The Drama of Science Education

How public understanding of biotechnology and drama as a learning activity may enhance a critical and inclusive science education

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Dissertation submitted for Doctor scientiarum
November 2000

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ISSN 1501-7710

Cover:
Inger Sandved Anfinsen

Series of dissertations submitted to the Faculty of Mathematics and Natural Sciences, University of Oslo
No. 115

Printed in Norway:
AIT AS e-dit, Oslo

Publisher:
Unipub forlag, Oslo 2001

Unipub forlag is a department of Akademika AS, owned by The University Foundation for Student Life (SiO)

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II: Ødegaard, M. (2000). *Dramatic Science. How drama can promote learning in school science*
Presented at 9th symposium of the International Organization for Science and Technology Education (I.O.S.T.E.) Durban, South Africa. June 1999.
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Acknowledgements

In order to complete the work of this dissertation I have leaned on help from several places, and I am in need of thanking all parts involved.

The present study is funded by the Research Council of Norway as part in the project 'Science, technology and citizenship'. I am grateful to have participated in such a challenging project. The work has been carried out at Institutt for lærerutdanning og skoleutvikling (Department of Teacher Education and School Development) at the University of Oslo. Thank you for taking so good care of me! I am also very grateful to the Faculty of Mathematics and Science at the University of Oslo that granted extra funding. Their generosity made the final completion of this dissertation possible. A part of the work has been in cooperation with the European group project: 'Life Sciences in European Society', which is funded by the European Union, and coordinated by George Gaskell, LSE, and John Durant, Science Museum, London. The project has funded several workshops for me that were very educating.

The project, 'Science, Technology and Citizenship', was initiated by Professor Svein Sjøberg, who has also been my supervisor. It has been an inspiring pleasure to work with him! Thank you for all the educating and challenging discussions and for advice along the way.

Professor Torben Hviid Nielsen has also provided me with valuable help and advice during the Eurobarometer study. Thank you for greeting me with open arms when I knocked on your door!

And then, I would like to thank Professor Bill Kyle for all the encouragement and help, and for many fruitful discussions. Working and writing together with such an experienced and insightful person is a privilege.

Empirical work has been conducted at two upper secondary schools. I am indebted to the teachers and students for the goodwill I have experienced during the studies. Thank you for the priceless help in preparing and organizing the data collection. A special thank you to Per Arne Øiestad and 2MDD for all the effort and creativity put in to the interdisciplinary project *Gen-Gangere*, and to Egil Thon who recorded it. I truly learned a lot during the process!

Others have shared this doctoral pathway with me. Dr.(!) Erik Knain and (soon to be dr.!) Stein Dankert Kolstø, thank you for always being helpful and offering many stimulating pleasant debates. Also thank you to the other doctoral students and colleagues on the 'Public understanding of science and technology'-courses and fellow students at other science education courses, for all the knowledge and enjoyable time we shared.

I am full of gratitude to Doris Jorde and Marit Kjærnsli, who has shown understanding empathy for me in a female doctoral situation, and who has in different ways (professional, psychological, and practical!) been of great help. Together with them I thank the rest of the colleagues at ILS for a friendly, motivating and homely working environment. Thank you for all professional help, and also for informal morning-coffee talks, lunches and corridor-chats that at times can be very educating!

Astrid, Merethe and Guri, the world would be a colder place without you! Thank you for your comments, pep-talk and consideration. I also wish to show grand appreciation to my other dear friends and former colleagues for many encouraging conversations. I owe you all flowers!

This dissertation would not been able to accomplish without the help and support of my beloved family. You disserve the biggest flower bouquet of all! Thank you so much, Mamma and Pappa, for all the times you were there for me. Thank you angel Boye, who never says no when I ask for help. And thank you John, Tone and Fredrick for practical and enjoyable assistance!

Og så har jeg spart det beste til sist. Kjære Ragnhild og Rakel, tusen, tusen takk for all den kjærlighet dere har vist meg i denne stressende tiden. Dere har vært utrolig tålmodige! Og dere fortjener en stor del av æren for at jeg har klart å skrive denne avhandlingen. Jeg er veldig glad i dere!

Oslo, November 2000.

Marianne Ødegaard

Summary

In the context of this study, I seek to inform and transform ideas of science education by exploring knowledge of public understanding of science, together with knowledge of the value of drama in the teaching-learning process. The vision I propose is a critical science education that is inclusive of all students.

This study shows that respondents to a survey demonstrate a complicated relationship to modern biotechnology. Even though many of the respondents think biotechnology will make our lives better in the future, they still often refer to it in negative ways. Philosophical and ethical issues are frequently mentioned as the reasons for such perceptions. I suggest that science educators ought to take this picture into consideration.

An analysis of a role-play about genetic testing indicates that in a contextualized and personalized situation scientific issues are discussed in ways where the learners' imagination is encouraged and different views and arguments are revealed. The analysis also indicates that the ethical discussion depends on the scientific knowledge available to the learners at the time of the deliberations. It is suggested that with professional guidance, learners may reflect on a role-play experience and relate personally to the scientific issue involved. The prediction is that a combination of an active experience and personal, critical reflection will empower learners in science education.

The dissertation consists of four papers, a video-documentation, and a presentation and discussion of the research questions involved. It is organized as follows:

After an introduction, selected debates in education and science are presented in Chapter 2. The notions of the Norwegian expression 'allmenndannelse' and the English 'liberal education' are discussed. Ideas of critical pedagogy and feminist pedagogies are seen in light of the situation of science education in Norway. Studies of the public's relationship to science are reviewed. And, finally, ideas on how these debates may inform a critical and inclusive science education are offered.

Qualitative and quantitative methodologies are utilized to address the research questions raised in the context of the various studies presented. In each paper the methodologies are presented, with a brief outline in Chapter 3. A summary of the papers is offered in Chapter 4.

Paper I is a study based on a survey of the Norwegian public's relationship to modern biotechnology. The respondents' associations to the notion of modern

biotechnology and genetic engineering are categorized and analyzed quantitatively and qualitatively. The public shows a complex relationship to modern biotechnology, and the paper recommends that ethical, emotional and philosophical elements should be taken into account in the learning and teaching process.

Paper II offers an elaboration of how drama can enhance science learning. Ideas of culture sensitive science education are viewed together with features of learning through drama based on educational debates. It is shown how through the use of drama ~ which combines cognitive, affective, and active learning ~ that students' enhance their abilities of meta-reflection and simulating realities.

Paper III is a critical review of drama and science projects. A structured survey based on different dimensions of science education and drama activity is offered. The study suggests that drama may help create meaningful and empowering learning environments.

Paper IV focuses on educational values of imagination, collaborative action, and critical reflection, and gives an example of how a role-play about genetic testing may serve these interests. Role-play dialogues involving groups of students from upper secondary school are deconstructed. The deconstruction illustrated that students think critically and creatively in the role-play situation. Role-play is recommended as a motivating, engaging and empowering learning activity.

The submitted video-documentation and the drama project *Gen-Gangere* are described briefly. The project was a collaboration between me, as a science education researcher, a drama educator, and his drama students in upper secondary school. Using results from Paper I and IV, Henrik Ibsen's dramatic works, and their own understandings of science, a dramatic presentation was made. The translated manuscript is presented in Appendix 3.

Implications and conclusions of these studies are discussed in chapter 5. It is suggested that in addition to factual scientific knowledge, there should be an emphasis on political, ethical and philosophical relationships between science and society. In order for science education to be critical and inclusive it is important for the learners to position themselves with reference to science, and to build the learning on learners' lived experiences. Drama may provide students with contextualized and personalized shared experiences on scientific and socio-scientific matters, which might form a basis for challenging, engaging and empowering learning.

Prologue

When I started the work of this dissertation I left my position as a science teacher. The school in which I had worked several years, was a Norwegian upper secondary school ['videregående skole]. My students were first year students of 16 and 17, and I taught all of them in a general science course. This is the last compulsory science course in our school system where you still have the opportunity to encourage future politicians, stock brokers, economists, and primary school teachers to gain insight in science, and it is the last chance of recruiting creative and reflective future scientists. In my class I had candidates for all of these careers, and science lessons were influenced by different interests.

On my last day, the class I was in charge of gave me a nice memorable surprise. The surprise was a going away gift: a colorful scarf, a picture of the class to remember them by, and one of the tough guys had made a poem. It was one of those moments that moves a teacher's heart, and the first thing I did when I sat down in my new office was to hang up the class picture. It was supposed to remind me where I came from and who should benefit from my work. How can science education meet the needs of the different young faces on my wall? What might science education offer them? Although I have herein written about science education in general, it is this core science course from upper secondary that has been in the back of my mind, and I owe the readers this information.

1. Introduction

Our global society is becoming more complex and complicated. Our Norwegian society is as well, and it is reflected in our schools and the influences upon education. Because of increased globalization and immigration, society is becoming more ethnically and culturally diverse. As a result, societal trends are apparent in our schools where the student population is more diverse. In addition, the Norwegian upper secondary school receives students of a wider range of ability levels because of our latest school reform that insures further education for all after the compulsory ten years of school.

Society's complexity consists also of other elements. Advanced science and technology offers humans many new possibilities and challenges, e.g. in the field of biotechnology. As the chance of actually understanding this new knowledge has decreased because of its complexity, the opportunity of being informed has increased because of information and communication technology. Thus, we are flooded with information we do not fully understand. How should this be addressed in school, and in science education? How can we empower students to take advantage of this societal situation so that they might utilize, develop, and guide modern science and technology for the benefit of their own personal lives and to create a future society of hope, equity and possibility? I believe these questions should be the basis of a constant, reflective dialogue between students, teachers, the public, and the science community.

This study is part of a larger project called 'Naturvitenskap, teknologi og allmenndannelse'[1] and the tentative English translation is 'Science, Technology and Citizenship'. The project's main goal was: *to analyze, survey and influence the public's understanding and respect for the place science and technology has in society and in our culture* (my translation). This dissertation, which consists of several studies presented as papers, has addressed a part of this goal, which is to analyze and survey public understanding of science and technology in the case of biotechnology. The intention was to be informed by the public and their relationship to science in order to reconsider a life-long science education for all.

A Norwegian segment of the European survey Eurobarometer 46.1 (European Commission, 1997) on the subject is used in Paper I. The analysis has focused on the public's associations and perceptions of modern biotechnology. The purpose was to explore the respondents' immediate associative answer to the open-ended question "What comes to mind when you hear the words modern biotechnology?", and also compare them to other answers to direct questions. What will the respondents spontaneous answers focus on, and are there any discrepancies between this and their direct answers? The idea was to let the

[1] The project is funded by the Research Council of Norway.

public's own perspectives be given a voice. This was also the idea behind another study in this dissertation, which explores a different aspect of public understanding of biotechnology. Groups of students were given a realistic, but hypothetical, role-play situation involving genetic testing. The students' dialogue is the basis for analysis and their perspective and way of discussing and/or solving the dilemma is put in focus. This has resulted in an emphasis on the ethical issues involved.

The studies presented in this dissertation on public understanding of science are continuously viewed in relation to science education. An important link between the areas of interest is creating virtual 'real life' situations where science is presented in a contextualized way, and thus, gives students life experiences that resemble what they later may be exposed to as citizens. Such situations allow individuals to relate to a whole range of learning and decision-making processes. And, as the present studies indicate; cognition, emotions, ethical and rational reasoning are all components of the mental processes utilized by the public when individuals consider scientific issues. The manner in which drama can help provide such experiences in science education for self-empowerment as future citizens is, therefore, also discussed thoroughly.

In addition to these works, I have aimed at giving an analysis of science and the concept 'allmenndannelse', which I have chosen to translate as 'liberal education'. I have tried to reestablish the concept of liberal education in critical educational theories, like critical and feminist pedagogy, while I believe that is a natural consequence of the nature and goals of 'allmenndannelse'. These theories, together with the notion of public understanding of science are further seen in the light of science education. Finally, some of these current debates are discussed in relation to my own work.

My background is being a science (biology), math and drama teacher in upper secondary school. My work herein has been influenced by my school-based teaching experiences and my reflections about the process of learning. My former school had a profile where student-based transdisciplinary projects were highly emphasized. Themes involving environmental science were encouraged and as a result students often chose to do projects where science was related to societal perspectives. My experience of teaching different disciplines also influenced several science projects in which drama was used in various ways. My students, colleagues and I found such experiences to be meaningful, informative and fun in the context of teaching and learning science. They have guided me intuitively and rationally as I developed this dissertation, both in the choice of theoretical perspectives and in the choice of research methods.

2. Setting the scene

One morning as I was listening to the radio, I was intrigued when the speaker began to address ideas about one's self-image. The speaker said his self-image was somewhat the truest, nicest and most vulnerable characteristic he possessed; but, he continued, he often had a problem with low self-confidence and was afraid that this could influence the image he had of himself. Common for all people is the need to feel accepted. If we take away a person's self-confidence, we take away the most important thing in his or her life.

As I was listening, I thought that this is what education is all about. Education is about enhancing students' self-image about themselves in the world. By enhancing each student's self-confidence, education may also raise his or her self-image. Education ought to be about enhancing children's self-confidence to assume responsibility for acquiring knowledge. Educators must hold children's individuality, self-confidence, and participation in their own education in high esteem. Education should enable individuals to live meaningful lives in interaction with other people in society.

Further, on the radio the voice said; 'unfortunately far too few experience that their self-confidence is reinforced in Christian communities today. Too many meet a demand for an admission ticket, about the right faith and moral lifestyle, before they feel accepted' (Nordengen, 2000). I then realized I was listening to the morning prayer. Still, I thought, are there any similarities between the church and school in this respect? Not that I at any point think education is a religion! But, historically education has also been viewed for its ability to socialize. Could it be that learning communities, for instance science education communities, have an admission ticket that for some students make the learning process feel like a demand to be socialized into an unfamiliar culture? Socializing processes may result in depriving one's self-confidence if the admission ticket is leaving your real self at the front door. To secure a positive self-image, and thus a belief in that you and your opinions count in the world, a person's individual way of viewing the world and his or her life experiences should be included and respected in the learning process. This may ensure meaningful and critical learning and knowledge usable for making a difference. For science education this may be especially true.

In this chapter I would like to offer a critical overview of some selected debates in education in general and science education in particular. It is not to be viewed as a theoretical foundation for my work, as several of the presented studies and theories caught my attention and were read parallel to my own work. These theoretical perspectives should be seen as critical comments to the educational debate.

2.1. 'Allmenndannelse' and liberal education

> ***Dr Fjeldbo:*** *You reproach your son; but what have you done for your son? You have arranged for schooling his talents, but not to found a character in him. [...] But it is so common here; the task is made to be learning instead of being. We also see what that leads to; we see it in the hundreds of gifted people that walk around half-finished and are one thing with their emotions and mood and something completely else in work and action.*
>
> *(from 'De unges forbund' ['The League of Youth'] by* ***Henrik Ibsen****, 1869/1995, p. 206, my translation)*

2.1.1. 'Allmenndannelse'

This dissertation has emerged from a research project around such themes as 'public understanding of science', 'scientific literacy' and 'science for all'. The central Norwegian concept is 'science as 'allmenndannelse''. There is no direct English equivalent to the expression 'allmenndannelse', though it is at times translated with 'citizenship', 'general education' and 'liberal education'. 'Allmenndannelse' is in one dictionary explained as knowledge and culture that has a common maturing effect on a person (Norsk Språk, 1999). The Norwegian expression is composed of the two words 'allmenn' and 'dannelse'. 'Allmenn' means general, common, public, universal, and 'dannelse' connotes culture, education and refinement (Kirkeby, 1999), or a certain supply of knowledge combined with a cultural and refined mode of thinking (Norsk Språk, 1999). 'Dannelse' has the equivalent expression 'Bildung' in German and 'formation' in French that both "...address basic philosophical issues relating to the meaning of life [...] personal growth, autonomy and independence are major concerns" (Sjøberg, 1996, p. 401). It may seem like when we use the word 'allmenn-dannelse' with a stress on 'allmenn', general education is meant, whilst 'liberal education' is a near translation when the philosophical issues of autonomy and independence are emphasized. In Norwegian, both these nuances are captured in the same word and hence there is no need to distinguish them. I simply wish to point at some difficulties in not writing in one's native language, and how the fact that English being the over-all language used internationally in science education research may influence the discourse.

In his introduction chapter about scientific 'allmenndannelse', Erik Knain (1999) recaptures historic trends of the general view of general/liberal education in the national Norwegian school system. He refers to Kjosavik's (1998) two variations of education ('dannelse'); the 'formal' education - with great importance attached to the curriculum as a means for building more general intellectual talents, and the 'material' education - with weight on the curriculum as such: practical and useful knowledge. The pendulum has swung between these two types over the periods of time. Compulsory school for all was introduced in Norway in 1827, with weight on 'formal' education. After about 1850 a more 'material' education was emphasized. Maybe Ibsen's Dr. Fjellbo is making a comment to this discourse at the time? Towards 1910 science eventually made its appearance and gained ground as a school subject.

As Knain indicates, these two types of education are not mutually exclusive. Svein Sjøberg (1998) explains in his book *Naturfag som allmenndannelse* ("Science as liberal education") what he sees as the original connotation of the expression 'dannelse', including both a 'formal' and a 'material' form of education:

> ...a person with 'dannelse' is independent and autonomous, can have a basis for making her/his own decisions, has control over her/his life, does not let her/himself be manipulated, has a rich set of all-round knowledge and skills and so on (Sjøberg, 1998, p. 36, (my translation)).

In modern times the concept 'dannelse' has been used in a rather narrow sense meaning cultivated and schooled, and thus gives association to cultural reproduction where learners acquire standard knowledge and serve an institutional purpose of reproducing society. Sjøberg has sought to revitalize the concept in the context of science education to the original meaning as quoted above, which is closer to the notion of being educated versus schooled. As opposed to schooling, education (in a progressive sense as developed by Dewey) includes both the production of knowledge and tenets of citizenship, in which individuals are able to ultimately act in critical and transformative ways (Kyle, electronic communication, 7th Aug. 2000). Further, Sjøberg (1998) notes that '*allmenn*dannelse' is used to emphasize something concerted and common that pertains to everyone, not just an elite.

2.1.2. Liberal education

In an additional effort to translate and deconstruct 'allmenndannelse', the above definition is compared to some definitions of 'liberal education'. Carson (1997) compares a liberally educated person with 'The Rennaissence Individual' who knows a little bit about everything. Carson draws connections to the classic times in Greece, and speaks of an education for liberty. His definition of liberal education resembles Sjøberg's, who states that education: "...equips people to think, to see alternatives, to analyze, compare, synthesize and contrast, to criticize, and to take morally and intellectually defensible judgments" (Carson, 1997, p. 228-229). Cronon (1999) describes a liberally educated person with ten qualities: the ability to listen and hear; read and understand; talk with anyone;

write clearly and persuasively; solve varied problems; respect rigor as a way of seeking truth; practice humility, tolerance, and self-criticism; understand how to get things done; nurture and empower those around them; and see connections. Such a definition does not contradict the above, but it does have more emphasis on the individual as a social being in interaction with others, and comes closer to the notions expressed by John Dewey (in e.g. *Democracy and Education* (1916) and *Liberalism and Social Action* (1935)).

In a defense of reform in liberal education, Nussbaum (1997) addresses the need for creating a community of critical thinkers, who respect the ability to reason and examine tradition critically. Nussbaum draws on Socrates and the Stoics and three core values of liberal education are defined: critical self-examination, the ideal of the world citizen and the development of the narrative imagination. The definition does recognize the individual as an independent and autonomous being and the need for critical thinking, and therefore does not seem to contradict Sjøberg or Carson. Nussbaum's perspective on liberal education is slightly different though, with the emphasis on narrative imagination, and thus shows a variation in the use of the expression.

Carr and Harnett (1996) write about liberal education in the following way:

> Historically, the type of education deemed appropriate for enabling future citizens to participate in the shaping of their society has been liberal education - a form of education first shaped in classical times to meet the needs of free and equal citizens actively participating in the common life of their community. The task of cultivating in pupils the knowledge, skills, and attitudes necessary for public participation requires a curriculum which fosters those forms of critical and explanatory knowledge which allow pupils to reappraise existing social norms and reflect critically on the dominant social, political, and economic institutions of contemporary society. Pedagogically, it requires participatory rather than instructional teaching methods in order to cultivate the skills and attitudes which democratic deliberation requires (pp. 43–44).

2.1.3. Liberal education in the Norwegian national curriculum

The Norwegian Core Curriculum (KUF, 1994) emphasizes the social aspect and puts less stress on the critical aspect of education, and states in the chapter about the liberally-educated human being:

> Schooling shall provide a multi-faceted and all-round general education with concrete knowledge about the human being, society and nature which can provide a broad outlook and perspective; with know-how and maturity to face life's practical, social and personal challenges; and with qualities and values

that facilitate cooperation between people and make it enriching and exciting for them to live together. (p. 25)[2]

In an analysis of the Norwegian educational discourse of the 1990's, including the above core curriculum, Guro Hansen (1995) concluded that ideas of administrative efficiency and control have superior position to ideas of communicative democracy. The ideas of education for productivity, industriousness and national-cultural identity have superior position to ideas of an education for acknowledgment and moral autonomy. Knain (1999) claims in his analysis that there is an ideological tension between socializing students to either an accepting relationship or to a critical relationship to their own situation. The idea of 'progress' is important, and therefore science and technology are positively portrayed, but critical reflections around science as a social institution are omitted.

Obviously an expression like 'liberal education' or 'allmenndannelse' has varying meanings depending on who expresses them. Education is a political act and should also be recognized as such by students!

Since there seems to be no contradiction between the definitions of liberal education and 'allmenndannelse', and they both seem to wish to define the same notion within the educational discourse, both with nuances, I will continue in the following sections to use the translation 'liberal education' for 'allmenndannelse'.

2.2. From 'allmenn*dannelse*' to '*allmenn*dannelse'

Before focus is given to science as a liberal education, and a discussion about scientific literacy and public understanding of science, I wish to emphasize the '*allmenn*', that is; a liberal education meant for *all*. As mentioned above, 'allmenn' connotes something common that should reach out to all in our growing complex society. But who are 'the *all*'? The all are many different groups, living in different settings, in different natural surroundings, belonging to different socio-economic clusters, with different cultural backgrounds. The *all* are exemplified by tremendous diversity among; different languages, different genders, different colors, different sexualities, different ages, different physical and mental abilities, different religions, e.g. urban and rural, Sami and immigrant cultures. And if we think globally there is even more and greater diversity. The differences go beyond varying student groups and includes teachers, school administrators, types of school and so on. Many of these

[2] The Norwegian Core Curriculum has been translated to English (KUF, 1994). In my opinion, the translation is not always accurate. In those cases I have chosen to translate myself and thus use the reference KUF (1996), which refers to the whole Norwegian National Curriculum.

differences constitute marginalized groups in our society, groups that are not associated with the dominant culture. If liberal education means to include everyone, we might want to ask and critique the following questions: How can we have a liberal education where marginalized groups are considered and feel included? Is there a universal education that can be applied for everyone? Is science such a universal canon that can and should be transmitted to everyone? Should science education instead be made available and act as a source of information and strategy for individuals to understand and act in their life, in society, in social responsibility with others?

There are several pedagogies that have their origin in the wish to create equal opportunities for diverse students to achieve liberal education. In fact, many would claim that this was the purpose of liberal education in the first place. Liberal education is oriented toward the individual (needs, background, etc.), the importance of student activity, collaborative learning and reflective thinking versus doctrinaire truth. Critical and feminist pedagogies recognize in addition that different forms of identity-labeling frame access to knowledge and power. They make special effort to empower marginalized groups, and there is an emphasis on reflecting critically on the foundations of institutions in contemporary society.

First, however, I wish to elaborate on the difference between traditional and liberal educational philosophies.

2.3. Liberal educational philosophy

Educational philosophy is about how the choice of teaching methods is justified, about the purposes that the selected curriculum content serves and about what precisely education is being taken to mean. Teachers are usually socialized into a teaching community where these questions are part of the culture passed on to new teachers as a kind of common sense, craft knowledge. Educational philosophy is thus practiced by teachers and consists of these common sense assumptions, values and beliefs that underlay their everyday activities (Carr, 1995). Carr states that the various educational philosophies adopted by teaching communities can roughly be clustered in two distinctive groups, which he calls 'traditional' and 'liberal progressive'. Because this agrees with my own teaching experience, I have chosen to use Carr's representations of educational philosophies.

Carr (1995) describes 'traditional' philosophy to have roots in pre-industrial society, which had an aristocratic view of society. It is ruled by an elite group who transmits traditional values and universal truths (as in Plato's *Republic*). The emphasis is on an academic curriculum of classic subjects (e.g. history, mathematics, grammar, literature) and 'modern' subjects are largely ignored. The teaching is characterized by an authoritative, instructional and didactic model.

'Liberal-progressive' educational philosophy emerged in the eighteenth and nineteenth century together with the liberal societies in Western Europe. The focus was no longer on transmitting culture, but there was a political goal of reproducing a 'good' life for free and equal individuals. Carr characterizes its ideology by rational autonomy and freedom. He elaborates his stance:

> Education is a process of rational development based on the common humanity of all rather than a process of cognitive acquisition based on the authoritative knowledge of an intellectual elite. For this reason, the curriculum reflects pupils' developmental needs rather than society's culture and its content is largely define as the basis of pupils' needs and interests. Academic subjects have a very limited curriculum role and the passive transmission of society's knowledge is always subordinate to the active development of the pupil's understanding. The teacher is primarily a guide rather that an instructor and teaching is largely a matter of stimulation pupils' natural curiosity and facilitating their own inquiries (Carr, 1995, p.54-55).

These two philosophies are not mutually exclusive. It is possible to find elements from both at the same school. This might be a result of existing contradictions between what teachers and schools think and say that they are doing and what they in fact are doing. Carr (1995) explains this partly by pointing to the fact that schools are social institutions that have an internal logic and a 'hidden' curriculum that inculcates predominant moral, social and political values. So even though teachers have a will of educating for rational autonomy and intellectual freedom, society's formulation of schools having a sort of 'ladder mentality', where subjects are taught just in order to provide qualifications for higher education, make this an impossible task. Because society "…is only concerned with fitting people with attitudes and skills necessary to be successful in a society in which a kind of instrumental rationality is endemic" (p. 58). Carr claims that there should be an emphasis on educational practices in which the education of students is allowed to count. Education should not merely have a social utility or a productive usefulness, for instance instrumentally using schools for other purposes than educational as for providing an adequate labor force.

If an education is supposed to result in an independent and autonomous person in social interaction with others, and who has control over her or his life and is not manipulated, then it should ideally not be an instrument of other political goals. However, since education always will be a political area of interest for society, education should at least provide the students with a critical tool of detecting underlying political assumptions to societal conditions and decisions.

A hundred years ago, Ellen Key, a Swedish feminist and educator wrote in *The Century of the Child* (1900/1995) :

> Whilst speaking beautiful words of individual development, one does not act towards the child as if they are the goal themselves, but rather as if they are here mainly to please their parents and make them happy and proud. And this is best achieved if the children are just like the others, so much effort is made to make them into honest and capable members of society. [...] Therefore life yields the old types: the good guys, the sweet girls, the honest government officials etc. But new types with higher ideals, wanderers on unknown paths, thinkers of un-thought thoughts, capable of doing the 'breaks' that break open new tracks – seldom come from conditions of conformity (pp. 17-18, my translation).

There are parallels between parents raising their children and society educating their citizens. I guess these words still have some significance today.

2.4. Critical pedagogy

> *"The seagull-child learned to master its elements: the rocks – the air – the water. It only took fifteen minutes.*
> *The human-children's elements are a complicated society. It takes years to know them.*
> *School should be a place where human-children learn to master their elements – not be mastered by them. A place where the wingspan increases – not a place where they clip their wings"*
> *(Mosse Jørgensen 1981, p.18-19 (my translation)).*

2.4.1. Radical school movements

Mosse Jørgensen is a Norwegian educator who was especially active in the 60s and 70s. She participated in founding what is considered one of the most radical school projects in Norway; 'Forsøksgymnaset' (The experimental Gymnasium) in 1967. The initiative came from three students (15-16 years old) as a political and pedagogical rebellion against the established 'dictatorial structure' (Andersen, 1994). This is a school based on total school democracy (students and staff each have a voice in policy matters), and dissolution of all ordinary school structures (class attendance is optional). The role models were the Danish Tvind schools and the Summerhill school. There was no unifying pedagogical idea as a basis for the school other then the wish to try alternative pedagogies. In Mosse Jørgensen's quote we see a call for critical reflection about society. This is quite similar to the above descriptions of liberal education; to have control over life and not be manipulated. So it seems that the wish for liberal, student active learning closely related to life was present in this radical, experimental school. Having studied the school from a pedagogical perspective Øygarden and Svartdal (1979) concluded: "...Forsøksgymnaset does not exemplify all the ideas of lifelong education. These ideas were not even known to the founders of the school. The principle intention of the founders of Forsøksgymnaset was to create an alternative to the traditional school, - an alternative that should be more in line with their ideas of democracy." (p. 58) In the 80s, the school's students became more passive and the engagement in the school democracy decreased, thus, the school ceased as an independent institution (Andersen, 1994). It is presently again independent, but exists under unfavorable conditions and has few applicants.

Radical educational movements emerged several places in the Western world in the 60s and 70s. In the 80s conservatives critiqued these attempts and education in general and called for more discipline and revitalizing conservative ethics in schools. (e.g. in the time of 'Reaganism' and 'Thatcherism') Opposed to the conservative critique, a group of critical educational theorists emerged that combined the best work of social theorists such as John Dewey and Paulo Freire in an attempt to extend and advance an emancipatory vision of public schooling. They have a concern for: "...linking the issue of education reform to the broader considerations of democracy, the ethical and political character of fundamental social relations, and the demands of critical citizenship" (Giroux and McLaren, 1989, p. xi). With a perspective of improvement, they also critiqued some of the early radical movements:

> Although the progressive educational movements of the 1960s and 1970s helped to inaugurate a number of important legislative programs, they unfortunately often exaggerated the concept of personal freedom, which at times collapsed into a form of vapid anti-intellectualism; they often legitimated infantile as opposed to theoretically mature forms of scholarship; moreover, they argued for a child-centered pedagogy which amounted to a romantic celebration of student culture and experience that made progressive reform patterns appear unrealistic – if not damagingly counterproductive – to the aspirations of parents of minority and working-class students and inhibited a more thorough theoretical investigation into other crucial aspects of racial and class domination (Giroux and McLaren, 1989, p. xv).

2.4.2. Theories of critical pedagogy

The ideas of critical pedagogy emerged out of the Frankfurt school of critical theory with Jürgen Habermas as one of the most influential philosophers. The main objectives of critical pedagogy are "to empower the powerless and transform existing social inequalities and injustices" (McLaren, 1998, pp.163-

164). In his *Life in Schools - An Introduction to Critical Pedagogy*, McLaren (1998) describes the foundational principles. It is important that teachers understand the politics of schooling. In order to develop critical and active citizens they must understand the role schooling plays in joining knowledge and power. It is important to be aware that schooling represents an introduction to a certain culture that prepares and legitimates particular forms of social life. Critical theorists maintain that because of school's knowledge industry system, they reproduce inequality, racism and sexism. Democratic social relations are fragmented because of an emphasis on competitiveness and cultural ethnocentrism.

Critical pedagogy is also founded on the conviction that educational goals of self-empowerment and social transformation are ethically prior to a mastery of technical skills, which are primarily tied to the logic of the marketplace. Thus, with a shift in schooling economics, learning to think critically attains a purpose other than just acquiring higher levels of cognitive skills.

By focusing simultaneously on both sides of a social contradiction, problems of society are recognized as part of an interactive context between individual and society. This dialectical nature of critical theory also enables an understanding of schooling to be both dominating in some senses and liberating in others. There is a wish to enlighten many sides to a problem, and importance is put to theorizing. For instance, Giroux (1988) makes the distinction between 'productive knowledge', which is characterized by being narrow and content-bound, and 'directive knowledge', which enables students to see bigger connections, and constitutes a socio-political application of knowledge. The goal is for students to recognize the social function of particular forms of knowledge. This is based on the critical theorists' claim that knowledge is socially constructed. Giroux's knowledge distinctions can be viewed as parallel to Habermas'. In *Knowledge and Human Interests*, Habermas (1972) describes three types of knowledge created by communities of inquiry. That is 'instrumental knowledge' (similar to Giroux's productive knowledge) from the empirical-analytical sciences that give causal explanation, 'practical knowledge' for understanding social events in a historic or developmental light, and 'emancipatory knowledge' (similar to Giroux's directive knowledge) for reflection on the relationship between instrumental and practical knowledge to see relations of power and privilege. (See also Ødegaard and Kyle, 2000.) Traditionally, instrumental knowledge has been considered 'true' knowledge. Critical theorists suggests that knowledge should be analyzed for whether it is oppressive and exploitative, and not on the basis of what is 'true'.

Other important concepts are 'hegemony' and 'ideology'. Hegemony refers to "the maintenance of domination not by sheer exercise of force but primarily through consensual social practices, social forms, and social structures produced in specific sites such as the church, the state, the school, the mass media, the political system, and the family" (McLaren, 1998, p. 177). Ideology refers to "the production and representation of ideas, values, and beliefs and the manner in which they are expressed and lived out by both individuals and groups" (McLaren, 1998, p. 180). Ideologies of the dominant culture may penetrate the curriculum, in for instance, descriptions, discussions, textbooks and course content. This refers to the hidden curriculum, that is, the unintended (in some cases intended) outcomes of the schooling process, which may in turn preserve hegemony.

Giroux, McLaren and other critical theorists have constructed both a pedagogy and a political vision. However, although they often have a background in teaching and have experienced how schooling may marginalize subordinate groups, they do not offer instructional aspects of pedagogical practice. The belief is that any instructional 'answers' to the political and pedagogical questions raised should be collectively and context-specifically developed. This has been critiqued by Jennifer Gore in her book *The Struggle for Pedagogies* (1993), where she looks at several strands of radical pedagogy. She claims that it seems like Giroux and McLaren assume that "to construct a political vision is to propose a pedagogy" (Gore, 1993, p. 36). Her objection is that they place the burden of change on teachers, while simultaneously refuse to offer concrete suggestions, and that this seems inconsistent of their project. She is especially concerned about the abstract ways in which they express themselves, and that they might limit their audience and thus the theories' political potential. Gore characterizes this strand not as critical *pedagogy*, but critical *educational theory*, which enables 'teachers as intellectuals' to develop their own critical pedagogy. She draws attention to another strand within critical pedagogy represented by Paulo Freire and Ira Shor that makes pedagogy as classroom practice the central concern.

2.4.3. Practices of critical pedagogy.

Very much of what is called radical pedagogy has originated from Freire's liberating pedagogy of the oppressed (Freire, 1968/1999), developed amongst poor workers and farmers in Brazil in the 60s. Central in his pedagogy is the dialogue and the idea of being a subject in one's life. It is about creating a new consciousness about oneself and a feeling of respect, and finding a way for people to start using their many possibilities of liberation. In their book *A Pedagogy for Liberation* (1987), Freire and Shor describe their instructional method for dialogical and seek a critical communication between teacher and student. They suggest the teacher might select objects of study and that the teacher re-learns the objects through studying them with the students. "..the educator *remakes* her or his 'cognoscibility' through the 'cognoscibility' of the educatees. That is, the ability of the educator to know the object is remade every time through the students' own ability for knowing, for developing critical comprehension in themselves" (Freire & Shor, 1987, p. 100). This strand of critical theory uses the same foundations of critical theory as above, and is grounded in a critique of dominant approaches to education, but their writing has a more practical perspective. The critique is expressed in Freire's description of the traditional 'banking education':

a. the teacher teaches and the students are taught;
b. the teacher knows everything and the students know nothing;
c. the teacher thinks and the students are thought about;
d. the teacher talks and the students listen – meekly;
e. the teacher disciplines and the students are disciplined;
f. the teacher chooses and enforces his choice, and the students comply;
g. the teacher acts and the students have the illusion of acting through the action of the teacher;
h. the teacher chooses the program content, and the students (who are not consulted) adapt to it;
i. the teacher confuses the authority of knowledge with his own professional authority, which he sets in opposition to the freedom of the students;
j. the teacher is the Subject of the learning process, while the pupils are mere objects (Freire, 1968/1999, p. 56).

As an alternative to this 'banking education' Shor (1992) suggests an empowering education where the goals are "..to relate personal growth to public life, by developing strong skills, academic knowledge, habits of inquiry and critical curiosity about society, power, inequality, and change" (p. 15). Teachers should democratically orient subject matter to student culture, and together teachers and students should examine the subjects systematically. Students should be encouraged to relate their experiences to academic knowledge, to power, and to inequality in society; and to approach received wisdom and the status quo with questions. As three roads to critical thought, Shor (1992) introduces the notions of 'generative', 'topical' and 'academic' themes. 'Generative themes' grow out of the students' own culture and express problematic conditions in daily life. Critical discussions connected to such themes are rewarding to generate. 'Topical themes' do not directly connect to students' everyday life, but are questions of importance locally, nationally or globally. They are delicately introduced by the teacher in relevance with work in progress, for cooperative study in class and in an understandable, engaging and preferably situated way for the students. 'Academic themes' are rooted in formal bodies of knowledge, structured knowledge from academic fields, and are also introduced by the teacher by choice or by requirement. Shor suggests participatory problem-posing, which can be asking questions contextualising the knowledge, as a means to transform remote academic knowledge into themes accessible to students.

2.5. Do Norwegian students need liberating?

I'm Nobody! Who are you?
Are you – Nobody – Too?
Then there's a pair of us?
Don't tell! They'd advertise –
you know!

How dreary – to be – Somebody!
How public – like a frog –
To tell one's name – the live-
long June
to an admiring Bog!
***Emily Dickinson** (1830-1886)*

Paulo Freire's liberating pedagogy was developed in developing countries in Brazil and in several African countries, in societies with great inequalities and poverty, and with authoritarian rulers of society. Do his ideas, with the vocabulary of domination and oppression, empowerment and liberation, have anything to do in the part of the world influenced by Western ideology and development? Freire and Shor (1987) seem to think so. In their dialogue book (Freire and Shor, 1987), Shor points to a large group of students that passively and silently listen to a didactic teacher who transfers knowledge. He compares it to what Freire calls a 'culture of silence', which suggests a passive tolerance of domination. There is no group of oppressors that violently hold force with physical beating, but Shor claims there is a 'symbolic violence' of rules, curriculum, tests, punishment, correction that establishes the authorities as the ones in charge. The passivity may hold different types of withdrawal. Some silent students may sit dutiful and copy their notes, others may sit and daydream, and still others may sit in anger, provoked by the situation forced on them. There is also an aggressive, negative resistance against this passivity that manifests itself as disruptive behavior in class. Shor calls this a 'culture of sabotage'. He argues that these examples of alienation in US schools requires a "counter-alienation pedagogy, one creative, critical and on the side of student subjectivity" (Freire and Shor, 1987, p.125).

Although both belong to the Western world, conditions in US schools can not automatically be compared to Norwegian schools. The US culture is more competitive and has a greater degree of difference in socio-economic class, race and poverty, than in our social democratic culture; but by no means are we deprived of these social concerns. In the introduction to the Norwegian edition of Freire's book *The Pedagogy of the Oppressed* (1999) Eva Nordland points to several groups that still constitute a 'silent culture' in the Norwegian society; groups that often consider themselves as 'losers'. It can be people with problems of language, work, skin color and health. "The students that are not clever in class, are stigmatized, ranked, graded and labeled, - and obviously loose human rights. [...] Incomprehensibly we are 'programmed' to fit into the system's logic, we are trained to be consumers, buyers, customers. In this way we become 'locked' in our domestic 'silent culture'." (pp. 14-15 (my translation))

There is another 'silent culture' that is manifest both in Norway, the rest of the Western world and in most other parts of the world, and that is the 'silent culture of women'. The failure to address gender issues is a major critique of the critical pedagogies, especially from a feminist stance. Freire's early work is by many viewed as unacceptable because of its masculinism. It emerged from a strongly patriarchal culture, and failured to theorize gender (Gore, 1993). Critical and feminist pedagogy still have gender biases. Critical pedagogy is strongly correlated to men, and feminist pedagogy, not surprisingly, is correlated to women. Even though recent writings in critical pedagogy include gender as a field of oppression, feminists claim that the inclusion has not made a difference.

In a literature class, the following was expressed about the above poem by Emily Dickinson:

> I couldn't help thinking of the idea of a mute culture within a dominant culture. A 'nobody' knowing she's different from the dominant culture keeps silent and is surprised to find out there are others who share the feeling. But they speak only to each other and hide otherwise. This is what it must have been like being a woman and thinking against the grain. But don't tell! At least if you are silent and no one knows, you can continue to live your inner life as you wish, your thoughts at least still belong to you. If 'they' the somebodies find out, they'll advertise and you'll have to become one of them. [...] But what if you don't want to be any of these things? Well, then you stay a nobody. Nobodies, though silent and secretive at least have their peace, their solitude and are free from the judgement of the bog (Maher and Tetreault, 1994, p. 104-105).

This illustrates how many people, both men and women, feel when they are in a different culture of some kind. However, it is suggested that girls constitute the majority in the 'silent culture' in schools, and especially in the science classroom (Bjerrum Nielsen, 2000). May it be that they feel alienated, and that there is no room for their perspective in the prevailing culture? In their interviews with silent women, Belenky, Clinchy, Goldberger and Tarule (1986/1997) found that words were perceived as weapons, and that the women were afraid they could be punished for using them. They did not assume that they could learn from them, and it made them feel 'deaf and dumb'. Other women expressed how 'gaining a voice' described their own experience of growth and development. Lewis (1993) is concerned with women's silence being coded in the academy, and wonders if it is a function of a multiple and complex social location. She points out that traditionally the understanding of women's silence has concretely reaffirmed women's non-existence. It should be a source of an active transformative practice.

