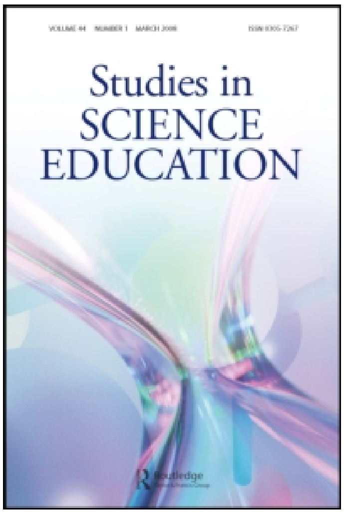

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Dramatic Science. A Critical Review of Drama in Science Education

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Dramatic Science. A Critical Review of Drama in Science Education

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INTRODUCTION

> '...the purpose of playing, (...) was and is, to hold, 'twere, the mirror up to nature; to show virtue her own feature, scorn her own image, and the very age and body of the time his form and pressure.'
>
> From Hamlet's speech to the actors, act 3, scene 2, in Shakespeare's *Hamlet*.

'Theatre' and 'theory' have a common etymological root in the ancient Greek verb 'theorein', which means: to see, to view, to behold. The *theoria* in ancient Greece viewed the dramas of everyday situations and extracted truth (Henry, 2000). This kind of knowing, attempting to draw universal generalizations based on specific observation, is also viewed as a key epistemological feature of scientific explanations (Leach and Scott, in press). What other connections may we find between these two remote fields? Can they possibly interact, with benefit for science education? There is evidence that the use of drama in a well-considered manner, guided by reflective science teachers, may provide empowering learning environments for students.

The aim of this article is to examine how drama and theatre activities may enhance learning in science education, by creating a learning situation that is significant in the lives of students. I offer a structured survey of different science and drama projects, together with theoretical reflections on the use of drama in science classrooms. Some of the projects I report on are not written papers, but self-experienced activities, internet-resources or informal written pieces. Though some might question the use of such material, I have chosen to make use of them, so as to show as broad a spectrum of ideas and practices as possible. It seems appropriate that, in a field such as drama which, of its nature, is immediate and lived, such material should not be excluded. The field of drama in science education is neither highly theorized nor highly researched. So while this article endeavours to review the work that has been undertaken in this field, it is not a conventional research review: it gives attention also to examples of the use of drama which can be identified, and places them within the framework of possibilities which I will offer in the following section.

Let me begin with a self-experienced example of how science, theatre and drama can intermingle and be mutually enriching.

Gen-Gangere – an example of drama in science

In this work, some drama students were challenged to look at their own understanding of biotechnology, compare it with a study of the public's opinion and develop it into a play. They were also challenged to use the universe of the playwright Henrik Ibsen as a framework (Ødegaard & Øiestad, 2002). What would classic role figures, like Nora from a *Doll's House*, Hedda Gabler and Peer Gynt, have thought about this modern technology? What did the students, young people of today, think, and why? How much did they actually know about biotechnology, and what about it was relevant for them? In this activity a meaning-making process with scientific and philosophical content was given a historical and universal dimension.

The *Gen-Gangere* (*Gene Ghosts* in English, or literally translated: 'gene walkers') project was a collaboration between a drama educator, his students in upper secondary school and a science education researcher. It was based on research about the public's images and associations related to the expression 'modern biotechnology'. By combining quantitative and qualitative results of analysis, categories of peoples' relationship to the new technique were made, and formed a structure which the drama students could explore. For instance; three of ten roles had negative attitudes toward biotechnology, reflecting approximately the proportion (31.9%) of the Norwegian public taking this view. Of these, one has little education and unfounded opinions, one is educated and mistrusts scientists, and one is educated and has ethical and philosophical objections. The aim was to find an Ibsen role figure to fit each category, and use these role figures as a cast of characters for developing a play. In this way the students had to find out more about biotechnology and explore their own opinions about it. They were forced to look at Ibsen through a different lens. Different Ibsen figures were related to the present time through the new science. In the play you hear the voice of Ibsen, the students' own voices, and the voices of the Norwegian public, all related to modern biotechnology.

Textbox 1. Example of a line from 'Gen-Gangere', using both Ibsen's and the students' own words.

> BRANN (priest):
> *Osvald, you carry the rare gene of a heritable and lethal disease. Where did you get it? Is it a ghost? The original sin? Who is your father? How can this be punished? You must not spread your seeds. Lock him up!*

Drama and theatre focuses on interpersonal interactions. Ibsen created role figures with personal conflicts that people recognize and still to this day can relate to. That is why he is a classic author. By using these figures in connection with science, and seeking to preserve their inner character, the students managed to create, through the role figures, a meaningful relationship to modern science.

