive/ Authoritative

(Scott 2005: 17)

Table 4 Scott's matrix of classroom talk

Discourse	*Example*
a. Interactive/dialogic	Teacher and students consider a range of ideas. If the level of interanimation is high, they pose genuine questions as they explore and work on different points of view. If the level of interanimation is low, the different ideas are simply made available.
b. Noninteractive/dialogic	Teacher revisits and summarizes different points of view, either simply listing them (low interanimation) or exploring similarities and differences (high interanimation).
c. Interactive/authoritative:	Teacher focuses on one specific point of view and leads students through a question and answer routine with the aim of establishing and consolidating that point of view.
d. Noninteractive/authoritative	Teacher presents a specific point of view.

(Scott et al. 2006)

Table 5 Examples of dialogic and authoritative discourse

Activity/Topic	**Subject**	**Age**	**Simulation strategy**	**Corresponding or analogous drama activity**
Medical ethics committee	Biology	13-14	Social	Consensus conference
Electronic structure of ion	Chemistry	12-13	Physical	Drama analogy
Car crash models	Physics	15-16	Physical	Drama model/devised
Limestone reactivity	Chemistry	13-14	Physical	Drama machines
Limestone demonstration	Chemistry	13-14	Physical	Drama machine
History of the atom performed dialogues	Chemistry	12-13	Social	Historical role play/devised drama
Young's Modulus	Physics	15-16	Physical	Drama analogy
Teacher in caricature	Chemistry	12-13	Physical	Teacher in role

Table 6 Observed drama activities across all cases

Activity	Subject	Year or Key Stage	Strategy PS: Physical Simulation SS: Social Simulation	Corresponding Drama Activity
Bioaccumulation	Biology	12-13	PS	Drama Analogy
Zeolites	Chemistry	13-14	PS	Drama Analogy
Mass Spectrometer	Chemistry	15-16	PS	Drama Machines
Democritus	Chemistry	12-13	SS	Historical role Play
Electrolysis	Chemistry	13-14	PS	Drama Machine
EMF	Physics	15-16	PS	Drama Analogy
Wavelengths Demonstration	Physics	15-16	PS	Mime
Wavelengths Whole Class	Physics	15-16	PS	Mime
Nephron	Biology	13-14	PS	Drama Machine
Committee on RDA	Biology	13-14	SS	Consensus Conference
Limestone reaction	Chemistry	13-14	PS	Drama Analogy
Limestone reaction demonstration	Chemistry	13-14	PS	Drama Machine
Hydrocarbons	Chemistry	14-15	PS	Drama Machine
UN conference	Chemistry	14-15	SS	Consensus conference
Wavelengths	Chemistry	A-level	PS	Mime

Table 7 Reported activities