There have been studies that reaffirm that girls in science classes literally have a weaker voice and are more silent then boys. In Norway it also seems like this is a case. Boys are more active in the science class than the girls, and it has been shown that teachers pay more attention to the boys, hence strengthening the impression of science as boys' domain (Bjerrum Nielsen, 2000). Another way of being a 'silent culture' in science is that there are few women in many science and technology related careers, and fewer girls than boys choose science as a subject of further education (with the exception of biology) (SSB, 1999). The Norwegian TIMSS study shows that boys achieve better in science, like science better and have greater self-confidence about science than girls in upper secondary school (Kjærnsli and Lie, 2000). These gender differences are greater in Norway than in any of the other countries in the TIMSS survey. How can this be? What are the reasons?

2.6. Are women marginalized by science or is science marginalized by women?

In Norway we like to think of ourselves as a country where liberation for woman has come a long way. We have had progressive politics for gender equality in public and private positions, payment, education and family economics. For instance, all school textbooks had to be approved for gender equity. United Nations Development Programme's *Human Development Reports* (UNDP, 2000) has developed a 'Gender Empowerment Measure', which includes participation in education, politics, professional life, equity in salaries etc., and the fact is that Norway tops this list of gender empowerment. The increase in gender equity in the late 80s and early 90s resulted in that the percentage of women in science increased both in upper secondary school and tertiary education, but towards the end of the 90s this tendency was reversed. There is especially a decrease in physics, engineering and technology (Kjærnsli and Lie, 2000, SSB, 1999).

How can girls' low interest in science be explained? Early studies concentrated on ways to enable women to fit into the way science traditionally is taught (eg. Skolnick, Langbort and Day, 1982). Sjøberg (2000a) claims that the reason does not seem to be the girls' lack of ability or lack of self-confidence, because even very able girls turn their backs to science and engineering. He believes the choices to be rather deliberate, based on value-orientations and emotional, personal factors. He found girls to have high person-orientation and relatively low orientation towards money, career and objects (Sjøberg and Imsen, 1987). Sjøberg suggests that science education perhaps should reconsider certain aspects to make it more 'girl friendly' (Sjøberg, 1998). Others claim that the perspective of making a 'girl friendly' science only will reproduce and consolidate the dominant discourse of existing science systems and traditional gender labels (Mayberry, 1998, Bungum, 2000). Bungum asserts that by emphasizing the differences between girls and boys, you get stereotype images of their learning preferences. Mayberry discusses programs of which the goal is to add women to science and where the reason for doing so is the country's growing need for a scientific and technological workforce. She claims that if there is no critical analysis of the relationship between science, political power and policy making, and science's relationship to the environmental crisis, technical advancement and unemployment, science will merely sustain gender, race and class inequalities.

Now if we as an thought experiment queered the situation and decided that the main political goal with science was to sustain the environment, we might be questioning the fact that fewer boys than girls take biology. When asked in TIMSS, boys see themselves to a small degree as biologists. Traditionally boys aim for jobs equated with more prestige, economic fortune and power. And even if Norway does top the international list of gender empowerment, men still hold nearly 70 % of the jobs in administration and management (UNDP, 2000). Is it not alarming that this half of the population shows less interest in biological issues? Boys want to learn about how cars work, not how to protect the environment or about how AIDS spreads (Sjøberg, 2000b). How will this influence the development of our society when these boys grow up to be men in influential positions? With sustainable development on our planet Earth as a goal, should we not stress why boys tend to not perform as well as girls in selected biology items in TIMSS (Lie, Kjærnsli and Brekke, 1997)?

There have been reflections regarding the Norwegian females' flight from science, especially in physics and technology. There seems to be a decreased perception amongst girls that they must demonstrate that they are as 'good' as boys, because it is taken for granted, which most likely is a result of gender equity. They simply do not choose science because they do not find it interesting and worth while. "What a waste of my intelligence!" This may be a possibility, and it is not unreasonable to offer a comparison to science education studies about people from non-Western cultures and their alienation to Western science (Ødegaard, 1997). (See e.g. Cobern and Aikenhead, 1998.) It is asserted that Western students also may perceive the culture, ethos and ideals of science as alienating, and it is suggested that a cultural border crossing (Giroux, 1992, Aikenhead, 1996) may be required. Border crossing may be a successful way for students to learn about the products and the nature of science, but it may not be enough to attract more students. A critical analysis of the alienating parts of science, science's place in society, and students' own relationship to science may also be required, in order to provide students with a tool of transformation if that is desired. And, in order to give each student a personal relationship and ownership relation to scientific knowledge, students should be given a chance to produce science connected to their everyday life.

2.7. Feminist pedagogies

Although I mostly agree with the educational philosophy of critical pedagogy, I would like to join in on some of the critique (Gore, 1993, Luke and Gore, 1992). From my personal reading, it is a recognition of our own (women's) absence from the 'master's' texts, and a description of 'one solution' to an educational problem. Although the profession of teaching has historically been 'women's work', it remains the theoretical and administrative custody of men. Women have acted as 'dutiful daughters in reciting the fathers' (Luke and Gore, 1992, p. 3). With subjective skepticism and critique based on long educational apprenticeships of women in education, feminist writers have critiqued the one 'grand theory' and the lack of addressing different identities.

Thus, feminist pedagogy is not characterized by a few 'canon' writers, rather by anthologies comprised of many contributors. It can be seen as a feminist community discussing not feminist pedagogy but feminist pedagogies. The different perspectives are contexualized according to the identities of both students and teachers, to the learning methods, and to the subject. For instance: 'black feminist pedagogy' (Foster, 1993), 'pedagogy for homeless children' (Barton, 1998a), 'liberating feminist pedagogy for women in academy' (Luke and Gore, 1992), 'feminist pedagogy for silent women' (Lewis, 1993), 'Maori women education' (Smith, 1993), 'creative writing within an enabling pedagogy' (Hildebrand, 1998), 'feminist science education' (Barton, 1998b) and 'engaged pedagogy' (hooks, 1994). Although within these pedagogical perspectives, both liberal, radical, socialist and poststructuralist feminist thoughts are represented, they are not often located and dedicated to specific forms of feminist thought.

A feminist pedagogy modeled by Weiler (1991) on consciousness raising, highlighted three areas of concern that might enrich and expand other liberatory pedagogies, possibly also in science education. The role and authority of the teacher is the first concern addressed. There was a conflict between the democratic and collective ideal of women consciousness raising groups from the

60s and early 70s with no leader, and the will to be academically accepted and thus enter a hierarchical institution. But because women were taught not to take power, the act of feminist teachers accepting authority became liberating. The authority, however, is intellectual and theorist in nature, and the aim is to enhance empowerment of students to theorize their own life and recognize their own power.

The second concern addresses the epistemological question of personal experience as a source of knowledge and truth. Both experience and feeling is looked upon as 'inner knowing'. The fact that they are shaped by society and manipulated by the dominant discourse is recognized, but at the same time it is claimed that feeling may contain an oppositional quality, by giving signals of what counters dominant schemes of truth. A sixty year old women in *Women's Way of Knowing* (Belenky et al., 1986/1997) gives an example of how she uses her 'inner voice':

> If I read something, and if it agrees with my senses, then I believe it, I know it. If it doesn't, I'll say, "Well, you may be right but I can't corroborate that." For me, proof is usually a sensory one. If you say, "Water falls," yeah, I believe it because I've seen it happen. If you call it gravity, then I say, "Oh, is that what you call it?" One doesn't have to be told in words. That's the point. That's the thing that's very hard for word people to believe – that there are other ways of telling.' (p. 75)

The third concern, especially challenged by Afro-American women and postmodernist feminists, is the question of difference. It is a critique of the concept of a universal 'women's experience'. Weiler (1991) elaborates that "...'the subject' is not an object; that is, not fixed in a static social structure, but constantly being created, actively creating the self, and struggling for new ways of being in the world through new forms of discourse or new forms of social relationships" (p. 467). The category of 'woman' or 'female' is challenged. Thus, different groups or even different individuals that turn to experience do not reveal a universal and common women's essence, but, rather that their own different experiences give different knowledges. This will not build solidarity, but raise tension of an articulation of difference. The goal is to acknowledge difference and conflict, but still have "a belief in the human capacity to feel, to know and to change" (Weiler, 1991, p.470).

I will later connect and refer to studies that connect both critical and feminist pedagogy to a science education. But first let us stop and gaze at 'public understanding of science'.

2.8. Public understanding of science. Is the public marginalized by science, or has science been marginalized by the public?

JERONIMUS: People could think you were mad or deranged, for how can a reasonable person be foolish enough to say that the earth is round?
MONTANUS: But, profecto, it is round; I must speak the truth.
JERONIMUS: So what is an eclipse of the moon, then?
MONTANUS: It is simply the shadow of the earth that robs the moon for sunshine; and since the shadow is round, it shows that the earth, too, must be round. It's all perfectly natural, and since we can predict eclipses, it's ridiculous to say that they give warning of misfortune.
JERONIMUS: Oh, Mr. Bailiff, this is more than I can stand – cursed was the day when your parents decided to let you study. My daughter is too dear for me to give her away to someone like you.
LISBETH: Oh, my sweetheart, won't you for my sake say that it is flat?
MONTANUS: I cannot, my doll. Nam contra naturam est. ["For it is against nature."]
JERONIMUS: Then, I will certainly not be your father-in-law. The earth is not round, and that is the point that weighs most heavily on my heart.
MONTANUS: My dear father-in-law. I will dispute no further on that matter. This alone I will say: that all learned people these days are of the opinion that the earth is round.
JERONIMUS: Oh... Mr. Lieutenant, let him become a soldier again until the earth becomes flat.
MONTANUS: My dear father-in-law, the earth is as flat as a pancake. Are you now satisfied?
JERONIMUS: Yes, now we're good friends again, and you shall have my daughter. Now all of you must come to my house and drink a toast of reconciliation. Mr. Lieutenant, do us the honor of joining us.

Selected excerpts from "Erasmus Monatanus" by ***Ludvig Holberg*** *(1731)*

What kind of education in science would help people make the social judgements required in the 21st century? This is a question often asked by science educators, and the answer is partly sought in the public's present relationship to and understanding of science, and partly in the science curriculum and its emphasis on life-long learning. This question may imply a tension between society's desire for economic growth and development, individuals' desire to make the world a better place to live in and a desire to preserve or transgress the dominant culture, whether it is a Western 'scientific' culture or an indigenous one.

In this connection, Ludvig Holberg's *Erasmus Montanus* offers a conflicting example of a well educated student who fails to convey his freshly gained scientific knowledge in a meaningful way to the people in his old village. Thus, he chooses to abandon this knowledge in order to 'make the world a better place to live in' for himself!

2.8.1. Norwegian national curriculum

The Norwegian national curriculum provides us with another example of this tension. In the general part of the curriculum it is said: "the education's goal is to expand children's, youth's and adult's capacity for cognition and experience, for empathy, development and participation" (KUF, 1996, p. 15, my translation). Thus, this points to a requirement for a quite active education and learning environment. Later in the chapter about the environmentally-aware human being the curriculum says:

> The interplay between economy, ecology and technology creates unique cognitive and ethical challenges for our present time, if we are to ensure sustainable development. Education must therefore provide a broad awareness of the interconnections in nature and about the interplay between humans and their habitat. [...] To them must be added the insights provided by social studies, economics and politics informed by ethics. Education must awaken their faith in the efficacy of joint efforts and collective action to solve the formidable global problems facing them (pp. 46-48, my translation).

The active learning environment has now reduced to 'faith in collective action', and an awareness of how things are. In the science curriculum the introduction says that science education should "...help students to acquire knowledge, competence and attitudes to be active citizens and participate to sustainable development" (KUF, 1996 p. 206, my translation). The specific goals are however, mainly to acquire knowledge about how science portrays and explains nature. A couple of places there are calls for discussion about conflicts of interest and measures of improving the environment. In his semiotic analysis of parts of the Norwegian national curriculum, Knain (1999) indicates how the conflicts of interests in science and technology are portrayed in ways that veil responsibilities; and, for instance, reduces the causal connection between economic growth and pollution. He claims that this has a preserving effect. The possibilities for external influence on societal matters concerning science and technology is reduced, and status quo profits.

Will adherence to the curriculum goals facilitate the publics' understanding of science? The public would perhaps be well informed, with a positive attitude towards science and technology, but no initiative of transgressing the status quo? Students do not always read the curriculum, but Knain (1999) made a similar conclusion when analyzing science textbooks. He concluded that interests of the 'civic culture', which consists of private organizations and social movements that are critical towards science and technology and demand influence in decisions (Kallerud, 1997), are not given satisfaction in the textbook discourse. Thus, will future citizens be both scientifically literate and able to transform society? If the goal is an empowered public that actively works for a sustainable development, how should this be achieved?

2.8.2. The public's understanding of science

'Public understanding of science' has been perceived in many different ways. Jenkins (1997) acknowledges that the term points towards a separation of science from general culture. He dates the separation in England to be related to the growing professionalization of science during the second half of the nineteenth century, which was marked by a devaluing of the popularization of science in favor of research publication within, and for, the developing scientific community. However, academic science promised, in a tacit social contract with society, to bring forth significant, but unspecified benefits in the future, in return for financial and public support. This contract is still prevailing, and when the academy feels the agreement threatened and there is a decrease in public support, then there is a tendency for the science community to explain this with a lack of public understanding of science. We see this presently in the case of biotechnology.

Miller (1983) argued that in order to portray a picture of adults' understanding of science it is necessary to measure each of three dimensions of scientific literacy:

i. understanding the scientific approach;
ii. understanding basic scientific constructs,
iii. understanding scientific policy issues.

Using these three dimensions, a single measure of scientific literacy was constructed, and a minimal accepted score was required in all three areas in order to be considered scientifically literate. Only 7 percent of the US respondents qualified, and these were primarily male college graduates. Miller concludes that if the communication between the informed public and scientists and engineers is to continue so "the science policy process can function effectively, there must be an audience capable of understanding both the substance of the arguments and the basic processes of science. We can accomplish this by addressing, without delay, the educational needs of the attentive public for science policy" (Miller, 1983, pp. 46-47). An underlying assumption seems to be that public acceptance of science is positively correlated with science knowledge.

Some years later Durant, Evans and Thomas (1989) indicated in their survey of public understanding of science in the UK, based on two main dimensions (science facts and scientific inquiry) that there were important relationships between public understanding and public attitudes. There was a tendency for better-informed respondents to have a more positive attitude towards science and scientists. They showed that there was a positive correlation between higher education and the level of knowledge of science facts. Although the public was largely uninformed it was also largely interested in science. However, in another study of a sample of the UK adult population that was interviewed about scientific issues, Lucas (1987) concluded that there was little evidence for the effect of science instruction. Non-scientists with the same level of education as scientists performed just as well. Thus, it seemed to be the level of education and not whether they had studied science or not that was the deciding factor.

These works seem to agree with what Layton, Jenkins, Macgill and Davey (1993) call 'the cognitive deficit model'. The model assumes that a more efficient, one-way flow of scientific knowledge from 'active producers' to 'passive consumers' will improve public understanding of science. In their book *Inarticulate Science?* they consider the perspective of the user of science. Thus, they make the same distinction as Ziman (1984), who points to the different viewpoints of 'insiders' and 'outsiders' with respect to science. Using qualitative methods, Layton et al. (1993) explored four different user-groups of science that were not professional scientists. This offers another way of understanding the public and its relations to science. The public is not a homogeneous group that needs supplies of the 'right' scientific knowledge from experts. The deficit model is challenged by the results of their case studies and related research. Instead, they claim that in order to use scientific knowledge in the realms of practical action, there is need to rework and translate it, if it is to become instrumental. This is 'the interactive model' of public understanding of science. They also address the fact that 'everyday thinking' and 'knowledge in action' are more complex and less well understood than 'scientific thinking'. Science education should consider all of these three ways of thinking.

2.8.3. Science for specific social purposes

The above shift of perspective initially started as a call for 'Science for Specific Social Purposes' (SSSP) (Layton and Davey, 1986). In a desire to increase public understanding of science, they claim that 'if science is to be returned to the people to assist their empowerment in relation to problems with a science dimension, then it will need to be structured in ways that relate to the interests of specific groups of adults (SSSP);'(p. 47). This should further lead to a reconsideration of needs, methods and values of scientists and citizens. Scientists should learn to communicate with the public and take into account the interests and needs of the audience while doing so. It should not always be the other way around.

Jenkins (1994, 1997, 1999) has elaborated further on this when describing 'science education for action' and 'citizen science'. (See also Irwin, 1995 and Wynne, 1996.) For most citizens, he claims, interest in science is linked with decision-making or action. However, 'citizens' should not be treated as a homogenous group, just as little as 'science' should be regarded as an undifferentiated field of activity. Implications for science education are that less attention should be paid to details in physics, chemistry and biology in order to pay more attention to controversial and less secure science issues. Science curricula should show more degree of differentiation and variation in order to recognize individuals' and countries' different interests. A third consequence is that science's 'excellence' and special position in problem-solving and decision-making is reassessed. Jenkins says further:

> To acknowledge the limitations of science is not in any way to undervalue the scientific endeavour. Rather, it opens the door to a richer understanding of the nature of a profoundly creative and imaginative activity tempered by a scrupulous honesty in the face of experimental evidence. It also permits a reexamination of the relationship between scientific knowledge and other forms of knowledge,... (Jenkins, 1999, p. 708)

2.8.4. Science stories

In an attempt to reform the science curriculum and create a new vision of science education for young people in the UK, British science educators held a seminar program with open and closed meetings for discussing and exchanging ideas of science education for the future (Millar and Osborne, 1998). Educating for understanding scientific issues in our daily lives was emphasized instead of educating future scientists. The seminar resulted in a report with ten recommendations. The central idea is to present science as a number of key 'explanatory stories' and important 'ideas-about-science'. "In focussing on the detail, we have lost sight of the major ideas that science has to tell, and we propose that science education should make much greater use of one of the world's most powerful and pervasive ways of communicating ideas – the narrative form" (p.13). However, the recommendations do not go far in enhancing the students' understanding of science as an institution influencing society.

Solomon and Thomas (1999) also suggest reducing the amount of traditional science facts and replacing them with science stories in order to make a more suitable science education for public understanding of science. The narratives should show topical science issues in a socio-political context, and only in such contextualized ways should there be science process learning. This is similar to educational thoughts in the STS ('Science and Technology and Society') movement (Solomon and Aikenhead, 1994). Belief, affect and the intention to act should be recognized as just as important in decision-making processes as science content and logical reasoning. Solomon and Thomas (1999) do not stop with a recommendation of altering the science content, but imply that curiosity should be the greatest factor of motivation in learning science together with increased student choice and some release from instruction. The learning process should predominantly be creative work on a topic chosen by students, who work in small groups. The learning environment should be communicative not manipulative. The goal is to 'give the student a voice' and enhance personal belief and social responsibility. They believe this to be equally valid for school science, vocational science education and adult science education.

2.8.5. Science as a human social activity

In order to answer the central question 'What kind of a society are we to have?', Cross and Price (1999) argue that citizens need to recognize science as a human social activity like any other, and that this is one of the driving forces determining our society. This is illustrated thoroughly by two case studies. The authors wish to encourage both a socially responsible science and a public mindful of the strengths and weaknesses of science.

The complex relationship between the public and science has occasionally led to recognition that the interpretation of survey data on public understanding of science must be informed by contextual information such as local culture, historical experiences, recent policy developments and controversies, and insights from qualitative research. (Bauer, Durant and Evans, 1994, Gaskell, Bauer and Durant, 1997) Recently, Bauer, Petkova and Boyadjieva (2000) even proposed alternative concepts and measures to public knowledge of and attitudes towards science. They measured knowledge of the workings of scientific institutions and attitudes to the nature of science, based on the ideology of science identified in the specialist literature (e.g. from Ziman, 1995). Thus, what is assessed is institutional knowledge and attitudes on a continuum from 'traditional-idealistic' to 'realistic-skeptical'. Bauer et al. (2000) suggest that the alternative measures may bring public opinion to bear on the recent controversies between natural scientists and humanists, and perhaps eventually contribute to a peaceful end to the 'science wars'.

2.9. Scientific literacy

Scientific literacy has not been discussed explicitly as a concept. The whole discourse above may be seen as treating the term. DeBoer (2000) claims that scientific literacy simply is synonymous with the public's understanding of science and that it necessarily is a broad concept. Based on a historical look at the discussion of scientific literacy in the science education community, DeBoer (2000) has composed a summary of nine goals for teaching science. By analyzing different discussions of why it is important for people to know science, he has derived what he considers to be the main goals discussed. DeBoer's findings seem to sum up several debates of scientific literacy:

1. Teaching and learning about science as a cultural force in the modern world.
2. Preparation for the world of work.
3. Teaching and learning about science that has direct application to everyday living.
4. Teaching students to be informed citizens.
5. Learning about science as a particular way of examining the natural world.
6. Understanding reports and discussions of science that appear in the popular media.
7. Learning about science for its aesthetic appeal.
8. Preparing citizens who are sympathetic to science.
9. Understanding the nature and importance of technology and the relationship between technology and science (DeBoer, 2000, pp. 591-593).

Traditionally the term scientific literacy has been used in a normative way, where science educators have decided what it is to be scientifically literate and students are assessed against this norm. If scientific literacy is about public understanding of science, and the understanding is open-ended and ever-changing, DeBoer maintains that there is no way to say when it is achieved. The above list should be schools' and teachers' pick-list for fitting local priorities.

I believe the term 'scientific literacy' much more fruitfully can be used in a descriptive way, where the individual's personal relationship to science is his or her science literacy. "Scientific literacy may be thought of as the metaphysical path from concrete encounters with science to student constructed understandings of the relationship between the encounters and their lived lives in society" (Ødegaard and Kyle, 2000). This is a shift in perspective from science forcing its worldview and its view of what is important to know on all citizens to science offering its products and way of knowing to publics for reaching goals of a better future.

2.10. Inclusive and critical science education for social responsibility

'Aldri mer skal du frydes som Eva i Edens have,
for nå er du temmet av lærdom.
Du åpnet ditt øye og ble lik som Gud.
Ditt liv skal formes av kunnskap om smerte og ondskap.'

[Never again will you rejoice like Eve in the Garden of Eden,
because you are now tamed by learning.
You opened your eye and became equal to God.
Your life will be formed by knowledge of pain and evil.]
***Thale**, 17 years, from Gen-Gangere, 2000.*

This study is part of a project based on the idea of science as part of liberal education, with goals of: independence and autonomy, the making of own decisions and having control over your life without being manipulated, and all-round knowledge and skills (Sjøberg 1998). I would like to add living and acting in ethical and social responsibility, and emphasize that this is a goal for all groups of learners. How can science education contribute to, and facilitate reaching this goal? Or, put another way: Is it possible to work towards this goal without science? Science is such an important and influencing part of our society, that if science education works contrary to these general educating goals, then they may be unattainable.

Being independent, autonomous and non-manipulated, describes an emancipated individual free from anyone or anything else controlling her or his life. The lines above are written by a student for a play about genetic engineering. She turned to the Bible for inspiration to express her feelings, and it is obvious that she does not consider learning to be a liberating act. She does of course not represent all students, but she may be looked upon as a representative for those students who experience science education as a way of controlling their way of thinking, knowing and living, instead of offering them freedom and competence to live their lives trying to fulfill their dreams of a better world.

2.10.1. Science and the purpose of education

In examining the linkages between science, scientific culture, liberal education, and democracy, Carson (1997) recognizes the influence of mathematics and science on the formation of Western culture. He proposes that science must be presented as integral with cultural studies, and recommends the use of a contextualized approach to science education. He thinks that the great tragedy of modern education in general is its fragmentation and its lack of a coherent cultural vision. With the 'Rennaissance person' and the classical curriculum as a kind of ideal, he describes education as "..a story of entire civilizations, from beginning to end, full of human drama, effort, emotion, wisdom, stupidity, literary beauty, poetry, vice, virtue, architectural achievement, and so forth" (Carson, 1997, p. 231).

Science education should appear in such a context, thus the learner is exposed to several distinct ways of knowing and several disciplined ways of thinking and we are freed from the tyranny of a single viewpoint. Carson acknowledges that science education can be used in a political sense, and states: "Science education is, inevitably, induction into bourgeois culture. It serves the interests of urban, industrial civilization while eroding the cultural support of rural, tribal, and traditional lifestyles" (p. 228). But even though Carson recognizes this, he does not offer an indication of how to address this fact in science education. His suggestion is to learn science in the perspective of history and philosophy, which he asserts has many advantages and possibilities (see also Matthews, 1994).

However, it may also enculturate the students into the existing dominant hegemony of science and science education if the underlying interests are not consciously scrutinized. In that case the science education may fail to educate students according to the aims of liberal education; equipping people to think for themselves. As Carson says himself: "Education of people for liberty, equips people to think, to see alternatives, to analyze, compare, synthesize and contrast, to criticize, and to take morally and intellectually defensible judgments" (Carson, 1997, pp. 228-229). If the 'story of entire civilizations' is sufficiently contextualized to fit the students' own culture or even cultures, (or should we say civilizations), the individual learners may very well achieve an education that enables them to think and act for themselves in a socially just manner.

If science education is to be a vehicle for this purpose and for the purpose of giving science back to the public, I believe it is essential that it absorbs elements from critical pedagogies described earlier; elements of action and change for a better and sustainable future, and a belief that learning is not necessarily just an academic task.

In order to counter the hegemonic control of the dominant culture in science education, Kyle (1991) suggests a reform in science education where the needs of oppressed groups are addressed, and where the lived experiences of the classroom are transformed to ensure students an opportunity to "develop the modes of thinking to fully and critically participate in a democratic community" (p. 404). He states that the hegemony of logical positivism and technical rationalism has ruled too long in science education and has marginalized both learners and citizens in society (Kyle, 2000). 'Science education for all' has in reality been 'science education for the privileged'. The purpose of education should be to foster a critical and participatory democracy, not to continue to reproduce the values of the cultural elite. This is further elaborated in an article about science education in developing countries (Kyle, 1999), where he presents a "Social Justice for All Vision of Education" founded on the principles of an equitable education and ethical responsibility to future generations. Science education should be linked to the learners' life world experiences, local contexts and issues of sustainability. "The notion of locality and the social constructions of science can facilitate creating a far more reflective and insightful science education"(p. 6). Kyle is concerned with science education's political foundations and connects in this way to critical theory.

2.10.2. Science education and critical methods for learning

Environment and health education are areas within science where critical pedagogy, action competence and empowerment have been promoted (see Jensen, 1993, Jensen and Schnack, 1994, Tones, 1994). Science about both health and the environment seem to provide ever-changing messages to the public, leaving them quite puzzled about what to believe. This may even lead to a rejection of science, if science is originally portrayed as an objective activity finding true answers. Nevertheless, even though the picture can be confusing, democracy demands responsible actions. Schnack (1994) offers a definition of action competence[3] as "...a capability – based on critical thinking and incomplete knowledge – to involve yourself as a person with other persons in responsible actions and counter-actions for a more humane world" (p. 190).

Jensen and Schnack (1994) are engaged in the aspect of action and action competence in environmental education. They claim that the concept of action competence is strongly connected to crucial educational problem complexes concerning political liberal education, which they further connect to critical educational theory. Fien (1994) states: "Critical theory provides an emancipatory framework for educational practice as it asserts that individuals and groups should be in control of their own lives and be able to determine their own destinies" (p. 21). Although Jensen and Schnack do not believe that the task of the school is to solve the political problems of society, they strongly believe that education for democracy is a fundamental educational task. Without this perspective the environmental education is too narrow and may merely result in a modification of students' behavior, for instance picking up garbage, instead of conscious action competence. The educational task is not to improve the world by letting students clean a beach. The crucial factor must be to help students learn from participating in such activities and start asking critical questions

[3] Action competence ['handlingskompetanse'] is a notion much used in education in the Scandinavian countries. It seems to be comparable to the notion of empowerment (self- and social-).

about the cause of the pollution. An action must be targeted towards the solution of the problem being worked with, or else it is simply an activity. "'Critical' in this tradition does not of course mean 'to be in opposition' or 'negative', but on the contrary, to have an interest in analyzing underlying structures, conditions and preconditions for the appearance of the phenomena"(Jensen and Schnack, 1994, p. 8). Jensen and Schnack distinguish between acting and action competence and claim that action competence includes the capacity to be able to act – now and in the future. Experiences of action helps to develop action competence. The school's challenge is to provide students with good experiences of action, and to build on learners' own lived experiences and further, help them start thinking critically to develop relevant action competence.

Fien (1994) elaborates on three aspects of critical pedagogy in environmental education; critical thinking, the formulation of a moral code (values education) and active participation in environmental education (political literacy). Critical thinking should help students develop a critical environmental consciousness and help them understand that the environment and its conditions have been 'constructed' by human decisions. The values and processes behind human decisions can be 'deconstructed' by asking critical questions. Three components of critical thinking are brought forth: factual inquiry and problem solving, personal evaluation and judgements and finally the capacity to explore and imagine alternatives. Traditionally critical thinking in science education has been linked to the rationality in science and the reasons for believing in scientific findings (see Knain, 1999 for elaboration).

In the values education, Fien points at the dilemma whether to teach directly towards particular values or to have a more liberal approach by adopting pluralism and claim neutrality. Fien argues that there is a paradox between this plurality and critical pedagogy, and questions the underlying explicit values of neutrality. Does the tolerance for different worldviews and different moralities obstruct us from action? He suggests that direct teaching of particular values should be included in the education within "an atmosphere of free and critical discussion" (p. 36). Further he points to that students should learn not only how to clarify values, but also why certain values are indispensable to reproduction of human life. The development of critical thinking skills and an environmental ethic provides the foundation for political literacy, and give means to active involvement in decision making and action to improve and maintain environmental quality.

We see that bringing critical pedagogy to science education recreates science into a political subject. Science is contextualized and appears as a natural part of society. The traditional way of viewing science education; as learning a collection scientific facts, is changed, but scientific factual knowledge is still one of more important components of critical thinking. The way science is done and its relations to other social institutions, obtains greater status. This is consistent with the demands put forward of science educators concerned with a science education for public understanding of science. (See Chapter 2.8.)

Another recommendation to science education for public understanding of science is not to consider the public as a homogenous group, but small differentiated groups with different needs, experiences and understanding. Obviously, science students should also be recognized as a differentiated group.

2.10.3. Approaches to a more inclusive science education

It has been said that "..science of any kind does not explain the unknown with the known, but the known with the unknown" (Schnack, 1994, p. 189). Constructed scientific theories are very often counter-intuitive. (See also Sjøberg, 1998; Wolpert, 1993) This may be one of many reasons for why groups of students have been marginalized in science education. Our aim is to enhance *all* students to be liberally educated. Barton (1997) asserts that feminist theory provides a 'refreshing lens' from which to reflect on inclusiveness in science in science education. "The conceptual framework central to this effort stems from attempts to rethink the nature of science and science education rather than from a belief that equality in the sciences can be reached through the implementation of compensatory programs for women and minorities" (p. 141). Thus, there is a shift from a perspective of deficiencies held by women or minorities to deficiencies and discriminatory practices in science and education. The challenge is to construct a science education that is liberatory for all students, instead of oppressive for groups of students. Barton asks the question: "Can we teach a science that is open to multiple ways of knowing in order to help *all* students value the contributions made by those traditionally silenced in science?" (p. 141). She suggests a liberatory education where critiques of science, knowledge of positionality and efforts to construct new language are essential.

In her book *Feminist Science Education* Barton (1998a) recapitulates feminism's different influences in science education. The first 'wave' of feminism in science education she describes as issues of equity, and refers to a focus on and a critique of inferior treatment received by girls and minorities in schools. This first wave had a very important influence on bringing women and minorities into science by pointing to the ways in which they were actively or passively blocked from entering. Programs and opportunities were created to get girls involved in science, containing elements like women role models, improved self-confidence and demystifying science. In this phase science itself is not critiqued. The second wave focused on 'the nature and practice of science' and 'ways of knowing science' and drew on the work of feminist philosophers of science such as Sandra Harding (1986) and Evelyn Fox Keller (1985) and their critique of the positivistic tradition in science. The objectivity of science was questioned and the analyses were grounded in social constructivism. The impact on science education was a gender-inclusive science education based on a social constructivist perspective incorporating multiple ways of knowing, like personal experience, relational knowledge and compassion for learning science. Both these waves utilized gender as an analytical category for understanding discourse and knowledge construction, and thus were separatist in nature highlighting differences, although the aim was to create inclusiveness and equality.

'Difference feminism' is by Schiebinger (1999) called one of feminism's 'blind alleys', and she shows how it has tended to romanticize those values traditionally considered feminine and does little to overturn stereotypes of men and women. Howes (1998) argues however, that difference feminism is an important critical tool, because it reminds us that science was historically not constructed under gender neutral conditions, and may help us include other characteristics in science that are culturally labeled 'feminine'. Thus, it may connect more students to science and give them a possibility of speaking with authority, but we must remain conscious of stereotyping.

The third wave feminism in science education that Barton (1998a) describes, relates to situated knowing and learning. The representation of science as it is enacted in schools is challenged, and there is a focus on that knowledge produced within the science community is not value-free or independent. This perspective "embraces the subject and searches for ways to ground science teaching and learning in understandings of embodied identities, differences, historicities, and multiple narratives of science and schooling" (Barton, 1998a, p. 16). A contexualized science is seen as a social practice with social reponsibilities and may enhance situated scientific literacy. The focus in the science classroom is continuously on the learners and their present and future relationship to science, and it is based on their lived experiences. The roles of science teachers and students are also challenged and situated. The new learning situation requires power of empathy. Barton states that "science education needs to be re-created so that teachers and students can collaboratively create and analyze science and its role in their lives. [...] Teachers need to help students create new and different representations of science that are inclusive of students' entire lives,.." (p. 18). The awareness of positionality towards science helps and clarifies in the learning process.

Other science educators have also been preoccupied with how to make science education culturally inclusive. By recognizing science as a special culture with its own norms and values, and with its own way of knowing, students may position themselves in accordance to science, and do not necessarily have to include themselves in the culture. Working with non-Western minority students in Canada, Aikenhead (1996) has described how acquiring scientific knowledge can be facilitated by explicitly speaking of science as a subculture of the Western or Euro-American society. At the same time it is acknowledged that students' own cultural identities may be at odds with the culture of Western science. The learner can then choose to border cross into the culture, 'pay a visit', get to know science approximately like an insider, or choose to stay an outsider on the inside and regard it. The point is that the learner has a possibility to border cross back to her or his own culture and does not need to be enculturated in science's culture (Aikenhead, 1996). The teacher should facilitate the border crossings and act as a culture broker for the students and guide them as much as needed. In this border crossing process there can be conflicts between the knowledge gained from science and previous knowledge about the same concepts. Jegede (1995) describes in this connection collaborative learning as having constructed science concepts side by side with indigenous concepts or life-world ideas (see also Aikenhead and Jegede, 1999). The different and often conflicting concepts belong in varying degree and with varying awareness to the student's different belonging cultures. Collateral learning is divided into different types; 'parallel' (conflicting schemata do not interact), 'dependent' (modifying existing schemas and unconscious interaction between them) and 'secured' (conflicting schemata consciously interact) collateral learning. Jegede also describes a fourth type; 'simultaneous' collateral learning, where learning in one culture can facilitate learning in an other. For example can knowing in the student's life-world enhance knowing in science.

Jegede portrayed 'simultaneous' collateral learning as rare and coincidental experiences. Barton (1998a) wants science education to facilitate such experiences. The science classroom should be open to the students' own lived experience, so they can produce science knowledge built on these experiences, but all the time with a critical awareness of science and of themselves as users and producers of science. Related to this is what is called 'feminist praxis', or reflection action, which is using critical awareness to act upon the world to change things, and understanding that individuals, alone or together with others can shape the process.

Basing science learning on the students' own experiences and including their own way of knowing enhances an inclusive science education that opens up for embodying the students' different worldviews. Cobern (1996, 2000) discusses how worldview includes both issues of epistemology and metaphysics, and elaborates on how important it is for the development of concepts or beliefs that they have 'scope' and 'force', meaning that they are central in an individual's thinking (scope) and that they are relevant for the individual over a range of contexts (force). He emphasizes that meaningful learning connects with empathy. Cobern urges science educators to acknowledge the parallel structure of knowledge and belief, and to re-introduce a discussion on the meaning of science and its impact on life. 'Knowing in your heart' necessitates including your worldview and combines both the rational and emotional part of knowing. Thus, science should in some way be connected to the learners life. Since very few of us has science as a monopolized worldview, it is necessary to locate scientific understanding within a wider view of knowledge. It is suggested that science should be contextualized in a 'science and technology in society' curricula in order to link it to the humanities and thus worldview questions. Cobern, Aikenhead, Jegede and Barton head towards an inclusive science education by including the learner's perspective on science. Although Barton does go further in also positioning the scientist in her or his social construction of scientific knowledge.

By consequently calling concepts about knowledge of the world, "the-way-things-are" beliefs, Duckworth (1987, p. 53) also includes the students own perspective and life-experiences in the learning process. She is especially engaged in encouraging students to explore the creative and imaginative parts of the scientific process and emphasizes the 'having of wonderful ideas'. She claims that it is necessary for both teachers and children to feel confidence in their own ideas, and that if teachers are deprived from using own ideas in science teaching, and feel they have to do things just as the book says, they cannot possibly accept the children's divergence and creations.

As mentioned before feminist education has multiple forms. Drawing on both critical and feminist pedagogy Hildebrand (1998) has evolved an alternative in science education called 'enabling pedagogy' that includes notions of: the affective, the creative, the critical, the cognitive and the language practices that construct oppression for some and power for others. These are embedded within the sociocultural contexts of students' and teachers' lives. Meyer (1998, 2000) draws especially on the feminist bell hooks' (1994) works and has adapted her 'engaged pedagogy' to science education, which emphasizes self-actualization and well-being for both teacher and student. She offers a science pedagogy that engages our bodies, memories and imaginations as co-participants in the phenomenal world. Both Hildebrand and Meyer use alternative methods for teaching science like; imaginative writing, dance, drama, role-play and other body movements.

2.10.4. Ethics in science education

Several science education researchers call for ethics being a part of science education (Barton, 1998a; Cobern, 1996, Kyle, 2000, Solomon and Thomas,

1999) Also, Ziman (1998) calls for scientists to be more ethical sensitive. Traditionally ethics and moral thinking has been a rather abstract and rational endeavor, where rationality's victory over emotions ensures the foundation of morality and vouches for impartiality (e.g. Rawls, 1971/1999 and Kohlberg, 1981). However, later works have critiqued this and claim that caring, empathy and emotions also have considerable influence on our ethical standards (Gilligan, 1982, Vetlesen and Nortvedt, 1996). Vetlesen and Nortvedt describe a closeness ethics with the 'you-and-me' relationship as central, and draw on the works of, amongst others, Levinas (1985) and Løgstrup (1956/1999) that focuses on meeting 'the other's face' and the ethical demand. Might not this be a meaningful perspective in the science classroom for engaging students?

The closeness ethics has been critique of being too reliable on 'you-and-me' and 'here-and-now', and being unable to meet demands of future generations and their need for a sustainable environment. Vetlesen and Nortvedt meet this critique with a quote from Kemp (1996 p. 116): "On long distance we can only act responsible if we conduct ourselves as if we were facing the absentees, also if it is about people we never have met and ever will meet. Our long-term actions are consequently ethical only when they are understood and conducted in *analogy* with our actions in the close environment." (my translation). These 'as if' meetings seem to be of great importance to practice in science in order to secure a global sustainable development. And with one of these meetings as a starting point, for instance done in a role-play, meaningful science education can evolve.

Fullick and Ratcliffe (1996) have produced a very interesting collection of material for teaching ethical aspects of science. Their purpose was to encourage an awareness of:

- ethical analysis as a rigourous mode of thought, in order to avoid the discussion of moral aspects of science-based issues being merely a diffuse gathering of opinions;
- the distinction between providing and analysing evidence (when science operates) and acting on that evidence (when ethics operates);
- the role of ethical analysis in dealing with science-based personal and social issues. (p. 8)

Reiss (1999) argues that many young people find science not relevant because of the lack of raising ethical issues, for example in considering genetic engineering. Although, there is a debate going on between philosophers of science and science educators about the nature of science, Reiss pragmatically suggests to "...side-step attempts to resolve this issue and proceed on the basis that whether or not ethics is an intrinsic aspect of science or entirely distinct from it, there are arguments in favour of science being taught in its social contexts and that, on a significant number of occasions, these contexts raise ethical issues that are both of interest to students and of valid concern to them" (p. 122). Reiss points to the following aims of teaching ethics in science: to heighten the ethical sensitivity of participants; increase the ethical knowledge of students; improve the ethical judgement of students; and make students better people in the sense of making them more virtuous or otherwise more likely to implement normatively right choices.

Reiss (1999) and Fullick and Ratcliffe (1996) seem to view ethics as a theme to be added in science, and that it should be assessed on line with other themes or issues. Is it possible to view ethics in a different perspective and see it as an integral way of relating to science? With ethical aspects of science as a perspective to science learning, many of the above themes of a critical science education may be addressed. Very often the public has to deal with ethical decisions concerning science, so having practiced making ethical decisions in school science may increase the students' action competence in public matters concerning science and ethics. It is a way of contextualizing science in society, because ethical dilemmas often originate in other worldviews conflicting with science. Bringing ethics into science education could be a way of drawing on the expertise of the learners and naturally including their life-experiences and worldview. It could be an excellent way of bringing together knowledge, beliefs and emotions and even motivate for a further exploration of scientific knowledge. Of course this calls for a kind of ethics teaching that has the learner as a starting point, and does not want to teach students 'right' ethical considerations. One could reformulate J.F. Kennedy's noted quotation and say: "Do not ask what the learners can do to be able to understand science's ethical standards, but what can science education do in order to understand and employ to good purpose the learners' ethical demands!"

2.10.5. Summing up an inclusive and critical science education

In order to enable students to be liberally educated and take part as democratic citizens in society, who individually think for themselves and make non-manipulated decisions that agree with their dreams and expectations of a better world for all in the future, we should offer an inclusive and critical science education of all students. Critical and feminist pedagogies scrutinize the underlying and often hidden political assumptions and implications of science by questioning science's objectivity and seeing it as a human construct in a societal perspective. This is important for individuals to see in order to make real democratic decisions involving science, position themselves to science and, have a more meaningful science learning. Again, it should be emphasized that 'critical' here is not a negative connotation, but a term for carrying out an extensive analysis. Science, as well as other societal institutions involved in a phenomenon, are all targets for scrutinization. Of this follows that science should be presented in a societal context. This is another important issue that has a broad support among science educational researchers (see chapter 2.8.); learning science in contextualized realities. Science education for public understanding of science broadly relies on it.