Science as an education for all

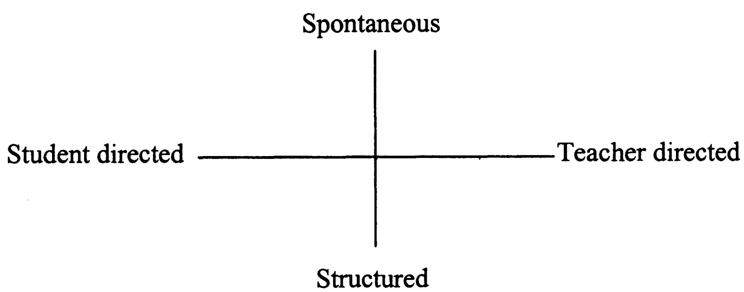
There is an ongoing discussion in the science education community about what it implies to have a science education for all. There has been a focus on perspectives of gender and equity (Baker, 2002; Brickhouse, 2001; Howes, 2002), poverty and urban environments (Barton, 2002; Kyle, 1999), culture and language (Lynch 2001; Aikenhead & Jegede, 1999), and socio-cultural and student-centered learning (Lemke 2001; Duschl & Osborne, 2002). There seems to be some agreement that 'science for all' does not necessarily mean 'one size fits all' (Lynch, 2001). In order for science education to change from just passing on a hegemony of uncritically learning about scientific concepts and products (conceptual change), to an agency for self- and social empowerment, based on children's own life-experiences, there has to be increased attention to political and social aspects of science (Kyle 2003). Sjøberg (1998) presents science as general education (a science for all) in three dimensions: science as a product, science as a process, and science as a social institution in society. School science has concentrated traditionally on the first dimension, science as a product, and thus on passing on science's conceptual structure. Sjøberg argues that in order to contribute through science to a general education, meaningful for all, there must be a different balance between the three dimensions. In congruence with Kyle, Sjøberg suggests putting more emphasis on the latter two of his categories. In this paper I will base my account on all the three. Though making scientific concepts come to life through the use of a dramatic model of them is not uncommon, it is particularly in addressing the nature of science and science in a societal context that drama has a lot to offer science education. It is in this area that, in general, drama seems to be an untapped resource in the science classroom.

The 'Gene-Ghosts' project does not easily fall into any one of the three categories, but embodies all of them in an interrelated way. The activity's value lies in the richness of the personal encounters with science which it promotes, involving multiple personalities and multiple voices. The drama students wished to explore and communicate how science may intervene in different ways in our lives. It was their way of giving science meaning: that is the underlying theme of this paper.

FORMS OF DRAMATIC SCIENCE IN THE CLASSROOM

Dramatic activity may vary and take many different forms in the classroom: in this section I identify some of the dimensions along which it varies. The drama may be structured in a way where students enact roles within the known framework of scientific theories: for instance playing electrons in a circuit to illustrate the scientific concept of electricity. The dramatic activity may be impulsive, creating the moment, as it were; students have to improvise who they are and what to say. At any point along this continuum a drama can be more or less spontaneous. An intermediate form could be an improvised role-play with a structured frame (e.g., role cards that describe the participating roles). Another continuous variable is the degree of teacher involvement: that is, whether it is the teacher that impels the drama or the students. A group of students who create their own model of a scientific concept are together reconstructing knowledge so as to enhance their conceptual understanding. In order to guide the students, it may sometimes be necessary for the teacher to provide scaffolds in complicated scientific matters. A similar four-way continuum is offered by Brown & Pleydell (1999), and a re-worked version of there approach is presented in Figure 1.

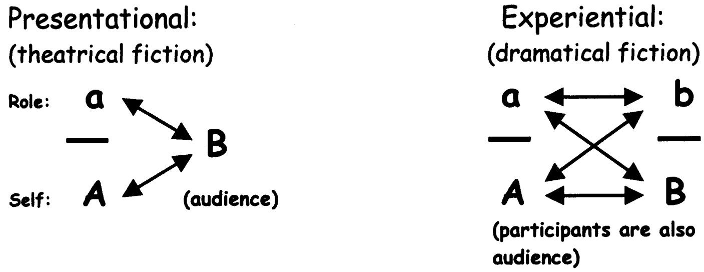
Figure 1. The forms of organization in 'dramatic science' activities.



Dramas may also be categorized according to whether they are presentational or experiential (Schaffner, Little, Felton & Parsons, 1984). Figure 2 offers a representation of this grouping, drawing also on Szatkowski's idea of 'aesthetic doubling' (see Ødegaard, 2001). The presentational dramas have a major emphasis on communicating something to others outside the drama (e.g., teacher, peers, or parents). When a small group of students dramatize a scientific concept (e.g., the 'meiosis ballet' below), the intention is often communication to others. The experiential dramas focus on attempting to live through some aspect of an experience and adopting a motivation, opinion or attitude (e.g., a role-play with role cards about ethical issues in biotechnology).

Depending on which scientific issue is in focus, the teacher decides what the nature of the drama should be. In each case, however, the ideal is to optimize the students' degree of spontaneity and creativity, in order to encourage them to think critically and vividly about the issue in focus, and thus offer possibilities for materializing their understanding. Instead of merely transmitting knowledge of science from the science textbook or from the teacher, it has to be re-worked and re-constructed by the students. The language (including body language) is used as an interpretive system (Sutton, 1996) for persuading each other of their view.

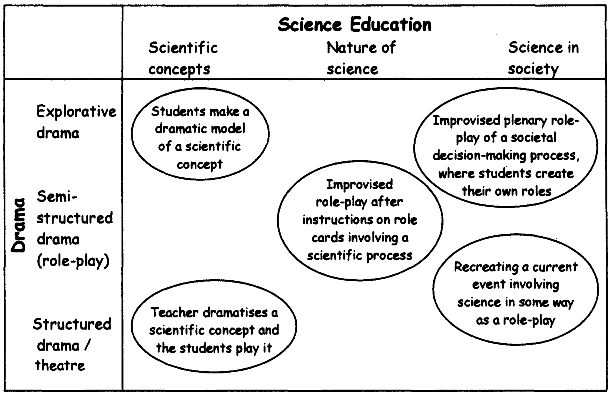
Figure 2. Aesthetic doubling (Szatkowski, 1985) in a theatrical fiction vs. a dramatic fiction.