By acknowledging that science as a human endeavor does not involve only one way of knowing, traditionally an objective rational reasoning, but also involves many individual ways of knowing, science may be opened to more students than those who easily adapt science's traditional rational way of thinking. Critical thinking does not only consist of rational thinking about factual inquiry, but also; imagination and creativity to explore alternatives, solve problems and 'having wonderful ideas', empathy and intuition to make ethical and social just evaluations and judgements. By emphasizing on contextualized ethical matters in science education this becomes apparent.

Barton and Osborne (2000) have made a comparative summary of critical science education, where they compare traditional school science, progressive school science and critical school science. The concept of 'critical science education' used includes both a critical and a feminist perspective, since they have the same goal of raising questions of power, knowledge and production in science and schools, and enabling students to act and change when interacting with the world. They state that since both traditional and progressive school science believe that science is an objective representation of the world, although progressive science does recognize scientific knowledge as produced by scientists, these school sciences position students outside science. Only the students can change in order to acquire scientific knowledge. Critical school science believes that science that is a human-made explanation of the world, and that scientific concepts are need-based explanations that emerge from dealing with societal, real life problems. In this way the students are positioned as producers of science.

Is there a parallel of marginalized groups in science education (of class, race and gender) and the public being marginalized by science? Can we not say that "Marginalized groups in science education today, will be the marginalized publics by science tomorrow!" In an inclusive critical science education the public is given the possibility to make informed decisions that are not only informed by the scientific community but also by their own deep-felt way of knowing. Thus, science is given back to the public.

3. Methodology

Research within the discipline of science education draws upon several other research traditions. Many science educators have their background in natural sciences. Philosophical issues of epistemology, ontology, and research methodology are not often discussed among researchers in the natural sciences. The research methods can be viewed as a kind of tacit knowledge, and they are often learned as a craft, where students of science gradually get immersed in the methods used by the supervisor or research team.

The discipline of science education and the research within the discipline is closer to what many individuals would regard as the traditions of the social sciences versus the traditions of the natural sciences. In the social sciences issues of epistemology, ontology, and methodology are often discussed, and competing 'paradigms' are often part of the discipline itself in academic studies. This may represent a challenge for researchers like myself, who has training in a typical natural science. To what extent the research traditions of social sciences and natural sciences really do differ is an interesting question, but I will not elaborate further on the issue.

The following is an overview and description of different, often competing, methods used in social science research. A birds-eye perspective is taken, and more details of methods used in this dissertation are given in chapter 3.2, and in each of the studies that comprise this dissertation.

3.1. Perspectives on qualitative research

Although I use both quantitative and qualitative research methods, in the following section I will dwell on the qualitative research methodology, as that is where my research has had its main focus. Quantitative methods are utilized and more fully described in Paper I.

There are several perspectives within qualitative research that reflect the aims of research interest, the researchers' worldview or philosophy of science, and the methods used by the researcher. Herein follows short overviews from two different books: Alvesson and Sköldberg (1994) from Sweden, and Guba and Lincoln (1994) from the US, and some personal reflections of resemblance.

3.1.1. The methodology of different voices

Alvesson and Sköldberg (1994) describe four directions of qualitative research based on different stances in philosophy of science and use of methodology. They are also described as four different voices: the voice of empirical data, the voice of in-depth interpreting insight, the voice of critique, and the voice of language.

What is called empirical-close (empirinära) movements, primarily grounded theory (Glaser and Strauss, 1967, Strauss and Corbin, 1990), is one direction that has a systematic and technical approach, and which at least started with a notion of the researcher as a neutral observer. The second direction is hermeneutics, which is a conscious interpretive activity with the researcher as the interpreter of social actions and texts. Assumptions and conceptions from theory held by the researcher are assumed to influence the interpretations.

Critical theory, or the voice of critique, is the third direction in focus, where the political-ideological character of the research is important, and is inspired by the influential Frankfurter-school. What and how research transpires will necessarily impact society politically and ethically. Understandings, and theories underpinning such understandings, are not neutral, but are part of and contribute to the construction of political and ideological conditions. Critical theory inspires the use of methods that give other perspectives than the empirical-close. The researcher's fantasy, creativity, and analytical and interpretive ability according to readings is emphasized.

The last direction described by Alvesson and Sköldberg (1994) is postmodernism, the voice of the language, which addresses issues of representation and authority. The hermeneutic methods used at this point disconnects the writer from the text, but also the text from an external reality, and both the researching subject and the researched object are put to question.

3.1.2. Research paradigms

Guba and Lincoln (1994) characterize qualitative research in relation to research paradigms. They acknowledge four major paradigms, and the division diverges slightly from the one presented above. The paradigms, which they view as basic belief systems, are based on ontological, epistemological, and methodological assumptions, with the methodological question constrained by the other two. The paradigms referred to are: positivism, postpositivism, critical theory with alternative paradigms, and constructivism. Following is a summary of Guba and Lincoln's account.

Positivism is based on realism, that is a belief in a 'real' apprehendable reality, and thus a dualist and objectivist epistemology with true findings. The investigator and the investigated object are assumed to be independent entities, where the investigator is capable of studying the object without influencing it or being influenced by it. The methods are mainly quantitative and pursuit verification of hypotheses. Alvesson and Sköldberg (1994) mention this paradigm under empirical-close methods, and denote that Glaser and Strauss' 'grounded theory' can be seen as a critique toward positivism.

The postpositivist paradigm is characterized by the ontology of a critical realism, which is explained as a process of wide critical examination where one continually gets closer and closer to the approximation of 'reality'. The relationship between the knower and what can be known is dualist and difficult to maintain, but objectivity is still the ideal. The methods seek to falsify hypotheses, and triangulation is important in the qualitative research structures, in which the inquiry transpires in more natural settings including local viewpoints. Grounded theory is a central contribution, and thus connects this paradigm also to the above mentioned empirical-close methods.

Critical theory and other related paradigms are distinguished by what is called a historical reality. A 'real' reality for all practical purposes, which is shaped over time by social, political, cultural, economic, ethnic and gender factors. The epistemology is exemplified as an interactive link between the investigator and the investigated object, thus the inquiry is influenced by values and is mediated as such. Creating a dialogue between the investigator and the subjects of inquiry is desirable, whilst the methods should reflect the transactional nature of the investigation. The goal is to, through a dialectical inquiry, detect and understand the historical structures of the reality in question and transform ignorance into informed consciousness, and link it to elements of critique and hope. This interpretation of critical theory is concurrent with Alvesson and Sköldberg's (1994).

The last paradigm Guba and Lincoln (1994) describe is constructivism[4], which is a parallel to Alvesson and Sköldberg's postmodernism. It differs from the other paradigms by having a relativist view on reality; or rather, realities that are contextually bound. The constructions of reality are not more or less true, but more or less informed. Also here the investigator and the investigated are interactively linked, but the findings are seen as literary creations of both. The methodology is hermeneutical and dialectical and aims to reconstruct previous held constructions.

One of the alternative paradigms connected to critical theory is feminism. However, as emphasized in the previous chapter, feminist research is a very multi-faceted activity, and different approaches may represent different research paradigms. Empirical-close feminism may, for instance, apply rigorous research practices from the postpositivist paradigm, but re-create them to be suited for a

[4] The notion of 'constructivism' used here should not be confused with the concept of 'constructivism' used in an educational sense.

feminist instead of andro-centric perspective. Most feminist approaches though, are connected to the critical or constructivist paradigm. Research practices may be re-created to fit a new perspective, and central is the accent of lived experience and developing criteria of evaluation based on ethics of caring, personal responsibility, and open dialogue (Denzin and Lincoln, 1994).

A consequence of linking research methods to basic beliefs of ontology and epistemology is that a researcher's worldview is taken into account when designing a research project. The inclusiveness and plurality of feminist research paradigm opens for a less rigid interpretation and necessity of following research method rules. Kyle, Abell, Roth and Gallagher (1992) remind us of how valuable it is for science education to enhance a wide range of research possibilities. "Our field needs the significant contributions of a variety of researchers, engaged in many types of inquiry, all seeking to advance knowledge in the field" (p. 1017). Using Habermas' (1972) categories of research interests (see also Ødegaard and Kyle, 2000 (Paper IV)) they show how different research questions lend themselves to different research designs. I will, in the following chapter, attempt to connect my basic beliefs and interests about the world, research and education to the methodology used in my work.

3.2. Perspectives of methodology in this dissertation

As indicated before, I have several years experience of being a science teacher. I also have research experience as a biologist in the context of my master's thesis. My work was part of a plant geography project that critically reconsidered and reexamined the theory of glacial survival (Nordal, Wesenberg and Ødegaard, 1988). The theory indicated that populations of Amphi-Atlantic species on the eastern and western areas survived the last glacial periods on nunataks, and thus must have been genetically isolated through more than two million years. A reasonable prediction from this theory was that genetic distances across the Atlantic Ocean are considerable larger than genetic distances between populations in Scandinavian mountains. However, the Canadian and Norwegian populations analyzed were genetically identical. The project resulted in a probable dismissal of the dominant 'nunatak survival' theory and the support of another survival theory (Haraldsen, Ødegaard and Nordal, 1991, Ødegaard, 1988). By using new biochemical genetic science techniques we believed to be a little closer to the 'real' explanation of how and when amphi-Atlantic plants colonized the continents. Even though the previous described paradigms do not aim to account for natural sciences, our plant geography science story demonstrates a postpositivist view on science, and represents my initial view on science when starting the design of this thesis.

However, being a teacher has influenced my view of education, learning and students as research objects. It was meaningless and impossible not to take these experiences into account when I was doing science education research. Suddenly, I found myself being a non-objective researcher, critiquing the existing state of things, seeking to transform science education to the better for future generations of students. The research paradigms I was moving within were critical theory and feminism. My work is denoted by different research approaches. I wish herein to reflect on my work by stepping back and giving perspective to my own interpretations.

3.2.1. Paper I. In the shadow of Frankenstein

My research interests in Paper I are to find the public's representations of modern biotechnology and try to understand their relationship to it. The research is empirical-close and interpretive. Both quantitative and qualitative methods are used. I, as a researcher, aspire a neutral position in order to portray as objectively as possible the public's response to an open-ended question of biotechnology. The material was therefore triangulated by letting two colleagues look at the categorization of responses, and a high degree of consistency was detected. However, since the material was from a European survey, it was conducted by a professional Gallup poll company, and the way the data was collected and the way the survey was formulated was impossible to control. After categorizing the whole material (see paper I), statistical analyses were conducted.

The study aimed for an exploration of the respondents' associations and representations of modern biotechnology. To detect more comprehensive discourses in the material, grounded theory methods were used for interpretation. No direct triangulation was used except for comparing the results with other European countries and the ALCESTE analysis (see Paper I).

3.2.2. Paper II and III. Science and drama

Paper II and III are both about the use of drama activities in science education. The research interests are to examine how and why the use of drama may enhance learning in science, and in Paper III additionally, to give a structured overview of how drama may be used in science. These papers are not empirical, although Paper III critiques empirical data from other written articles. The papers critically scrutinize and interpret discourses of science education and drama and seek to find links. Paper II is theory-based but inspired by my experiences of being a science teacher and using drama in science lessons and interdisciplinary projects. And, as mentioned previously, Paper III offers a critical review of drama and science projects and hence structures and reconstructs written material and practical examples.

3.2.3. Paper IV. Imagination and critical reflection

Our interest of research in Paper IV is to explore how role-play may empower students in science. Hence, this places the study closest to a critical theory research paradigm. The study is based on empirical material, which is role-play dialogue. The role-play about genetic testing was semi-structured with role cards (see Appendix 2 for role-play material). Thus, the students received relatively strong guiding on what the role-play was about and where to focus the dialogue. The interpretation had therefore to be attentive towards the difference between the students' own words and thoughts, and the role cards'. Since the students were in role during the activity there is also no way to be sure whether what they said was their own opinion or one they constructed for their role figure. For this reason it gave no meaning to attach the dialogue and opinions to single students and make them the research objects. The students can rather be seen as interactive participants in exploring the role-play activity. The deconstruction of the conversation text was carried out by linking fragments of texts to ethical and scientific arguments, using the analysis program ATLAS. These fragments were then analyzed and the result is presented in the paper.

3.3. A portrayal of the working process of *Gen-Gangere*

As part of my thesis I have chosen to enclose a video of a performance inspired by and partly based on the scientific work presented in this thesis. A summary is given in chapter 4, and the manuscript can be read in Appendix 3. The working process is presented here.

The play *Gen-Gangere* is composed by students in a drama-class at an upper secondary school in Norway, as a result of a cross-curriculum project with the subjects drama, science/biology and mother-tongue (Norwegian), amongst others. With the universe of the play-write Henrik Ibsen as a frame-work, the students have worked in a complex subject area, modern biotechnology. In the play we hear the voice of Ibsen, the students' own voices, and the voices of the Norwegian public.

First, a short elaboration on the title *Gen-Gangere* is appropriate. It is almost identical to the Norwegian title of Ibsen's play *Ghosts*. In Norwegian it is called *Gengangere*, which means ghosts, but literally translated it would be something like 'again-walkers', someone that walks again, or someone who comes over and over again. As 'gen' is also the Norwegian word for 'gene', the Norwegian title of this play literally means 'gene-walkers'! It points to the notion that we all are 'walking genes', and that our genes reoccur over and over for generation after generation.

The idea of the project *Gen-Gangere* emerged from this present study about public understanding of biotechnology, which is part of the larger project, 'Science, Technology and citizenship'. The play is based on data-material from a) the Norwegian part of a European survey (Eurobarometer 46.1), where one of the questions were "what comes to mind when you hear the words 'modern biotechnology'", and b) an analysis of a role-play about genetic testing. The material in itself was so rich that a research report did not seem to give justice to it as a mean of mediation. With *Gen-Gangere* the material has been given an artistic modification and presentation.

But *Gen-Gangere* is much more than a 'dramatic' research report. It is an explorative journey through modern science, national literature treasures and experimental physical theatre, undertaken by students, teacher and researcher. It has one foot in science education, but the other firmly set in the subjects Norwegian and drama, with focus on Henrik Ibsen, the Norwegian play-write. The project has to a great extent obtained inspiration and substance from the dramatic works and role figures of Ibsen. The idea of biotechnology was quickly connected to the idea of exploring different Ibsen figures and relating them to present time through this new science. In the initial phase the drama educator and science educator worked together finding connections between science and Ibsen's dramatic universe, and additionally finding ways to organize the project for students in a drama production class.

As a preparation to producing the actual play, the students were introduced to the area of science education research, different role-plays with scientific themes of biotechnology, and a science introductory and update coarse on the areas of genetics and biotechnology. The students themselves gave a group of fellow students specializing in biology, an assignment of providing them information of things they wanted to learn more about. At the same time the students read *Ghosts* by Ibsen, discussed and interpreted the play. Later they searched through the total dramatic production of Ibsen for role figures that could coincide with different ways of relating to biotechnology. The public's different attitudes and preferences toward this modern science had been quantitatively and qualitatively characterized in my research (see article nr. I), and this was used as a basis for the play. The distribution of the number of roles mentioning biotechnology with respectively negative and positive modes of expression, reflects the statistical material. For instance 30 % of the statements from the study were characterized as neutral when talking about biotechnology. Therefore it was decided that 3 of 10 roles were to express a basically neutral attitude in the play. Likewise, lines were derived directly from the research material as well as from Ibsen's plays. The students' own understandings, opinions, attitudes and not least imagination and creativity, have also been important resources during the preparation of the play and has clearly influenced the final result, since they have also composed texts themselves inspired by Ibsen, modern biotechnology and Genesis in the Bible.

The project also used elements from several different art forms. During the production both dance, contact-improvisation and music production provided ideas and direct contributions. For instance the introduction music used is DNA-music, which is base-sequences in DNA transcribed into notes and thus gives a basis for a music composition. The rest of the music was chosen by the students.

4. *Summary of studies*

This thesis consists of several components: four papers and a video-documentation of a dramatic interpretation and further artistic development of my research. In this chapter I will give a summary of these works. The discussion of how they relate to one another and to the theme of this dissertation follows in the next chapter.

4.1. Paper I. In the shadow of Frankenstein

This is an empirical study of the public and their relationship to modern biotechnology, and has the subtitle: The public's perceptions of modern biotechnology, and further implications for science education. The data are from the Norwegian part of a European survey (Eurobarometer 46.1 in 1996, see Durant, Bauer & Gaskell, 1998). In order to presuppose as little as possible and let the respondents themselves choose the angle of incidence into the complex area of modern biotechnology, I chose to analyze an open-ended question in the survey. The respondents were asked: "What comes into mind when you think about modern biotechnology in a broad sense, that is including genetic engineering?"(official English version). The responses were written down and later analyzed. In this way I wished to illuminate the public's immediate response to the issue, and perhaps capture a part of their 'gut feeling' about it.

The associative replies have been analyzed in line with variables of the public's evaluation of biotechnology and the area of content to which they refer. Each reply was categorized as either positive, negative, neutral, ambivalent or I don't know. The content variables are cited in Table 2 in the study (paper I), and they indicate whether the response refers to for instance, animals, food, medicine or nature, or if fear, progress and moral statements are expressed.

The responses have been compared to other variables in the same survey, like knowledge and faith in biotechnology, educational background and sex. The results indicate that there are no clear relationships between the way people refer to biotechnology and their educational background or base of knowledge. However, not unexpectedly, increased level of education increases the share of neutral responses. The respondents tend to want to explain what they believe biotechnology to be. More unexpected is the result that the number of positive statements decrease with increasing levels of education, a tendency that is stronger for those with a background in science education. In accordance with this, we see a tendency that a high level of science education correlates positively with the respondents' ethical hesitation towards biotechnology. Another rather surprising result is that there is no relationship between the respondents' faith in biotechnology making our future lives better, as expressed in one of the survey's questions and the variable called "evaluation tone". People may express negative feelings even if they have answered that biotechnology will make our future life better (see Figure 5 in Paper I).

The data have also been described qualitatively, where the modes of negativity, enthusiasm and so on are portrayed. Positive responses express a faith in that this technology might solve many of our problems. The faith may be conveyed in a naive, or a more knowledge-based manner. Negative responses also vary from simple demonstrations of fear of tampering with nature to more well-founded arguments about the risks of biotechnology. As mentioned, some of the neutral answers leave a 'schooled' impression of wanting to give the right answer, while others tell about different applications. Some responses give synonyms to modern biotechnology, like 'gene manipulation' and 'cloning'. The ambivalent answers indicate an understanding of ethical conflicts involved in this scientific area. The ethical discourse in the material focuses on man's right to tamper with nature, what genetic screening may do to human dignity, and what research does to animal dignity. There is also a risk discourse about loosing control. Otherwise, the risks are mainly positively estimated. Further, the analyzed material is seen in the light of known classical or mythical stories about man, control, nature and people's affiliation to science and knowledge.

The study demonstrates what a complex area biotechnology is in the public sphere, and that the way people think about it, learn about it and make decisions about it, are multifaceted processes that involve their worldview, knowledge, emotions, ethics and moral reflections. This is not only because the area of biotechnology is scientifically and ethically complex, but because the public consists of individuals. It is suggested that science education should take this complicated picture into consideration. By contextualizing biotechnology it is presented in a meaningful way to the students and the cultural and societal bound nature of scientific knowledge is more easily acknowledged. An ethical and moral perspective could be offered to permeate the whole learning and teaching process. Alternative learning methods to contextualize, but also to involve emotional and philosophical elements, are recommended.

4.2. Paper II. Dramatic science - How drama can promote learning in school science

In this part of my work, I draw on my own practical experience with the use of drama in the science classroom, theories of drama education and frames of discourse in the science education research community. The human values of creativity and imagination are equally important in science as in learning in general. Paper II discusses how drama has an intrinsic ability to promote these values and how this source should be tapped in science education. I also make the point that drama can help to create a learning environment that makes science meaningful for all, because it easily can situate science in a societal context. In much of the science education literature, especially about public understanding of science, the value of contextualized science is emphasized.

Science educators have also been engaged in creating a science education that is culturally inclusive. Paper II draws on many of these ideas and shows how drama can be a useful learning activity in this respect. In an anthropological perspective, science is regarded as a subculture that learners are able to border cross in and out of. In this way they might not feel that the relationship to their own culture is violated. The idea of entering another culture is very easily practiced in drama activities. When an individual enacts a role, he or she automatically enters another culture. It is the nature of drama to create fictitious worlds. In science this can be used to create and substantiate subcultures. Taking on roles is a main activity in drama, and it is also well known for most of us from playing when we were small. In science education, roles can be utilized to facilitate and make explicit border crossings.

Another aspect of science education that is brought up in the paper is the use of scientific language. Research has shown that the science classroom is largely teacher dominated, and learning is described as a transmission model with the teacher as an informer. By using drama activities to enter and explore the scientific culture, accessibility of talking science is also facilitated. When a student enters the role of a scientist, for instance, it is easier to try and formulate the, for some, 'strange and different' language, because it does not need to sound natural. Everyone knows that the student is only trying out the new vocabulary, and thus the student is given more freedom to engage in trial and error. Through exploring scientific language the learner is also introduced to the epistemological framing and basic assumptions that science has about the world.

By introducing some works by drama educators and theatre developers in the study, drama as a way of learning is revealed. With a foundation in Paulo Freire's work on liberating education, the Brazilian Augusto Boal developed a liberating theatre, where the key issue is for the audience or learners to take an active part in changing the reality as it is presented in a play. The idea of active participation for future empowerment, based on freshly gained knowledge, is of great relevance for science education. Dorothy Heathcote, a British drama educator, describes how students can explore expert roles, and how to reflect upon the universal in a special situation created in a role-play. During a role-play the learners experience that they are both in role and themselves at the same time. The actions are taken by their role figure, and at the same time they emotionally experience them. The pedagogical advantage of drama is the possibility to step out of role and reflect at a distance on their own personal experience, which gives opportunity for metacognition with empathy. The learner's own worldview is emphasized, and science and the way of knowing science are positioned according to it. In this way the learning process is embedded in and built on the students' personally and culturally constructed ways of knowing.

For learning about science in the context of society, drama can be used for making simulations of the 'real everyday world', where science is recontexualised for specific purposes. The learning process is thus enhanced and guided by the 'real' and meaningful situation. The paper suggests that the learner's 'zone of proximal development' (explained by Vygotsky), is expanded. The drama activity provides a situation where students experience using cognitive, affective and active aspects of learning science.

4.3. Paper III. Drama in science – A critical review

Science education should seek to be anti-authoritarian, critical and creative to reflect the ideals of science. Drama may help create meaningful and empowering learning environments, which inspire such an image of science. With this in mind, several drama projects in science have been reviewed in Paper III. The research conducted on drama in science projects shows that students are enthusiastic about it, but teachers feel more uneasy. When specific projects were studied they often show that drama as a method is no better (but also no worse) than other methods in enhancing factual recall, but students showed a deeper understanding of science concepts, and an increased ability to explain science in a broad and integrated perspective.

A framework to structure how different drama projects relate to science education is offered. A drama process can be highly structured or it can be spontaneous, strongly directed by a teacher or by the students themselves (see Figure 1 in Paper III). The process can have a presentational perspective, where the goal is to make a product to show an audience, or an experiential perspective, where the experiences during the process are the goal (see Figure 2 in Paper III). Finally, the science educational focus may differ and result in different drama processes (see Figure 3 in Paper III).

In the review, I have chosen to present the different works according to which science educational focus they have. The three dimensions of science education used are: science as a product, science as a process and social activity, and science as a social institution in society. When the focus is 'science as a product', the drama activities concentrate on dramatizing a scientific model, or making a dramatic model of a scientific explanation of a phenomenon in nature. For instance, the teacher uses the students to illustrate the complicated menstruation cycle, or a drama model of electricity is instructed, or the students make their own models of the cycles of matter, or they make a ballet of cell meiosis. By dramatizing an ecosystem the students are emotionally involved in developing a mental model of living systems. The products of science may in this way be presented in a narrative form, where the drama model is a visualization of a science story.

The nature of science, or what I have chosen to call science as a process and social activity, may also, with advantage, be focused on through a dramatic simulation. The students may themselves enact as scientists and, for instance, do research experiences and later present and discuss them in the form of a scientific conference. Another way of dramatizing a science process and illustrating the nature of science, is to recreate a historical science process, e.g. Jenner's development of the smallpox vaccine, or a blasphemy trial against Darwin.

The paper brings up the importance of focusing on science put in the context of society. Classroom dramas offer numerous well-suited possibilities to do so. In the science laboratory we may simulate processes from nature, similarly, in the science classroom we can simulate societal processes that involve science, e.g. an international environmental conference, a consensus conference on genetically modified food, or other democratic processes. In this way science is recontextualized and the students are able to reflect about science in relation to other institutions with differing perspectives (e.g. financial institutions) and in relation to their own way of viewing life. Students are also offered the opportunity to use newly gained knowledge in a meaningful and empowering way. It is emphasized that these 'science in society' dramas should focus on conflicts. Like good literary dramas, they are thrilling, engaging and stimulating when different points of views are brought together. The conflicts can be personal or societal. By introducing ethical conflicts through role-playing, the emotional and caring aspects of the issues are attended to by the learners as well.

Because drama offers the ability to engage in science in different ways, in its different dimensions, and then later step aside and reflect on the experiences with empathy, independent critical thinking is enhanced.

4.4. Paper IV. Imagination and critical reflection

This paper focuses on the educational value of imagination, collaborative action and critical reflection and how science education can serve the emancipatory interests of learners. The dialogue in a role-play about genetic testing is deconstructed from the perspective of critical theory and educational research. The role-play was conducted in a Norwegian upper secondary school with 18-19 year old students. They were all in their last year of school and the role-play was not done in a science lesson context. The idea was to explore the students' understanding and handling of a scientific issue they might meet in their future life. How well are they equipped for meeting life's challenges? And in what way does this role-play empower them for the future?

The role-play conflict was an ethical dilemma about whether a young couple that is expecting a baby should take a genetic test of it or not (see Appendix 2 for role-play material). They are asked by their doctor to participate in a European genetic screening, where they can chose which traits to test. The couple discusses the prospect of participating with her family, and they have to make a quick decision. What nobody knows, except the coming mother's mother, is that one of the testable diseases runs in the family. The dialogues following from this setting are quite engaged and thrilling to follow.

In order to consider how good a basis the role-play is for an empowering education on science-related societal issues, the dialogue was evaluated using an action guide as a frame of reference. The action guide was developed by professionals to ensure patients' ethical competence in decision-making about genetic testing. The issues that were brought up and discussed were:

- the *duty* to know or not to know (whether it was the parents' duty to know everything about the child so they possibly might prevent future diseases, or if they have a duty not to know so they do not spoil the child's life by being too protective),
- the *right* to know or not to know (whether the children's right to know or not to know about diseases in the family is in conflict with the parents' rights),
- the duty to *inform* or the duty to not inform (whether it is the parents' duty or not to inform the child about possible diseases),
- and medical and moral *risks* influencing the situation (the risks for getting the disease, the moral risk of getting an abortion because of obtained information, and the moral risk of consequences for society when genetic information is outspread).

The deconstruction showed that the students were urged to think critically in the situation, and most of the above elements were reflected upon and creatively explored. Most of the groups involved in the study did also manage to make a well-founded decision. The scientific issues that traditionally would be emphasized in this case, like the risk of getting the disease, and how the disease is inherited, were very poorly treated. Did it seem irrelevant to the participants or was it lack of knowledge? The study does not give an answer, but this deficiency seems to be a good starting point for a genetics lesson. It is recommended that role-play is used as a motivating, engaging and empowering way to introduce and work with scientific issues in science education. Because the students reflected critically about how to act, the role-play is a good preparation for citizenry in a democratic society. They might possess a feeling that they are able to transform the world according to their dreams and hopes, find their own voice, and in that way serve their emancipatory interests.

4.5. *Gen-Gangere* – A 'science in drama' project (Appendix 3, submitted video)

4.5.1. Background

The process of the *Gen-Gangere* project is described in chapter 3.3. A short description of the product's dramatic plot follows. I would like to stress that this did not start out as a research project, but as an investigation into how to present research material in a different way. The project turned out to be much more. It turned out to be an explorative voyage into the worlds of biotechnology, Ibsen's literary heritage, and the students' own relationship to scientific knowledge. A broader and more in-depth documentation and evaluation of the process and its possible implications for science education will need more consideration and investigation, and will consequently be presented in the future. For the time being we have the voices from these different worlds put together in a dramatic way for us to reflect upon.

The students chose to stage the performance in our post-modern time with contemporary music, costumes and make-up (read tattoos!). The scenography was brick-blocks, poles and barbed wire. The wish was to create a cold and impersonal atmosphere. They did not want the play to be 'nice'. They wanted to disturb the audience, because they felt the issue in focus was disturbing. With this in mind they created uneasy incidents on the stage through out the performance so the public watching would not sit relaxed.

During our discussions in the introductory phase of the project the students continually circled around philosophical issues of knowing. They claimed that science is about wanting to know everything, and biotechnology is wanting to know what life itself is about. Some claimed that science in this way may destroy life's and nature's beauty. The ultimate story about this was for them Genesis in the Bible, so they decided they wanted to use it in the play.

4.5.2. Dramatic plot

The performance starts with a sound-collage based on the DNA bases and all kind of words containing the letters GEN. Following is a scene where two men rip themselves out of plastic cocoons, discover each other, talk and introduce themselves to the public but do not communicate. They fight. It gives associations to the Kain and Abel brother fight. In the following scene, the rest of the characters in the play are introduced by using lines from their character's Ibsen play and lines from the research material. Recall that each character is a figure from one of Ibsen's plays chosen on the basis of a certain attitude towards biotechnology.

The next scene is the scene of Genesis, told by a storyteller. Eve tempts Adam with the apple, which in this case is a genetically modified tomato. The 'fall of man' is enacted as a dance, and they are driven out of Eden, but with an ability to 'see'.

All the students had during the process made their own story about their role figure's relationship to biotechnology. Of course they were situated in our time. One of the stories was selected to be in focus, Regine's story. In the play, however, all of the characters present part of their stories and reflections related to them. Then, Regine's story is presented as a genetic testing dilemma about her unborn child, and it involves Osvald, who is the child's father. Both these characters are from *Ghosts* and the dilemma resembles the one presented as a role-play in Paper IV. Elements from the role-play analysis are used in the dialogue. The other characters express different ethical arguments about what to do. Osvald is tested first, and it turns out he carries a gene for an extremely rare lethal disease. He is locked up to prevent the disease to spread. (The disease in mind is Tay Sachs, which is a single gene, autosomal recessive trait. The name is not mentioned in the play.) Regine's baby is then tested and the test results show that the baby has the lethal disease. Not only does this reveal that Regine is a carrier too, this result shows that Osvald and Regine inherited the gene from the same source and are half-siblings. The 'original sin' is passed on.

The closing scene is a continuation of God's creation process in Genesis. It starts on the seventh day and continues until day thirteen. We are presented with what man has done with his knowledge, and it is not a pretty picture. This scene represents the students' critique of our society. Knowledge is portrayed as the tempting serpent. The play ends with a persistent search for light and knowledge.

5. Discussion and implications

A discussion follows of some of my results and conclusions of public understanding of science, the use of drama in science teaching and the possible connections to and implications for science education.

5.1. Complexity of public understanding of science

5.1.1. Intricate findings

Paper I, *In the shadow of Frankenstein,* offers a complicated picture of the public and their relationship to science in the case of biotechnology. We seem to have a diverse public with many worldviews, which do not follow from their educational background. There also seems to be an ambivalence within individual respondents. Despite these intricate findings, we do see that an increased level of science education appears to correspond with increased critical reflection. Ethical issues frequently emerge in the responses, which often deal with questions of power and control. It is suggested that ethical matters of science should be central in science education and be presented in a contextualized manner.

In chapter 2, Erasmus Montanus and his complicated relationship between science and his personal life, was humorously portrayed by Ludvig Holberg. Layton et al. (1993) took the relationship between science and people's lives seriously, and tried to recapitulate from the publics' various points of view, how intricate considerations concerning science can be for different individuals. Holding this perspective, there are especially two points I would like to emphasize from Paper I. First, I would like to dwell upon the results presented in Figure 5 showing no relationship between the answer to the question: "How will biotechnology effect our life the next twenty years?" and the associations to the open-ended question: "What comes to mind when you think about modern biotechnology in a broad sense, that is including gene technology?". What are the implications of this finding? It could mean that there is something seriously wrong with the design of the survey, so the questions asked do not address what they are meant to, and that the open-ended question is too open and thus impossible to interpret. Or could it be that they do actually capture a part of the very complex picture of what public understanding of science is, and that it is not the survey that is contradictory but the public itself?

The free association shows us that people have many different understandings of what biotechnology is, and people see positive as well as negative sides of it. Even if a respondent has answered that biotechnology will make the future better, they still may give negative descriptions of it when asked what comes to mind. I do not believe that this necessarily is inconsistent, but an expression of a diverse understanding. People rightfully see this as an area of complexity, scientifically and ethically. Other innovative technologies have historically given similar reactions. New technologies give us many positive new possibilities, but they also change the society in which they are produced (Andersen, 1997). People may have experienced this with other technologies and are cautious. They seem critical. When teaching in a constructivist manner, it is essential that different conceptions and attitudes are allowed to emerge and are addressed. The inherent critical sense people have towards new innovations should form the basis for learning about the subject.

The second point I wish to emphasize is another unexpected finding. There are not many significant correlations between educational background and the manner in which biotechnology is expressed. Other things, like individuals' values of life and worldview, are likely to count more when biotechnology is considered. Cobern (1996) showed how students often have a very broad worldview when reflecting on nature. The worldview involves both scientific thinking and seeing nature as a sacred place, close to God. Science teachers often have a conception of nature that consists mostly of a scientific worldview. The responses in the open-ended question often contained an aspect of nature. It is not unlikely that a person's view of nature is linked to perspectives of biotechnology. Students, like the public, are a colorful assembly, and can not be treated as a homogeneous group. This is obvious when we speak of the public, but do we remember this in the science classroom? It has been argued that traditional science teaching comes mostly across to those already familiar with a scientific worldview (Aikenhead, 1996, and Cobern, 1996).

In Paper I we do see, however, a tendency of those with high scientific educational background to be more critical than others. This might be viewed as a positive outcome of education. Knowledge does seem to increase an ability to be critical. Essentially this does not mean that higher science education leads to non-acceptance of science and scientific innovations. It indicates rather that natural skepticism towards new unknown science and technology is developed. There is a broad agreement that science education should foster critical thinking. However, there may be some disagreements about what that implies. Should it also imply being critical towards the political aspects and functions of science? The public in this study seems to think so. They question scientists' right of using biotechnology in nature and wonder about the risks it implies. Should not students and individuals in the public ask critical questions about things they do not know enough about? Blind embracing of science and researchers is not being critical.

5.1.2. Changing perspective

Working with the Frankenstein material in Paper I has caused many frustrating moments, because there were not many clear findings. It is disappointing when expectations are not met. When I started my work I wanted to study people's understanding of biotechnology in an as natural way as possible. In my naïvety I thought I could capture some sort of 'truth', if only the setting was as open as possible and not guided by predetermined answers. The material I obtained was overwhelmingly rich but almost impossible to 'tame'. I could not find any clear relationships. This frustrated me until I realized that there might not be any clear cause and effect relationships of the public's understanding of biotechnology if you look generally. Everything depends on who the members of the public are and the special purposes involved. This agrees with similar works already cited (e.g. Layton et al., 1993 and Wynne, 1996), and also with my experiences as a science teacher. Students came as individuals to my classroom, they all had different interpretations of what happened there, and they all obtained different outcomes of the experience. Students are not like my grass plants, from my days as a biology researcher. I could control the plants in the green-house, give them the same treatment and read their differences as genetic variation! My results reflect a public who has a diverse but critical understanding of biotechnology, and who do not react in a certain way because they are told to or have learned to.

5.1.3. Science and the public

Paper I's results indicate that the public has a strong need to address aspects about the importance in life. Sometimes these philosophical considerations may conflict with the progress in society. A democracy should have a public that is critical toward the people in power. Scientists represent such a factor of power. Science education should not educate people only willing to cater to the needs of scientists. The science classroom should be a place for an equal dialogue between the needs of science and the needs and hesitations of students. This is in line with ideas of a critical education (Giroux & McLaren, 1989). However, one of science education's goals has historically been; "preparing citizens who are sympathetic to science" (DeBoer, 2000, p. 593). We also see this call today as a reaction towards anti-science based on a growing movement of New Age and alternative medicine (Holton, 1992).

Several years ago a biotechnologist said to me: "It is not only our business to decide. People must help us make decisions about what is right and wrong; important and less important, to do research on. It is too big a responsibility for us to carry alone. Why are not people engaged in these matters? Do they not see the significance?" Paper I does imply that the public cares about these matters. But perhaps these significant questions may have been hard to see in the jungle of scientific facts and details that students are loaded down with in school.

Maybe scientists should stop looking at the public as ignorant and unaware of the greatness of science, and start seeing them as a resource and guide to what they should do? Is it possible for science to turn towards the public and ask for advice? We have seen attempts of this in events known as consensus conferences (e.g. see Sandberg and Kraft, 1996). Maybe school science should educate citizens who can act as scientists' advisers? Then education would be meaningful, even for those who are not potential scientists. It is not necessary for students to learn the highly specialized knowledge that scientists know, but they should acquire sufficient knowledge to be able to engage in critical decision making and the analysis of complex issues. Similar to ideas in the STS movement (Solomon and Aikenhead, 1994) and the *Beyond 2000* report (Millar and Osborne, 1998), I suggest that school science should practice decision-making and action-taking on scientific incidents in context.

The nature of science with its way of knowing has tremendous penetrating and persuading power. Students should gain insight in how scientific knowledge is used and the influence it has. By giving students a voice, they can then offer advice in particular scientific matters of interest. Students should pick a few science areas of interest, preferably current affairs with an ethical dimension, and practice on giving their advice to scientists or politicians.

5.1.4. Understanding science and the public through drama

Paper IV studies the use of role-play as a means of discussing ethical issues. It finds it profitable, and the study shows that students are capable of profound ethical reflections in such a role-play context at the end of their general education. However, the relationship between the ethical reflections and the understanding of scientific risks should be further explored. The study offers insight into the role-play's potential of imagination and critical reflection, and how the richness, fun and joy of science might be mediated. As stated in the paper : "The goal of science education should be to facilitate both students' and the public's ability to identify possibilities, to seek challenges, to use their imagination, to transform. Students' experiences with science ought to be self-involving, socially just, and emancipatory" (Ødegaard and Kyle, 2000, p. 23).

Turning to this empirical work, what more is significant for the discourse of public understanding of science? Paper IV informs us that decisions in socio-scientific matters, like genetic testing, are not necessarily made with scientific arguments. Ethical arguments seem to be given primary consideration. This does not mean that the science involved is not important. If there is a change in the scientific knowledge involved, it may lead to a change of the ethical considerations because the foundation of arguments may now differ. So after, for instance, a role-play like the one presented, where the students have obtained a personal relationship to the question involved, it is the science teacher's task to explore and question the foundation of arguments. If the students get more information, or better understand the information, will they change their ethical decisions? The study showed that the ethical considerations did change during the dialogue when the family secret about a case of Huntington's disease in the family was revealed. Thus, scientific information is important for the ethical considerations. The source of information is also a crucial point. These are significant questions for a critical democratic citizen, and they create a basis for critical communication between teacher and students (Freire and Shor, 1987).

Study V (video and manuscript) also illuminates the public understanding of science issues. It shows an example of creative young individuals who feel that knowledge is taming them and tying them down. They have not experienced learning as an emancipating process as described by Freire (1968/1999). Yet, they do focus on essential questions. Questions similar to the questions raised by students in the genetic testing role-play are asked, such as: Will we be happier by knowing? Similar reflections were brought up by one of the public groups in Layton et al.'s (1993) study of public understanding of science. They preferred not to know too much about how the nuclear power-plant functioned, because they were employed there and dreaded the knowledge of the risks involved.

5.2. Drama in an inclusive critical science

Weiler (1991) highlighted three areas of concern that was addressed by feminist pedagogy. The role and authority of the teacher, personal experience as a source of knowledge, and the question of including differences, are all matters of importance for creating an inclusive education. Drama as a learning activity has its own way of attending to these issues. The authority of the teacher is not necessarily questioned as an intellectual guide and challenger, but during drama activities the focus is on the students and their experiences throughout the process, thus the teacher is not the keeper of 'right' answers. The learning is based on the experiences the students have in role enacting role figures, and does therefore also enhance empathy. Since drama focuses on individuals' encounters, differences should be wished welcome in order to enrich the whole class' common experience. The metacognitive learning process is based on each student's enactment of their role, whether it is a nature phenomenon, a scientist, or another person with a relationship to science. Because differences add to a richer experience for the whole class, drama may say to have an inclusive nature.

The use of drama in science education, presented in Paper II and III, is valuable for creating specific contextualized learning environments, where not only the scientific issue in focus is in context, but where the participants are set in a social and personal context. Science might for instance, be portrayed explicitly as a special role with its own set of norms and values, and the learners are invited to put on the mantle of science, border cross into its culture and explore it. Paper II describes how drama might help to offer an inclusive science education, based on ideas of a cultural sensitive science education developed by amongst others; Aikenhead (1996), Cobern (1996) and Jegede (1995). The main features are science as a special subculture of a Western society with its own worldview, acknowledging that students have their own worldview and border cross into science; the importance of talking science; building on the students' way of knowing and teaching science in context of society; and drawing upon the nature of drama to create fictitious worlds and be an agent of metareflection. The possibility of closeness and intimacy in role, makes it possible to reflect upon experiences with empathy but with a rational distance because of the option to step out of role. The learning is based on their own cultural integrity and personal ways of knowing.

Paper III gives several examples of how drama can be used in science education. Learners may explore an academic science with its products and ways of knowing, but also science's influence and place in society. It also unites different dimensions of learning: cognitive, affective and active. Jensen and Schnack (1994) claimed that experiences of action helps to develop action competence, a capacity to be able to act now and in the future. One of the main ideas in drama is rehearsing life situations to build competence.

In paper IV however, another frame of reference is used. The students are confronted with an ethical dilemma initiated by science and must use their own ability of ethical reasoning for making a decision. A scientific understanding of inheritance and disease development constitutes a foundation for arguments. The described role-play and its implementation can be viewed in different ways. It can be viewed as a means to learn science. And thus, its success is assessed according to whether it makes students interested in science, which also gives it the perspective of academic science. The study was not designed to detect the students' interest in obtaining further knowledge, so this can not be evaluated, although students did show a general enthusiasm about new knowledge during the course of the role-play. Another way of viewing the role-play is for its means to engage students in taking ethical positions in scientific matters. The paper shows that the role-play is well suited for that purpose. Because the situation is personalized, the 'you-and-me' relationship is central and can be linked to closeness ethics (Vetlesen and Nordtvedt, 1996). This perspective may give a critical view on science, critical in the sense that it is the individual learner and his or her relationship to and understanding of science and its ethical concerns that is in focus. The goal is the students' transformation of critical scientific knowledge to make a difference in their own life.

I have claimed above that drama as a general learning activity, is inclusive by nature. In chapter 2.10. ideas of an inclusive and critical science education was put forth. Importance was given to questions of power, knowledge and production of science, together with student empowerment to interact with the world and change society to fulfill dreams of a better future. Seeing science as a human endeavor and positioning oneself according to it are basic elements. (See e.g. Barton and Osborne, 2000.) I believe drama can make valuable contributions to such a science education. Working on making dramatic simulations of societal processes will naturally concern questions of knowledge and power, seeing science in the perspective of other institutions and visualizing the human social dimension of the process. As asserted by Giroux (1988), it is important to focus on both sides of a social contradiction in order to recognize the interactive context between individuals and society.

Students may enact scientists and thus get familiar with the social processes in science in addition to getting to know the products of science. If they know the scientific process behind the products, they should be able to participate in a discussion of the values of such knowledge. If the drama role-play also involves e.g. economists, the conflicts of different values and worldviews will be illuminated. Students get personally and emotionally involved, and the complexity of the situation is disclosed. Complex situations hold the danger of appearing paralyzing, unabling the participants to act. In my experience, if the context of the situation is directed towards action and making decisions, the students are very creative in the process of suggesting alternative solutions. Having run through such a complex process is valuable when learning about a complex world.

By bringing art forms into the science classroom (e.g., stories, poems, dance, drama, concerts, paintings, films, plays, interviews) the variety of shared experiences is broadened beyond laboratory activities, experiments and excursions. These shared experiences may supplement the students' everyday experiences, which science education usually relies on. The students are allowed to portray their understandings of science in creative representations. The *Gen-Gangere* project (Appendix 3) gives an example of how the aesthetics of drama allow a combination of science and philosophical questions of knowledge, epistemology and the meaning of life to be addressed. Because drama involves conflicts, different views are allowed to emerge to enrich the process and prospective product. In *Gen-Gangere* all student views were attempted to be included, and hopefully the participants felt the process as inclusive.

5.3. Science and liberal education

In chapter 2.1. I discussed the terms 'allmenndannelse' and 'liberal education', and concluded that with a special notion of 'allmenndannelse' in mind, the meanings of the terms overlap. The emphasis is on a child-centered science education for all, based on needs and interests of the students. Subjective knowledge is acknowledged and the education is oriented toward goals of equity, autonomy, and social justice.

The Norwegian discussion about science as 'allmenndannelse' (Sjøberg, 1998) and discussions about scientific literacy (e.g. Driver, Leach, Millar and Scott, 1996), have often put forth different arguments for the importance of science education. The arguments are categorized according to Sjøberg as: *economic arguments*, (profitable for the individuals as preparation for a future job, and for the society as educating a working force), *utility arguments* (for mastering everyday life), *democratic arguments* (for informed decision-making) and *cultural arguments* (knowing how science as a cultural achievement has influenced society). Driver et. al (1996) promote an additional *moral argument* (knowing the norms and commitments of science, which have wider values). DeBoer (2000) gives still another argument: *an aesthetic argument* (knowledge of the great variety in the natural world can offer emotional satisfaction).

There have been extensive discussions of these arguments several places (see e.g. Sjøberg, 1998, Knain, 1999, Quale, 1997, Shamos, 1995, Henriksen, 1999), and I draw upon these in the following sections. I will suggest that the arguments should be assessed according to one's general philosophy of education. Thus, if there is a wish of having an inclusive student-centered liberal education that aims for autonomous and intellectually free individuals, who are able to create a future of sustainability and social justice, then arguments for science education should reflect this. Perhaps science education should place an emphasis on arguments of personal growth, responsibility, the ability to take action and feelings of well-being?

5.3.1. Utility in science education

The utility argument is usually discussed as an argument for learning about the products of science. Historically, science has been seen as one of the useful subjects to learn since it can explain for us some of the mysteries of the world and help us control nature. Students are helped to see applications of science in their daily life, and they may gain a more informed and intelligent experience with the natural world. However, it has been claimed that scientific knowledge actually has little direct value when solving everyday problems, and instead it is technological skills that are useful. Thus the utility argument is reconsidered.

I agree that knowledge of many of the products of science often has little significance in everyday life. But instead of having students and teachers understand and adjust to the idea of science as something abstract, superior, and above our ordinary everyday lives, I think science education should make an effort and change in order to meet this important argument. By actively finding and pointing to situations where scientific knowledge makes a difference in the daily lives of individuals, this goal might be accomplished.

Science classes have traditionally included hands-on experiments and laboratory work. Can this work be channeled towards producing science for the needs and interests of students? Making science education useful might also imply having a greater emphasis on other aspects of science education than the products of science. Knowledge of the nature of science and science as a social institution can be very useful. I have pointed to several examples in Papers II, III and IV where this is so. The examples can be realistic, but fictitious, or from real life. The power of science is often perceived to be its focus upon rationality and critical thinking, however science can also be characterized as innovative and explorative. Science education should provide learners with the opportunity to experience the innovative and explorative aspects of science in their everyday life so that they might take control in creating their future!

5.3.2. Democracy and science education

Teaching science for democracy and citizenship is an important argument for learning science. However, if decision-making processes are not practiced directly in science classes, this may be an argument for 'banking education'. Students learn about the products and processes of science and store it as a 'bank of information'. Later, hopefully, one is able to evaluate and make decisions about scientific matters or participate in discussions based on the knowledge one has stored. Because of rapid development and increasing intricacy of science, there have been doubts of the usefulness of factual scientific knowledge in this respect. Thus, the ability to evaluate researchers' work is emphasized.

Kyle (2000) notes that "Science educators must articulate a vision of and assume agency for an education in science that creates opportunities for self- and social-empowerment, whereby all learners are able to engage in participatory action-taking in a democratic society." I believe that in order to learn science for citizenship, in a democratic perspective, one has to practice making decisions. The best way of preparing for this in the future is by rehearsing a realistic contextualized decision-making process involving a scientific issue. In this way newly gained science knowledge may be used at once and not just saved for possible use later in life. Also, the likelihood of remembering the knowledge is increased when students have the opportunity to engage in decision making. So, again, if the goal is science for democracy, science education should meet that goal and involve students with practical examples, like simulating an international environmental conference (see Paper II and III), a consensus conference (Kolstø, 1999), or involving them in local decision processes (Christensen and Kristensen, 1999).

5.3.3. Culture and science education

The cultural argument of teaching science aims for learners to appreciate the achievements of science and how science has influenced society. This argument is understandable for legitimizing science and all its endeavors. Since science is an integral aspect of our society, it is important for people to comprehend how knowledge relates to power in order to understand connections and development in society in general. However, it is vital, like all history writing, for the story to be told in a critical perspective with focus on science as a political factor. If not, students are not given a chance of scrutinizing the dominant hegemony of science in society. Looking at my years of teacher experience, some of the most meaningful moments of teaching are from projects that did allow students to scrutinize political power relationships of science and other institutions in society. (See Paper II, III and Appendix 3.)

Driver et al. (1996) articulated a moral argument to emphasize the importance of conveying the norms and values of science. In addition, scientists have ethical and moral responsibilities for the knowledge they create and potentially for how it is used. Most scientists are concerned and responsible citizens, and they are rightfully offended when their morale is questioned. Even so, they very often hide behind the argument that they can not be held responsible for all future applications of their ideas and findings. In Paper I, we see that questions of control are very often addressed. People are concerned about who is in control of research and whether we are controlling nature. They dispute scientists' perception of their ethical responsibility. Could there be a science education that educates students in sharing this ethical responsibility and enables students to become a future public that is able to advise scientists in ethical matters?

5.3.4. Enjoying science education

In Norway, the school discipline 'science' is called 'naturfag', which gives more associations to nature than science. In compulsory school, 1. to 10. grade, the name changed in 1997 to 'natur- og miljøfag', which might be translated with 'nature and environmental studies'. Because of the name students likely have an expectation of learning about nature with an emphasis on the diversity in the natural world. Thus, there is no intrinsic notion that the knowledge of nature taught in school is obtained by science and that science is a human endeavor. The notion is a description of nature.

Nature has always been an important part of the Norwegian culture. We like to think we are a people that live close to nature, or at least who used to live close to nature. In building a national identity after gaining independence in 1814, the natural history and environment of Norway was emphasized. One of the main goals of our education is to learn to appreciate nature. The Norwegian national curriculum says: "Learning must enhance joy about physical activity and the greatness of nature, about living in a beautiful country, about the lines of landscape and the changing seasons" (KUF, 1996, p. 48, my translation). The aesthetic argument is quite significant.

Because of the blurred boundaries between nature and science in the school subject this may be a source of conflict. Sjøberg (1995) refers to primary school teachers that think they only should teach biology when they teach 'naturfag'. Some students may have their appreciation of nature disturbed by importunate scientific explanations. In the extensive discussions I had with the teacher and students in the drama group during the *Gen-Gangere* project this situation emerged and led to a focus on Genesis and 'the Fall of Man' in the play. Some of the students were concerned about how knowledge of the world influences our experiences and feelings of joy about nature. This has also been discussed by other science educators, e.g. Aikenhead (1996) and Cobern (1996).

Another aesthetic dimension in science education is fun, humor and entertainment. Science has always been a source for wondering, exploring, experimenting, and speculating. People have been amused and engaged by nature and exciting scientific inquiry since before the birth of modern science itself. It is part of human nature to curiously explore. Numerous entertaining science 'tricks' have been designed. There are manifold of engaging and interesting science and nature stories that are told. And there are various amusing and stimulating science games that have been developed. Science students should be given the opportunity to engage in all this fun!

5.3.5. Arguments and goals for science education

Arguing why science is important in our general education differs from establishing goals for science education. I believe that we should consider goals of general educational and redesign science education to try and fulfill such goals. In this way the science curriculum would be based directly on student needs of a life long education, and less on the need to present science as an academic discipline. This agrees with voices speaking for queering the notion of the public understanding science to science understanding the public (e.g. Cobern, 1997, Jenkins, 1997, Layton et al., 1993, Sjøberg, 1997, Wynne, 1996). A parallel would be a change from the need of students to understand science education to science education's need to understanding students. If a general goal of liberal education is learning for citizenship and democracy, then science education should try and meet this goal for all students. If another general goal is learning for social justice, then science educators should be conscious about this and design the curriculum to ensure that the students experience how science education can enhance social equity. The science curriculum should be coherent with and guided by a general philosophy of education, for instance a critical, inclusive and liberal education. It should be emphasized that this does not imply criticism of factual scientific knowledge. Instead, it should be interpreted as a motivation for seeking the importance of factual knowledge, not only the practical need of particular facts, but the significance of having a broad knowledge base.

5.3.6. Visions for the future

On the basis of my own experiences and studies as well as other studies of public understanding of science and science education, I would finally like to suggest a science education with a changed focus. The traditional disciplines of science in academia is biology, chemistry and physics etc., and has been and still partly is the organization of school science, although it is taught as one subject. In the new Norwegian science curriculum for compulsory school (KUF, 1996), science issues are grouped around the themes of: body and health, our chemical everyday life, our physical world, and nature's diversity. Even though these groups represent different topics of interest and are open for cross-disciplinary teaching, they still reflect an academic way of structuring and categorizing our surroundings. This is quite natural and convenient since school science has emerged from academic science and teachers are educated in the academic tradition. But, this structure was not developed to serve the interests of the learners and it is not necessarily the best way to organize science education.

One might consider structuring school science after dimensions of scientific literacy: products of science, nature of science and understanding science as a social enterprise. But while this is fruitful in analyzing science education it probably is not very practical for making a meaningful and inclusive science education. Perhaps a structure with an emphasis on the learners' future use of the knowledge gained in science education would be better? In this way the 'why to learn' is all the time embedded in the learning process, and it is not left to the learners themselves and their teachers to construct a meaning behind the pre-assigned list of issues in the science curriculum. How can science education be of use to students, and be a benefit to their lives and our common future? How can learners use and produce science so it serves their own personal needs?

By giving students a voice in socio-scientific matters, science education could be perceived as useful both for future citizens and future scientists. If the students were offered opportunities to study a limited number of such matters with the purpose of offering themselves and others personal and political advice about issues concerning science, it might present the impression of a dynamic science, open and interested in listening to new voices. Thus, *counseling science* might both put science in a meaningful context and add an active element of empowerment by, for instance, simulating public decision-making processes. Perhaps this shift might recruit more students to science careers.

Science education has held a significant component of practical, experimental and laboratory work. How can this work be channeled towards students producing science? I once heard of a couple of schoolgirls and their science project for the local science fair. They had made a project out of testing different brands of detergents and nail polishes to find the best products. They used and produced scientific knowledge for their own needs and interest at the time. Other students would have other requirements of products or phenomenon to explore. A number of STS and SATIS units of this kind have been developed by science educators eager to make science meaningful to students. The empowering element is that knowledge of doing science is applied to the students' world of experience, and that projects are developed by the learners themselves. For our Western part of the world, which is a highly developed consumer society, *consumer science* might be an example of useful knowledge production. A remedy used in navigating in our jungle of consumer products, and not least to help focus critically on this side of our society. By looking beyond expensive brands and fancy wrapping, science may help students gain useful knowledge and a critical eye towards power forces in society getting richer because of consumer ignorance and by our consumption of resources an behalf of future generations.

What about all the useful knowledge that science already has produced? What about major scientific breakthroughs and innovations that have made us reconsider our way of viewing and acting in the world? How should they be communicated to the students? In the perspective of viewing science as a special subculture and facilitating students' border crossing into it, mediating the products of science in the context of how they were produced, told as *histories of science*, might be fruitful and meaningful. Additionally, it may help students position themselves in relation to science.

Again, I would like to emphasize the issue of enjoyment and curiosity. Together with histories of science I think *entertaining science* or perhaps *circus science* would be an excellent way of enhancing interest for science. Science for amusement only, for teasing our fantasy and imagination, for provoking our curiosity and for enjoying the wonders of nature, should constitute an important part of science education. And of course this might represent a bank of ideas for further exploration.

My vision of a critical and inclusive science education, exemplified above, would thus consist of producing science meaningful to learners' lives (consumer science), critically considering and reflecting upon science and its place in society (counseling science), learning about selected histories of science portrayed as human endeavors (histories of science), and enjoying and exploring scientific phenomenon (entertaining science). Preferably this should be in contexts of future utility and social justice.

5.4. Summing up

The presented studies of public understanding of biotechnology indicate that the public is in part critical toward this new technology. It is suggested that this skepticism should be addressed and used in science education, and that this might be done by integrating ethical decision-making about socio-scientific matters into the science curriculum.

Part of the skepticism is directed towards the control of research, and the right to control nature. Therefore, it is suggested that political aspects of science and philosophical ideas of nature should be addressed in science education.

I have indicated how the use of drama may help and enrich science education, when used in activities that meet the above suggestions. Drama offers modes of contextualizing and personalizing science. It makes socio-scientific issues more relevant for the students and easier to understand.

I have put an emphasis on science as part of society in this dissertation. I have also claimed that science education should have a critical science perspective and seek to be useful for students. This does not mean that I wish to weaken the importance of scientific knowledge. If anything, I want to strengthen it by letting the knowledge serve a direct purpose. By preparing for a role-play and then enacting it, students' newly acquired knowledge may be used in intelligent ways. Or students may experience situations created by drama, where they have insufficient knowledge and might be motivated to learn more.

In the beginning of this dissertation I described how the emphasis on education historically has varied between a 'formal' education for building general intellectual talents and a 'material' education for practical and useful knowledge. Sjøberg (1998) also describes these two grounds of education as the argument of liberal education ('dannelse') and the argument of utility ('nytte'). I believe that there is not necessarily an antagonism between the two, and that the utility argument is important for creating a meaningful learning environment with the possibility of being critical. How can students be critical about what they learn if they do not know why they are learning it? I believe that by offering to create and give experience of fictitious future situations, drama might help students to see the utility of liberal science education, and that more learners will feel included in the learning process.

Epilogue

Having come to the end of my dissertation, I look at the picture of my old class. Have I met their different needs through my work? It is hard to say. Do I have a suggestion of what science education might offer them? I have offered visions and ideas that might be accommodated to the upper secondary science course we had together. With the extended use of drama, we could try and create a useful and intellectually challenging science course for all, both future scientists and non-scientists. However, these ideas of a science education for the benefit of all learners to create a better future need to be practically explored and debated further, and the debate should involve all constituencies in the teaching-learning process.

Science education needs to be continuously reformed as society and the world changes. I hope that I am now better equipped to participate in this process, and that I will have possibilities to take part and think in new ways about how science education may contribute to the future.

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Paper I

In the Shadow of Frankenstein

The public's perceptions of modern biotechnology, and further implications for science education

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Abstract

In a European survey (Eurobarometer 46.1) the public was asked what came to mind when confronted with the expression 'modern biotechnology'. Trying to illuminate the public's relationship to this new area of science and technology, these associative replies have been analyzed based on categories of the public's evaluation of biotechnology and the area of content to which they refer. The responses have been compared to other variables in the same survey such as knowledge and trust in biotechnology, educational background and sex. They have also been described qualitatively and compared to myths about people's affiliation to science and knowledge. The results of this study indicate that there are no clear relations between the way people refer to biotechnology and their educational background or base of knowledge. However, there is a tendency of respondents with higher education in science to be more critical than respondents without science. There is not a relation between their faith in biotechnology for our future lives and the variable called 'evaluation tone', which has the categories positive, neutral, ambivalent, negative and I do not know. People may express negative feelings even if they think biotechnology will make our future life better. This shows us what a complex area biotechnology is in the public sphere, and that the way people think about it, learn about it and make decisions about it, is a multifaceted process that involves worldview, knowledge, emotions, ethics and moral reflections. Science education might wish to take this complicated picture into consideration. Should students be put off with half an hour of ethical discussion after the 'science part' of biotechnology has been taught for a week? Or might an ethical and moral perspective permeate the whole learning and teaching process? Alternative learning methods, also involving emotional and philosophical elements, might be considered.

1. Introduction

This present study is based on Norwegian data from a European survey about public understanding of biotechnology. (Eurobarometer 46.1 in 1996, see Durant, Bauer and Gaskell, 1998.) The research area of the public and scientific knowledge in general, and biotechnology in particular, is very complicated. Modern biotechnology is a relatively new emerging scientific-industrial area - a complex of research, development and implementation. Relating to and trying to understand this complex is not easy. For the public it does not only involve acquiring the understanding of a new scientific concept, but it also involves the way people relate to science and life as such. Rationality and emotions seem to be equally important in judging the new phenomenon. Several research traditions struggle with this field in between logical arguments, affection and acquiring knowledge, e.g. psychology, pedagogy, social psychology and science education. I will present several theories that concern this same area but are developed with different perspectives. In this way I hope they may illuminate and supplement each other and the results of the present study. I further wish to offer an interpretation of the data in light of implications for science education.

2. Frames for interpretation

2.1. Science Education

A goal for meaningful science education for all students might be to empower people to live their lives as they wish in social responsibility with others and with the help of scientific knowledge. Having science incorporated in one's life in a natural way would reflect scientific literacy. In order to be able to provide such an education we should know how people who are not professional scientists interact with scientific knowledge. Various studies point to a changed relationship between science and the public. (See Durant, Bauer and Gaskell, 1998; Osborne, 1997; Sjøberg, 1997) Science and scientists were before, and are still in some parts of the world, regarded as modern 'saviors', that were close to the contemporary reality, full of optimism. "*...the future in their bones*" (Snow, 1959/1995, p. 11). A series of serious problems and disasters has partly undermined public confidence in science, and its technical and industrial manifestations has led to the removal of science from its pedestal. The atomic bomb, oil spills and the Chernobyl accident are examples, and recent developments in the field of gene technology do appear to enable researchers to 'play god', which naturally creates public concern. Layton, Jenkins, Macgill and Davey (1993) comment on the fact that much public understanding of science research and science education has adhered to a 'cognitive deficit model' (e.g. the public is ignorant and needs to be 'filled up' by expert producers of science). This model is challenged by the results of their case studies and related research. Instead they claim that in order to use scientific knowledge in the realms of practical action, there is need to rework and translate it, if it is to become instrumental. They also address the fact that 'everyday thinking' and 'knowledge in action' are more complex and less well understood than 'scientific thinking'. Science education should consider all of these three ways of thinking. Layton et al. (1993) describe the relationship between them as in Figure 1.

Cobern (1996) expresses how worldviews influence how we accept different types of knowledge as true. Learning school science has mostly been an intellectual process about understanding scientific concepts and how to bring about conceptual change. Cobern (1996) claims that for students to comprehend scientific knowledge, to accept it as valid or true, and not just understand the concepts, it must be central in a person's thinking and it has to have relevance. The process of 'knowing in your heart' is metaphysical and is related to a feeling of empathy. Comprehension is dependent of the synergetic relations between all aspects of humans, both thinking, feeling and acting, and eventually leads to an understanding of the ethical and action implications of the knowledge. All of this depends on a person's culturally based worldview.

						OTHER KNOWLEDGE AND JUDGEMENTS ↓↓↓↓↓↓		
EVERYDAY KNOWLEDGE	→	PROCESS OF SCIENCE EDUCATION	→	SCIENTIFIC KNOWLEDGE FOR UNDERSTANDING	→	PROCESS OF TRANSLATION OR REWORKING	→	KNOWLEDGE FOR PRACTICAL ACTION IN SPECIFIC SITUATIONS
		CONSTRUCTION				DE-/RE-CONSTRUCTION		

Figure 1. Construction and de-/re-construction of scientific knowledge (Layton et al., 1993, p. 128).

Lev Vygotsky touches also upon these subjects. In his studies of motivational determinants of behavior, he distinguishes the concept of 'sense' (smysl) from the concept of 'meaning' (znachenie). He describes the 'meaning' of a word as a formal definition, like a separate item recorded in the lexicon. The totality of all the psychological facts arising in our consciousness caused by the word can be called the word's 'sense'. It is a fluid and complex structure constantly changing "*from consciousness to consciousness and, for one and the same consciousness, from one set of circumstances to another*" (Vygotsky, 1982, p. 347). In a person's inner dialogue the word's 'sense' has precedence to the word's meaning. This explains why personal experiences and worldview are so important in apprehension of new concepts.

Fitting a person's worldview into Layton et al.'s (1993) picture of construction and de- / re-construction of scientific knowledge (Figure 1), can be seen as a filter between the process of science education and scientific knowledge for understanding. Scientific concepts may have different 'smysl'(sense) for persons with different experiences. A person's worldview will of course also influence a person's process of translating or reworking scientific knowledge for practical use, because 'other knowledges and judgements' will closely be related to a person's values and way of looking upon the world.

2.2. Social representations

How do people discuss a new scientific phenomenon they do not know a lot about? What images do they use to describe it? Do they use the same scientific expressions as scientists do, or another vocabulary? Do different groups of people use different words? In the 50's Moscovici was interested in the public's understanding of the new phenomenon psychoanalysis. He developed a theory of social representations that can be understood as symbolic coping for understanding the quality of a new phenomenon and it is consequences (Moscovici, 1961/1984). The social representations are defined as an ensemble of beliefs, images and feelings about a phenomenon, which is shared among the members of a social unit. Moscovici states "...the purpose of all representations is to make something unfamiliar, or unfamiliarity itself, familiar" (1961/1984, p.24). They represent a link between our pure abstract sciences and beliefs in general and our concrete activities as social individuals. The representations are regarded as products of a discourse between people and the media, and between the individual and the collective. The purpose is to serve everyday communication. This means that within a social group there will likely be a development of common social representations. Moscovici's description of social representations seems to touch upon what in science education is called 'everyday knowledge', 'scientific knowledge for understanding' and 'other knowledges and judgements'(see Figure 1). Even though Moscovici did not seem interested in the process of learning, but in the language of communication in different social groups, others have been interested in the connection between learning and language. Sutton (1996a) speaks of science learning as "learning to talk in new ways" and seeing science lessons as offering "access to new conversation". He points out how scientists use language as an interpretive system for making sense of new experiences and to persuade others to share their view. It is used in an analogical or metaphorical way (Sutton, 1996b). However, later on when there is an established body of knowledge, there is much less doubt about how to express it. He calls language at that stage for 'language as a labelling system'; words label definite things.

The social representations themselves are described as having two facets: both iconic (giving images) and symbolic (giving meaning). They are often structured in a pictorial way: as images and metaphors. Thus, 'gene modified food' is an idea associated with bigger and better food, food that lasts longer, and at the same time it evokes an image of very red tomatoes or overgrown oxen. Moscovici also indicates that: "Social representations should be seen as a specific way of understanding, and communicating, what we know already. They occupy in effect a curious position, somewhere between concepts, which have as their goal abstracting meaning from the world and introducing order into it, and perceptions, which reproduce the world in a meaningful way" (Moscovici, 1984, p.17).

Similarly, Jerome Bruner sees language as referential and discusses three forms of representation: a) one-active representation that is directly associated with a concrete incident of action, b) iconic representation associated with images, and c) symbolic representation associated with language (Bruner, 1966, 1972). Language has many functions, of which one is to act as a code representing something. A pedagogical consequence of this understanding of language is that you must master something substantially in order to set words to it. Thus, learning the content and linguistic development is closely related (Øzerk, 1996). In the case of biotechnology, the content is not very well known, and may therefore increase the need of iconic representation.

2.3. Summary of frames

We have seen that several research traditions work on the same area but with different perspectives: Layton et al. (1993) claim that the public goes through a process of construction and de-/re-construction of scientific knowledge in order to make it meaningful and use it in action, and that this process is complex. Cobern (1996) supplements this with his theory of how our worldview influences how we perceive science. Moscovici (1984) describes how images or symbols of new scientific phenomenon in everyday communication, called social representations, reflect social groups' relationship to science. Herein I wish to explore whether the essence of special representations of biotechnology are connected to any social groups, especially groups with different educational background. Moscovici claims that some social groups may have a common way of living, but without necessarily a self-referential identity. For instance, mothers bringing up young children may not necessarily regard themselves as a special social group with a common identity, but they may have a common pattern of mass media exposure. This study wishes to explore whether a group with similar educational background could have common social representations. Could it not be expected that academics with a science background filter information from the mass media differently than non-academics with no special science education? And could we not expect that these different groups construct different social representations?

By involving classical myths about people's relationship to knowledge, for example the Frankenstein myth (see Text Box 1), I also wish to look at whether mythical perceptions may inspire the way the public perceives new scientific topics. The public's representations of biotechnology are revealed and presented in this study in order to explore the public's relationship to science. This may form a foundation for considering implications for science education. A student's everyday knowledge of biotechnology will likely be reflected in his or her representations of the issue and will in turn condition the student's understanding of the topic, as we have referred to above (Figure 1). In addition, there is an aspiration to explore whether or not different types of education and gender equips people with different frameworks or worldviews, and thus social representations, for interpreting new knowledge.

Text Box 1. The Frankenstein myth.

> In a dark attic in a spooky castle, Dr. Frankenstein is working on his great devotion; creating life. We see the image of his creature before us, an ugly robot-like monster, kind and gentle in the beginning, wanting to help people he meets. But after a while the monster turns on Dr. Frankenstein and destroys everything he cares for, his work, his family and eventually he rips the heart out of his bride. Perhaps he even will destroy the world? Mary Shelley's famous book is about the scientist and his dream (Shelley 1818/1992). Is the myth still alive today?
>
> *«Tampering with nature can be good now, but it will strike back on us in a couple of years.»*
> *«Animals that are so big that their legs break under them or their udders burst because of milk.»*
> *«The danger of uncontrolled spreading of artificial life.»*
>
> These statements are made today by members of the public about one of our newest areas of science and technology; biotechnology, and it is obvious that they fit the Frankenstein-myth perfectly.
>
> The concept of myth is here not used in the sense of a prejudiced conception of something, but as a classic story that continuously is told and re-told because it "speaks" to people. It continues to live because people find it meaningful. Like this myth of Frankenstein that expresses people's fright of research related to life or even creating life itself.

In this present study I wish to explore the public's perception of modern biotechnology and gene technology. This is done by studying people's immediate associations aroused by the words 'modern biotechnology' and 'genetic engineering'. Since gene technology is a new and expanding area of research, I assume that the majority of the public has not had any science education in the subject at school. Therefore it is likely that the knowledge the public possesses mostly can be looked upon, as a kind of everyday knowledge, and possible construction of scientific knowledge has been through interaction with the media. It is my aim to reflect upon and understand a little more of this everyday knowledge and how and by what it may be influenced.

3. Methodology

The Eurobarometer 46.1 was administered by the European Union in collaboration with a group of scientists from European countries in and outside the Union as a concerted action. The extended study by this group, led by John

Durant, George Gaskell and Martin Bauer in London is partly founded on the theory of social representation (Moscovici, 1984), and is placed in a social psychology research tradition. The survey was conducted in November 1996 in 17 European countries. The Norwegian survey has 970 respondents and was done as structured interviews where the interviewers wrote down the responses.

The data presented is drawn from an open-ended question (question 7, see Appendix 1a) that functioned almost like a word association: "What comes into mind when you think about modern biotechnology in a broad sense, that is including gene technology?" Associative replies have been analyzed according to categories of evaluation and content (Evaluation refers to the tone that is used in describing biotechnology; and by content refers to the themes that emerge). Ten percent of the material was cross-checked by one colleague in Norway and one in Sweden working on the corresponding Swedish material. Crosstabulation and correspondence analysis has been used on the categorized material. Interesting inter-correlations to indicate common factors were not found using factor analysis. An additional analysis was done using the computer program ALCESTE, which executes an automatic statistical procedure that allows identifying classes of discourse (see Reinert, 1983, 1990). Different words or word complexes that often occur together are recognized and similar responses are put together in discourse classes. The nature and content of each discourse class was identified afterwards by examining them qualitatively. However, it must be emphasized that this categorization is done automatically, and results from the ALCESTE analysis can merely give indications or tendencies about the material. The data has also been analyzed qualitatively in order to give a richer description of the material and to identify special images, metaphors or patterns of reflection about biotechnology. The qualitative analysis was carried out in interaction with quantitative methods. The statistical material was used in an explorative way to make a basis for the qualitative approach.

The material has been analyzed according to sex and education. The educational variables were level of education; 'primary school' (P), 'lower secondary' (L-S), 'upper secondary' (U-S) and 'university/college' (C/U), and type of education; 'science' and 'non-science'. This last variable was made based on whether the respondents considered themselves having any specific science education or experience after the age of 19. 'Science' is here used as a collective term for the subjects; engineering, medicine, chemistry, physics, biology, botany, ecology, anatomy and physiology (see Appendix 1a).

4. Results

In order to give an overview of the Norwegian biotechnology discourses found in the material, the ALCESTE analysis is presented in Table 1. The ALCESTE analysis from some other European countries is also presented. (Wagner et al., in press) Different discourse classes in different countries emerged from the analysis, reflecting what the public associated with 'modern biotechnology' and how they expressed their perceptions. This indicates how some countries have broad discourses and some have narrow. For instance, Austria has only one discourse class about the content of biotechnology, where it seems like the Norwegian public, with their five classes, more than the other countries are especially focused on the content of biotechnology. The only country specific discourse at the time of the survey appears to be in Sweden. They were specifically preoccupied with the brand of cattle called 'Belgian Blue'. (Please note that the survey was conducted before 'Dolly, the cloned sheep' was known.)

Table 1. Overview of discourses in some European countries based on the ALCESTE analysis (Wagner et al. in press). (See Appendix 1f for a large version.)

	WHAT IS BIOTECHNOLOGY? FOCUS ON CONTENT					IS BIOTECHNOLOGY GOOD OR BAD? FOCUS ON EVALUATION					COUNTRY SPECIFIC			
	General (rather neutral)		Specific: Domains of Application (evaluation involved)			Positive	Ambivalent	Negative Evaluation				Lacking knowledge		
	Research (progress)	*Manipulation/ Alteration*	*Food*	*Reproduction*	*Medicine*	*Good*	*Good but risky*[1]	*Risky/ Dangerous*[2]	*expression of fear*	*Interfering with nature*		*Echo*[3]	*Guessing*[4]	*Don't know*
AUSTRIA	Biotechnology is a scientific activity applicated to plants, animals and humans (food, reproduction, medicine) (27%)						Good but risky/ dangerous (fear) (22%)	Unknown effects/ dangerous (16%)		Interfering with nature STOP! (36%)		see Interfering with nature		see unknown effects
FRANCE	Research (11%)		Food/ Agriculture (15%)	Reproduction (2%)	Medicine (14%)	Improvement (10%)	Dangerous/risky although there can be good effects (also morally dangerous) (8%)		Fear Against nature (18%)			Echo (3%)	Guessed (16%)	Don't know (3%)
GERMANY		Manipulation of plants, animals, humans/ Agriculture (16%)	Food (also medicine and reproduction) (15%)		Medicine (12%)			Good but risky risky/dangerous (fear) (37%)		Interfering with nature STOP! (11%)		see Medicine Good but risky		Don't know (10%)
NORWAY	Research (8%)	Alteration of plants, animals, humans (21%)	Food (8%)	Food and Reproduction (16%)	Medicine (14%)		Good but frightening Unspecific worry (22%)			Interfering with nature (10%)		see Medicine Good but frightening		
SWEDEN	Research (19%)	Manipulation of plants and animals (11%)		Food and Reproduction (7%)			Good if used the right way/ dangerous (15%)		Fear too fast (19%)	Interfering with nature (21%)	Belgian Blue (9%)	see Research		
UK			Food (21%)	Reproduction (7%)	Medicine (21%)				Unspecific worry/dangerous (fear) (16%)	Interfering with nature (18%)		see Medicine		Don't know (17%)

[1] Good but risky: may have good effects but is risky and dangerous, therefore must be applied properly, demand for control
[2] Risky and Dangerous: biotechnology is unpredictable and therefore dangerous, fear of loss of control
[3] Respondents repeat technologies mentioned in the preceeding question ("telecommunication", "solar energy", etc.)
[4] Associations evoked by the terms "bio", "gene" and "technology" (mostly positive: e.g. ecologically beneficial or optimistic view of science)
Numbers in parenthesis indicate for each country the percentage of responses being classified to a specific discourse

4.1. Quantitative analysis

The Chi-square test of significance was used as a statistical test when different variables were compared. The Chi-square tests do not show many differences at a 0.05 level. However, I have chosen to comment on tendencies of difference.

4.1.1. Evaluation tone

All of the responses to the open-ended question in the Norwegian material were categorized according to evaluation tone. The categories and the percentages are presented in Figure 2. The tone is predominantly neutral and negative. Figure 3[1], shows a comparison of the evaluation tone with other European countries. Norwegians are the third most negative in the way they speak of biotechnology. One example of a neutral response is: *With gene technology they can manipulate this to get a desired characteristic.* And a negative: *I'm afraid that there is too much tampering.* If these results are compared to another question in the Eurobarometer ("How will biotechnology change our life in the future?"), the data reveal an inconsistency. Here the most frequent answer is that biotechnology will make life better (Figure 4). Replying to a direct question, the public believes that biotechnology will contribute positively to our society, but at the same time they may have a negative image of biotechnology. There are also other interesting disharmonies between the replies to the direct question about biotechnology in future life and the evaluation tone in the open-ended question (see Figure 5). No correlation is shown between the public's expectancies of biotechnology and the tone in which they mention it. This will be discussed later.

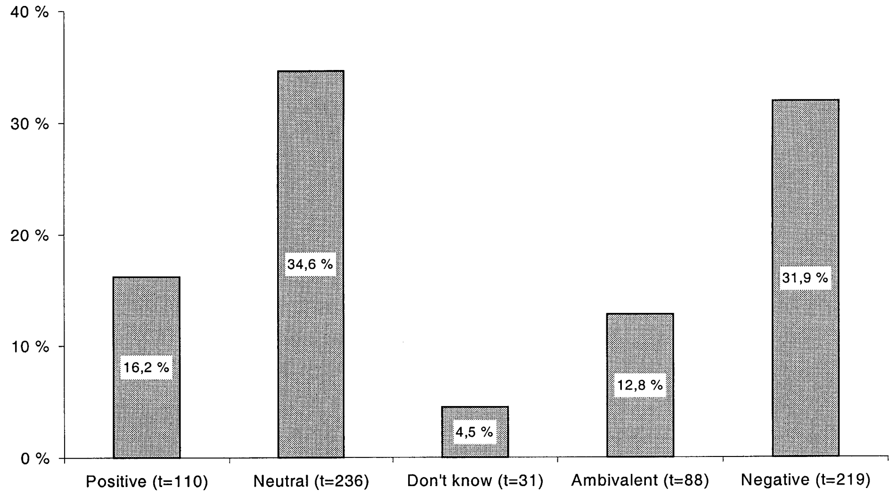

Figure 2. Evaluation tone in the Norwegian open-ended question.

[1] The data in Figure 3 are not analyzed in Norway together with the rest of present study. The Austrian team that did this analysis treated the 'I don't know' responses differently, thus the Norwegian percentages are slightly different in Figure 2 and 3.

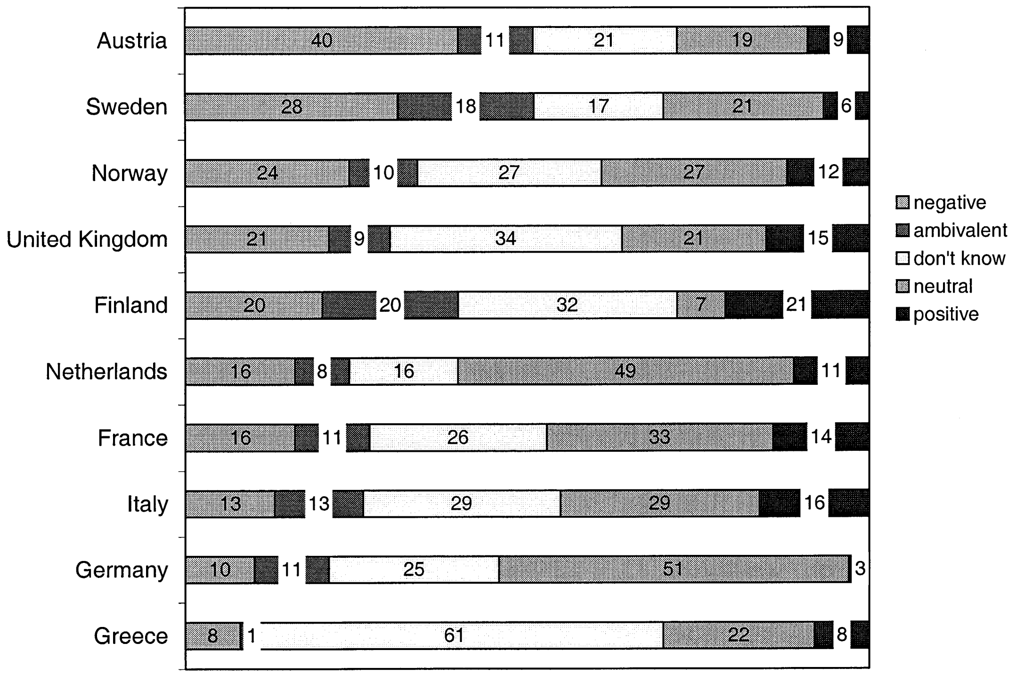

Figure 3. Evaluation tone in European countries in percent.

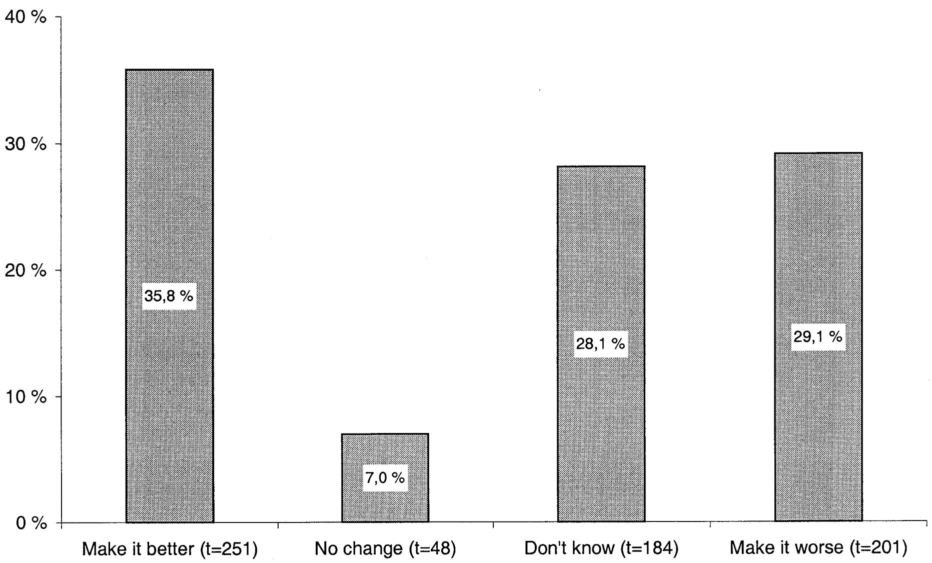

Figure 4. How will biotechnology change our life? (Question 6 in the Norwegian survey. See Appendix 1a.)