The teacher's role can be as an active agent directing the drama, or less active, as merely giving frames for a role-play and observing passively. Science teachers are seldom actors, but acting skills appear not to be a necessary requirement! The invaluable role the science teacher plays is guiding the students in their reflection after a drama activity about how their experience relates to their own life and their relationship to science (see Ødegaard, 2001; Ødegaard and Kyle, 2000).

The remainder of this paper is structured around the three different aims identified earlier and due to Sjøberg: understanding scientific concepts; understanding the process and nature of science; and understanding the scientific community and culture and its effect on society (see Shamos, 1995; Sjøberg, 1998). I have chosen to structure the relationships between these three perspectives and the nature of drama as shown in Figure 3. The nature of drama is multi-faceted, so reducing it to one continuum is not easy. When drama is depicted on a continuum from structured to explorative, it is implied that a structured drama/theatre most often is initiated and directed by the teacher (or actors) and is presentational (in the theatre there is an audience). Explorative drama is spontaneous, often student-driven, and experiential. In the following I introduce examples of science and drama projects under the headings of each of the three science education perspectives. Under each heading, an attempt is made to present them in order of increased dramatic freedom.

Figure 3. An overview of how drama may be used in science education.



SCIENCE AS A PRODUCT

Dramatizing science concepts

School science has historically focused on learning scientific facts or on the products of science (e.g., conceptions, theories, laws, models). The dramatization of this material can often be undertaken merely to enliven what might otherwise be a rather dull lesson, but it can, in the process, transform the teaching-learning process. The process of transferring the model or description from the text-book to a three-dimensional live model requires the students to reconceptualize their knowledge. Research identifies students' increased understanding, and the teacher's increased ability to assess students' understanding immediately, and informally in the course of using drama in science (Bailey & Watson, 1998; Kamen, 1996; Linfield, 1996; Tveita, 1998).

Tveita (1996, 1998) created a drama model of electricity that he used with teacher education students and students in lower secondary school. This is an experiential drama structured by the teacher. The model gives the students concrete and personal experience with the representation of voltage, current and resistance, and it helps the students develop a better understanding of these basic concepts. These results are supported by Palmer (2000) and Carlsson (2002). Carlsson developed a structured dramatization of photosynthesis in order to facilitate students' understanding of the particle model and material transformation. She argues that this is possible because the drama creates amusement, engagement and activity amongst the whole student body. In another dramatization of a scientific concept, a science class performs a meiosis-ballet; a highly structured model produced for presentation (see van der Kooij in Ødegaard, 2001).

Bailey (1994) produced a dramatic model of the complicated interplay in an eco-system. This is an experiential and semi-structured drama. The rules of the activity are set, but the children will strongly influence the form and outcome. In this role-play game, children play the roles of different organisms in an ecosystem. The role of the sun provides energy in the form of a card, which can be passed around in the nutrient web. When a role receives an energy-card a mark is placed on it, but it must be given away if someone higher in the food chain wants to eat it. By reading the energy-cards, students can afterwards recapitulate how energy flows through the ecosystem. In this way, the ideas of food chains, webs and the cycling of nutrients are dramatized. During the role-play the participants may stop and reflect on problems that occur, articulate them by using the scientific expressions introduced, try to solve problems aided by careful questioning by the teacher, and reflect on how *The Ecogame* relates to their view of nature.

Even though the children are distanced from their roles (humans are not a part of the nutrient web involved), Bailey and Watson (1998) suggest that once they have experienced a personal involvement in a living system, the affective domain has been brought into play and a sense of responsibility in environmental matters may well be initiated. Further, if students can appreciate that their actions as humans can materially affect the living system they have collaboratively modeled, then they may construct an understanding of the unity of all living beings and life processes and see themselves as part of the global community. In this way, through *The Ecogame*, Bailey and Watson claim to enhance emotional involvement in the development of mental models of living systems. Preliminary evaluation indicated that *The Ecogame* approach enhances children's understanding of ecological concepts (Bailey &Watson, 1998).

Interactive plays are other examples of semi-structured drama activities where children together with actors model or explain scientific concepts (Baird, 1997). Again the actor/teacher frames and strongly guides the learning situation.

Students can also use improvised drama to synthesize what they learn in a science course (Kase-Polisini & Spector, 1992). Kase-Polisini and Spector suggest that in the course creative drama was initially intended as an evaluation tool to assess whether or not students had synthesized and internalized their experiences. As the creative drama process unfolded, the science staff discovered the process to be a dynamic diagnostic tool for identifying students' conceptions and a vehicle for enabling students to revise their conceptions to fit with currently accepted scientific knowledge. This harmonizes with findings of Linfield (1996) and Kamen (1991, 1996), where drama as an assessment tool is discussed.

Assessing dramatizations

The process of designing and presenting a representation of their conceptions enables students to think about the concept in a way that is meaningful to them; they become 'owners' of the idea. During the process the teacher may gain insight into the students' understanding of the concepts and carefully support them, enabling instruction and assessment to occur simultaneously.