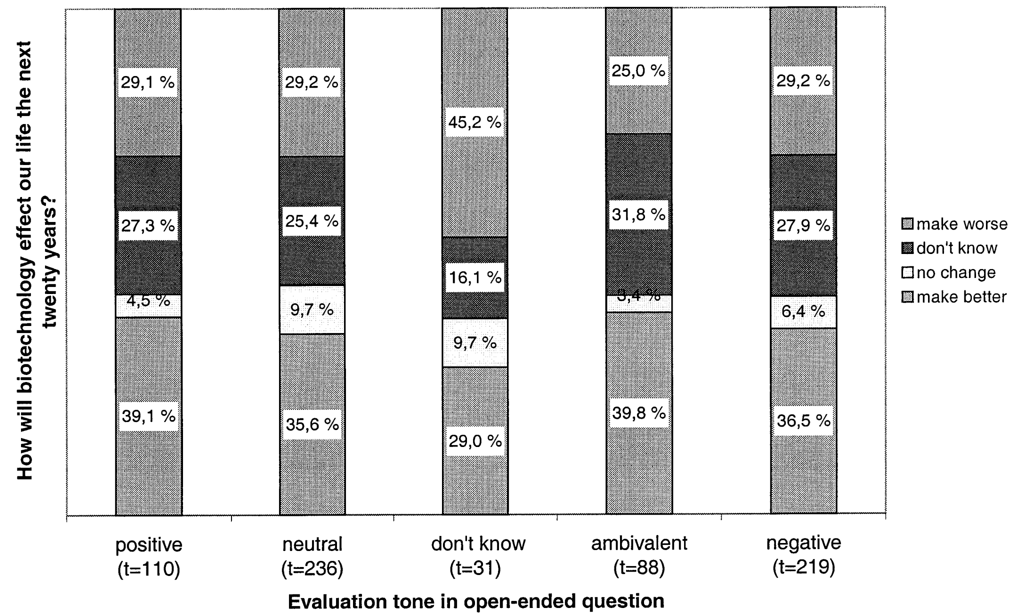

Figure 5. Comparison between the open-ended question and a direct question about biotechnology.

When the evaluation tone is compared to the level of education (Figure 6), we see that there is a tendency for respondents to have less positive evaluation tone as they acquire higher levels of education. A negative tone is most common in the group with upper secondary school educational level. If the educational level is further broken down to science and non-science education (Figure 7), then there is no clear pattern. It does not seem as an education in science has made any difference in the way biotechnology is evaluated in symbolic expressions. There are some interesting tendencies though, for instance that for the scientist group the amount of negative expressions increase together with increased educational level. Non-scientists are generally more negative then scientists and this also increases with the level of education accept for that the highest educated scientists are more skeptical than the non-scientists. Women and men show statistical differences in evaluation tone. Women are more negative and less neutral than men, and they more often give a 'I don't know' answer (see Figure 8).

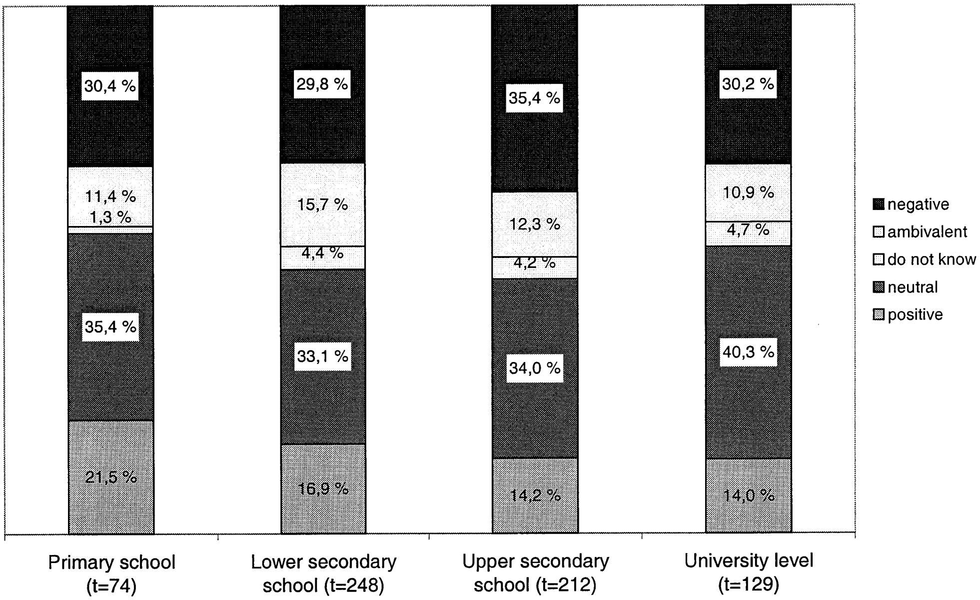

Figure 6. Evaluation tone of respondents by education backgrounds.

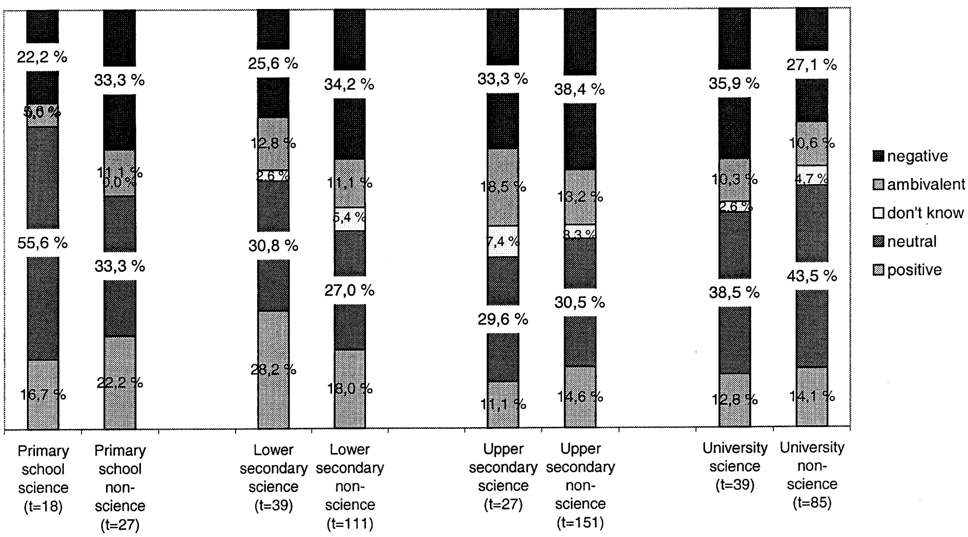

Figure 7. Evaluation tone by different kinds of education.

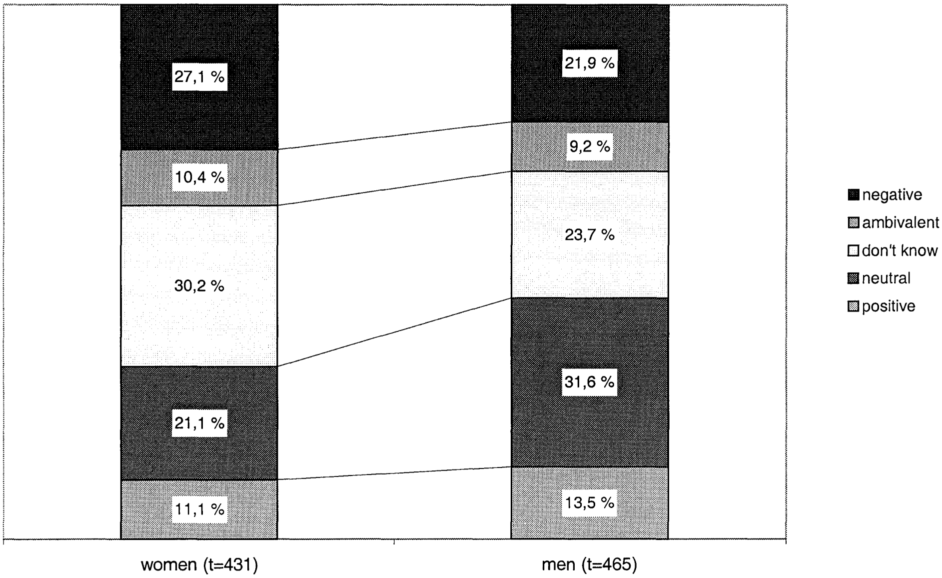

Figure 8. Evaluation tone of biotechnology by sex.

4.1.2. Content

In Figure 9 an overview of the topics mentioned and associated with biotechnology is presented. The three most frequent topics are: animal, food and medicine, which may agree with the fact that the most frequent evaluation tone is 'neutral'. The results are compared to education in Table 2, and again there are no striking differences between those with science education and those without. The number of responses for each educational variable are very few and therefore it is difficult to trace significant differences. Nevertheless it is worth calling attention to Figure 10, which shows how moral topics decrease with higher education for non-scientists, but increase with science education. Of those with lowest education and no science background, 21,4 % refer to moral issues in their response. The number decreases to 13,5 % for respondents with university level education. The picture is the other way around for respondents with a science background. Of low education respondents, 14,8 % refer to moral, and with higher science education there is an increase in moral responses to 20,8 %.

Men more often mention food, plants and refer more to progress than women. There is also a tendency of women bringing up moral issues, fear and a reference to nature more often. (See Appendix 1b.)

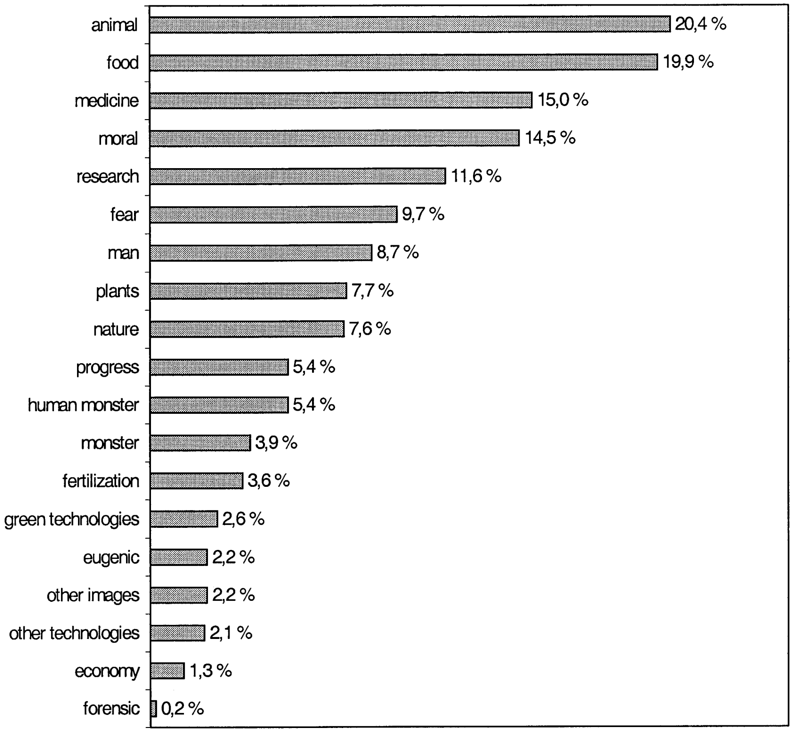

Figure 9. Topics associated with biotechnology.

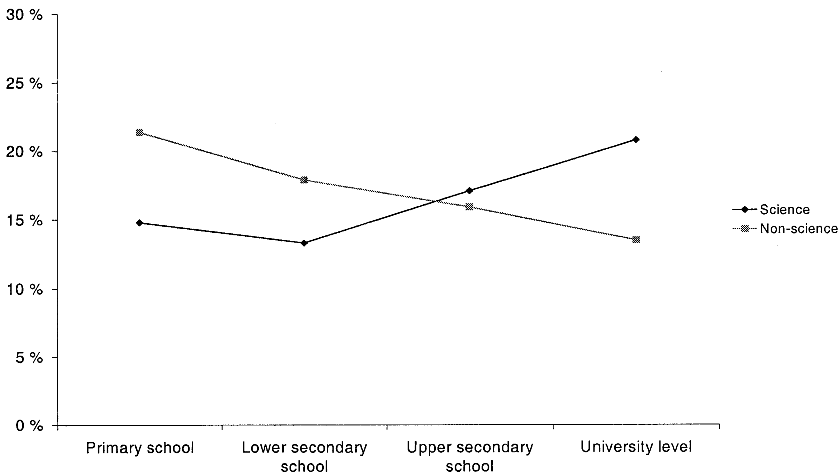

Figure 10. Reference to moral tone by education backgrounds.

Table 2. Associated topics by education backgrounds in percent.

	Science level				*Non-science level*			
	P	L-S	U-S	C/U	P	L-S	U-S	C/U
Animal	14,8	11,7	22,9	27,1	28,7	19,3	21,5	17,1
Food	18,5	18,3	20,0	22,9	25,0	23,6	16,4	20,7
Medicine	14,8	21,7	20,0	12,5	25,0	11,4	15,9	11,7
Moral	14,8	13,3	17,1	20,8	21,4	17,9	15,9	13,5
Research	11,1	6,7	5,7	10,4	10,7	12,9	11,8	14,4
Fear	3,7	11,7	8,6	8,3	7,1	10,0	12,8	12,6
Humans	7,4	6,7	8,6	8,3	14,3	12,1	8,2	6,3
Plants	7,4	3,3	5,7	12,5	17,9	4,3	10,3	7,2
Nature	3,7	8,3	8,6	6,3	10,7	10,0	9,7	4,5
Progress	3,7	5,0	2,9	6,3	10,7	9,3	5,6	4,5
Human monster	0,0	3,3	8,6	6,3	3,6	7,9	6,2	3,6
Monster	7,4	3,3	5,7	2,1	3,6	3,6	5,6	2,7
Fertilisation	0,0	1,7	0,0	8,3	7,1	6,4	3,6	4,5

4.1.3. ALCESTE

The ALCESTE analysis resulted in seven classes of discourse (see Table 3). By looking at the words typical for each class and looking at examples of responses, an interpretation was done on determining which seven discourses could be separated. The biggest class was the one called 'Good, but frightening', which contains principally unfounded ambivalent statements. One class is called 'Alternation', which is mainly neutral and that describes superficially the content of biotechnology. 'Possibilities' informs of different possibilities in using biotechnology in basically food and reproduction. The forth biggest discourse class gives positive prospects related to medicine and is called 'Medicine'. 'Nature' is concerned with biotechnology interfering with nature, but 'Research' is influenced by research and improvement. The discourse class named 'Food' refers to food in a rather neutral manner. Distributed on the different varieties of education background, there is not many notable differences or patterns that could point to the notion that one class of discourse is influenced by the level of education of the respondents. (See Appendix 1c.) However, the degree of groundless worry, and statements about tampering with nature, seems to decline with more education. There were no significant sex differences.

Table 3. Description of the Norwegian ALCESTE classes.

Class discourses	*Typical words*	*Typical responses*
class1 – **Alternation** (21,33%) Neutral (toward negative), superficial knowledge of the content of BT	animals, humans, plants, development (evolution), change (alteration), crossing, food production, experiment, matter of inheritance, oversized, to mess,	"change in the development of animals, humans" "crossing plants, animals, humans"
class2 – **Possibilities** (15,85%) Possibilities in using BT; manipulation of food and reproduction	get, fruit, vegetables, genes, manipulate, bigger, children, will be, growth, characteristic, foetus, meat, people,	"can get children with special characteristics, the animals will be bigger" "manipulation of genes to get the products you wish, especially fruit and vegetables"
class3 – **Medicine** (14,09%) Positive prospects related to medicine	diseases, new, against, better, less, cancer, aids, vaccines, give, everyone, become, thing, some, possibility, everything, fight, easier, man, improve	"get new vaccines against, diseases, impair old age, improve, life for everyone, cleaner energy, enough food for everyone, vaccines against diseases as aids"
class4 - **Interfere** (10,37%) Interfering with nature	nature, tampering, like, in, scaring, very, destroy, should, to mess	"tampering with nature" "don't like interference with what's natural"
class5 – **Research** (8,41%) Research and improvement	research, medicine (medical), gene manipulation, improvement, food, gene research, foetus, develop	"improvement of food production, treatment in medicine, gene manipulation" "gene research, gene manipulation, medical research"
class6 - **Food** (7,63%) Food	food, gene manipulated, artificial, gene, production, living, life, change, make	"gene manipulated food" "artificial production of living creatures"
class7 – **Worry** (22,31%) Unfounded ambivalent statements "Good but frightening"	is, gene technology, negative, positive, will, biotechnology, bio-, technology, something, a little, both, must, shall, frightening,	"gene technology is completely wrong, something positive and negative" "very in doubt about bio/ gene technology"

4.1.4. Knowledge

Before turning to the qualitative research, I would like to present the knowledge score from the Eurobarometer and relate it to the educational variables. The score is derived from ten knowledge questions (see Appendix 1a for full text; see Figure 11 and 12). Figure 11 shows a correlation between educational level and the number of right answers on the knowledge questions in the survey. But if the data are further differentiated into science and non-science, Figure 12 shows that non-scientists score better on the knowledge questions! There are no sex differences (see Figure 13).

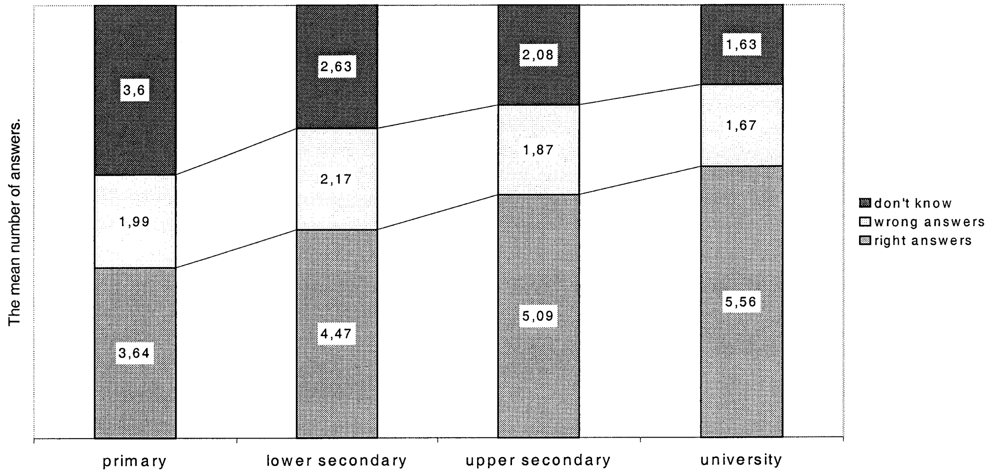

Figure 11. Knowledge questions from Eurobarometer 46.1.

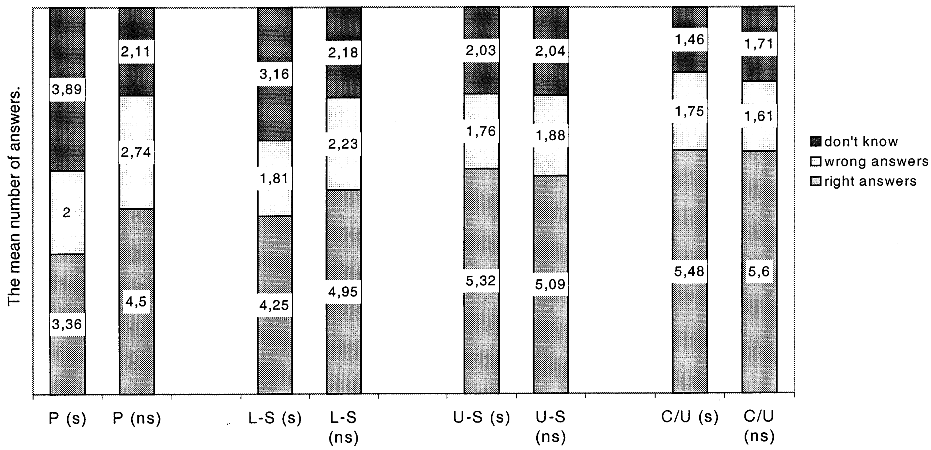

Figure 12. Knowledge questions by education backgrounds.

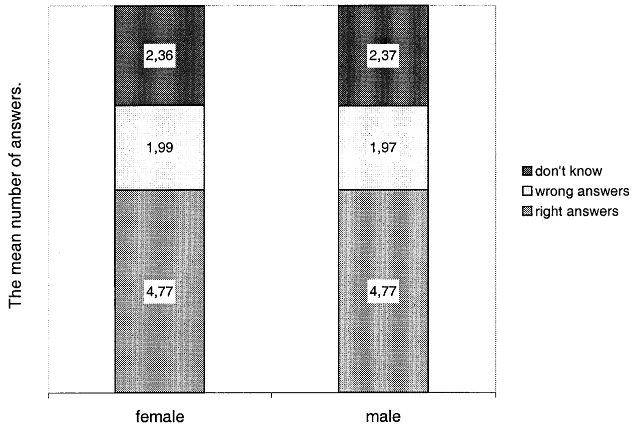

Figure 13. Knowledge questions by sex.

4.2. Qualitative analysis

First I will give a picture of the evaluation tone of modern biotechnology, and further illuminate the discourses that emerge from the material. No differences by sex could be detected in the material. Educational background does appear to have some influence on groups of responses.

4.2.1. Evaluation tone – negative

The Norwegian data have a greater performance of negative responses when compared to most of the other European countries. Just Austria and Sweden are more negative. The responses with a negative tone are characterised in different ways. Some simply state that they do not like, are skeptical or afraid of modern biotechnology, and do not state the reasons for it. '*Do not have a feeling for gene technology'. 'Looks very scary'. 'Doubtful. Irresponsible.'* Others give moral arguments. '*Wrong to tamper with nature', 'Creation is as it is decided. It is negative to tamper with it'.* It is stated that humans have no right to tamper with nature, and that it may be dangerous. Nature is given its own identity, and has its own value. '*Think that nature is well enough made as it is'.* It is seen as an intrusion of what is natural. '*Unnatural tampering with nature'.* These kinds of statements tend to be made by people with less educational background.

Some refer to biotechnology as 'playing God'. You manipulate with man, and create humans as you want them: perfect, with no diseases. A mistrust towards researchers is revealed. '*Tampering with reproduction. Manipulating life'. 'They mess up with what is created by Mother Nature ['naturens hånd'] It is like when* *they made the atomic bomb. That was also a mistake. People should keep their fingers away from this'.*

Many of the respondents are afraid of the consequences of biotechnology. They perceive that it can result in a damaged world, either ecologically, medically, or we could get a society we do not want. *'Am against gene technology. Can destroy what nature gives us'. 'Can get an unbalance in our nature. Dangerous with too much research on plants and animals'. 'Cloning. Robots'. 'Am afraid development goes the wrong way. All science and technology will have too much influence on our way of living. Nature should not be researched on or tampered with'. 'Risk of new diseases. Possibilities of different transplants. Immortality'.* On one hand people are afraid we do not know enough about what may happen, and on the other hand they express a fear of humans, and especially researchers, knowing too much. *'Something about patterns of inheritance. Research about this can easily go too far'. 'Will create chaos. Humans touch things, which they should not'.* People with these kinds of responses; 'playing God', and 'worried of the consequences', tend to have more education. It may seem as if there is a fright of loosing control. This will be elaborated later under the risk discourse.

4.2.2. Evaluation tone - positive

Like in the negative responses, some of the positive ones merely state that they have a positive attitude. *'Look upon it positively'.* Others just express that they think this kind of research is good and for the better. Both cases are typical for respondents with little education. The words 'better', 'good' and 'improve' are frequently used. The new technology is looked upon as the solution to many of our problems. There is faith in the experts. *'Can be good to improve things', 'Fewer diseases on plants. Vaccines against illnesses'. 'Research makes life better'.*

Respondents with more education tend to show some knowledge of what the new technology implies and see the positive sides. *'Can change people's genes to avoid inherited diseases or defects'.* The responses show faith in the future, and that the world will be a better place to live. *'Our knowledge will be much greater. We learn to take care of our environment. The prospects for the future will be better with this new knowledge'.* Modern biotechnology is recognized as a good instrument for combating diseases and hunger. *'A way humanity faster can reach a better exploitation of nature. Politicians must distribute the benefits. Possibly better the world's poverty'.*

4.2.3. Evaluation tone - neutral

Some of the neutral responses are characterized by mentioning different products respondents consider to be a result of modern biotechnology, like new vaccines, test-tube babies and durable food. *'Gene modified tomatoes', 'New plants that grow faster. New brands of grain', 'Corn with double harvest. Breeded fish that grows 3-4 times of natural growth. Apples as big as grapefruit'* Some of the responses could be interpreted as negative visions, but there is no evaluation connected to them so this study has chosen to evaluate them neutrally. Examples are: *'Strange organisms', 'Animals with hormone disturbances', 'Abnormally big animals because of gene manipulation', 'Perfect children'. 'Artificial food',' Gene manipulation', 'Humans that can have pig hearts'*. These respondents tend to have more then primary education.

Neutral responses may also contain a short explanation of what respondents think modern biotechnology is. They often have the form of an 'examination reply', like what you would be expected to answer on a school test. *'Crossing of genes within food production', 'Research on genes and reproduction', 'Genes decide how a living organism will be. By gene technology they can manipulate this to get a desired trait. They can transfer genes from one species to another'*. There does not seem to be any connection between education and this type of response.

Single words that can be seen as synonyms or alternative phrases for modern biotechnology constitute a large part of the neutral evaluation. Biotechnology is expressed in a different way, like: *'Medical research', 'Gene manipulation. Cloning', 'General development', 'Biology'*. Other single words can be what is believed to be the targets for the new technology. *'Food. Fetus. Animals', 'Hospital', ' Salmon breeding'*. Usually these respondents have little education.

Philosophical reflections also occur. *'The world is in a constant development.', 'Research on life at all.' 'New ways to have babies. Research of the future and of the past.'*

4.2.4. Evaluation tone - ambivalent

In ambivalent responses there are both a positive and a negative element. Modern biotechnology is portrayed as a helper within food production and medicine, but unfortunate effects are also brought ahead. Moral reservations are also expressed. *'Good in medical contexts. Morally difficult questions.', 'Dangerous to busy oneself with nature/people. Cloning. Good that they invent new medicine.'* Sometimes the ambivalence appears in the same sentence, and truly shows people's conflicting relationship to this new technology. *'Biotechnology must be held under control to be positive'. 'Research has come a long way, should put on some brakes' 'Progress is a bit quick nowadays.'*

4.2.5. Representations

By extracting from the methods used on the open-ended question in the Norwegian material, and actually counting appearances (see Appendix 1d for an overview of the 'Monoconc' word count), the most frequently occurring representations for biotechnology found are: tampering, manipulation, interference, big or bigger, cures cancer and AIDS, artificial, durable, designer-babies, hormones, tomatoes and "super-creatures" (animals, humans etc.). No representations seem to be specific for any educational or gender group (see Appendix 1e).

4.2.6. Ethical discourse - Is it right to apply biotechnology?

The greatest concern for those that raised a ethical discussion in the Norwegian material, is whether it is right for man to tamper with nature. Nature is being manipulated and destroyed, and man will be punished for the intrusion by nature itself. *"Tampering with nature can be at the present, but it will hit back at us in a couple of years."* There is also a general concern of too much research being done. Man is not meant to have so much knowledge.

Other special issues being raised in this context is reproduction and human worth. Because one sees a possibility for biotechnology to be used for human selection, for instance in pre-natal testing and cloning, there is a fear for a general lowering of human worth. Norwegians also refer to the concept of designer-babies and often mix it with test-tube babies. *"Not good: making children in tubes and sorting the children accounting to if they are good or bad."*

Animal worth is additionally mentioned as important in the ethical discourse. People image huge monster-like animals in wild experiments, suffering for the benefit of mankind or merely for the benefit of the scientist. And this is of course not morally defendable.

4.2.7. Risk discourse - Is biotechnology good for us?

The biggest general risk expressed in the Norwegian material is the loss of control, which also was articulated under the negative responses. *"Uncontrolled spreading of artificial life."* This risk is expressed either like; man loses control and nature itself takes over, or; man takes over and tries to control processes that before were God's (or Nature's) domain. There is also a fear of researchers taking over and controlling our lives. *"Mad scientists that will use this in a wrong way. Everything will come out of control"*.

When talking about the risk of food and biotechnology, Norwegian people are mostly neutral and positive. They mention it in a consumer context, and are not particularly concerned about the food being unhealthy for humans, or influencing the ecological balance. The main emphasis is on biotechnology improving the food's taste, looks and keeping quality, and improving the food production, making the growth more efficient and the individuals bigger. Negative statements that occur are fear of food being destroyed or spoiled because of manipulation and a concern for animals and plants and their unnatural growth, often caused by hormone disturbance.

The medical application of biotechnology is highly viewed as positive for people as consumers. Biotechnology will bring new and better medicine that will assist in fighting diseases. Because the knowledge of diseases will become greater, they will be easier to detect and easier to fight. Some people have an image of biotechnology as a weapon for getting rid of all illnesses, or at least the inherited ones, by changing the human's genes. Medical research is often mentioned. The few negative responses to biotechnology in medicine, is based on a fear for how this research can be used to select perfect humans. There is also a fear of new diseases. Only one respondent mentions a fear of resistant bacteria.

5. Discussion of results

In the introduction a discussion of science education, the public's relationship to science and scientific knowledge, was raised. Being scientifically literate was described as having science naturally present as part of one's way of living. This does not mean that one has to undertake a scientific epistemology, but that one is able to relate to science in meaningful ways. Now, how does this include being able to meet and understand new scientific concepts? This study does not reveal people's 'level of scientific literacy'. A free word association is certainly not an assessment tool for measuring levels of understanding. But the associations may be used for exploring how people cope with a new scientific phenomenon. What frames of discourse do they draw on? What images do they apply? And what language do they use? The present results may be valuable for broadening the perspective of scientific literacy. The results may also offer ideas for science educators with respect to how to introduce new scientific phenomenon in the curriculum in order to contribute towards the public's understanding of science.

The quantitative analysis of the material does not show much correspondence between type of education and categories of evaluation and content. What we do see is a small decrease in positive evaluation tone with higher education, and an increase of a neutral tone. When the material is distributed on scientific and non-scientific education, as mentioned, there is higher skepticism (negative evaluation) amongst those with science in their university level education than amongst those with a non-science university education. If people have some science education, the tendency seems to be that they become slightly more negative towards biotechnology with the higher education acquired. This can also be seen in the 'moral' variable in the content part of the quantitative analysis. The higher level of science education, the more ethical issues raised in the responses. For the non-scientists, the picture is the opposite: with higher education there was a decrease in ethical perspective in the responses. This similar pattern can be seen with the variables 'animal' and 'food' (see Table 2). How can this be interpreted? A general belief has been that a scientifically literate public will be more inclined to show support for developments in science and technology. This present study, however, appears to contradict that belief. If a goal of science education is to examine critically new phenomenon, it seems like that part of the education partly has succeeded. Other works have also shown that increased knowledge about science issues may be supported by a general skepticism (Gaskell, Bauer and Durant, 1998; Hviid Nielsen, 1997a). Even though ALCESTE is an inaccurate analysis, it does neither in any way show a correspondence between higher science education and a support for biotechnology.

It is usual to believe that higher science education corresponds with an increase in knowledge. As Figure 11 and 12 show, however high knowledge corresponds with high education, those with high science education do not score higher then those with high non-science education. In his study of a sample of the adult population that was interviewed about scientific issues, Lucas (1987) concludes that there is little evidence for the effect of science instruction. This seems to agree with the results presented here.

Regarding social representations (Moscovici, 1961/1984), as a conclusion of this study it does not seem like science education constitutes social groups with special social representations. Almost regardless of type of education there are no clear indications that one group receives and interprets this new science/technology differently then another. All groups have representatives that are in favor of and that are opposed to the new technology. There is no exclusive group preoccupied with special contents of biotechnology, and no educational group refers to it using a special image or metaphor. However, it is interesting to point to the fact that people with higher education in science are not, as many may presume, especially positive or future optimistic about biotechnology. As mentioned above, there is a small correspondence between science educational level and moral tone: the higher science education the more concerned people are. They stand out from the other groups because their concern seems not to be based on a picture of threat. This conclusion is grounded on the facts that they do not see biotechnology as 'tampering' (see Appendix 1e) and have few 'monster' associations (Table 2). Although they do have some 'human monster' associations, when these are analyzed qualitatively, they may be seen as ethical considerations around the notion of screening for successful people ('super-humans'). This reflects an ethical risk of a changed society with different norms and values. Moreover, in another question in the Eurobarometer 46.1 about the likeliness of biotechnology resulting in 'designer babies', Norwegian respondents were far above the European mean in believing this (Durant et al., 1998).

By looking at the present study as a whole, one thing that is clear is that the public's relationship to biotechnology is very complex, which confirms the presented statements of Layton et al. (1993). (See also Wynne, 1996.) Education with or without science does not seem to make a big difference in how people relate to this new technology, except for a slight increase of skepticism with higher science education. This complexity is expressed in Figure 5. There is no correlation between future expectancies and the tone in which they mention biotechnology. Respondents who think biotechnology will make our life better still may refer to it as negative or ambivalent, and respondents who think it will make our life worse also see positive sides. This intricacy is demonstrated in other questions in the Eurobarometer reported by Durant et al. (1998). When the mean values are summed over six applications of biotechnology they show that the Norwegian public see the usefulness of the technology, especially in medicine, but they also think that it has a high risk factor, that it is not morally acceptable and that it should not be encouraged. It leaves the impression of being helped by someone you do not trust.

In the introduction there is emphasis on the importance of a person's worldview and his or her relationship to science (Cobern, 1996). Science education alone has not shown to be a frame of reference important to shape peoples' image of biotechnology. Interestingly, Hviid Nielsen (1997b) has shown how different worldviews can result in similar attitudes towards science. European skepticism towards modern biotechnology is so widespread and recalcitrant Hviid Nielsen declares, because it is made up of two distinct factions, one with traditional ('blue') values and one with modern ('green') values. The 'blue' critique is based on nature as God's creation, and the 'green' skepticism is based on unacceptable risks and uncertainties.

As described, 'tampering', 'manipulating' and 'interfering' were the most common representations of this new technology, and is consistent with the risk discourse. People are concerned with the loss of control, which can be seen as a Janus-face. On one side there is a fright of man controlling nature, man 'playing God', especially of researchers that 'manipulate' and 'tamper', and in the special situation of biotechnology 'nature' also includes 'man'. This view is reinforced by the fact that 43% of the respondents agreed to the statement that biotechnologists would do whatever they like irrespective of regulations (Durant et al., 1998). On the other side there is a fright of loosing control over nature. Nature will 'strike back' at us and take its own ways. And perhaps we may loose control over ourselves? The notion of man controlling nature is also closely associated with science. Francis Bacon wrote that science should lead to the sovereignty, dominion, and mastery of man over nature, the 'command of nature in action'. Through the powerful objective reasoning characteristic of science, human beings can control the world.

We can see a reaction opposing this rooted in Western mythical culture, for example in myths like 'Frankenstein', where the wish to control life and death leads to "an uncontrolled spreading of artificial life", and 'the Sorcerer's apprentice', where insufficient knowledge about control leads to a catastrophe. The notion of knowledge and control has always been one of the Western culture's big questions. Even the myth of creation, 'Genesis', is based upon the dilemma, and 'the fall of man' happens because man chooses to gain the knowledge of right and wrong and is thus no longer controlled by God. Through knowledge man attains control, but also greediness and the struggle for staying in power. There are also myths, or folk tales that can answer to the positive and innovative attitudes people may have for biotechnology. A common Norwegian folk tale figure is 'Askeladden', who always gets to marry the King's daughter because he is curious, helpful and always sees possibilities in how to use things he finds! An explanation of the concept 'myth' is offered in Text Box 1. I have wished to use these retold classical stories as examples of another kind of 'truth'. Not a 'scientific truth' about nature underpinned with empirical data, but a 'truth' about how man always has been preoccupied with these 'eternal questions' of knowledge, power and control. Biotechnology represents knowledge of the nature of man and simultaneously it is a technology that people perceive as an instrument that is able to change the nature of man. I suggest that this is one of the reasons for people's inconsistency.

6. Implications for science education.

Barton (1998) claims that scientific facts are consequently treated in schools with the same respect with which religious facts were treated only a century ago. They are given as 'truths' about nature. Lemke (1990) describes how the dialogue in the science classroom transpires between the teacher and the students; and how the dialogue substantiates a picture of science as having true answers about nature. The teacher possesses the knowledge, asks the questions, and the students have to find the right answers. In his work on beliefs about science and language, Sutton (1996b) describes how science in the classroom is mainly associated with 'language as a labeling system' for describing, reporting and informing. The language is apparently independent of a person's voice, is definite and precise. Thus science is experienced as a way of transmitting knowledge about nature. In our survey there are many responses of this labeling nature especially amongst the neutral evaluation tone. Barton refers to Fox Keller (1985) that equates this power picture of science with paranoia:

> Grounded in the fear of being controlled by others rather than in apprehension about the loss of self-control, in the fear of giving in to others rather that to one's own unwelcoming impulses, the attention of paranoid is rigid, but it is not narrowly focused. Rather than ignore what does not fit, he or she must be alert to every possible clue... Everything must fit... All clues fit into a single interpretation...with no room for alternative explanations. (Fox Keller, 1985, p. 121)

In this way one single explanation is promoted and this could be seen as the dominion of science over nature. Could this view of science being objective and resulting in independent, unbiased knowledge, be the reason for parts of the public to fear that biotechnology could take control over our lives? From a feminist perspective Barton (1998) suggests a rethinking of science education where scientific knowledge is acknowledged as culturally and socially bound. Many science education researchers have come to similar conclusions (e.g. Jenkins, 1994; Kyle, 1991; Solomon, 1996; Sjøberg, 1998).

In line with this, Sutton (1996b) calls attention to that science also is a tool for trying out ideas, for figuring out what is going on, for interpreting the situation. Thus, you have to use language as 'an interpretive system' for making sense of new experience. Here the language is clearly a product of a person's voice. It is analogical and metaphorical. It is persuading others towards a new point of view, building up a new community of thought. This is exactly the nature of the bulk of responses in this study. Sutton asserts that teachers should to a greater extent, present science in a interpretive language and hence as a human product of scientists. Or else, he claims: "They come to expect the transmission mode of 'the labeling system', and are ill-prepared to use their own language interpretively to re-express in their own words what the scientists meant"(Sutton, 1996b, p. 13). The interpretive language is an important implement for empowering students to relate science to their lives.

Further, Barton (1998) argues that "science education needs to be recreated so that teachers and students can collaboratively create and analyze science and its role in their lives" (p. 18). The role of science in society should be analyzed, for instance how scientific knowledge has been constructed through specific political agendas. Teachers need to help students create new and different representations of science that are inclusive of students' entire lives. Students should be helped to 'possess' their own scientific knowledge, both facts and knowledge of science as a culture. Solomon (1996) claims that in this way everyone can appreciate new developments and may evaluate them for their own and others' style of living. She also points to the need of linking science education to ethical sensibility and simple enjoyment.

The data in this study also show the public's concern on ethical issues and biotechnology. The question of animal worth is often brought up as well as the question of human dignity. *'Tamper with life so the perfect human being is possible', 'Improvement, People/ animals will be produced in series'.* What Bronowski (1956/1975) puts in the mouth of Harding, the humanist in 'The Abacus and the Rose' seems to express this same concern:

> People are protesting against the invasion of their lives, not by this death-dealing machine or that, but by the machine itself – by the machine as a form of spiritual death. [...] No; they are protesting against the mechanics of all that is happening to life: against the domination of life by mechanics. They are not afraid that mankind will perish; they are afraid that *humanity* has perished already under the big wheel of scientific progress. (Bronowski, 1956/1975, pp.107-108)

There obviously is a need to address ethical-philosophical issues in biotechnological education, and there should be recognition of emotional reactions in addition to rational reasoning. Biotechnology education should also include learning and teaching strategies that enhance imagination and critical reflection, both affective and cognitive aspects of learning. Examples of this may be the use of literature, narratives and myths, as well as the use of role-play and drama. So, why not invite Frankenstein into the science classroom! Why not use the students' own associations to biotechnology as a starting-point, hopefully with analogies and metaphors, and with both positive and negative attitudes grounded in science expectations and moral hesitations. Encourage them to use an interpretive language and let the students explore their own associations and scientists' explanations.

Pointing to the importance of investing in human resources, Kyle (1996) requests that science education be transformed from the passive, technical, and apolitical orientation that is reflective of most student's school-based experiences to an active, critical, and politicized life-long endeavor that transcends the boundaries of classrooms and schools. Modern biotechnology is a very exciting new scientific and technological development. It may give unperceivable possibilities. It may change our lives in unexpected and positive ways. Many respondents express this optimism. *'A faster way mankind can find a better exploitation of nature. Probably improve the poverty in the world', 'Get new vaccines against diseases, impair old age, improve life for everyone,* *cleaner energy, enough food for everyone, vaccines against diseases as aids'.* In order to enjoy and make the most of these possibilities in a way that harmonizes with their perspectives of a better life, students should not be left feeling alienated towards the subject because emotional, ethical and philosophical aspects are not addressed. For all students it is important to get used to seeing science in multi-faceted, multi-dimensional and multi-cultural ways. That may be the best empowering resource student can gain in science education and use in handling the future's possible 'new biotechnologies'. One of the respondents answered as follows when asked what comes to mind when thinking of modern biotechnology: *'Research forwards and backwards in time'.* It could be paraphrased to apply for science education. 'An education about the past, for the future'.

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Paper II

Dramatic Science

How Drama Can Promote Learning in School Science

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Abstract

It is the nature of drama to create fictitious worlds. In science education this can be used to create and substantiate subcultures, for instance a research community. Taking on roles is a main activity in drama, and it is also well known for most of us. In science education, roles can be utilized to make explicit and facilitate border crossing into the subculture of science. The pedagogical advantage of drama is the possibility to step out of role and reflect at distance on personal experience, which gives occasion for metacognition with empathy. To learn about science in the context of society, drama can be used for making simulations of the 'real everyday world', where science is recontexualised for specific purposes, and where students experience using cognitive, affective and active aspects of learning.

This article establishes a connection between a science teacher's practical experience of the use of drama in the science classroom and frames of discourse in the science education research community. The role of creativity and imagination in science and in learning is discussed in relationship with drama. Likewise how drama can help to create a learning environment that makes science meaningful for all is explored. This is discussed against works about the public's relationship to science and science learning in a cultural perspective. By introducing some works by drama educators and theatre developers, drama as a way of learning is revealed, and it is concluded that drama methods may promote a meaningful and culture sensitive science education.

Introduction

Having been both a science and drama teacher for several years, I experienced the value of cross curriculum projects and how it enhanced students' cross curricular thinking. I experienced students who became motivated to learn science because of a cooperative learning environment, such as classroom drama; as well as students who experienced new and unfamiliar challenges. Drama activities enable teachers to construct social contexts for science where students can both learn about and enact citizenship. Students can simulate democratic decision-making processes, have moral discussions about science, or discuss ethical scientific dilemmas. I want to draw on these personal experiences, and similar science and drama projects reported in the literature, and argue how drama can encourage meaningful, life-long learning.

A meaningful, life-long science education implies knowledge that is owned by the students. Thus, students can use their knowledge for surmounting challenges in future life endeavors. If knowledge of science and the culture of science is owned, then it can be used to change or restructure the society in which students live. By being able to evaluate the impact of science (and technology) through critical reflection, students choose how to use their constructed knowledge according to how they want to live their lives. Education that offers cultural awareness and action competence may enable students to make these choices and serve their emancipatory interests.

Education should not only serve individual needs, but also rest on a foundation of social justice. It should assist students in their present and future moral judgements and decisions about difficult social and scientific issues in society, and in this way be connected to a child's life. Hutchinson and Romano (1998), drawing on a more holistic model of teaching, conceptualize two different but complementary ways of teaching for social justice. One is to give students experience and practice in social just traits, such as democracy and tolerance. Another way is for students to critically examine their curriculum with social justice concerns in mind.

Kyle (1999) notes that the focus of an education in science ought to be upon an education that fosters learners' ability to work collectively toward a better society. He also suggests that when the emerging issues of development and sustainability are addressed, it should be in a global context. Herein, 'sustainability' is defined as: a method of harvesting or using a resource so that the resource maintained is not depleted or permanently damaged. In the instructional example provided in Textbox 1, one non-sustainable planet is presented (it exploded), and the students' assignment is to find out if Earth is a sustainable planet that is capable of supporting life. This classroom drama touches directly upon and enlightens the scientific concept of sustainability, and it certainly does so in a global context! This way of letting a story provide a long-term learning environment is an illustration of the method of 'Storyline' developed in Scotland and Denmark (Eik, 1999). But does this role-play help students learn about the culture of science and collaborative action towards a better society? I believe so.

One may also pursue 'sustainability' in another manner; used as a metaphor for life-long learning. School science should preserve and enhance students' natural curiosity and respect for science. Thus, science education should strive to present science as compatible to students' worldview (Aikenhead, 1996; Cobern, 1996). Alternatively, if language or actions in a group, for example a science class, have little or no meaning to a person who happens to be in that group and who needs to accomplish some action, then the person may experience "cultural violence" (Aikenhead and Jegede, 1999). The result may be that the person feels completely alienated and is not able or willing to act in the science class context. Students have many ways of perceiving nature, science, and their place in the world. Understanding science and scientific concepts depends on their worldview and whether the science seems to be meaningful and important for their lives (Cobern, 1996).

Textbox 1.

> A science class is waiting for their teacher when he suddenly appears with a serious expression on his face and says: *"Officers- no, please don't get up - I have sad news. Our own dearly loved planet has exploded. We are the only survivors. Let us be silent for a moment, in memory for our planet. - ... I do have some hopeful news. We have sighted another planet, which may be suitable for us to live on. It is called Earth."*
>
> The teacher is using a drama technique called 'Teacher-in-role' to picture a science-fiction scenario. The teacher stops and asks the students who they think he is and who they are, and before the drama continues they form their roles. The students identify with their new roles as aliens and create the following drama together with the teacher.
>
> *"I am informed by the video-scanner department, that we have picked up some pictures from the planet Earth. It is still a long way off, and it has taken 38 of what the Earth people call years for the pictures to reach us. I invite you, as experts, to join me in the video-scanner department, to watch the pictures carefully, and give us your opinions as to whether Earth would be suitable for us to live on."*
>
> Science and the role as researchers are introduced to the students. With an anthropological perspective, the students are to describe, in a scientific mode, our life on Earth. This imaginative science and media project, that occupied the students for several weeks, was developed by David Sheppard at the Drama and Tape Centre, London,UK, and is an example of how drama can be used in science teaching to facilitate student learning.

Creating meaningful situations that engage people emotionally is the essence of drama. Could drama serve as a method for providing students with a personal relationship to science? If students engage in a conflict situation involving science, both mentally and emotionally, could the experience of needing, understanding, or merely relating to science be transferred to other situations? Koballa (1995) points to the significance of all three of the domains for human learning:

cognitive, psychomotor and affective. It is reasonable to suppose that a personal relationship to science, involving all three domains, may increase the possibility of life-long learning.

Can Drama Promote Learning in School Science?

Trying to explain and assess an observed learning process is not easy. Teachers may get a feeling of its successfulness when looking at engaged and motivated students. A drama process is not only a cognitive experience for teachers and students. It involves the whole body, as it is aesthetic, emotional, physical and cognitive. It is an experience of entirety. Drama processes often create engaged students that experience 'magical moments', moments of special awareness. This may be why reports from drama-projects tend to be almost exclusively positive. Martin-Smith (1995) even uses quantum theory(!) for explaining children's experience of role-play. He offers metaphorical equivalence:

> The quantum leap is what an excited electron makes when it moves from one orbit to another (p. 34)...when the child casts off or comes out of role, the energy required for the role-taking is released, and often radiates (p. 35)...signalled by photons of light dancing in the eyes of the children whom we have guided on imaginative journeys toward self-discovery. (p. 42)

This illustrates the enthusiasm many teachers feel, and the will some have to express the quality of the learning process. Is drama a good method for learning science, as these few devoted teachers claim? How can the nature of drama help when learning science?

The practice of science is inspired by imagination and creativity. Bronowski (1956/1975) reminds us that the hallmark of the pursuit of science is independence, originality, and dissent. He notes that "as originality and independence are private needs for the existence of a science, so dissent and freedom are its public needs" (p. 62). The public practice of science offers the following safeguards: free inquiry, free thought, free speech, and tolerance.

Thus, the values of science are human values. Just as science is inspired by imagination and creativity, imagination plays a critical role in the process of learning. Further, when learners come together, they have the potential to reveal themselves as subjects, as unique individuals. The educational value of imagination and student disclosure is seldom tapped in a curriculum oriented toward cultural reproduction and transmission of knowledge. Other ways of learning should be explored to integrate the notions of community, collaborative action, and critical reflection (Ødegaard and Kyle, 2000).

If science is to be a subject useful and meaningful to every student, a 'science for all,' then school science lessons and the science curriculum should reflect such a perspective. Several authors shed light on how to reach as many students as possible and ensure the best learning environment for them. The general public and their relationship with science is the focus of studies by Layton, Jenkins, Macgill and Davey (1993); Jenkins (1994); and Wynne (1996), while other studies view student learning in a cultural perspective (Aikenhead, 1996; Aikenhead and Jegede, 1999; Cobern, 1996).

Meaningful Science Education

Jenkins (1994) points to the fact that lay people find conventional scientific knowledge of little or no use as a basis for action in their social context, unless it is reworked, restructured and recontextualised. He describes recontextualisation as integrating relevant scientific knowledge, where it exists, with other situation-specific knowledge, often idiosyncratic and personal, and with judgements of various kinds. Jenkins draws upon the notion of 'science for specific purposes' (Layton, Jenkins and Davey, 1986) and how it serves to emphasise the importance of context and of knowledge for action, rather than for its own sake. The attention is drawn to purpose and, thereby, to values and decision making that conscious action requires. Thus, Jenkins (1994) suggests that 'science education for action' should replace the slogan scientific literacy. And, while scientific knowledge within the context of action is essentially about empowerment, he asks what kind of science education at school can best empower future citizens for action in relation to matters having a scientific dimension? I believe that drama may be helpful in recontextualising science so students sense a bridge from the science classroom to their future lives.

Another perspective on meaningful science education is giving consideration to how students move between their everyday-life world and the world of school science, regarding these 'worlds' as different cultures in an anthropological sense and with different worldviews. A Norwegian poet, Hans Børli, has written a poem titled " A Prayer for the Dream" and it ends as follows: *Let me long believe, that the forest's whistling is more then a physical phenomenon: The friction of branches against flowing air* (Author's translation). This illustrates a longing for the opportunity of looking at nature from multiple perspectives. Cobern (1996) has studied students' and science teachers' conceptualisation of nature, and it seems like students often have a very diverse view of nature with space for mystic and religious feelings, whereas teachers often have a more restricted and reductionist view of nature. He concludes that:

> ..it is important for science educators to understand the fundamental, culturally based beliefs about the world that students bring to class, and how these beliefs are supported by student's culture. (Cobern, 1996, p. 603).

Learning school science has mostly been a mental intellectual process about understanding scientific concepts and conceptual change. Cobern (1996) claims that for students to apprehend scientific knowledge, to accept it as valid or true, and not just comprehend the concepts, it must be central in a person's thinking and it has to have relevance. The process of 'knowing,' in your heart, is metaphysical and is related to a feeling of empathy. Apprehension is dependent of the synergetic relations among all aspects of humans' thinking, feeling and acting. You could say even further that it is understanding the ethical and action implications of the knowledge. All of this depends on a persons culturally based worldview.

In his introduction to 'border pedagogy' Giroux (1992) notes that: 'Border pedagogy is attentive to developing a democratic public philosophy that respects the notion of difference as part of a common struggle to extend the quality of public life.'(p. 28). It may also well extend the quality of science education. A student is influenced by many different cultures or subcultures in our society (Aikenhead, 1996); for example, the subculture at home, the subculture of friends, the subculture of school, and the subculture of school science. Aikenhead uses Phelan's (Phelan, Davidson and Cao, 1991) definition of culture, as the norms, values, beliefs, expectations, and conventional actions of a group. A subculture is identified by such factors as language, ethnic group, gender, social class, profession, or religion. All of these subcultures have their own way of knowing, interacting, feeling and their own set of values. Crossing the cultural borders between subcultures is called 'border crossing' (Giroux, 1992, Aikenhead, 1996) and may lead to cognitive conflicts if the subcultures are different. Aikenhead (1996) notes that school science is a subculture of the scientific community, which in turn is strongly influenced by the Western world. In an anthropological perspective, learning science means acquiring the culture of science. Students from non-Western countries may have cultural backgrounds that differ strongly from the subculture of science. Hence, this border crossing can be tremendously difficult and may lead to an alienation of the students to science, or an alienation of the students to their own indigenous culture, in instances where science conflicts with the student's everyday-life culture. This does not only happen in non-Western countries, but may also happen with students in Western countries, whose cultural background (e.g., a fundamental Christian community) does not match the rational, scientific culture (see Sjøberg, 1986).

Some students with non-scientific backgrounds seem to manage quite well in science. How do they manage? Jegede (1995) asserts that the duality in the mental schema of non-Western learners, with a resilient indigenous knowledge framework, results in collateral learning when they learn Western science. Collateral learning represents the process by which a non-Western learner in school constructs scientific concepts, side by side and with minimal interference and interaction, with their indigenous knowledge. Lugones (1987) writes about her life experience as a black female in a white male dominated world, where she is capable of successful border crossing using a sense of flexibility, playfulness, and/or feelings of ease. Aikenhead and Jegede (1999) summarise success in science as depending on: the degree of cultural difference, how effectively students move from their everyday-life world culture to the culture of science, and the assistance the students receive in the transition between cultures.

This gives some implications for science teaching. Cobern and Aikenhead (1998) proposed that instructional methods and materials should:

1. make border crossings explicit for students,
2. facilitate these border crossings,
3. promote discourse so that *students,* not just the teacher, are talking science,
4. substantiate and build on the legitimacy of students' personally and culturally constructed ways of knowing, and
5. teach the knowledge, skills, and values of Western science *in the context* of it's societal roles (social, political, economical, etc.). (p. 50)

Knain (1999) links the notions of worldview and border crossing to the concepts of rational beliefs and critical thinking. He notes that critical thinking has an emotional component. This component supports an individual's personally constructed beliefs that can be discussed rationally, or are acknowledged as arational, and are part of a person's worldview. He further notes that since the rationality of science is grounded in the social practices of science (e.g., comparing results, discussions, argumentation) the equivalent in science education is critical thinking and argumentation. In order to get an epistemic distance to the rationality of science it is necessary for students to make conscious border crossings, as the distance is an important part of becoming autonomous persons. In the process of reflecting on the rationality of science from outside the subculture of science and filtered through a person's beliefs, the ability of critical thinking is developed, and additional beliefs can be justified.

I believe the above perspectives on science education, with their respective implications, may lead to a meaningful science education. The students will not feel alienated in the science classroom because they will realise fully that science has its own culture, and facilitated by the teacher, they are able to visit it and use the culture of science. In the process of reflecting on the culture of science, the students are rooted in their own culture, and in this way the possibility of life-long learning of science increases. As articulated below, I also believe that drama may provide a way of doing so.

Drama as a Way of Learning

Drama may create different worlds with different cultures. The participants also create fictitious persons and through them may explore unfamiliar cultures and obtain experiences, which originally belong to these dramatic worlds. But by reflecting on the experiences, and relating them to themselves in real life and their own subculture, the students may broaden their perspectives, gain empathy, and empowerment. The goal is that they transform knowledge to knowing, based on cognitive, affective and active aspects of learning. I would like to present some examples of drama / theatre used in ways that also could be interesting for science education.

In the drama community there is a movement that corresponds to Jenkin's 'science for action.' The Brazilian theatre personality, Augusto Boal, challenges his audience to take action and change situations in their life. He encourages the spectators to participate physically in the action of the play, and combines the role of the spectator and the actor in the combined expression the 'spectactor'. His *Theatre of the Oppressed* invites the 'spectators' onto the stage to change the oppression they have witnessed in the play, which is a symbol of reality. Using the method of Forum Theatre (Boal, 1977), the actors and 'spectactors' together repeat a scene of oppression and improvise a new outcome. In that way the audience of ordinary people can practise ways to change their own oppressed lives. There is obviously a strong link between Boal and Paulo Freire's pedagogy for the oppressed (Freire, 1972). Freire wished to liberate people from the traditional passive nature of education and created pedagogy based on dialogue and critical reflection in the context of people's everyday life, changing oppression into empowerment. Boal was elected in 1993 as a Member of the Legislative Chamber for Rio de Janeiro. He used his theatre methods to meet the public on the streets, and through their participation and suggestions he proposed bills of law to the Parliament. *The Legislative Theatre* is Boal's attempt to use theatre within a political system to create a truer form of democracy (Boal, 1998). Several of Boal's theatre methods are very useful in science education, especially in cases of 'science in society' and 'science for democratic action' (see Lunngård, 1999).

Inspired by Boal another Freirian based theatre developed in post-colonial Africa: 'Theatre for Development' (Byam, 1999). It is based on the assumption that community theatre is performance about the people by the people 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.

Brecht also wanted to educate his audience to take action for changing the society and he created the 'epic' theatre. By using a contrast of intimacy and distance the audience was not allowed to be lulled into an emotional state and escape from reality in theatrical dreams. Brecht would always break up an emotional situation with a song or poem, or by simply letting the actors act in a distant manner, in order to remind his audience that they were attending the theatre, it was not reality and they should not be passive spectators. He called this technique "*verfremdung*" (alienation).

'Mixing one's wines may be a mistake, but old and new wisdom mix admirably' (Brecht, 1955). Both Brecht and Boal wanted people's new knowledge to be actively built on the knowledge they already possessed. The old wisdom is knowledge of their present and past life, which is presented on stage. The new knowledge comes out of reflecting over new ideas in the light of the old. Conceptual change and the notion of constructivism in science education have similar mechanisms (Driver, Asoko, Leach, Mortimer, and Scott, 1994; Piaget, 1970). In the world of theatre there is a concept of "catharsis." Catharsis means purification and indicates the result of an emotional experience of a situation that gives insight and understanding of this situation's content and complexity. Could catharsis be an equivalent to or at least a part of sciences' conceptual change? As it is first described in Aristotele's *Poetica*, it is attached to the spectators' sense of adventure of the Greek tragedy. In an improvised role-play, where there are no ordinary spectators, there is interplay between the role figures in the play, but also between the different participants' personal reactions to the other role figures' initiatives. Everyone in the play is a spectator of the others and at the same time a part of the play (Szatkowski, 1985). So in a role-play the participants can attain an 'active catharsis' because they also have a distance to the play as a spectator. My personal experience of 'catharsis' has been when I, in a role-play, suddenly realise that a special situation can be transferred to real situations in 'my world.' It is the same feeling of insight as when I understanding a new scientific concept.

Heathcote uses the expression "dropping to the universal"; to describe how she helps students to reflect about the universal in a special situation created in a role-play or a classroom drama: "from the particular to the universal" (Wagner, 1983). The play is improvised and both the students and the teacher must learn to tackle challenges spontaneously, and evolve an ability to reflect on the consequences of different possible choices. *The Mantle of the Expert* is a type of classroom drama developed by Heathcote (Heathcote and Bolton, 1995), which could perhaps be an equivalent to Aikenhead's (1996) anthropological instruction. The students are given the role as experts in a specific field and must help the teacher in role or other students in some way. The experts can be scientists, or they can be other experts, like aliens from outer space trying to explore the planet Earth as portrayed in Table 1.

In Heathcote's pedagogical drama processes, there are three central constructs: role taking, focus, and tension (Butler, 1989). In role taking, the students must be taught to concentrate on the attitude of the role they assume and not on physical or vocal appearances. They have to bring to the role their own inner knowledge in order not to just reach for stereotypes. The play tends to be a highly cognitive activity where the students work with ideas and attitudes and test out ('playfully and with feelings of ease') hypotheses about significant problems. The students are asked to believe in the assigned roles, to think for themselves and to act on their own initiative based on their own life experiences. The focus is the action in which each of the individuals becomes involved, and if it is properly chosen it brings the students out of their ordinary 'school-selves' and enables them to be themselves in more responsible roles where they have power. They border cross into another subculture, but playing a role in this sub-culture should seem true and right for them. The third construct is tension, for example manipulating time. Putting a time constraint on the play would urge the roles to engage in a significant dialogue. A good focus could also create so much tension that the role-takers enter the make-believe situation and find themselves saying things that they didn't know they could say, that they had never thought of saying. If the focus is on genetic testing, then the tension could be raised by letting one of the role-takers have the task of revealing a secret (e.g., a lethal genetic disease in the family).

Drama as a Way of Learning Science

Why is drama useful in science education? Learning school science has mostly been an intellectual process about understanding scientific concepts. The advantage of using drama in science is that you challenge a student's thoughts, feelings, and action ability. In a drama process it is possible to work simultaneously with facts, skills, and attitudes towards the topic of current interest. Imagine the scenario of a classroom drama inspired by Heathcote: because of a new airport a community has to consider the building of a new highway across a residential area, and arranges an open hearing so the inhabitants can express their opinion. Families that may lose their homes are represented and so are local construction-workers that need and hope for a road-construction job. An international enterprise for constructing tunnels is there, but their offer is more expensive and implies foreign expertise workers. Scientists on air pollution are invited, environmentalists and locals afraid of increased pollution are present at the meeting. All of these people may be enacted by students in the role-play in an environmental science lesson. The students will soon discover that if they want to be heard, they have to know the facts about the technical construction, car pollution, respiratory infections and so on, and in addition they must manage the task of handling and mediating information. The role-play also provides a context for knowledge to be remembered and be reflected upon.

Cobern and Aikenhead (1998) stated that science education should make border crossings explicit for the students and that they should be facilitated. It is also important that the students can talk in their own cultural interpretative framework and in the framework of Western science, without cultural violence. Going in and out of role is a very explicit border crossing. It can be symbolised as taking on and off a hat, and all the students know how to do it. Role-playing is a game everyone has played when they were small, and actually it is a way of learning we all experienced before we started school. Role-playing also provides a setting where you can use the framework of science when being in role, and your own cultural framework by stepping out of role and reflecting on the way you acted in role. This possibility of stopping the play in order to step out of role and reflect is what makes drama such a powerful pedagogical tool. The drama's 'pretending' character (e.g., the play as a symbolic expression) creates the necessary distance to reality that enables reflection. In the alternation between experiences in the play (the pretend world) and from the reality outside the play (the everyday world), new knowledge and new insight can appear. Bruner (1986) states that reflection and distancing are crucial aspects of achieving a sense of the range of possible stances, which in time creates a sense of one's self; a metacognitive step of huge import. This interplay of intimacy and distance, of empathy and reflection is fundamental for the epistemological potential in the dramatic role-play. The participants must hold these two realities in their head at the same time. The concrete symbolic action of the play is a symbol of what the students want to explore (e.g., air pollution) in a scientific world. The fabricated role or situation creates the necessary distance that makes it possible to hold to different worlds in the head at the same time (Sæbø, 1998). Szatkowski (1985) describes this as the aesthetic doubling, in which actors have "at the same time, an experience *in* fiction and an experience *of* fiction." (p. 143, author's translation; see also Figure 1). Transferred to science education, this means that a student can experience a scientific concept as true in the role of a scientist or expert, and at the same time does not have to accept it as valid knowledge in the everyday-life world.

Nevertheless he/she comprehends the concept and has perhaps also had the experience of apprehension, in role, and now has the opportunity of reflecting on the experience and choosing to make it a part of his/her own world. This voluntariness is an important part of the process, which has been missing from traditional science teaching, where the students were accustomed to being served scientific truths about nature. My allegation is that when a student senses a choice, through personal experience in fiction, then conceptual change is facilitated. This is autonomous acculturation using anthropological instruction, defining the role of research as corresponding to anthropological research. Aikenhead (1996) claims that anthropological instruction is too academic and too removed from the life world of what he calls 'I Don't Know' students (students from a sub-culture inconsistent with the sub-culture of science). I believe that if it is accomplished in Heathcote's *Mantle of the expert* manner, then it is perceived as the opposite of academic and most students could find it meaningful (see Heathcote and Bolton, 1995).

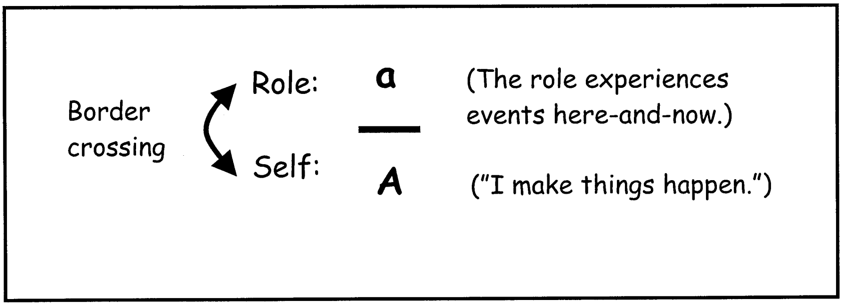

Figure 1. Relationship between border crossing (Aikenhead, 1996) and "aesthetic doubling" (Szatkowski, 1985).

Knain (1999) also pointed to the fact that it is necessary to create an epistemic distance to the subculture of science in order to reflect and develop critical thinking on the rationality or the nature of science. Having a personal and emotional experience should facilitate epistemic reflection. I also believe that the personal role-play experience may provide a door into an empathic understanding of the rationality of science, even though the student may not wish to include the same rationality as a belief in his or her worldview. Knain argues that merely being able to reflect or think critically on the rationality of science shows that the student already has included rationality as a belief.

To reject the rationality of science is a rejection based on science's epistemology. It is also possible to reject science as a cause of what scientists do (Knain, 1999). Let me give an example and indicate how drama can help. In 1995 my class wanted to do a project about France's nuclear test bombing in

Mururoa. We decided to work towards a role-play of a public inquiry. The problem was that no one wanted to play "the bad guys." Students did not want to learn about and communicate the nuclear science and the official French politics. Who wants to volunteer to learn about making bombs? And who wants to learn to argue in favour of testing them? Only when they understood how important those roles were in order to get a full and realistic picture of the situation, did some students accept this difficult challenge. While they were very reluctant to learn about nuclear physics in the beginning, the students in role as nuclear scientists did a great job in teaching the rest of the class about the atom bomb and arguing for nuclear testing. After the role-play it was essential for these students to debrief the roles (see Szatkowski, 1985), and remind everyone that they were only acting. The learning strategies these students internalised during the French nuclear project would probably have been impossible to do through traditional teaching in a class hostile to nuclear power.

Drama, Science and Social Constructivism

Social constructivism in science education has been influenced by Vygotsky's ideas and theories. Using drama in the learning process highlights some of these ideas. One of them is *the zone of proximal development*. This concept's focus is on social interaction as a basis for learning. The individual must be seen in a historical and cultural context. The child's competence is both a consequence of cognitive processes already experienced, the *actual* level of development, and the *potential* level of development, which is a level of development in reach for the child. Vygotsky meant that collaboration or interaction with more competent persons was of great importance:

> The zone of proximal development is the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under guidance or in collaboration with more capable peers. (Vygotsky, 1978, p. 86)

Having this in mind, one way in which thinking and communication skills can be nurtured is through scaffolding, which means doing some of the work for the student who isn't quite ready to accomplish a task independently. Like the supports that construction workers use on buildings, scaffolding is intended to be temporary. It is there to aid the completion of a task and it is eventually removed.

In a drama process, for instance a role-play, a child can experience knowledge in a natural social context (or actually a symbol of the natural context). The dramatic situation helps to develop the child's zone of proximal development and the teacher and the child's peers can provide guidance, or scaffolds, for mastering problems. Analysis of the dialogue in a role-play about genetic testing shows how the situation of role-play makes it possible for students to stay in focus by merely staying in role. The students guide each other by asking questions (Ødegaard and Kyle, 2000). In the former example of 'researchers in a spaceship,' the situation of exploring the planet Earth to see if it is liveable, is so many-faceted that it can provide multiple zones of proximal development. The teacher-in-role as the spaceship manager, is able to help the class as a whole or the individual child in their research about the planet Earth. The children are also helped by the situation itself, encouraging them to bring out their full potential through their roles as experts. The role-play can provide guidance by helping the child focus on the problem and perhaps open up new learning strategies for science. Acting as a scientist makes it easier to internalise learning strategies for science, and these may be used in other appropriate situations, not necessarily in role.

In light of the implications for science teaching proposed by Cobern and Aikenhead (1998), the students can explore, using flexibility, playfulness and/or feelings of ease, the scientific culture without having to assimilate it, and at the same time they use learning strategies developed by the scientific community. This would be close to apprenticeship learning, which is stressed by Vygotsky. Traditionally when students learn about the scientific method, they do science experiments, and the social interaction among scientists is seldom integrated into the teaching-learning process. Drama techniques enables students to include the social process of science, and to also step out of role and reflect on the situation and the learning strategies involved, making it possible to have a valuable metacognitive reflection and discussion. "Much of the process of education consists of being able to distance oneself in some way from what one knows by being able to reflect on one's own knowledge" (Bruner, 1986, p.127). The student learns to think like a scientist. The next section is about learning to talk like a scientist.

Talking Science: From Language to Thought?

One of Cobern and Aikenhead's (1998) implications for a culture sensitive science education is that it should promote discourse so that students, not just the teacher, talk science. Enacting the role of a scientist offers a natural setting for talking in a scientific language. May pretending to be a scientist and talking science give students insight in the science community? I believe it can. Since language is one of our most important carriers of culture, one may at the same time get a feeling of the subculture into which one crosses the border. Sutton (1996) speaks of science learning as "learning to talk in new ways" and seeing science lessons as offering "access to new conversation" (pp 150, 148). Sutton also suggests that science teachers should persuade pupils of the value and reasonableness of those new ways. If I had a sceptical drama class in science, I could say: In order to play the part of `Faust´ or another scientist, and really get under the skin and understand the role, you have to learn their way of talking and thinking. I could say the same to any class in science: If you want to understand science and scientists later in life, in the newspaper, on TV, you have to understand their language. The persuasion of value and reasonableness would be important in order to understand fully the scientist and his or her epistemology, and for the role to be played truthfully and with genuineness. Perhaps the student also is persuaded of the value and reasonableness of the new knowledge, and can choose to internalise it and make it one's own knowledge.

Scott (1998) discusses the issue of teacher talk and meaning making; pointing out that the process of internalisation, as envisaged by Vygotsky, cannot simply involve direct transfer of ways of talking from social to personal levels; there must be a step of personal interpretation or personal sense-making. Learning to talk science runs deeper than simply learning to articulate the words and phrases of a new speech genre. It involves differences in the epistemological framing and basic assumptions about the natural world. In order for students to get to know the scientific language, they must articulate it. Some students may believe it feels alien and sounds foreign in their mouth, as illustrated by Bakhtin:

> Not all words submit equally easily to this appropriation, to this seizure and transformation into private property: many words stubbornly resist, others remain alien, sound foreign in the mouth of the one who appropriated them and who now speaks them; they cannot be assimilated into his context and fall out of it, as if they put themselves in quotation marks against the will of the speaker. (Bakhtin, 1981, p. 293-294)

Bakhtin´s utterance can also be interpreted as a description of a bad actor; an actor not giving a truthful portrait of a `whole´ person. Because he does not understand the role´s basic assumptions and way of viewing the world, the lines come out with `quotation marks.´ Scott draws upon Wertsch (1998, p.55) who says: "whenever we speak we must 'buy into' an existing set of linguistic terms and categories. In science we must buy into, and learn to work with, the conceptual tools, epistemological framing, ontological perspectives and forms of reasoning of the scientific community" (Scott, 1998, p.75). If the student is able, for the time being, to understand and enact the role of a scientist without quotation marks, then this student will have the opportunity to have a personal interpretation or personal sense-making of the culture of science without having to undertake the whole cultural frame of Western science personally. Understanding is enhanced through the role-figure. When the student is out of role, the student is afforded the necessary emotional and epistemic distance to reflect on the experiences in role and relate them to personally and culturally constructed ways of knowing (see Cobern and Aikenhead, 1998).

Newton, Driver, and Osborne (1999) believe that argument is a central dimension of both science and science education. In science, the function of argument is to construct plausible links between the imaginative conjectures of scientists and the available evidence, and also to determine which conjectures are the most convincing explanations. In science education, argument is used to become socialized into the scientific community, and to help learners to articulate reasons for supporting particular conceptual understandings. However, the findings of Newton et al. show that classroom discourse is largely teacher dominated and tends not to foster the reflective discussion of scientific issues. The dominant model appears to be a transmission model with the teacher as informer. This is confirmed by Lemke in his *Talking Science* (1990). In a research report on drama, language and learning (Schaffner, Little, Felton, and Parsons, 1984) it is shown that classroom language normally is informational (concrete and generalised, content is 'matter', utterances follow chronologically), which agrees with the results of Newton et al. (1999). By contrast, almost half of the language sampled during drama activities was interactional (e.g., persuations, regulations, commands) and expressive (individual expression of thoughts, abstract, implication of facts, focus on people and society, logical in sequence as in an argument). The expressive language is mainly used during the reflection phase of a drama process and in experiential dramas. This indicates that drama may provide learning environments that encourage students to express and explore their opinions.

Final Comments

I hope to have disclosed some of the potential that lies in the use of drama in learning science. Drama methods are manifold and many-sided, and as mentioned involve using both cognitive and affective aspects of learning. (See Ødegaard, 2000) Thus, it does not only have great potential in learning science, but also in manipulating people and situations by creating special contexts. For instance, students could easily be manipulated to believe that Western science is the answer to all our problems, or the opposite that science is the cause of the world's misery. Therefore, the method requires committed science educators to assist in making critical and social just teaching materials, and be guides in the students' metacognitive process after a drama activity. In order to offer a meaningful, life-long science education with knowledge owned by the students, drama provides a basis for linking students' lived experiences to science.

Boal (1998) describes his Forum Theatre as a reflection on reality and a rehearsal for future action. "In the present, we re-live the past to create the future"(p. 9). Shouldn't this also be applicable to science education?

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Paper III

Drama in Science

A Critical Review of Drama Projects in Science Education

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Abstract

Science education should seek to be anti-authoritarian, critical and creative to reflect the ideals of science. Drama may help create meaningful and empowering learning environments that inspire such an orientation to science education.

Using drama in science education is not a very widespread activity. This article reviews studies where drama has been used in connection with science. A structured survey is then offered based on perspectives of science and the degree and nature of drama improvisation. The science projects reviewed are divided into those focusing on learning scientific concepts, those learning about scientific processes, and those learning about science in a societal context. This is followed by discussions of educational value.

Introduction

If science education is to be meaningful and significant in the lives of students, we must encourage students to ask critical questions. The learning process should have as a primary goal empowering students to question knowledge, science, society and experience, thereby enabling students to reflect on their own relation to knowledge. By not asking critical questions students will tacitly endorse and maintain the status quo, which is the dominant ideology in society (see Kyle, 1991 and 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, p. 13.) Science is ideally rational and anti-authoritarian by nature. It is also an enterprise that heavily relies on creativity and imagination. Despite this, studies of classroom science have shown the dialogue between teacher and student to be quite authoritarian, and the dominant language to be a labeling system that transmits a description of nature (Lemke, 1990, Sutton, 1996). This is a paradox. Thus, science education must seek non-authoritarian and creative learning environments, which enables students to be critical and curious about science and the world that surrounds them, and at the same time offer them an insight to the value of science and scientific processes to undertake critical reflections.

Herein, I offer a structured survey of different science and drama projects. I believe that using drama in a well-considered manner, guided by reflective science teachers, may provide meaningful and empowering learning environments for students. In Ødegaard (2000a) I put forward arguments for how drama can promote learning in school science. In this regard, I will first offer an overview of research focused upon science and drama projects and the efficacy of such a perspective to science education.

Research on Science and Drama Projects

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 hardly ever used this instructional method. Evidently, students are much happier with drama than the teachers, who feel uneasy. If drama has a positive effect on learning science, then it seems there lies an unused potential here waiting to be tapped.

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 be a vehicle for students to develop important insights regarding scientific concepts and meaningful learning. A similar study was conducted by Bailey and Watson (1998), in which students in experimental groups participated in Ecogame, a role-play of an eco-system, and the control groups received 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. The most explicit result of both studies is that drama enhanced students' ability to explain science in a holistic perspective.

The evaluation of Y Touring's play of mental illness, *Cracked* (Evaluation Associates, 1998) is also quantitative and based on pre- and post-tests of over 2000 students. The students watched the play and subsequently participated in a workshop using drama techniques. The results show an increased level of knowledge and understanding and sympathetic attitudes toward mentally ill people, and also a deeper understanding of mental health issues after watching the play.

Issues associated with health and wellness are a significant part of the science curriculum. Such issues are easy to personify and similarly able to be dramatized. Health and wellness is also an important part of nursing education; and like science teachers, health practitioners have the role of mediating science to the public. Thus, it is interesting to note that nursing students who developed health education programs with the help of drama techniques expressed increased knowledge, as well as improving their confidence, self-esteem, communication skills and group work skills (Kerr and MacDonald, 1997; Riseborough, 1993). Again, the greatest impact upon student performance is in the domains of higher-level cognitive skills and affective measures (vs. 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. Science is put in the context of society in these projects. The most important observations were high levels of student activity, expressed as 'broad debate' and 'interesting discussions', which shows that the students take 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.

When drama is used to create a model of a scientific concept (e.g., eco-system, molecules and change of state), the studies showed that students constructed 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 show the need for evaluation focused upon student performance. Further, there is the perspective of empowering education for future action. Albeit impossible to evaluate, it should not disqualify it for being a focus of education.

Drama and Science in the Classroom

Dramatic activity may vary and take many different forms in the classroom. The drama may be structured in a way where students enact roles with known patterns, for instance playing electrons in a circuit to illustrate the scientific concept of electricity; or the dramatic activity may be spontaneous, creating the moment, where 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. Something in between could be an improvised role-play with a structured frame, (e.g., role cards that describes the participating roles). Another continuous variable is teacher involvement; whether it is the teacher that impels the drama or the students. It is obvious that a group of students who creates their own model of a scientific concept are together constructing knowledge that may 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 illustrated by Brown and Pleydell (1999) and a re-worked version is presented in Figure 1.

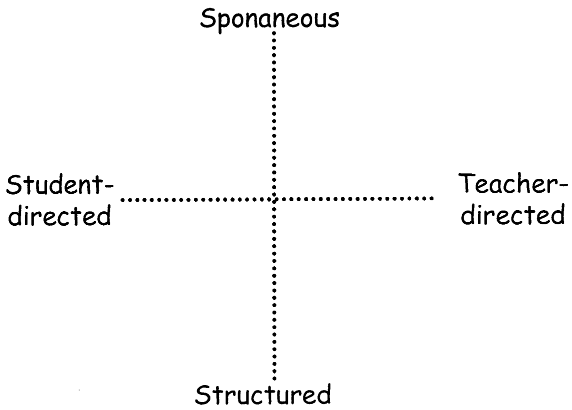

Figure 1. A representation of how to organise drama and science activities.

Dramas may also be grouped according to whether they are presentational or experiential (Schaffner, Little, Felton and Parsons, 1984). In Figure 2 I offer a representation of this grouping in the relationship to Szatkowski's 'aesthetic doubling' (see also Ødegaard, 2000a). The presentational dramas have a major emphasis on communicating something to others outside the drama (e.g. the teacher, peers, or parents). When a small group of students dramatize a scientific concept (e.g., make a 'meiosis ballet'), the intention is often communication to others. The experiential dramas have focus on attempting to live through some aspect of an experience and adopting an opinion or attitude (e.g. a role-play with role cards about ethical issues in biotechnology).

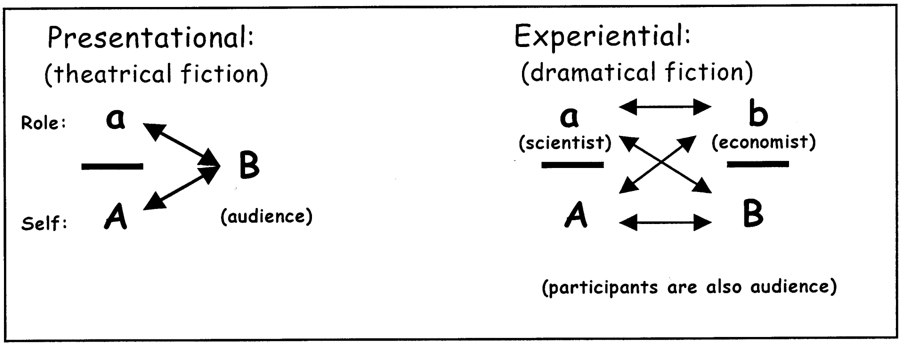

Figure 2. Aesthetic doubling (Szatkowski, 1985) in a theatrical fiction vs. a dramatic fiction.

Depending on which scientific issue is in focus, the teacher as a professional 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 construction of knowledge. 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, where the language is used as an interpretive system (Sutton, 1996) for persuading each other of their view.

The perspective of science can also be extended, from understanding scientific concepts to understanding the process of science and further to understanding the scientific community and culture and its effect on society (see Shamos, 1995; Sjøberg, 1998). I have chosen to structure the relationships between the nature of drama and the dimensions of scientific literacy as illustrated 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 and is presentational (in theatre there is an audience). Explorative drama is spontaneous often student-driven, and experiential.

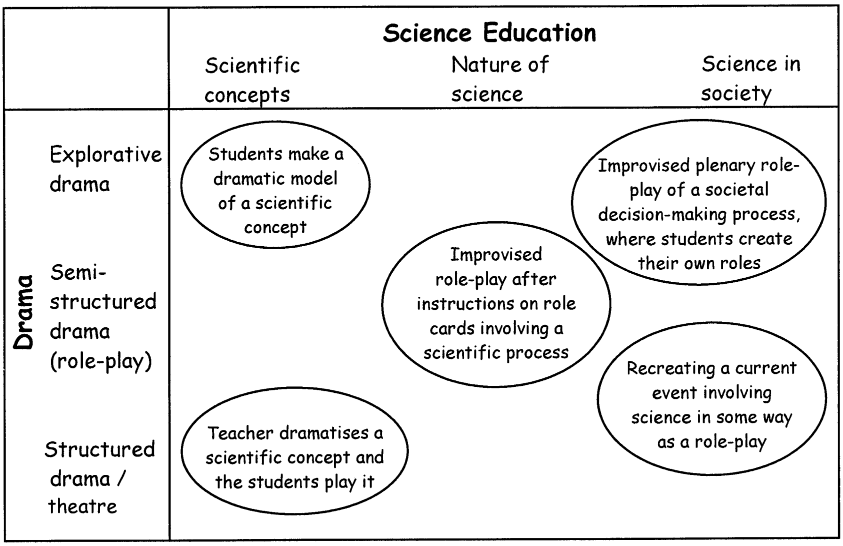

Figure 3. An overview of how drama may be used in science education.

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

Science as an Education for All

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. School science has concentrated traditionally on the first dimension, science as a product, passing on science's conceptual structure. Sjøberg argues that in order to teach science as a general education, meaningful for all, there must be a different balance between the three dimensions, putting more emphasis on the two latter. Examples are given of how drama can be used in science lessons in these three dimensions.

Science as a Product

School science has historically focused on learning scientific facts or on the products of science (e.g., conceptions, theories, laws, models). When I began my teaching career, my science lessons had this characterization. I found it boring, and so did my students. In order to transform the teaching-learning process, we started to dramatize scientific models and theories (e.g., the menstruation cycle, photosynthesis, protein synthesis, and cycles of matter). In the process of transferring the model or description from the text-book to a three-dimensional live model the students often had to reconceptionalize their knowledge. Prior research notes students' increased understanding, and the teacher's in-creased ability to assess students' understanding, when using drama in science (see Bailey and 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. 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). Figure 4 offers another dramatization of a scientific concept.

Bailey (1994) developed a drama model of the complicated interplay in an eco-system. 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 from the teacher, and reflect on how '*The Ecogame*' agrees with their view of nature.