It might be argued that using creative drama to assess science places too great an emphasis on creativity, rather than scientific understanding. Yet creativity is indeed part of what is understood by science (Bronowski, 1975), and ought to be both developed and assessed in the context of science education. Moreover, our assessment techniques should be congruent with our teaching techniques, including the most imaginative. Kyle (1997: 852) has put the point well:

> 'Assessment ought to be oriented toward what we value. Assessment, in the context of the total teaching-learning process, ought to be epistemologically sound; the richness of the learning process ought to be reflected in the assessment protocols; and the quality and value of the total education and science experiences ought to be evident.'

Visualizing a science concept story

Bruner (1986) describes two complementary modes of thinking which are important ingredients in our rich world of cognition. We use one of them when we tell and understand a good story: the narrative mode. The other is used to form a good argument: *the paradigmatic* or *logico-scientific mode*. An argument intends to convince us about truth with the help of formal and empirical evidence, while stories want to convince us of their life-likeness, and thus give meaning in an other way. A teacher may use the narrative mode when teaching science, offering a contextualized story of science (Stinner, 1995), or tell a 'science story' when giving a scientific explanation. Ogborn, Kress, Martins & McGillicuddy (1996) describe scientific explanations as being analogous to stories in the following way:

> 'Firstly there is a cast of protagonists, each of which has its own capabilities which are what makes it what it is (protagonists might include entities such as electric currents, germs, magnetic fields and also mathematical constructions such as harmonic motion and negative feedback); secondly the members of this cast enact one of the many series of events of which they are capable; lastly these events have a consequence which follows from the nature of the protagonists and the events they happen to enact.' (9)

This may very well be an account of the making of a drama model of a scientific concept. A drama model is a visualization of a scientific concept story, where students play the parts of protagonists. Using Tveita's example (1996), the students enact electrons and batteries and their instructions on how to act and react are analogous with the protagonists' capabilities. The drama starts when the students enact an event, the electric current, which can be varied in different ways, according to the electrons' movement and the battery's capability. The different outcomes of these events are then discussed as consequences of the interaction of protagonists and the context of the event. This last discussion, stepping out of role and reflecting upon the different outcomes, is important if the students are to understand the key aspects of the scientific concept. They use the language of the 'story' (e.g., electrons, current, circuit, resistance) to describe what happened and to describe what they think *might* happen in a hypothetical situation. If the students are able to participate in such a discourse, then they demonstrate to themselves and the teacher that they have understood the concept. Since it is based on the students' own shared experience, the learning environment may easily convey an anti-authoritarian tone. Arnold and Millar (1996) contend that the story-based approach leads to improved learning. It introduces characters (protagonists) with different capabilities that can lead to different events, in a way which is typical of a narrative.

THE PROCESS AND NATURE OF SCIENCE

Scientific processes are centrally concerned with scientists' experimental and conceptual work, both in the laboratory and elsewhere (Knain, 1999a). The students' only experience of this is often through pre-designed laboratory exercises, which do not authentically reflect the scientific process. In particular, the important communication process between researchers, in which discussion and debate occurs, is seldom mentioned. In addition 'the nature of science' is a contested domain (see Alters, 1997; Jenkins, 1996). However, once given insight into a set of science stories, students will have the opportunity to understand that the nature of science is not the same as pre-designed laboratory exercises. Through stories of science and experiences in enacting scientists, students are offered more possibilities to gain insight into the reality of the process of scientific practice. Many students find drama methods lively and stimulating, and thus more memorable (Christofi & Davies, 1991). They give a sense of the richness and complexity of the events they relate to, beyond that of simple textbook or other written accounts.

Stories of science

Histories of science can provide much knowledge about the nature of science. Students may gain an appreciation of the interactive nature of science and see experiments as trying out explanations, rather than mere positivistic empiricism (Solomon, Duveen, Scott & McCarthy, 1992). Through stories, science emerges as a human endeavour, and students are offered insight of the importance of creativity within science processes.

In 1998, I had the pleasure of meeting the historical figure 'Edward Jenner', and listening to him describe how he conceptualized the idea for the smallpox vaccine. An actor embodied the scientist and drew a picture for us of a scientific process in historical light.[1] The story showed us an interactive process of experiment, theory, and discussion with fellow scientists. Because it was an interactive performance, the audience (usually children, but this time science teachers) was able to question Jenner about experiments that he had done and compare them with those which could have been done today. Ethical aspects of medical science were also discussed with this 'historical scientist', and because he was situated in a different era, insight was offered with respect to ethical standards at that time. Looking at a historical film or reading a science story also gives valuable information and insight into science processes, but the drama method of an 'actor-teacher' as a historical person provides the students with the possibility of a critical dialogue with the past. The drama is structured by the actor-teacher, but because it may be influenced by the students' interactive dialogue, there is a greater prospect for the students to feel ownership of the knowledge in the learning situation.

The nature of science may also be revealed by a role-play of a historical trial. The trial of Galileo and a supposed trial for blasphemy of Charles Darwin are examples of episodes of science which have been developed as role-plays 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. The role-play presents a learning opportunity which focuses both on scientific epistemology and scientific personality. Instead of an abstract schema of 'the scientific method,' science is portrayed as richly personal, and students are encouraged to understand it as such by the empathy generated. It is claimed that it is precisely by following scientists as people that we best learn about the nature of the science that they carry out (Duveen & Solomon, 1994; Fuller, 1988). In a partly improvised role-play organized as a trial there is a lot of opportunity for students to engage in critical thinking. They scrutinize and challenge each other's roles and perspectives, and in this way the historical science process generates empathic understanding. Gaining critical insight into what this historical process may tell us about science today is facilitated by a shared experience, though it is reliant on the science teacher.

Another advantage of role-play is that newly acquired knowledge about evolution and natural selection (either learned in traditional science lessons or in dialogue with fellow students motivated by the play) is activated by exercising it in the improvised role-play. The use of learned concepts encourages their assimilation and retention. Finally, argument is brought into the science classroom. As one teacher comments, 'They (the students) actually see that the cut and thrust of scientific debate has a real meaning in the real world' (Duveen & Solomon, 1994: 581; Duschl & Osborne, 2002).

Students as scientists

To get critical insight of a scientific process, students may also enact more sociological versions of the process. Dorothy Heathcote, an acknowledged authority in drama education, developed the technique 'mantle of the expert', and had children (8-9 years old) playing scientists trying to find a cure for cancer (Heathcote & Bolton, 1995). The result is a highly explorative drama activity where the students have significant freedom to affect the play, but where the teacher gently guides, to keep the focus and tension. The children started by designing a place to work and conceptualizing what a scientist is and does. They further received a limited amount of funding from the 'President' to work on a project in Mount Fujiyama. The students made an imaginary journey and arrived at a mountain where they discovered some precious, but dying, plants. The plants became a metaphor for dying cancer patients, which the children readily accepted as they began the cancer treatment process. The metaphor was introduced in order to protect the students emotionally in the drama, because dying plants are easier to deal with then dying humans. A sick plant guardian represented the link to the human cancer problem. Another important reason for the plant-metaphor is that it made the children 'real' experts. They had knowledge of plants and how to treat them, but in the case of cancer they could make up a fantasy cure. In this drama-adventure the students perhaps did not learn a lot about cancer and medical research; but they learned about scientists, how they work and the meaning and issues associated with funding.

Another explorative drama, in science-fiction mode, is the 'researchers in a spaceship' drama developed by David Sheppard at the Drama and Tape Centre, London, UK. The students enact the roles of researchers from another planet that has just exploded: they wonder if they possibly can live on planet Earth. With an anthropological perspective, the students study and describe life on Earth. Distance to earth-life is established, both physically and metaphysically, so the students are free to create and fill their own expert/researcher roles. This offers several advantages: the students can re-invent the process of research for their own purpose, and may eventually discover the usefulness of scientific methods. The students are challenged to develop scientific creativity. Because of the fictional setting, the students can make real discoveries of known material. For instance, they discovered the term 'blood-red' in some written material, and had to make inquiries in order to verify as a scientific fact that 'earthling' blood was red. They also had to write a report on the findings to their commander. Being aliens, the students had a *need* to know. Drama strategies could readily be employed to make all this knowledge immediately *applied* knowledge, and indeed, to identify for the teacher the learning that has taken place.

The 'researchers in a spaceship' project is an example of a drama-version of the Storyline method developed in Scotland and in Denmark (Eik, 1999). Storyline is an interdisciplinary and a problem-oriented educational activity where students learn by discovery, reflection and action. The students and the teacher make a theme-story together and develop a fictitious world that is populated by people with whom the students identify.

SCIENCE AS AN INSTITUTION IN SOCIETY

Science and drama for action

Classroom dramas are beneficial for focusing on the science in society dimension in science education. Just as a well-known method in science is to make a simulation in the laboratory of a phenomenon in nature, so it is possible to simulate societal processes that relate to science, for instance an international environmental conference, a consensus conference, or some other democratic processes. The real world is brought into the classroom in the context of practical action. Divergent interests and ethical conflicts are essential to decision-making processes, as is also shown in all good plays and dramas. In role-play the conflicts, combined with the personal relations the students develop to the issue, makes them able to act (Boal, 1977: 1998). Students explore situations that create empathy and identification: thus both thoughts and feelings are stimulated and give room for action. Science is recontexualised to a situation where it has human scope and force. It thus offers the opportunity for students to reflect upon the subculture of science in relation to their own world view, as well as to see the subculture of science against other subcultures (e.g., economy or bureaucracy; see Aikenhead, 1996; Cobern, 1996; Ødegaard 2001). The cross-curricular potential in drama gives the opportunity for a style of learning that does not break knowledge and skills into artificial units, but permits exploration of the world using whatever medium is appropriate. Students develop the ability to explore the world, and through the practice of action-taking they potentially acquire competence to transform the world and create the future (see Boal, 1977; Freire, 1972).

Issues involving the role of science in society are often marked by conflicts of interest, relating to theoretical, environmental, economic or political issues. Role-play may be an arena for the interest groups to meet, exchange arguments and perhaps educate each other. In these settings, as Jenkins (1994) has noted, traditional science is challenged in favour of a science grounded in action:

> '[Scientific] knowledge is to be accommodated alongside other knowledges, is seen as inseparable from institutional and social connections, and is esteemed less by reference to its universal validity than by its usefulness in addressing the problem in hand.' (608)

Role-plays may be based on conflict situations. Dorf (1994) distinguishes between intermediate conflicts (misunderstandings), personal conflicts, interpersonal conflicts, structural conflicts and the individual's and society's conflict with the environment. Plenary role-plays may address interpersonal and structural conflicts. They may also reveal misunderstandings. Role-plays are enriched if they include personal conflicts. Such conflicts add an emotional dimension to the play, which is valuable in cognitive reflection (see Ødegaard 2001). Littledyke, Ross and Lakin (2000) introduce a study case of how drama can be used to explore a social context where the care of the environment competes with the need for employment. The study was reported to result in high levels of interest and motivation, and better and more complex understanding of science concepts and reasoning.