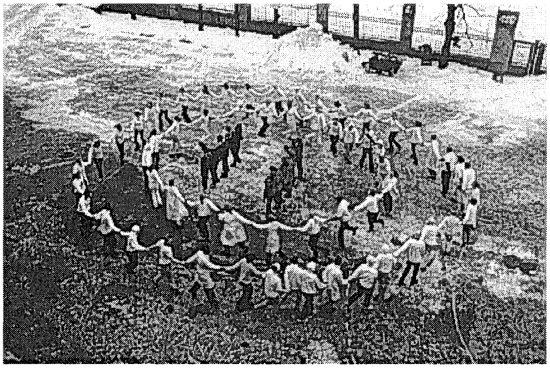

Figure 4. The cell prepares for meiosis, (2n=2). Biology students at Fagerborg Upper Secondary School, Oslo, made a schoolyard dance about the process of meiosis. Martin, a student, states: "Managing the dance presupposes understanding." (Photo: van der Kooij)

Even though the children have a distance to 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 the equation 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 enhance emotional involvement for developing mental models of living systems. Is there reason to believe that the students also are able to assume a critical attitude toward the science involved? Preliminary investigation indicated that '*The Ecogame*' approach enhances children's understanding of ecological concepts (Bailey and Watson, 1998). Hence, '*The Ecogame*' does give students an experience of imaginative science education, but they are dependent on guidance from an intentional teacher in order to have an opportunity of critically using the concepts.

Interactive plays are examples of children together with actors modeling or explaining scientific concepts (Baird, 1997). Students can also use improvised drama to synthesize what they learned in a science course (Kase-Polisini and

Spector, 1992). Kase-Polisini and Spector inform us that initially creative drama was 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 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 are discussed. 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 aid them, enabling instruction and assessment to occur simultaneously. A critique of using creative drama to assess science could be what you are assessing is the students′ creativity. Surely similar qualities would be enhanced by such activities, and according to Bronowski (1975), they are such an important part of science itself, thus the same qualities are important to develop in science education as well. Kyle (1997, p. 852) states that: "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." I believe using creative drama as a combined assessment and instructional method has potential both in the science classroom and in educational research.

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 a good story, *the narrative mode*. The other is used to form a good argument, *the paradigmatic* or *logico-scientific mode*. An argument intended to convince us about truth with the help of formal and empirical evidence, stories want to convince us of their life-likeness. 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 and 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. (p. 9)

This may very well be a recipe for making a drama model of a scientific concept. A drama model is visualizing a scientific 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 electron's 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 event. This last discussion, stepping out of role and reflecting upon the different outcomes, is important for the students to understand the key ideas of the scientific concept. They use the language of the 'story' (e.g. electrons, current, circuit, resistance) to describe what happened and also 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. And, 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, typical of a narrative. Bruner (1986) offers a picture of the nature of science as a mountain of knowledge profiled by the rise above all of the narratives, and the creation of an abstract world of laws, rules and explanations. But in order to guide the students up this abstract mountain the science teacher has to provide them with some stories as ladders.

Science as Process and as a Social Activity

The scientific process is often described as scientists discovering a phenomenon either through doing experiments in the laboratory or through studying nature (Knain, 1999b). The students' only experience of a process is pre-designed laboratory exercises, which do not reflect a scientific process or the nature of science at all. The important communication process between researchers, in which discussion and debate occurs, is seldom mentioned. In the Norwegian science curriculum (KUF, 1996) it is stated that students should be acquainted with the nature of science and science processes, and they should design and test their own experiments. Once given a multiple of science stories students will know that the nature of science is not the same as predesigned lab exercises, and that 'The Scientific Method' does not exist. 'The Nature of Science' is also a concept of some conflict (see Alters, 1997; Jenkins, 1996). I believe through science stories and experiences in being a scientist that students may be able to extract the essence of science. Drama offers science teachers several ways of exploring aspects of scientific processes together with the students. Students find drama methods memorable and usable in constructing a more realistic understanding of the nature of science in addition to being lively and stimulating (Christofi and Davies, 1991).

In 1998, I had the pleasure of meeting 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. 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 experiments that Jenner had done and compare them with what we could have 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 in science processes, but the drama method of an 'actor-teacher' as a historical person provides the students with the possibility of a critical dialog with the past. Students can learn much about the nature of science through history. Students construct an appreciation of the interactive nature of science and see experiments more as trying out explanations, rather than mere positivistic empiricism (Solomon, Duveen, Scott and McCarthy, 1992).

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 both role-plays constructed for the science classroom (Duveen and 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. The role-play presents a mixture of scientific epistemology and scientific personality. Instead of an abstract schema for "scientific method," it is richly personal, and encouraged to be understood 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 are carrying out (Duveen and Solomon, 1994; Fuller, 1988). Another advantage of the role-play is that newly acquired knowledge about evolution and natural selection (either learned in traditional science lessons or in dialog with fellow students motivated by the future play) is activated by exercising it in the improvised role-play. The use of learned concepts encourages their assimilation and retention, and also 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 and Solomon, 1994, p. 581). In a partly improvised role-play organized as a trial there is a lot of opportunity for students to engage in critical thinking. The students scrutinize and challenge each other's roles and perspectives. Thus, the historical science process obtains empathic understanding. Gaining critical insight in what this historical process may tell us about science today is facilitated by a shared experience, but once more it is reliant on the science teacher.

Another way students may get critical insight of a scientific process, is letting students enact the sociological process. Heathcote and Bolton (1995), using the technique 'mantle of the expert' have children (8-9 years old) play scientists trying to find a cure for cancer. The children start out designing a place to work and conceptualizing what a scientist is and does. They further receive funding from the President to continue a project in Mount Fujiyama. The students make an imaginary journey and arrive at a mountain to discover some precious, but dying, plants. The plants became a metaphor for dying cancer patients, which the children automatically accept as they begin 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, but could be overlooked by students who found it too distressful. 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. The drama ends when the President's helicopter brings them home. In this drama adventure the students likely did not learn a lot about cancer and medical research, but they learned about scientists, how they work and the meaning of funding(!).

Another drama scenario, with a more science-fiction mode, is the 'researchers in a spaceship'-drama developed by David Sheppard. The students enact researchers from another planet that has just exploded and now 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 reinvent the process of research for their own purpose, and may eventually discover the usefulness of scientific methods. Because of the fiction, 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 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 with people with whom the students identify.

Science as a Social Institution in Society

Classroom dramas are good for focusing on the science in society dimension in science education. A well-known method of science is to make a simulation in the laboratory of a phenomenon in nature. It is also possible to simulate societal processes that relate to science, for instance an international environmental conference, a consensus conference, or other democratic processes. The real world is brought into the classroom for practicing action. For this, divergent interests and ethical conflicts are essential, as they are in all good plays and dramas. In role-play the conflicts combine with the personal relations the students develop to the issue, which 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 give scope and force, and it offers the opportunity for students to reflect upon the subculture of science in relation to their own worldview, as well as to see the subculture of science against other subcultures (e.g., economy or bureaucracy; see Aikenhead, 1996; Cobern, 1996; and Ødegaard 2000a). The cross-curriculum potential in drama gives 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 obtain the ability to explore the world, and through the practice of action-taking they acquire competence to transform the world and create the future (see Boal, 1977; Freire, 1972).

"Science knows only one commandment - contribute to science." This is stated by Andrea in Berthol Brecht's play *The Life of Galilei* (1938-39) and illustrates a common picture of science that is a bit out-dated. Science is not only a search for knowledge, but also an important part of our culture and society. It influences our personal lives by giving us new democratic and ethical challenges. Play-writes have at times been preoccupied with science and its place in society. Early plays, like Brecht's *The Life of Galilei*, Ibsen's *An Enemy of the People* (1882), Bjorneboe's *Semmelweis* (1968) and also Goethe's *Faust* (1808), all deal with scientists and their struggle between knowledge, demands from the surrounding community and personal happiness. The theme is often (except in *Faust*) one man with un-popular scientific knowledge standing up against society. Science and scientists are portrayed as rebellions, and democracy is questioned. *"The majority is never right. Never, I tell you! That's one of these lies in society that no free and intelligent man can help rebelling against"* (Dr. Stockman in *An Enemy of the People*). In later plays science is no longer portrayed as the hero and savior, but it is a cause for people's (both scientists and lay people) dilemmas and ethical choices. *Copenhagen* by Frayn (1998), Luckham's *The Choice* (1994), *The Experiments with an Air Pump* by Stephenson (1998), and Wertenbaker's *After Darwin* (1998) are such examples. This development in plays reflects how the image of science has changed from being a rebel at university opposing the established (Snow, 1959) to being the cause of opposition itself, for instance, after the atomic bomb (Sjøberg, 1997, Osborne, 1997). Or also, science being an establishment providing helpful knowledge, but which requires ethical consideration (e.g., biotechnological and medical industry). Dramatic literature draws upon science as a scenario and a source for interesting personal conflicts. Shouldn't science education in return make use of the theatre's ability to engage and motivate for empathy and perhaps use some of these plays in learning about science?

Y Touring Company is a professional theatre group that has written plays with the focus on science and its implications in society. Between 1995 and 1998 they developed and produced a trilogy about contemporary biotechnology and bioethics for school students. Each play is followed by a debate and supported by a resource pack. Evaluation confirms that the project was successful. The plays are reported to have a positive impact on the students' attitudes, understanding and knowledge (Evaluation Associates, 1998). The biologist Lewis Wolpert (1998) indicates that the plays are moving and engaging and that this is a brilliant way of bringing science to the people. Recognizing the advantages of drama, several groups have developed a health education program for secondary school students, where the emphasis is on drama and discussion. They use Boal's (1977) drama techniques that enable the spectators to take part in the play's action as a practice for situations in real life (see Ødegaard 2000a for more about Boal and science education). The programs were designed to educate the students, as well as nursing students; improve their communications skills, ability to feel empathy, and empower other people (Kerr and MacDonald, 1997; Riseborough, 1993).

Another way of using theatre to put science in the context of society is through creative drama. Students make and act in their own play. Event-centred-learning, which is an approach to teaching Science, Technology and Society (STS) issues, is an example of using role-play and drama in reconstructing real events (Watts, Alsop, Zylbersztajn, and Silva, 1997). Actions or circumstances from TV and newspaper reports, articles, books and popular accounts are explored and given life again in the classroom. Events 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. I believe that the potential is not fully exploited if a class is satisfied with a reconstruction of a television documentary. The students should play the roles of critical journalists.

Making imaginary conferences, hearings, official consultations and inquiries of scientific issues of current interest is also my experience of engaging and motivating science lessons. Cross-curriculum projects inspired by real events in society, such as natural catastrophes, environmental policy or decision-making processes in scientific matters, are interesting and popular in secondary school. Bringing in the drama element may offer students an extra motivation to learn and internalize the knowledge because they are obliged to use it in the following role-play. Role-play science projects can be organized in different ways, but the main feature is first a period of inquiry, information gathering and formation of roles, and then the accomplishment of the goal, which is a plenary role-play where both students and teachers are in role.

Science in society issues are often marked by conflicts of interest. Conflicts occur when group differences reflect disharmony between interests or values. Different groups of people may have diverging interests and diverging moral standards. Antagonisms between nature and society may result in an environmental issue, which creates conflict between different interest groups and leads to political situations. Role-play may be an arena for the interest groups to meet, exchange arguments and perhaps educate each other, and the aim should be a resolution of the conflict. Traditional science is challenged in favour of a science grounded in action as Jenkins (1994) has noted:

> [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. (p. 608)

Role-plays are 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 described above address interpersonal and structural conflicts. They may also reveal misunderstandings and conflict with the environment. Role-plays are enriched if they include personal conflicts, and if the roles are designed by the students this should be stressed. Personal conflicts add a personal and emotional dimension to the play, which is valuable in cognitive reflection (see Ødegaard 2000a; Ødegaard and Kyle, 2000). 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, better and more complex understanding of science concepts and reasoning. My personal experience with contrasting the environment with the need for employment when working with small children, is that children seldom personally feel the need for employment as a real conflict (an exception is if they have unemployed parents). In these cases, I believe the environment may 'win' too easily.

Emphasizing conflicts does not make science lessons easier for science teachers. Jenkins (1994) says such a form of science at school presents:

> Formidable challenges to science teachers who may be asked to abandon existing and familiar practises 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 (p. 607).

So, 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 border cross into the subculture 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.

Democratic processes involving science do occasionally lead to agreed solutions though. Consensus conferences are good examples, and a simulation or role-play of one may provide an excellent pattern for a science in society project (Kolstø, 1997; Sandberg and Kraft, 1996). These conferences seek to offer an informed piece of advice to the government on debated 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, and 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 time painful process of reaching consensus.

Other democratic decision-making processes have been made into role-plays or simulations where teams of different actors are described with background information, interests, and goals in the process. In Denmark, Lars Klüver and Hans Erik Svart (personal communication, May 1998) made a role-play about an application to set out genetically modified Populus ssp. where the different actors in the process are: The Ministry of Environment, industry, environmental organizations, researchers, consumer-organizations, farmers, and the media. In addition to the background information, each team of actors is given a 'Joker', which is additional information in their favour, which can be used during the play. 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.

Science and new technologies continually offer us new ethical challenges. Biotechnology is a good example. Here ethical challenges often involve personal conflicts, where on one hand there can be great medical, environmental or economical benefits, but on the other hand there might be great insecurities about the consequences and the moral right to change the 'code of life' (genes) and interfere with nature. The decisions in these cases involve not only rational, scientific and moral considerations, but they are also strongly influenced by irrational or perhaps non-rational feelings and underlying (more or less conscious) ideologies (Knain, 1999a; Ødegaard, 2000b). It may be argued that in science lessons one should only consider the rational part and leave the irrational for other experts. The day the problem becomes real, one can hope that the rational judgement once done without the involvement of feelings may help in a deeply emotional situation. On the contrary, I strongly believe that not considering and addressing non-rational factors is doing school science a disservice. Students may get the impression that science does not recognize that ethical decisions are complex and complicated and may loose confidence in the scientific society. I also believe that the best preparation for making ethical choices is experiencing the complexity of reason and emotion and reflecting on the different parts. Using role-play in dealing with ethical dilemmas may provide a tool for that purpose (see Ødegaard and Kyle, 2000).

Final Comments

For a structured overview of the science and drama studies and projects presented in this article see Figure 4. It has been stressed herein, that science should seek non-authoritarian and creative learning environments. In the present discussion, we have seen different projects with different degrees of structuring. A teacher directed drama activity is not necessarily authoritarian. It is the teacher's responsibility, as a professional, to evaluate how much guidance the students need in learning about different science issues.

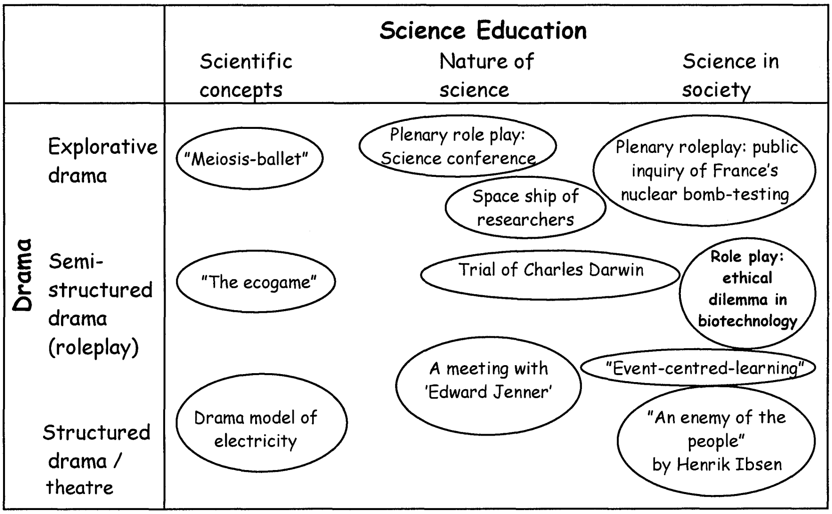

Figure 5. An overview of some of the science and drama projects presented in this article.

When drama is used to focus on science as a process or science in society, we have seen that the central scientific concepts often take second place after the human drama. In different variants of role-play, (e.g. an environmental conference, ethical family debate) people, in our case students, are put in focus. Some scientific knowledge is obtained, but the emphasis is on the affective (e.g., empathy, self-confidence, engagement and motivation). These qualities are not as easily measured and assessed as factual scientific knowledge, but are all important ingredients of being an educated and reflected person. In order to be an independent critical thinker, both cognition and affection is vital (Knain, 1999a).

Even though I have argued that drama activities give examples of non-authoritarian and creative learning, others may argue the otherwise. On the contrary, drama and role-play, because it does involve feelings and affective elements, may be manipulative and authoritarily directed in a 'hidden' way. Janis (1968) describes how role-playing can be used in attitude change. If people 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. In his master's degree in drama, film and theatre, Nilsen (1986) also concludes that role-playing may influence the participants' private perspective. He writes (author's translation):

> 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 suitable for 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. (p. 141)

The perspective of wonder and alternative solutions to problems raised by science in society are precisely elements that should be an important part of a critical, including science education based on a constructivistic view of learning. In their deconstruction of a role-play about an ethical decision-making process of biotechnology, Ødegaard and Kyle (2000) perceived that although each group did the same role-play based on the same role cards, it resulted in different decisions of both individuals and groups. But as opposed to Janis's role-plays, the participants were not given distinct attitudes to enact, merely different life situations, and it was up to the participants to form their role figures and their opinions.

The goal of this article has been to discuss how different science and drama projects may contribute to science education by providing meaningful and empowering learning environments. The pedagogical advantage of drama is the possibility to step out of role and reflect at distance on personal experience, which gives occasion for metacognition with empathy. The metacognitive process is very much dependent on adjustment and organisation by the science teacher and is of great importance for the students in order to get a conscious relationship to science. Especially in learning about science in the context of society, drama can successfully be used for making simulations of the real everyday world, where science is recontexualised for specific purposes, and where students experience using cognitive, affective and active aspects of learning.

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Paper IV

Imagination and Critical Reflection:

Cultivating a Vision of Scientific Literacy

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A presentation at the 73rd Annual Meeting
of the National Association for Research in Science Teaching,
28 April - 2 May 2000, New Orleans, LA, USA.

Abstract

Imagination plays a critical role in the process of learning. Further, when learners come together, they have the potential to reveal themselves as subjects, as unique individuals. The educational value of imagination and student disclosure is seldom tapped in a curriculum oriented toward cultural reproduction and transmission of knowledge. Herein, we argue that the essence of the curriculum ought to be transformed to focus upon the "life of the mind" in which we find ways to integrate our notions of community, collaborative action, and critical reflection. In essence, from a pedagogical perspective, we will engage in an ideological critique of the science teaching-learning process and offer recommendations for how science education can be transformed to serve the emancipatory interests of learners.

A biotechnology role-play, which was conducted in a Norwegian high school with 18-19 year olds is deconstructed from the perspective of critical theory and educational research. In the spirit of critical reflection and emancipatory action, discussion focuses upon cultivating a vision of scientific literacy in which students are active agents in a teaching-learning process oriented toward the public understanding of science and social change.

Introduction

Over the course of the past 15 years, the expansion of knowledge in molecular and cellular biology has been extraordinary. For example, when the Human Genome Project (HGP) was being contemplated, many scientists were concerned that the HGP's effect would reduce biology to DNA. Now, 12 years into the 15 year HGP initiative, the result has been that genomics is a very broad platform that has opened up new perspectives in biology. Scientists are now working in new fields such as bioinformatics, functional genomics, molecular epidemiology, molecular evolution, and pharmacogenetics.

Within the scientific community there is also a new emphasis on interdisciplinary research in which scientists from different specialities collaborate to address science-related societal issues. Notable examples are as follows: Karl-Henrik Robert, a Swedish cancer specialist, has led a science-based environmental movement (The Natural Step) and asserts that scientists must lead the way because technological and industrial applications of science have contributed to many of the world's most pressing issues. Ingo Potrykus, and his Swiss research team, has found a way to add key nutrients to rice through genetic engineering; this development could help address the malnutrition that affects nearly 1/3 of the world's population, thus it could be the most dramatic use yet of biotechnology to improve human health through food. Fatimah Jackson, a US biologist and anthropologist, has concentrated much of her work on the biological histories of African peoples and the patterns of human ecogenetic variation; specifically, the influence of dietary cyanogenic glycosides from common foods on human metabolic biology and the potential for human-plant coevolution (e.g., the link between cassava - a staple in the diet of 400 million people, the high levels of cyanide contained in cassava, sickle-cell anemia, and malaria). Much of her research provides an integrated approach to the question of modern human diversity.

The sense of excitement amongst biologists today - the sense of being on the verge of knowledge that is truly revolutionary - perhaps rivals the excitement amongst physicists in the first half of the 20th century. It is most intriguing, however, that during this period of time in which the essence of scientific inquiry is in the process of being transformed, the essence of the school science curriculum has remained static for close to 50 years. While there have been efforts in many countries, including Norway and the US, to conceptualize an intended science curriculum reflective of present-day science, the science curriculum as implemented has remained static. Equally as distressing, the understandings of science required by the general citizenry is seldom a part of the school-based curriculum. The essence of the curriculum ought to be transformed "to enable students and adults to fully contribute as active agents in a democratic society" (Kyle, 1995a, p. 1009).

Both authors have sought ways to transform the nature of the science curriculum, thereby enabling students to be active agents in a teaching-learning process oriented toward the public understanding of science and social change. Marianne has been both a science and drama teacher for several years. She has experienced the value of cross curriculum projects and cross curriculum thinking, in which drama activities enable students to construct social contexts for science where students can practice good citizenship. Bill has taught courses in Environmental Science, Social Issues in the Natural Sciences, and in 1979 developed and taught the first Bioethics course at the University of Iowa. Thus, through their collective teaching experiences, both authors have sought instructional praxes in which students can simulate democratic decision-making processes, engage in moral discussions about science, or discuss ethical scientific dilemmas.

Rationale

We wish to focus upon the link between science, scientific knowledge and use, and the public's understanding of science (see Kyle, 1995b, 1995c; Shamos, 1995). The practice of science is inspired by imagination and creativity. Bronowski (1956/1965) defines science as "the organization of our knowledge in such a way that it commands more of the hidden potential in nature...it admits no sharp boundary between knowledge and use" (p. 7). He asks, "What is the insight with which the scientist tries to see into nature?" and "Can it indeed be called either imagination or creativity?" (p. 10). He asserts that the hallmarks of science are linked to independence, originality, and dissent; and, notes that "as originality and independence are private needs for the existence of a science, so dissent and freedom are it public needs" (p. 62). Bronowski views the safeguards of both the private and public needs of science as: free inquiry, free thought, free speech, and tolerance. Further, in discussing why the logical-positivists and behaviorists accounts of science appear mistaken, Bronowski claims that what makes rational behavior different "is a creative process, the exploration of likenesses; and this has sadly tiptoed out of the mechanical worlds of the positivists and operationalists" (p. 36).

Thus, the values of science are human values. Science is inspired by imagination and creativity. Similarly, imagination and creativity play a critical role in the process of learning. Further, when learners come together, they have the potential to reveal themselves as subjects, as unique individuals. The educational value of imagination, creativity, and student disclosure is seldom tapped in a curriculum oriented toward cultural reproduction and transmission of knowledge. Herein, we argue that the essence of the curriculum ought to be transformed to focus upon the "life of the mind" (Greene, 1995, p. 89), a process which Greene suggests enables learners to make sense of their lived lives, to make connections, and to construct meanings. Further, we assert that as educators we must find ways to integrate notions of community, collaborative action, and critical reflection. In essence, from a pedagogical perspective, we will engage in an ideological critique (see McLaren and Giarelli, 1995) of the science teaching-learning process and offer recommendations for how science education can be transformed to serve the emancipatory interests of learners.

Dramatic Science:

Fostering Imagination and Critical Reflection

Science is both a search for knowledge and an important part of our culture. The societal impact of science, as well as its influence on our personal lives, offers us new democratic and ethical challenges. Role-play, in different variants, may be a successful way of bringing these matters into the classroom. Drama offers an ability to get a near and personal relationship to issues concerning science and citizenship. Further, it is the nature of drama to create fictitious worlds, and this can be utilized to explore both possible and impossible (e.g., historical or future events) situations in the light of science in society. Students can explore science and they are able to border cross (refer to Giroux, 1992 for a description of the initial notions of border crossings in an educational context; see also Aikenhead, 1996) into the sub-culture of science by taking on a role. Further, students gain experience with the human values so essential to ethical deliberation - that is, about the relationships we construct between ourselves and others. Hence, they get an opportunity to reflect upon choices and decisions made by themselves, but they are not committed to them because the choices were made by their role-figures. This possibility of stopping the play in order to step out of role and reflect is what makes drama such a powerful pedagogical tool. The drama's 'pretending' character (e.g., the play as a symbolic expression), creates the necessary distance to reality that makes reflection possible. In the alternation between experiences in the play (the 'pretended world') and from the reality outside the play (the 'everyday world'), new knowledge and new insight may appear. This interplay of intimacy and distance, of empathy and reflection is fundamental for the epistemological potential in the dramatic role-play. Students must affirm these two realities in their heads simultaneously. The concrete symbolic action of the play is a symbol of what the students want to explore. The fabricated role or situation creates the necessary distance that makes it possible to hold two different 'worlds' in the head at the same time (Heathcote and Bolton, 1995; Sæbø, 1998). Bertolt Brecht (1964) used this 'distancing-effect' ('Verfremdung', 'alienation') in his pedagogical or epic theatre. He claims that the audience's degree of identification with characters and events is thus controlled, and they can more clearly perceive the 'real' world reflected in the drama. By re-creating situations from the 'real' world in the science classroom, students may reflect on reality (from a being-in-time perspective) and at the same time rehearse and explore what might be possible to do in real life in the future. Boal notes that "In the present, we re-live the past to create the future" (1998, p. 9).

The Setting

The biotechnology role-play was conducted in a Norwegian high school in a non-science class environment with 18-19 year old students who were ready to leave school and begin their life as citizens in society. Thus, as their general education is approaching an end, the question one might ask is "How well prepared are students to address ethical issues related to science?"

The material on which this study is based is eight audio-taped role-play dialogues, conducted in four classes in one upper secondary school outside Oslo, Norway. The role-plays were conducted in the mother tongue lessons as a preparation for a school essay on biotechnology. In addition to these eight dialogues there is a role-play dialogue that was conducted by biology teachers who attended a bioethics course in biology education. Because biology teachers are considered to be scientifically literate (all the participants possessed a Master's degree in biology) this dialogue was submitted to our study group as a frame of reference.

When the project was conceptualized it was envisioned that the role-play could be used to assess students' scientific literacy. That is: How would the students react in a situation related to a scientific issue involving ethical decision making? How well prepared were they to engage in such deliberations? What decisions would they make and what scientific knowledge did they use to make such decisions? If and when students' used scientific knowledge, how did their scientific understandings assist in the ethical decision making? As the empirical research stage progressed, it became clear that role-play was not merely an assessment tool, but that the experience of participating in the role-play offered a valuable learning experience.

Initiating the role-play can be viewed as the teacher introducing a topical theme (see Shor, 1992) for setting the scene and providing the students with a shared life experience. Role-plays are characterized by being problem and conflict orientated. A good conflict helps to "drive" the story forward and is common for all dramas. The students get information and instruction about their role figures on role cards. The role card provides both personal and scientific information on the situation, but it does not present ready-made opinions. Rather, it offers a personal conflict as a starting-point, which the person in role has to deal with using personal (out of role) experiences together with interaction experiences during the role-play. The 'actor' has great freedom in forming the role. In this way a world is created that does not reflect pre-designed opinions, but rather how roles with different life experiences and life situations offer different perspectives to the same issue. The role-play develops the students feeling of empathy. Students are not allowed to look at each other's role cards, but everybody is introduced to the situation and to the other actors. The students then improvise the actual role-play, revealing information or antagonisms as desired throughout the progress of the play.

It is important to stress that the student 'actors' are to concentrate on the attitudes of the roles they assume, not on physical or vocal appearances. They have to bring to role their own inner knowledge, while not portraying stereotypes. The play tends to be a highly cognitive activity where the participants work with ideas and attitudes and test out "playfully and with feelings of ease" (Lugones, 1987) hypotheses about significant science and technology based social issues. Students are asked to believe in the assigned roles, to think for themselves, and to act on their own initiative based on their own life experiences.

"The rapidly changing science and practice of genetic testing raise a number of scientific, ethical, legal, and social issues" (Jonsen, Veatch, and Walters, 1998, p. 288). The investment in the Human Genome Project will greatly increase the capacity to detect genes leading to genetic susceptibility. And, the emergence of the biotechnology industry increases the likelihood that these findings will be translated into readily available test kits and diagnostic products. As genetic testing and screening becomes more widespread, we may bypass current ethical and regulatory standards. In light of new genetic screening capabilities, several genetic diseases and pre-dispositions for these can be detected much earlier and much more accurately then ever before. In addition, prenatal screening and diagnosis is available for a variety of genetic disorders, but is typically discouraged for identification of trivial characteristics/conditions or for the determination of fetal sex for the purpose of preferential selection of the sex of the fetus. Genetic testing of individuals is able to reveal inherited conditions that may cause symptoms at any time during one's lifespan (newborn through adult disorders) and/or reveal carrier identification for purposes of reproductive planning.

The probable increase in the practice of genetic testing and the results of genetic tests will necessitate that the public be able to engage in ethical decision making. In this regard, Kielstein and Sass (1992) have proposed a medical-ethical action guide for physician-patient interaction (see Table 1). They suggest that if such a guide is used it will prepare the patient for possible choices of action. They stress the patient's right to make an informed decision and state:

> The more experienced the individual citizen's ethical competence in decision-making, the stronger society will be; scenarios of governmental paternalism will only weaken parental and patients' competence in moral choice. (Kielstein and Sass, 1992, p. 403)

Using the Action Guide in Patient Centered Predictive Medicine as a frame of reference, we wish herein to explore whether students who participated in the biotechnology role-play study address the issues in the Action Guide. If the student dialogue during the role-play addresses the issues recommended by Kielstein and Sass as requisite for a real life decision making, then we consider the role-play to be a good basis for an empowering education on science-related societal issues.

Table 1

Action Guide for patient centered predictive medicine.

1. Identify the problem
   a. collect genetic data;
   b. collect human data;
   c. identify value elements.
2. Develop alternative scenarios for action
   a. establish medical/genetic prognosis for each scenario;
   b. identify ethical principals in each scenario;
   c. discuss ethical issues in each scenario.
3. Discuss risks and uncertainties of prediction
   a. discuss medical and moral uncertainty;
   b. discuss medical and moral risks;
   c. assist patient to identify 'best solution'.
4. Challenge the patient's medical-moral decision
   a. ask patient to clearly specify her/his reasoning;
   b. help patient to understand risks and uncertainties;
   c. ask patient to defend her/his decision.

(Table 1 in Kielstein, R. & Sass, H.M. 1992. Right not to know or duty to know? Prenatal screening for polycystic renal disease. *The Journal of Medicine and Philosophy* Vol.17, nr. 4: 395-405.)

The Role-play

In light of the setting established above, the role-play is about genetic testing and the associated decision making. The role-play consists of four roles:

Gro: 22 years old; a nursing student who is happily pregnant (9 weeks); her husband is Vegard.

Vegard: 24 years old; a teacher who is happily awaiting the birth of their first child.

Barbro: 43 years old and working in a bank.

Tor(a): 18 years old, an upper secondary school student who is preoccupied with environmental issues and maintaining a healthy diet.

Gro and Vegard are expecting their first child. They arrive for dinner at Barbro's house, Gro's mother, who is divorced and lives with Gro's brother/sister Tor(a) (depending on the composition of the group this role can be played by a male or female). Gro and Vegard have been to see the doctor for the first time that day. Barbro and Tor(a) are anxiously awaiting to hear about the initial visit to the doctor. While at the doctor's, the parents-to-be were asked to join a genetic screening research project. Only Gro and Vegard are informed of this before the role-play begins. They are provided with information about the research project, as well as with a list of genetic traits for which the fetus may be tested. Barbro's father, Gro and Tor(a)'s grandfather, is senile and living in a nursing home. Barbro's mother died more than twenty years ago of a brain tumor. Barbro is their only child. The play starts around the dinner table.

Role-play Analysis

We have constructed a role-play prototype using excerpts from the nine role-play dialogues. In the analysis we will occasionally refer to the prototype.

Role-play Prototype (Selected Excerpts)

B: How did it go at the doctors today?

G: It went well.

B: Good. Did you find out anything exciting?

G: Yes, everything is OK, for now anyway. We were asked if we wanted to be included in a project.

B: Oh, yeah?

G: About this gene... technical... kind of... It is a research project.

B: Oh, that is exciting.

T: A research project about what?

V: They are going to test some things about the child.

G: Genetic characteristics and diseases.

B: Oh?

T: So you are going to know if the child will be good in math at school and stuff?

V: They can map the fetus' genes and find out if she is predisposed to heritable diseases later in life.

G: Everything was OK with

Deconstruction of the Role-play using the Action Guide as a frame of reference

The role-play is initiated by the students having read their role cards. An opening line is provided to ensure that all the role-play groups get a focused start. Barbro is to say: "How did it go at the doctor's today?"

According to the action guide there should be a phase of identifying the problem. This is what one calls the exposition-phase in a drama. It is where there is an introduction to the play and information is provided so all the participants feel orientated and understand the issues raised. Technically, this is an important phase because basic misunderstandings can be detected quickly and there is no problem starting the play over (which one of the groups did without disturbing the rest of the role-play).

Brief information is shared in all the groups and not much attention is given to the written information provided in this phase. The next dramatic phase is where conflicts gradually come to a head.

In the action guide there is a call for a development of alternative scenarios. The analysis of the role-play has revealed three different scenarios for action. One is to test the fetus, one is not to test the fetus, and one is to wait and test the child some time after it is born. Beside these main scenarios, there are other suggestions of action, or non-action, that has to do with whether the other family members should be genetically tested. The scenarios do not appear separate, but throughout the duration of the role-play discussion. To clarify the alternative scenarios for the reader, each role has been provided one scenario in the role-play prototype. The

the fetus and I'm very happy, but I am puzzled about this European research program. We have to provide an answer by tomorrow.

B: Do you want to participate?

Duty to know / not to know:

G: The best thing is to know...

T: Not everything [diseases] is possible to do something about, so then there is no use in the kid walking around thinking about it. But that is perhaps a little bit dumb for us too?

V: Yes, then we should rather wait until they find solutions... It doesn't help to anticipate sorrows.

G: We will not anticipate sorrows, rather take precautions.

V: You can take such tests like that later in life, but if you do it now you get the child's whole genetic code embroidered before she is

choices are based on what each role seems to argue for the most, and thus reflects to some degree their role card description. Again, the role cards can be used for ensuring that different perspectives appear in the play.

In our case, Gro is the one who initially wants to test the fetus and argues for that action scenario. Tor(a) does not want the child to be genetically tested and Vegard believes they should wait.

After the exposition phase of the role-play, different ethical principles and issues are discussed.

Duty to know or not to know:

The principles of duty and responsibility towards the unborn child are discussed. If we look at Gro's arguments, she claims the parents possess a duty or responsibility to know, or to gather information about the child. In other words it is their duty to test the child. Some students in role use their imagination and sense of critical reflection in deliberating the ethical arguments in the context of the issue, but we would like to stress that the opinions belong to the role figure and not necessarily to the student (see Ødegaard, 2000 regarding the role of the double aesthetic). Some students do not underpin this duty with a reason. They merely state that knowing is good: "the best is to know..", "you would regret it if you didn't know..", "it is wise to know.." This seems to express a worldview where knowledge is technical and controlling (i.e., an empirical-analytical perspective). The duty to know arguments used by some students suggest that *born. It is so drastic.*

T: I just hope that it doesn't destroy anything for the child. Like when you are applying for a job later on; "no, you are predisposed for that...", and then you will not get that job, and...

B: It could be an advantage to find out if the child gets any permanent diseases....

G: What if my kid gets a disease then, would you...? Think about that! Then you would really regret not knowing.

V: But we couldn't have done anything anyway.

T: There is no reason for knowing that when there is no treatment. It is just so incredibly depressing.

G: I understand that too, but with today's rapid progress, you never know what will happen... If you know he is predisposed for these diseases, then in the future if there is a cure against them, and if you know that he is, then you can be early and...

V: I really look forward to having a child right now, so when, or if I get to know in advance I am afraid it will

such knowledge will increase the quality of life for the child. The knowledge of a disposition for a disease could lead to the parents taking precautions. The child is given an opportunity to get an early start if new cures are developed, because the parents are more alert about both the development of the child's disease and any new advances in science's for that particular disease. The parents can also, it is claimed, be more helpful and supportive to the child by organizing and preparing the child's life in such a way that the dangers can be avoided. Here the students touch upon the nature – nurture issue. Even though the child has a disposition for a characteristic, he or she does not necessarily have to develop it, if well nurtured by the parents. The parents can, for instance, provide the child with a healthy diet. Some students assert a counter-argument to this, which is a fear of a self-fulfilling prophecy.

For some students, the duty to know is also underpinned by the fact that they may find out that the child does not have any genetic diseases. Thus, the parents and the child will have increased life quality by not having to worry about the prospect of any genetic disorders.

Another argument that occurred in one of the role-plays (in the teachers' role-play) is the parents' responsibility of being sure they can offer their child a high quality life. That is, if the child is expected to have a low quality life because of severe handicaps, for instance, the parents have a responsibility to consider an abortion.

spoil it. But if we wait until the child comes, then I would rather let it be..

T: Yeah, because why should you know that a child will be manic depressive after a while? Things like that must be influenced by the environment too, I think. And, if we go around and think all the time that our child will be manic depressive, then he or she probably will be. And about the alcoholism, I don't know.

G: But then we can help and support him so he does not become an alcoholic. Help him prevent it.

V: I think a bit about Grandfather; that there is... there is something about senility here so, I am not quite sure I want to know that the cute little baby is going to be senile.

G: But you could know if it is a boy or a girl, and start buying clothes right now!

T: Yeah, but you do not need to take a genetic test to know the sex of your child. You could have an amniocentesis, or even just an ultrasound. Ding-ding-ding. No, I don't think you should do it. If we were supposed to know what

Turning to Tor(a)'s lines that represent the scenario of not testing, we see that a duty not to know is supported by the argument of not putting the child in the difficult situation of knowing and thus worrying. It is the parents' duty to give the child a life with as few sorrows and worries as possible. Especially if there is no treatment for the disease, then it seems meaningless to know if the child has such a predisposition. There is also the case of providing the child with genetic information that may be misused later in life.

In some of the statements there seems to be an underlying view of veneration; that life is spiritual. The gift of life itself and the course of one's life are something natural that should not be disturbed. Lines of reasoning are: "we are not meant to know", "it is not natural to know beforehand", and "getting sick is one of life's challenges". In conjunction with such perceptions, an argument often used is that regardless of what they find out they will love their child.

Vegard advocates the 'wait and test later' scenario, seems to recognize the parents' duty to know and thus the 'knowledge is good' regime, but wants to postpone all the unpleasantness associated with such knowledge. He wants to wait until they find a cure, or until the child is older. The case of genetic determinism appears to frighten him. Some students also give the impression of being afraid of knowing about genetic qualities before the baby is born, perhaps being afraid of having to confront the option of abortion, or maybe merely letting the thoughts of future diseases destroy the joy of becoming a parent.

we are and what we will be, then we would have known in a natural way.

B: Oh dear. I think this is a major choice to make. A big step.

V: So if it is, maybe it is better to let the kid decide... Maybe wait until it grows up and stuff, ...like understands.

T: It is a very good point you have there that you can... we have to understand that, by taking the test now we are not letting the fetus decide for itself at all.

G: Maybe we could pick out some... select some of the results? ...some that we want to know and others we do not want to know.

V: That's right, we can choose what information we want. It is only to help out in a project to detect the distribution of diseases or those.., what was it?, ..genes in Europe. We do not need to know.

Disclosure of the "life lie":

G: Mom! I actually think your opinion is important here.

B: Yes. I guess it is. It... I

Disclosure of the "life lie":

In role-plays with role cards it is possible for participants to have secrets that others are unaware of until the information in the cards is disclosed. In this case, the mother has a secret about the family history. Her mother died of *am sitting here with a little secret, that I have had for many years but that I really refused to... It has something to do with Mother. She didn't die of a brain tumor, she didn't.*

V: What?!

G: Oh, what?

B: She didn't. It was only a...

V: There, there..(comforting)

G: Oh no, and I have given money to the Cancer Society all those years!

B: That was just something we had to say.

G: Oh? Well, what was it?

B: The doctors said she, she was... Yes, she did not die of a brain tumor, like everybody thought, and I did not think I would have to tell you this, but as it is now, it sort of popped up again, like a ghost. And my Mother actually died of Huntington's. She did. So I thought you should know before.., now that you are..., so..

V: What is that?

Huntington's disease. It is up to the student that plays the mother to reveal the secret. The role card does indeed encourage her to do so, but not all of the students manage to disclose the information. In this study, one of the student groups did not reveal the information and neither did the teacher group.

When the secret or "life lie" is disclosed it raises the tension of the play and it can be considered the play's climax or turning point. In dramatic texts this is called the peripeti (see Figure 1).

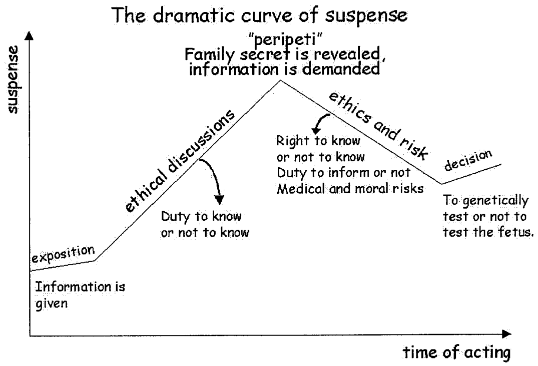

Figure 1. A schematic overview of the role-play discussions inspired by Svensen's (1985) curve of suspense and Kielstein and Sass's (1992) Action Guide.

The "life lie" disclosure has an impact on the participants. They seem more personally and emotionally involved. There are more spontaneous outbreaks like: "Oh, no!", "What?!" and "Why haven't you said this before?!". Suddenly the participants seem more eager to gather information, and the question of the disease's inheritability gets a new meaning. They are not only engaged in whether the baby may get

G: Did she? Is it true?

B: It is true, yes.

V: Oh no!

B: So that leaves me.., I am also in the danger zone.

G: Yes.

B: This is something I really was not going to tell, but… It had to be revealed now as this test… is brought up.