Emphasizing conflicts does not make science lessons easier for science teachers. Jenkins (1994) maintains that this form of science at school presents

> '...formidable challenges to science teachers who may be asked to abandon existing and familiar practices in favour of strategies which involve engagement with issues which, like most "real" issues are controversial, messy and have to be brought into focus only to lack a unique or even (initially or eventually) an agreed solution.' (607).

It is important that both teachers and students are aware of the difference in science lessons concerning scientific knowledge and science lessons where the participants actually cross into the culture of social science, where science is looked upon as a societal phenomenon, and where the goal is not to find the best explanation but to explore multiple perspectives.

Dramas of science in society

Dramatic literature draws upon science as a settings and as a source for personal and societal conflicts. Seeing a professional play can not be considered a drama activity in the sense which I am using the term here, but professionally performed theatre draws upon the same means and gives room for students to identify with the characters and to see science in a contextualized way. A performed play may be involving but not explorative to the students. However, they may explore the situation afterwards with the professional guide of a teacher (Giroux, 1988; Shor, 1992). For students to perform a scripted science play will of course involve them more, and encourage them to reflect about what they want to communicate (Braund, 1999; Szatkowski, 1985).

Y Touring Company (http://www.ytouring.org.uk/) is a professional theatre group that has written plays with the focus on science and its implications in society. Based on ideas of 'Theatre in Education' (TIE) (O'Toole, 1976; Jackson, 1993), Y Touring developed and produced five 'Theatre of Debate' productions, between 1995 and 2000, about contemporary biotechnology and bioethics for school students. Each play is followed by a debate and supported by an educational resource pack. The plays are reported to have a positive impact on the students' attitudes, understanding and knowledge (Evaluation Associates, 1998). The biologist Lewis Wolpert (1998) suggests that the plays are moving and engaging, and that this is an important and powerful way of bringing science to the people. Recognizing the advantages of drama, several groups have developed a health education programme for secondary school students, where the emphasis is on drama and discussion. They use Boal's (1977) drama techniques, enabling spectators to take part in the play's action as a practice for situations in real life (see Ødegaard 2001 for more about Boal and science education). The programmes were designed to educate the students in science issues as well as improve communications skills, the ability to feel empathy, and the empowerment of other people (Kerr & MacDonald, 1997; Riseborough, 1993).

A variant on these approaches was employed when the school system in Costa Rica introduced environmental education as a new subject. Here interactive radio instruction was used. The objectives were to support teachers in school, promote environmental ethics and encourage students, teachers, parents and community members to protect the environment. A soap opera drama, *The Econauts*, was developed, combining a carefully crafted and entertaining storyline with environmental information and proposed action in the community. The students were not involved directly in the drama, but it provoked debate. The approach was evaluated, and regarded a success (Vargas 1995).

Another way of using theatre to put science in the context of society, is exploring real events through dramatization. Event-centered-learning as an approach to teaching Science, Technology and Society (STS) issues is an example of using role-play and drama in reconstructing authentic incidents (Watts, Alsop, Zylbersztajn, & Silva, 1997; Cruz & Zylbersztajn, 2002). Events or circumstances from TV and newspaper reports, articles, books and popular accounts are investigated and given life again in the classroom. Occurrences are reconstructed by making, for example, an imaginary television documentary about a nuclear accident, or establishing a commission of inquiry to investigate the risks, costs and benefits of constructing a nuclear power plant. In order for the potential of this kind of explorative drama to be fully exploited, a class should not be satisfied with merely reconstructing a television documentary. The students would need to play the roles of critical journalists. Conferences, hearings, official consultations, international environmental conference and public inquiries are all activities which have been undertaken in classroom settings (Ødegaard, 1999).

Democratic processes involving science do occasionally lead to agreed solutions: consensus conferences are good examples, and examples exist of simulations or role-plays which offer a basic pattern for a science in society project (Kolstø, 1997; Sandberg & Kraft, 1996). These conferences seek to offer an informed piece of advice to the government on controversial issues, often with some scientific content, and consist of a panel of citizens and a panel of experts. The experts provide answers to questions the citizens are interested in, though it should be emphasized that the citizens set the agenda. Based on scientific information and comments from experts and their own discussions, the citizens strive to reach consensus on the issue in focus and document this in a report. Students, acting as citizens, can decide whether they want to use real experts, use older students as experts, or take on the role as experts themselves. In any case they would have to consider different interests, different ways of viewing the matter and experience the at-times painful process of reaching consensus.

In Denmark, Lars Klüver and Hans Erik Svart developed a role-play about an application to set out genetically modified Populus ssp (personal communication, May 1998). The different actors in the process were: the Ministry of Environment, industry, environmental organizations, researchers, consumer-organizations, farmers, and the media. This role-play was not made for school science, but for a conference about genetically modified plants, where the different political actors participated. In the role-play, the participants had to play other roles than their own in order to broaden their perspective and be forced to think and argue differently about the issues.

Another Freirian-based theatre, inspired by Boal, developed in post-colonial Africa is the project 'Theatre for Development' (Byam, 1999). It is based on traditions of communal performances, such as festivals around planting and harvesting, wars, ceremonies of power passages and personal rites like weddings and funeral. Here the assumption is that community theatre is performance about the people, by the people and for the people. The community engages in research, investigating their own ideas of development, which is the basis for the theatre. Thus, the play offers the participants a means of investigating and analysing their history, past and present, while also providing the forum for discussion and a practice of action. Both 'Theatre for Development' and Boal are influenced by Bertolt Brecht.

Science and new technologies which offer new ethical challenges, notably biotechnology, have also formed the basis for such work. Here ethical challenges often involve personal tensions, where, on one hand, there can be great medical, environmental or economical benefits, but, on the other, there might be great insecurities about the consequences and the moral legitimacy of such interventions. The decisions in these cases involve not only rational considerations, both scientific and moral: they are also strongly influenced by irrational or perhaps arational feelings and underlying (more or less conscious) ideologies (Knain, 1999b; Ødegaard, 2001). Can these various elements be disarticulated, and treated separately, or must they be understood within the full complexity of the lived situation? If the latter is the case, then the opportunity to participate in dramatic enactments of the issues can be offered as going some way to allowing this full complexity to be experienced, if only in a vicarious form. It may be argued that in science lessons one should only consider the rational part and leave the remainder for other experts. But this may be impoverishing school science. If students are to gain an appropriate level of understanding, they need to recognize that ethical decisions are complex. If the best preparation for making ethical choices is experiencing the complexity of reason and emotion and reflecting on the different parts, then role-play in dealing with ethical dilemmas can provide a tool for that purpose (Ødegaard & Kyle, 2000).

FURTHER ASPECTS OF DRAMA IN SCIENCE TEACHING

Research studies

In a survey of teaching styles, Christofi and Davies (1991) found that 70 per cent of students were enthusiastic about drama, but over fifty per cent of the teachers surveyed never used drama in their teaching. Secondary school teachers in particular hardly ever used this instructional method. Evidently, students are much happier with drama than teachers. If the view that drama has a positive effect on learning science can be sustained, then it seems there is a large unused potential here waiting to be tapped.

Nearly two decades ago Metcalfe, Abbott, Bray, Exley, and Wisnia (1984) conducted an empirical investigation of the effectiveness of teaching science using drama. While there was no significant difference in factual recall between the experimental group and the control group, experimental group students' ability to offer explanation and interpretation of concepts was significantly better. It was concluded that drama could help students to develop important insights regarding scientific concepts and promote meaningful learning. The study by Bailey and Watson (1998) of *Ecogame* involved experimental groups and control groups receiving traditional lessons. The experimental groups showed an increased level of understanding, particularly for the concepts of population relations and pyramids of numbers/bio-mass, which requires comprehensive biological understanding. Both studies suggest that drama enhanced students' ability to understand science in a holistic perspective.

The quantitative evaluation of Y Touring's play of mental illness, *Cracked* (Evaluation Associates, 1998) based on pre- and post-tests of over 2000 students, showed an increased level of knowledge and understanding of mental health issues after watching the play. Nursing students who developed health education programmes with the help of drama techniques displayed increased knowledge, as well as improved confidence, self-esteem, communication skills and group work skills (Kerr & MacDonald, 1997; Riseborough, 1993). Again, the greatest impact upon student performance is in the domains of higher-level cognitive skills and affective measures, rather than merely in factual recall.

Duveen and Solomon (1994) and Watts, Alsop, Zylberztajn, and de Silva (1997) used qualitative methodologies to evaluate the use of drama in science. The focus of these studies was science in the context of society. The most important observations were of high levels of student activity, expressed as 'broad debate' and 'interesting discussions', showing students taking an active part in their own construction of knowledge. It is argued that the students profit from exercising this newly acquired knowledge in role-play, and that the observations are consistent with constructivist learning and epistemology.

The studies referred to above suggested that when drama is used to create a model of a scientific concept (e.g., eco-system, molecules and change of state), students developed a deeper understanding of the concept. When drama is used to focus on a scientific process or science in relation to people or society, the central scientific concepts often take second place to the human drama. Some scientific knowledge is acquired, but the emphasis is on the affective domain (e.g., empathy, self-confidence, engagement and motivation). These qualities are not as easily assessed as factual scientific knowledge, and this demonstrates the need for evaluation focused upon student performance. Albeit difficult to assess, these qualities remain important parts of science learning. In order to be an independent critical thinker, both cognition and affect is vital: dramatic techniques provide an opportunity to involve the latter (Knain, 1999b).

Critiques of the use of drama

Even though I have argued that drama activities give examples of non-authoritarian and creative learning, the approach has received some criticism. Drama and role-play, because it involves feelings and affective elements, may be manipulative and authoritarian in ways that are not apparent. Janis (1968) describes how role-play can be used in attitude change. If participants are asked to enact an attitude they do not share, then they might change their own private opinion because of the role playing experience. The likelihood of attitude change is increased if the role-play's sponsorship condition is positive and consonant with the subject's own values.

Elspeth Crawford (1999) warns about the pitfalls in drama. She maintains that drama is a powerful medium for mobilising emotion, and can have effects quite different from those which were intended. For example, in the context of activities addressing problematic aspects of science the conclusion might simply be 'Science is horrible', with no commitment to reflect further on ideas, or integrate the new learning with what that learner already knows. Rasmussen (2001) describes this pitfall as 'alienation'; we get a feeling of being 'played with' without being able to intervene. He argues that this is a result of a de-construction without a re-construction. If the encounter (e.g., in a role-play experience) is not addressed through further discussion and/or reflection, a permanent distinction between an empathic understanding of standpoint (in role) and the participants' own worldview may be generated. In this case the participant may not develop any sense of ownership of the activity, and there is a risk of alienation.

Crawford (1999) urges teachers to allow the unfolding of queries in relation to the perceptions which individuals bring to a dramatic event, or else they may miss important aspects of what has happened. Since we do not know in advance just how the dramatisation may touch the concerns which a particular student carries, in the conduct of the event we should include preliminary briefing, and de-briefing afterwards. Then we can be open to recognizing this impact and the involvement can then lead to fruitful reflection.

Social scientists have historically used role-play as a mean for behavioural analysis and modification. In 1971 a large-scale role-play experiment was conducted at Stanford University, USA, in which a prison was simulated in the cellar of the Psychology Department, with voluntary participants. The aim was to study how the prison environment influenced the behaviour of prisoners and guards. The result was dramatic. After two days the experiment had to be called off because of uncontrolled riots! (Rasmussen 2001) The role-play was criticized by other researchers because the participants failed to distinguish between being in prison and being part of a role-play. They did not act 'realistically', from a prison environment point of view, because they reacted as private persons, not as the prisoner they were supposed to enact. After this incident there was an increased scientific scepticism about the use of role-play in research. Rasmussen comments that role-play is not 'real life'. Acting will always give an interpretive perspective of life, and it is this 'dissimilarity' that constitutes the creative potential of role-play.

In his study of drama, film and theatre, Nilsen (1986) recognizes that role play may influence the participants' private perspective, but he also identifies an aspect of its creative potential. He writes:

> 'Given the reasonable conditions that the role-play is prepared and put into an accepted theoretical context, and that it is re-worked and reflected upon afterwards, participation in such activities will be effective at influencing the participants' perspective of problem-seeking. Especially the perspective of wonder, for example looking at known situations in new ways or seeing new alternatives in a problem, is influenced.' (141, my translation)

The perspective of wonder and the recognition of alternative solutions to problems raised by issues of science in society are precisely elements that should be an important part of a critical pedagogy. In their deconstruction of a role-play about an ethical decision-making process of biotechnology, Ødegaard and Kyle (2000) found that, although each group undertook the same role-play, based on the same role cards, it resulted in different decisions in the cases of both individuals and groups. Here, in contrast to the role-plays described by Janis, the participants were not given distinct attitudes to enact, merely different life situations, and it was for the participants to form their role figures and their opinions. In this way they were constantly reminded that they were playing a role.

Empowering science education

The goal of this article has been to discuss and analyse how different science and drama projects have contributed to science education by providing meaningful and empowering learning environments. Sinnes and Ødegaard (2003) have argued that science education should emphasize both internal and external empowerment. Internal empowerment is concerned with developing and perhaps changing scientific content. External empowerment is concerned with science in its societal and historical context and with influencing and steering the external frameworks for scientific activity. This distinction could have been applied to the science and drama projects considered here.

The perspectives of science as a product, in for instance the dramatic electricity model (Tveita, 1996, 1998), and science as a process, in for instance the trial of Darwin (Duveen & Solomon, 1994), would both provide internal scientific empowerment. Students use drama to understand scientific explanations of natural phenomena, and, not least, are challenged to use scientific language. Research has suggested that the science classroom is commonly teacher dominated, and learning is understood in terms of transmission (Lemke, 1990). By using drama activities to enter and explore the scientific culture, the possibility of talking science is facilitated. Entering the role of a scientist helps the student to employ what is, for some pupils, the 'strange and different' language, in a setting where it does not need to sound natural. It is understood that the student is trying out a new vocabulary, and thus he or she is given more freedom to engage in trial and error, and to explore the epistemological framing and basic assumptions of science.

The simulation of consensus conferences (Kolstø, 1997) provide an example of external scientific empowerment. The learning process would have as a primary goal empowering students to question knowledge, science, society and even their own experience, thereby enabling them to reflect on their own relation to knowledge and science. Without these opportunities, in an appropriate pedagogic environment, to ask critical questions, students will tacitly endorse and maintain the *status quo* (see Kyle, 1991; Shor, 1992).

> 'Education can socialize students into critical thought or into dependence on authority, that is, into autonomous habits of mind or into passive habits of following authorities, waiting to be told what to do and what things mean.' (Shor, 1992: 13.)

Science is ideally rational and anti-authoritarian by nature. It also relies heavily on creativity and imagination. Despite this, studies of classroom science have shown the dialogue between teacher and student to be authoritarian, and the dominant language to be a merely descriptive labelling system (Lemke, 1990, Sutton, 1996). This is a paradox. To fulfil its educational potential, science education must seek non-authoritarian and creative learning environments, which enable students to be both critical and curious about science and the world that surrounds them, and at the same time offer them an insight into the value of critical reflections within science and scientific activity itself.

The pedagogical advantage of drama is that it can create such environments. The possibility of stepping out of role and reflecting at distance on personal experience provides opportunities for metacognition with empathy. This metacognitive process is heavily dependent on the adjustment and organisation of the learning environment by the science teacher, yet it is of great importance if students are to achieve a conscious and critical relationship to science. Drama can successfully be used for making simulations of the real everyday world, especially in learning about science in the context of society, or where science is recontexualised for specific societal purposes. In sum, it offers students the possibility of experiencing cognitive, affective and active aspects of learning in an integrated way.

NOTE

[1] Gary Brooking from The Famous People Company, London, http://bshs.org.uk/educ/drama.htm#role

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