V: The truth will always be revealed, you know Barbro.

G: If you have inherited it then I have it too then, perhaps?

B: Maybe. Maybe Tor too, in that case.

V: Wow.., what was it again?

T: That was some news..! So she didn't die of a brain tumor then?

B: No that was something we said, but…

G: What does this disease imply, then? This stuff with the brain?

Huntington's, but also the risk of getting it themselves.

The general engagement in the role-play raises when the participants get a personal interest in the results of the gene test because the risk of getting Huntington's is considerably higher after the information about the family history. We do not know how the role-play would have proceeded if everybody knew this from the start. But it is a generally known method for engaging the audience (in this case the role-play participants are both actors and each other's audience; see Ødegaard, 2000) to introduce them to the play's environment first and make them comfortable, and later to change the focus for emotionally touching them. Our role-play happens during a family dinner, and can resemble a 'real' situation. In his modern contemporary plays, Henrik Ibsen often had a relatively short time of action, perhaps just a couple of days. This can be a means for creating a reality illusion. In Ibsen's dramas he often integrates an analytic exposition of the past. It can be a letter, an old bill of loan, or an old acquaintance that brings up something from the past and contributes to the past being reintroduced. This is the basis for concentration and intensity that distinguishes his realistic plays. There is a big retrospective element in our role-play. The gene test in itself acts as a retrospective remedy that makes the past suddenly become very present for Barbro in our play. It even becomes the future embodied in the little baby to come!

Besides a raised engagement in the role-play, the life lie revelation has another interesting impact with respect to the science education goals. After the participants have had this emotional stir, there

B: A disintegration of the brain, yes.

T: Is there something..? ..to prevent, is there a cure?

B: No.

T: No treatment, yeah...

G: There has to be a medicine you can take so you can like postpone the illness in a way?

T: No treatment, huh? Then we don't have to care about testing, while there is no cure..

V: Is it a new disease or something?

B: No.

G: It is dominant.

V: A disintegration of the brain, bah!

G (to Barbro): But then you are...? Yes well, no. It does come pretty late.

V: But then we all have to..., then all of us should...

B: Is there a cure now? Is there more research done on the subject? I haven't managed to...

seems to be an increased motivation to gain more scientific information. They want to know more about the disease, the course, cures, medicine and so forth. The question of how Huntington's is inherited and the percent risk associated with the disease becomes important, as well as an increased need to understand the scientific expressions in the written information they are provided.

Science education has a history of rationality and emotional neutrality. Science education has emulated the perceived objectivity of science and adorned itself with being unaffected by feelings. Paradoxically, the role-plays reveal that greater student emotional engagement enhances their motivation to acquire scientific knowledge. Studies have shown non-scientists ability to conceptualize science in a short amount of time if the personal motivation is high. Wynne (1991) states, "when people do see a personal or practical use for scientific understanding and are sufficiently motivated, they often show a remarkable capability to learn and to find relevant sources of scientific knowledge" (p. 117).

On the other hand, Layton, Jenkins, Macgill and Davey (1993) describe how parents of children of Down's syndrome judged the scientific accounts offered by the hospital to be irrelevant and of little practical value. "For most parents their most potent resource was not formal science, the medical profession, ancillary services, or even voluntary organizations. It was themselves. As the mother and father of a twenty-five year old Down's syndrome man expressed it, both parents being early school leavers with no formal educational qualifications, 'We've only learnt it through ourselves'" (p. 57). The body of practical knowledge the parents had themselves constructed was a powerful alternative to the 'high science' available from medical and other experts. Too often, it seemed, parents had received from such experts a message of despair when they were desperate for one of hope.

Right to know / not to know:

Another ethical principle brought up and discussed is the individual's right to know. During the course of the role-play this issue is often raised, and the focus of attention is the birth of the baby. But, after Barbro revealed the secret of her mother dying of Huntington's, the other participants felt a sense of indignation and personal violation. The fact of having been lied to violated their right to know and this was expressed regardless of which scenario they supported. Even individuals who declare their right not to know feel deceived. The right of family planning according to the family's genetic history is the most used reason. Several mention this in a tone, which implies that it is too late now, and that is the reason for the indignation and anger. Abortion is not an easy option for the students to consider. Only three groups brought up the prospect of abortion, two student groups and the teacher group. In the student groups it was brushed aside quite quickly as a non-option. The teacher group showed more uncertainty in what to do and seemed to consider abortion as a viable alternative.

The right not to know is underpinned by reasons such as the fear that the knowledge would spoil the quality of life. Several express uneasiness with 'mapping' one's life with a genetic test. As mentioned previously, additional reasons relate to

G: No.

Right to know /not to know:

T: But, isn't it a little bit wrong that you haven't told before?

G: So, were you like going to keep your mouth shut you whole life?

B: It was difficult.

T: But even so. If you think about it, if you had told earlier…, and since she is pregnant now… You should have said it before.

V: Now I almost think that we should take the test, to... if that is… Is it too late for an abortion?

T: I do not want to take a genetic test myself. If I find out that I have the disease then, then I just know that I am going to die, some time or another. I don't want to know anything that can ruin life.

G: But, you know the things you said before *about going around worrying about the child being sick? Then we could also take away that fear if it is healthy! Yeah, so we could, if the child is healthy avoid worrying about what can happen to our child.*

Duty to inform / not to inform:

V: But should we if possible tell it to our child? If it is sick?

T: No, you mustn't tell!

G: If the child for instance has a predisposition for alcoholism then of course we have to say so. We can't just go out and have some beers, can we?

B: But what about the child?

T: Yes, you know how you will react to it, or at least you perhaps have qualifications to know how you would react if the child has a lethal disease, but how will the child react to it? I have no idea how…

V: How about when the child is old enough to understand it himself? 'We've known all the time that you are going to get

the veneration or naturalness of life, the notion that unexpected events are part of life; and that other unexpected events occur that are not genetic.

Duty to inform / not inform:

The last ethical principles that will be described associated with the role-play is the duty to inform or not to inform. This can be distinguished from the other principles when the focus is on the persons that possibly will obtain or has obtained genetic knowledge and how such information might be managed. The focus is thus divided between Barbro and her handling of the genetic information of Huntington's in the family, and Gro and Vegard, the parents to be. Barbro is accused of not doing her duty by previously refusing to enable the young couple to choose whether or not they wanted to give birth to a child that might have a lethal genetic disease. The other focus is whether or not Gro and Vegard should tell their child about the possible genetic information. The arguments for telling are grounded with it being irresponsible not to tell for practical reasons, like avoiding situations that may enhance the risk of getting the disease, or they are morally grounded in the context that it is wrong to lie to the child. The parents' duty not to tell can be seen in relation with an extensive empathy with the child's possible reaction to the knowledge.

Some students show a rich use of imagination when the discussion concerns the unborn child growing up and confronting his or her parents on issues related to ethical dilemmas. Obviously, this is a point to which they feel 'at home' and can easily empathize. They use fantasy and their *this disease.'*

T: 'All the time from you were born.'

G: 'From before you were born.'

T: 'From before you were born.'

B: 'We knew that you were going to die very early.'

G: 'We have loved you all the same.'

T: 'We thought it was best to spare you of it.'

V: 'We have prepared ourselves for it, so then it doesn't matter.'

G: No, we would have felt it as a deceit from our side if we held it a secret from the child that we knew the whole time.

current lived experiences, such as going to parties, meeting friends, and drinking beer, as they imagine what it would be like to get to know that you were predisposed for alcoholism (Note: Norwegian teenagers leaving upper secondary school have an extensive period of partying at the end of the final semester; this is a tradition called "russetid." The role-play was conducted during this period of time). In the prototype role-play there is an example of how they use their creativity to make a 'play within the play'. They imagine how it would be to tell the child something they have known all the time. It is a good example of how the role-play can create spontaneous situations where the students cooperate in 'playing' and exploring alternative ways to act. It starts with a line by Vegard imagining what would happen when the baby grows up and gets to know about the disease. Suddenly the other participants join into the fantasy, which in itself expresses a playful ironic distance to the serious issue in question. The students treat the tragedy of bringing news about a lethal disease to someone as a kind of comedy. They make each other laugh within the context of the absurd situation. This is often how adults facilitate their conceptualization of tragic events - with humor. Using imagination and critical reflection in role, the students explore the difficult psychological position they would have to confront having access to the scientific knowledge about genetic disorders.

Discussing risks and uncertainties:

B: Well, at least I do not know if I have got Huntington's disease.

Discussing risks and uncertainties:

The risks and uncertainties that emerge during the role-play dialogues have several aspects and focuses. One is the medical risks and uncertainties associated with the actual gene test.

G: But is that something you are guaranteed to inherit, or just like maybe?

B: You can inherit it, and I don't know if I have inherited it. That is why I was asked to take an examination when mother died. But I thought it was difficult, because I would rather not…

V: Do you know of other instances in the family?

B: No.

T: Can I have inherited too, then?

B: Yes, maybe so.

The risk of the gene test giving a wrong indication is touched upon by one group. Some groups had concerns about the test being dangerous for the mother and fetus, while the other groups assumed it was safe. The information given in the role-play states that the only thing the mother has to do is provide a blood sample. So, the fear of the genetic test is actually a misunderstanding on the part of some students. Interestingly, one student seems to image a gene testing laboratory that the mother and baby come to and act as guinea pigs. "I don't feel like sending the kid through a test like that." Even though the others point out that there is a microscopic chance of anything going wrong, the student states "…maybe the chance is one out of a thousand that someone is hurt, and what if they check exactly one thousand and Gro is exactly that person. No matter what, there is always a chance." This is clearly not the 'scientific way' of seeing risk. His fellow student draws a logic consequence of this and says: "..well, then you shouldn't drive a car, just walk, and actually stay in bed the next nine months."

Medical risk:

T (reading): But here it says that it is also little chance for the child to be a carrier of that gene, no…, not known… yeah, no, OK if you do not know any instances…, but we do, so then I misunderstood this one. But it's clear then, there is a chance for you being a carrier, since it is in the family.

B: And then it says about Huntington's chorea that it

Another domain of medical risk that is discussed is the risk of getting one of the diseases, for instance, alcoholism or manic depression. This risk seems to be evaluated mainly according to whether there are any known instances in the family; but also the quoted distribution in Europe, age, and the notion of nature and nurture are taken into consideration. After Barbro has told the family secret, the focus turns to the risk of getting Huntington's disease. None of the groups make any calculations considering the direct risk of the disease. Two groups separate between a small chance and a big chance, by noticing that the information sheet does the same. It says that *is a dominant hereditary disease.*

T: Hmm..

G: Dominant, then it is most likely that the child will get it.

Moral risk:

T: I don't actually think that would be very good. Well, think if that develops, so in about twenty years time then all children will be genetically tested when they are born. And then it happens; aha! This child here has a tendency for crime! So they send it, and then a psychiatrist says: We should give the police notice about this. Then they put everything in a computer, and every time something happens they can just go to... and just: You! Have you done something... tonight?

the probability of the fetus carrying the Huntington gene is infinitely small if there are no known cases of the disease in the family. Further, the information about Huntington's as a dominant hereditary disease is also only touched upon by two of the groups, and none of them show an understanding of the concept. The overall notion of risk seems to be that either there is a chance of getting the disease or there is not. The probability is not an issue discussed. There is a distinction though between if the trait is inherited for sure. Also, if several family members have the trait, it is assumed to be easier to get. Not all the groups show an understanding of the fact that there is a chance that Gro and Tor(a) together with the baby could inherit the genetic disorder.

Finding moral risks of taking a genetic test requires imagination and insight. The students have to think ahead in time and envision what consequences the testing might offer. These might include the individuals involved, like the fear of a sick child being burdening for the relationship, or the fear of genetic knowledge leading to abortion. The consequences may also be societal. As portrayed in the role-play prototype one of the moral risks is a future society controlled by genetic information. One of the students declares: "I think this is a matter of principle for all the people in the world. We have to consider this really carefully, this genetic research..."

Kielstein and Sass (1992) claim that patients are not well equipped to become risk assessment partners with physicians. Looking at the role-play dialogue this could seem to be true. No one makes calculations involving the risk of getting Huntington's chorea, for instance. It may well be that they are not capable of doing such a calculation. Although it was present in the science agenda two years before, it is easily forgotten. There is also a possibility that such a calculation simply does not feel relevant.

Decision making:

G: No, we are not going to be a part of this. The child is our responsibility. We do not have to worry about diseases or things like that. It is going to grow up and get the best possible life quality without anyone of us worrying about a disease that can happen. If it happens it happens, and then we just have to accept it that way.

V: Yes, I agree.

B: Yes, I fully support you in that decision.

V: Thank you, Barbro. That is warming.

G: Thank you, Mom. And we hope everything works out for you.

B: Yeah, I guess it will. You know, I have lived my life.

G: You haven't lived your life. You are just forty-three years old! You can even have more kids!

Decision making:

We will turn to the last part of the role-play where some of the groups actually make a decision. On what grounds are the decisions based?

We have described a dramatic text as having an exposition and a phase where conflicts become more critical, resulting in a climax or turning-point (peripeti). The last phase is conflict resolution by the actors as they decide what to do (Svensen, 1985). In our role-play, the decision to be made is whether to have a genetic test of the unborn baby or not. In Kielstein and Sass's action guide this is described as assisting the patient to identify the 'best solution'.

Of the nine role-play groups, six reached a decision during the act. Three groups decided not to take the test, two decided to take the test, and one group decided to wait and take the test later when the child is born and older. Three groups did not reach a decision, and among these are the two groups that did not reveal the family secret. Again this indicates that personal and emotional involvement influences the course of the play. The fact of a known disease amongst relatives might facilitate making a decision about genetic testing. Presumably the decision-making process becomes easier because the discussion is more focused.

B: Yes, I have thought of that, but..

G: Have you come in your menopause yet?

B: No!

G: Hot-flushes and stuff?

B: No!

V: It was nice that we got to the bottom of this, folks!

G: Yeah.

T: Yeah.

B: Yes, it feels like a stone fell from my heart.

G: That's good.

B: A burden is gone.

T: Should we have some dessert?

V: Yeah!

The groups that decide not to participate in the genetic testing offer the perspective that they do not wish to know genetic information about the child beforehand. For two of the groups there is in the beginning a positive attitude towards testing, but after having knowledge of Huntington's and reading more information about it they do not want to take the test. One of the groups considers the possibility of the test clearing the suspicion of the disease, but after rethinking decides that the option of gaining access to such knowledge is too difficult.

The two groups that decide to go through with the genetic testing ground their decision in a faith in science that may one day find a cure for the disease. In addition, they prefer having the possibility to mentally and physically prepare themselves and the child for a probable disease. There is also the argument of not having to worry unnecessarily if the baby does not have one of the diseases.

Waiting to take the genetic test later is a compromise between Gro, who wants to take the test, and Tor, who strongly argues not to take the test. Barbro offers the solution of waiting, using the ethical argument that the child should have a right to decide later in life whether he wants to gain access to such knowledge or not.

Discussion

In the spirit of critical reflection and emancipatory action, discussion will focus upon cultivating a vision of scientific literacy in which students are active agents in a teaching-learning process oriented toward the public understanding of science and social change. The impact and possible applications of research in the basic sciences can often lead to social considerations, including ethical and legal issues. Thus, while it is necessary for students to acquire conceptual understandings of science, it is no longer sufficient. An education in science ought to enable students to construct understandings of the social considerations of science as well. A transformed science education would be personally relevant, would acknowledge the political, social, and cultural forces at work in scientific labor, and would be linked to local contexts.

Role-play enables children to appreciate what others are communicating and allows them to express their feelings directly. Ødegaard (1999) states that the pedagogical advantage of drama / role-play is the possibility to step out of role and reflect at distance on personal experience, which gives occasion for metacognition with empathy; noting that to learn about science in the context of society, drama can be used for making simulations of the real everyday world, where science is recontextualised for specific purposes, and where students experience using cognitive, affective, and active aspects of learning. The nature of the instructional strategies offered herein represent ways in which the goals of preparing all students to be active, critical, and risk-taking citizens can be achieved. In essence, the learning process empowers students to acquire an active voice and students discover how meaning is constructed actively through the multiple formations of lived experiences that can foster a sense of hope and possibility. Such a perspective to learning matches well with Giroux's (1988) perception that students should learn to understand the transformative possibilities of experience. Our lived lives are valuable learning experiences. The pedagogical advantage of a role-play is the *shared* life experience that the teacher can use as a basis for critical reflection.

Just as Bronowski (1956/1975) asserts that the hallmarks of science are linked to independence, originality, and dissent, students construct their understandings of ethical dilemmas in science by invoking the same human values. Students are able to portray their roles in ways that are intellectually honest in the context of their scientific understandings. The role-play facilitates student dialogue and decision making, while enabling a variety of moral and ethical perspectives to be portrayed.

Students in role are observed to change their minds during the course of the play as new information is presented. Some students engage in critical reflection, as the ethical issues are often issues they have not yet had to deliberate upon within the context of their lived experiences. Many students argue strongly for their view, and in so doing may be exceptionally persuasive. In essence, when learners come together, they have the potential to reveal themselves as subjects, as unique individuals, and they have the potential to be influenced by the perspectives of others.

Common for all the role-play groups is the fact that all the decisions are based upon ethical and social arguments. Paradoxically, although the biotechnology problem posed relates to advances in genetics, molecular biology, and the associated medical application/care, students rarely use scientific arguments. What are the implications of this finding for science education?

Thus, role-play facilitates active learning, in which students draw upon prior knowledge as well as seek new understandings during the play. Active learning is initiated by those choosing to learn. Yet, active learning necessitates a why; and, in order to investigate a why, the capacity to imagine what is not yet (Greene, 1995). The role-play groups identify the "why" and the capacity to imagine, while seeking ethical decisions to science related social issues. While transforming scientific knowledge into ethical decisions, students often have a sense of reaching toward something. Greene (1995) suggests that this kind of awareness must be linked to imagination. Dewey (1934) saw imagination as the "gateway" through which meanings derived from past experiences find their way into the present; noting it is "the conscious adjustment of the new with the old" (1934, p. 272). Dewey believed that consciousness always has an imaginative phase, and imagination, more than any other capacity, breaks through the "inertia of habit" (1934, p. 272). When nothing intervenes to overcome such inertia, it joins with the sense of repetitiveness and uniformity to discourage active learning. New beginnings become unlikely; yet, as Arendt (1961) asserts, it is only in new beginnings that persons feel themselves to be the initiators, the authors of what they are doing or intending to do. In a curriculum oriented toward cultural reproduction and transmission of knowledge, we loose the educational value of imagination and creativity employed by students to disclose new beginnings. Ultimately, the question is "How can science education facilitate students' ability to reach for the unknown?" We pose three critical questions for science educators to deliberate.

Should science education facilitate the emancipatory interests of students?

With an emphasis on imagination and critical reflection, rather than cultural reproduction and transmission of knowledge, science education may facilitate the emancipatory interests of students. If we want to educate students for citizenry in a democratic society, then students must possess a feeling that they can transform their world, they must be able to imagine something coming of their hopes, and they must be able to find their own voice.

Is there any wonder why within the traditions of science education so few students are able to "see" themselves in science? Experiences in which students are unable to see themselves or find explanations for particularly stirring phenomena result in a sense of hopelessness and powerlessness. We believe that science educators ought to ensure that students have participatory encounters that integrate cognitive rigor and analysis with affective response.

"The main point of education (in the context of a lived life) is to enable a human being to become increasingly mindful with regard to his or her lived situation - and its untapped possibilities (Greene, 1995, p. 182). Can such an image possibly serve as a purpose for science education as well? We believe so; especially in light of the nature of science portrayed by Bronowski (1956/1965; refer to the Rationale section above).

The values of science are human values. Yet, science is taught in a very rigorous and authoritarian way. Lemke (1990) describes how the dialogue in the science classroom transpires between the teacher and the students; and how the dialogue substantiates a picture of science as having true answers about nature. The teacher possesses the knowledge, asks the questions, and the students have to find the right answers. Lemke describes this as the Triadic Dialogue (teacher question, student answer, teacher evaluation). Thus, the dialogue in the typical science classroom fails to portray the ideals of active learning, participatory democracy, and self- and social-empowerment. Science education often fails to convey the importance of participatory democracy in the practice of science, while concomitantly failing to highlight the importance of imagination, creativity, and critical reflection. Merely having students act as if they derive "new discoveries" to questions for which the answers are already known will not suffice.

Students' emancipatory interests are best facilitated when they are provided rich opportunities to engage in critical reflection in the science classroom. As Bronowski (1956/1965) notes, the safeguards of science rest on principles of free inquiry, free thought, free speech and tolerance. Students in science classrooms ought to be afforded the opportunity to experience science in the process of learning science. By experiencing science, students are also able to experience what Arendt (1958) refers to as a "web of human relationships" (p. 183), thereby enabling science educators to integrate notions of community, collaborative action, and critical reflection.

What is the role of imagination and creativity in the context of science teaching and learning?

Just as science is inspired by imagination and creativity, then similarly imagination and creativity must play a critical role in the process of learning science. Bronowski (1956/1975) claims that what makes rational behavior different "is a creative process, the exploration of likenesses" (p. 36). Bronowski asserts that he "set out to show that there exists a single creative activity, which is displayed alike in the arts and in the sciences" and he "found the act of creation to lie in the discovery of a hidden likeness" (Bronowski, 1956/1975, p. 27).

Bruner (1986) describes two modes of thought that are completely different, but complementary, which are important ingredients in our rich world of thought. We use one of them when we tell 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, stories convince us of their lifelikeness. Bruner claims that we know a great deal about the paradigmatic mode of thinking, but preciously little in any formal sense about how to make good stories. Perhaps this is why Greene (1995) is so emphatic when she argues strenuously for the presence of the arts in classrooms. She emphasizes that encounters with the arts have the unique power to release imagination. Stories, poems, dance, drama, concerts, paintings, films, and plays all have the potential to provide remarkable pleasure; and all have the ability to be intrinsically linked to the science curriculum in meaningful ways. We need to find out more about how storytelling facilitates students understandings of science, how drawing helps, how drama helps; and we need to create situations in which something new can be added each day to a learner's life.

Bruner, in referring to Rorty, offers the following thought: "Perhaps Richard Rorty is right characterizing the mainstream of Anglo-American philosophy (which, on the whole, he rejects) as preoccupied with the epistemological question of how to know truth – which he contrasts with the broader question of how we come to endow experience with meaning, which is the question that preoccupies the poet and the storyteller" (Bruner, 1986, p.12; see also, Rorty, 1979). This touches upon one of the conflicts science teachers confront; that is, whether to convey science as a way of knowing the truth about nature, and/or to provide a meaningful science education for all. With respect to the role of imagination in the context of science teaching and learning, is there a conflict between the role of imagination in science teaching and learning in science? A meaningful science education would require imagining contexts where scientific knowledge is relevant. Consequently, this means telling a story. Bruner (1986) notes "if we are to appreciate and understand an imaginative story (or an imaginative hypothesis, for that matter) we must 'suspend disbelief,' accept what we hear for the time being as putatively real, as stipulative" (p. 51). Does this conflict with students' ability to develop an understanding of science's critical scrutiny of knowledge? In science we learn to not take anything for granted, to underpin all our arguments with theories or empirical data. Is there a conflict between this and asking the students to believe in a role-play story about genetic testing? We believe not, as students demonstrate they know when to be imaginative in a narrative way and in a scrutinizing paradigmatic way. These perspectives are not mutually exclusive, but potentially enriching of one another.

To achieve the goal of educating students for citizenry in a democratic society, students have to develop and use their imagination and creativity in the science classroom. We envision a learning environment where current and emerging scientific, ethical, social, and legal issues frame the nature of the students' experience, in which they are encouraged to engage in critical reflection and action-taking thereby creating their own 'action competence.' In such a learning environment, students have to imagine scenarios, consequences, and possible outcomes. They have to imagine future scientific discoveries, who may benefit, and why? The goals of such pedagogy "are to relate personal growth to public life, by developing strong skills, academic knowledge, habits of inquiry, and critical curiosity about society, power, inequality, and change" (Shor, 1992, p.15). We claim that students ought to and will develop their imagination and ability to feel empathy, which is a special kind of imagination, when experiencing a science education that focuses on socio-political and ethical issues. The science classroom will become a meaningful place for the lived lives of students.

What is the value of role-play in science education?

One of our most beloved activities as children was to play 'pretend.' We would often pretend to be different persons in contextually different situations from their lived lives. We explored unknown worlds and what could happen in them. Through the playing we learned, and we became more critical in how we played in the 'pretend worlds.' Eventually the one that had to play 'father' started to complain. It was boring just being sent off to work...out of the play's focus. And it was unfair that 'Maid Marian' had to sit still in a tower and was not allowed to climb trees! As children with free spirits we could challenge the stereotypical roles when they prevented us from achieving our desires, but the challenge was not without struggle!

The others, Robin Hood and Little John, didn't want Maid Marian to climb trees. That was breaking the rules of the established story! You had to have pretty good arguments to be able to do that; sometimes the rules were altered, sometimes not. Our guess is though, that we wouldn't have thought of altering rules if we merely read the fairy tale instead of engaging in role-playing.

Role-play has emancipatory potential as it enables students to ask questions and seek knowledge in the context of a dialogical community. It has an imaginative effect because students may explore social roles and attitudes in relation to science and reflect on them with empathy. Our imagination is challenged when you are in role improvising what you say and how you convey the message. However, the greatest imaginative challenge is when you out-of-role reflect on connections and similarities from your own lived life and your prior conceptions of knowledge to the new role-play experience (see, for example, the notions of Dewey (1934) and Greene (1995) discussed above). In this process the students also make use of their critical rationality. Knain (1999) pointed to the fact that it was necessary to create an epistemic distance to the subculture of science in order to reflect and develop critical thinking on the rationality or the nature of science. In this phase though, it is important to have a teacher that can mediate and help make visible the relationship between new and old conceptions and also mediate the relationship to outside authorities and formal knowledge (Shor, 1992).

Using role-play in science education may have many different functions and many different expressions. (see Ødegaard, 2000). It can be everything from the students making a dramatic model of the ozone layer to a simulation of an international environmental conference. The teacher may have pre-planned the whole play, or the students may stage it themselves. The present role-play is initiated by the teacher and further developed by the students within certain frames provided by the role cards. It can be compared with what Shor (1992) refers to as a topical theme, a social question of key importance that is not generated directly from the students' conversation. It is introduced by the teacher with care as problem-posing for critical study and adds critical potential to students' thought and action. Shor states: "The topical theme fits when it is relevant to the work in progress, when it is introduced as a problem for cooperative study in class" (1992, p. 55). Based on the values of empowering pedagogy, some advantages of using role-play as a way of introducing a topical theme in science classes are sketched out. Role-playing is participatory and affective by nature; and thus involves students both intellectually and emotionally. It is situated and problem-posing in such a way that students have a concrete situation with which to relate and discuss; and it provides students the opportunity to step out of their own culture and border cross into the culture of the role-play and its figures. In this way it may create an empathic understanding of other perspectives. Role-playing encourages and gives opportunities for students to take action, to practice action-taking, but also to reflect about actions taken and relate them to their own life in their own social reality.

A Vision of Scientific Literacy

This study offers insight into the potential of imagination and critical reflection in the context of a biotechnology role-play. The role-play provides a shared experience for students to mediate the richness, fun, and joy of science, while critically reflecting upon ethical and social issues. Shared experiences may be particularized in science (e.g., laboratory activities or experiments) or they may be evidenced through many art forms (e.g., stories, poems, dance, drama, concerts, paintings, films, plays, interviews) in which students portray their understandings of science in creative representations.

Scientific literacy may be thought of as the metaphysical path from concrete encounters with science to student constructed understandings of the relationship between the encounters and their lived lives in society. The understanding may take the form of a will to change the relationship or to accept it, but either should be an active decision. Science teachers have the opportunity to guide students on that metaphysical path of understanding and critical reflection. The nature of role-play has an ethical or socio-political context; that is, an understanding of 'self in society' is already an issue. The metaphysical path is linking the role's self with the student's self. Thus, the path is shorter and intellectual guidance by the teacher may not be as extensive.

Historically, however, just as the philosophy of science has been dominated by the writings of the logical empiricists (whom Habermas regarded as presenting a 'scientistic misconception' of science), the discipline of science education has been dominated by an uncritical acceptance of logical positivism. While Popper's critical rationalism offered a number of challenges to logical positivists, his work ultimately served to strengthen their conceptions of the foundations of scientific inquiry. Habermas has argued that Popper covered only half of the distance that it was necessary to cover in his move away from the mainstream position to some more satisfactory view of human scientific knowledge. He failed to recognize and accept the full implications of his view that facts are objectifications constituted in a community against the horizon of expectations generated in critical discussion (see

Young, 1990, for a critique of Habermas' perceptions of Popper's shortcomings). Habermas (1972) described this more comprehensive rationality in *Knowledge and Human Interests*, where he argued that knowledge was created in communities of inquiry, guided by sets of rules or conventions for warranting propositions and theories. These sets of conventions were expressive of three deep-seated anthropological interests of the human species, in control, in understanding, and in freedom from dogma (see Table 2).

Table 2. Habermas's Theory of Knowledge Constitutive Interests

Interest	*Knowledge*	*Science*
Technical	Instrumental (causal explanation)	Empirical-analytic or natural sciences
Practical	Practical (understanding)	Hermeneutic or 'interpretive' sciences
Emancipatory	Emancipatory (reflection)	Critical sciences

When students experience an education in science under the guiding interests of instrumental reason, they are denied a form of knowledge that enables them to develop and change culture, including the culture of science. It is imperative that students have the opportunity to experience the hermeneutic and critical sciences in the context of their formal education in science. The goal of science education should be to facilitate both students' and the public's ability to identify possibilities, to seek challenges, to use their imagination, to transform. Students' experiences with science ought to be self-involving, socially just, and emancipatory.

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Appendix 1

- supplements to Paper 1

APPENDIX 1a

Questionaire

Q.6. *Science and technology change the way we live. I am going to read out a list of areas in which new technologies are currently developing. For each of these areas, do you think it will improve our way of life in the next 20 years, it will have no effect, or it will make things worse? (show card)*

Read out		*Will improve*	*No effect*	*Will make things worse*	*Don't know*
a) Solar energy	11	1	2	3	4
b) Computers & information technology	12	1	2	3	4
c) Split ballot A : biotechnology Split ballot B : genetic engineering	13	1	2	3	4
d) Telecommunications	14	1	2	3	4
e) New materials or substances	15	1	2	3	4
f) Space exploration	16	1	2	3	4

Q.7. *You've just indicated to what degree you think various new technologies will change the way we live. Now, I would like to ask you what comes to mind when you think about modern biotechnology in a broad sense, that is including genetic engineering.*
(INT: write verbatims in full, prompt 'anything else?', after each word or phrase)
1. . . . .
2. . . . .
3. . . . .
4. . . . .
5. . . . .

Q.8. *Here are some statements. For each of them, please tell me whether you think it is true or false. If you don't know, say so and we will skip to the next statement.*

Read out top/bottom alternately		*True*	*False*	*Don't know*
a) There are bacteria which live from waste water.	17	1	2	3
b) Ordinary tomatoes do not contain genes while genetically modified tomatoes do.	18	1	2	3
c) The cloning of living things produces exactly identical offspring.	19	1	2	3
d) By eating a genetically modified fruit, a person's genes could also become modified.	20	1	2	3
e) Viruses can be contaminated by bacteria.	21	1	2	3
f) Yeast for brewing beer consists of living organisms.	22	1	2	3
g) It is possible to find out in the first few months of pregnancy whether a child will have Down's Syndrome, trisomy, Mongolisme. (Use the one or two appropriate terms according to local language.)	23	1	2	3
h) Genetically modified animals are always bigger that ordinary ones.	24	1	2	3
i) More that half of the human genes are identical to those of chimpanzees.	25	1	2	3
j) It is impossible to transfer animal genes into plants.	26	1	2	3

D.8.b). Have you, after the age of 19, had any education or practice in one of the following disciplines?

	Yes	*No*	*Don't know*
Technical disciplines/engineering	1	2	3
Medicine	1	2	3
Humanistic disciplines	1	2	3
Social science	1	2	3
Chemistry	1	2	3
Physics	1	2	3
Biology	1	2	3
Mathematics	1	2	3
Botany	1	2	3
Ecology	1	2	3
Anatomy	1	2	3
Physiology	1	2	3
None of these	1	2	3

APPENDIX 1b

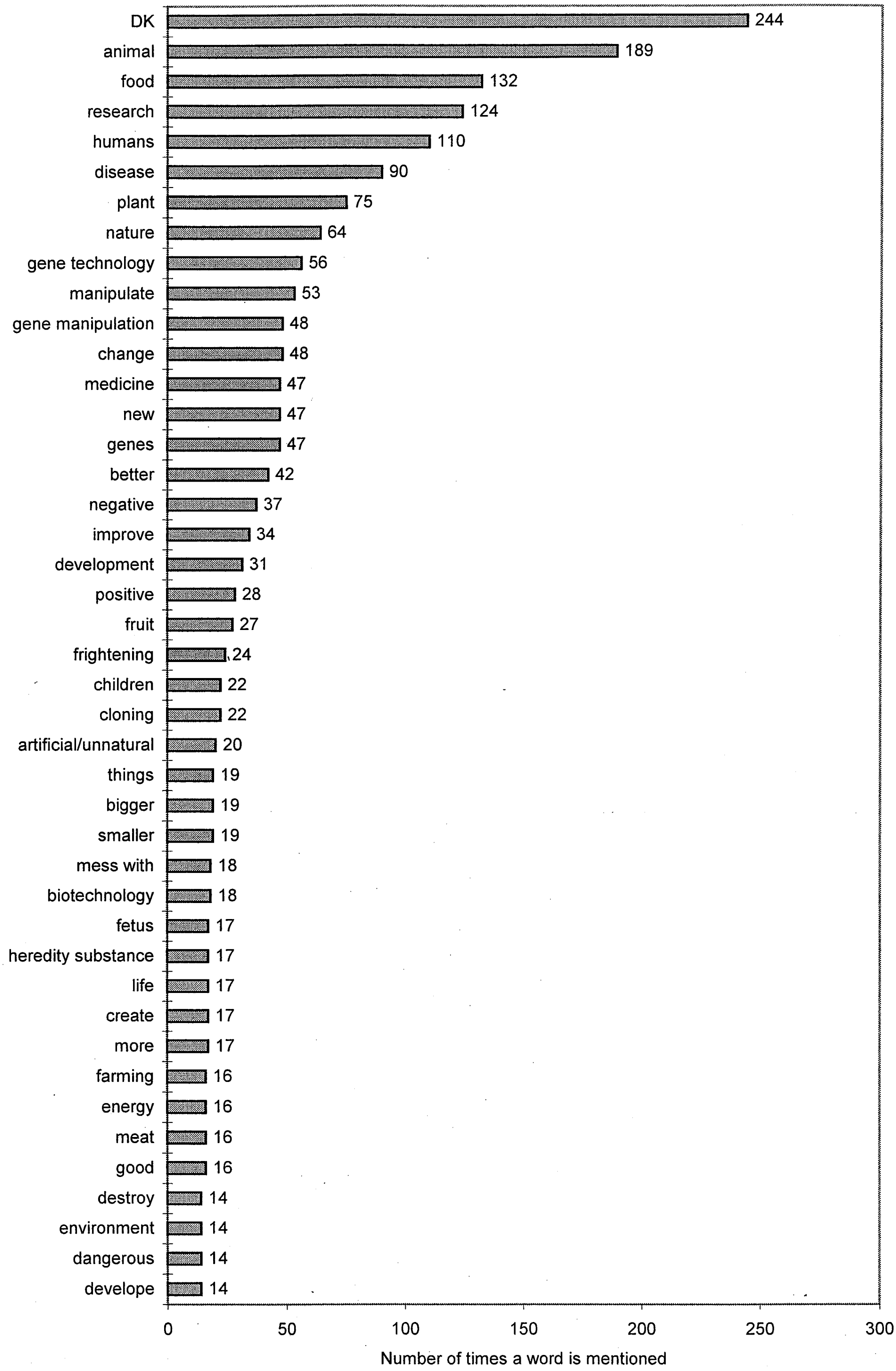
Content of associations by sex.

	male	*female*
Animal	19,8%	19,3%
Economy	1,8%	1,3%
Eugenic	1,8%	2,45
Fear	7,9%	10,8%
Fertilization	2,6%	4,1%
Food	21,8%	17,1%
Research	11,7%	11,5%
Human monster	4,4%	5,9%
Medicine	16,0%	14,5%
Monster	3,6%	4,1%
Moral	12,1%	15,4%
Human	6,9%	9,5%
Nature	5,7%	8,5%
Plants	9,3%	5,0%
Progress	7,9%	4,6%

APPENDIX 1c

	Science level				*Non-science level*			
	P	L-S	U-S	C/U	P	L-S	U-S	C/U
Alternation	5,3 %	10,6 %	16,4 %	10,6 %	6,3 %	15,3 %	17,9 %	16,2 %
Posibilities	3,1 %	10,6 %	3,3 %	10,6 %	0,0 %	9,0 %	9,2 %	21,9 %
Medicine	0,0 %	14,9 %	13,3 %	14,9 %	6,3 %	10,8 %	9,2 %	10,5 %
Interfer with nature	26,3 %	4,3 %	10,0 %	4,3 %	12,5 %	6,3 %	8,7 %	2,9 %
Research	0,0 %	10,6 %	0,0 %	10,6 %	6,3 %	8,1 %	6,4 %	6,7 %
Food	5,3 %	8,5 %	20,0 %	8,5 %	0,0 %	3,6 %	6,4 %	7,6 %
Worry	15,8 %	6,4 %	10,0 %	6,4 %	25,0 %	18,0 %	12,7 %	7,6 %

APPENDIX 1d. Monoconc word count



APPENDIX 1e

	Science level				*Non-science level*			
	P	L-S	U-S	C/U	P	L-S	U-S	C/U
Tamper	11,1	8,3	5,7	0	3,5	2,9	7,2	3,6
Manipulate	3,7	1,7	14,3	8,3	3,5	5	5,1	17,1
Change	3,7	6,7	5,7	10,4	0	5	5,6	9
Improve/ better	0	13,3	0	8,3	0	5	10,3	11,7
Big/bigger	3,7	0	2,9	10,4	3,6	2,9	2,1	2,7
Artificial	0	0	8,6	4,2	0	0,7	2,1	4,5

APPENDIX 1f

	WHAT IS BIOTECHNOLOGY? FOCUS ON CONTENT					IS BIOTECHNOLOGY GOOD OR BAD? FOCUS ON EVALUATION					COUNTRY SPECIFIC			
	General (rather neutral)		**Specific: Domains of Application (evaluation involved)**			**Positive**	**Ambivalent**	**Negative Evaluation**				**Lacking knowledge**		
	Research (progress)	*Manipulation/ Alteration*	*Food*	*Reproduction*	*Medicine*	*Good*	*Good but risky*[1]	*Risky/ Dangerous*[2]	*expression of fear*	*Interfering with nature*		*Echo*[3]	*Guessing*[4]	*Don't know*
AUSTRIA	Biotechnology is a scientific activity applicated to plants, animals and humans (food, reproduction, medicine) (27%)						Good but risky/ dangerous (fear) (22%)	Unknown effects/ dangerous (16%)		Interfering with nature STOP! (36%)		see Interfering with nature		see unknown effects
FRANCE	Research (11%)		Food/ Agriculture (15%)	Reproduction (2%)	Medicine (14%)	Improvement (10%)	Dangerous/risky although there can be good effects (also morally dangerous) (8%)		Fear Against nature (18%)			Echo (3%)	Guessed (16%)	Don't know (3%)
GERMANY		Manipulation of plants, animals, humans/ Agriculture (16%)	Food (also medicine and reproduction) (15%)		Medicine (12%)		Good but risky risky/dangerous (fear) (37%)			Interfering with nature STOP! (11%)		see Medicine Good but risky		Don't know (10%)
NORWAY	Research (8%)	Alteration of plants, animals, humans (21%)	Food (8%)	Food and Reproduction (16%)	Medicine (14%)		Good but frightening Unspecific worry (22%)			Interfering with nature (10%)		see Medicine Good but frightening		
SWEDEN	Research (19%)	Manipulation of plants and animals (11%)	Food and Reproduction (7%)				Good if used the right way/ dangerous (15%)		Fear too fast (19%)	Interfering with nature (21%)	Belgian Blue (9%)	see Research		
UK			Food (21%)	Reproduction (7%)	Medicine (21%)			Unspecific worry/dangerous (fear) (16%)		Interfering with nature (18%)		see Medicine		Don't know (17%)

[1] Good but risky: may have good effects but is risky and dangerous, therefore must be applied properly, demand for control
[2] Risky and Dangerous: biotechnology is unpredictable and therefore dangerous, fear of loss of control
[3] Respondents repeat technologies mentioned in the preceeding question ("telecommunication", "solar energy", etc.)
[4] Associations evoked by the terms "bio", "gene" and "technology" (mostly positive: e.g. ecologically beneficial or optimistic view of science)
Numbers in parenthesis indicate for each country the percentage of responses being classified to a specific discourse

Appendix 2

- supplements to Paper IV

Role-play:

THEME: *GENETIC TESTING*

Gro and Vegard are expecting their first child. They come to dinner to Barbro, Gro's mother who is divorced and living together with Gro's brother/sister Tor(a). Gro and Vegard have been to see the doctor for the first time today, and everybody is wondering how it went.
The play starts around the dinner table.

Gro: 22 years old, a nurse student and happily pregnant (9 weeks) with her boyfriend Vegard.

Vegard: 24 years old, a teacher and also happy for the situation.

Barbro: 43 years old and working in a bank.

Tor(a): 18 years old, goes to upper secondary school and is preoccupied with environmental issues and keeping a healthy diet.

Barbro's father, the children's grandfather is senile and living at a resthome. Barbro's mother died for more then twenty years ago of a brain tumour. Barbro is their only child.

Role-card:

Your name is Barbro, 43 years old, divorced and working in a bank. You are looking forward to having a grandchild. Today you are excited about how Gro's visit to the doctor went, so you are looking forward to meeting her and Vegard for dinner. The future seems bright and nice. The only thing making a shadow is the knowledge of your own mother's death. She died in her 50's of a heritable disease, Huntington's chorea. You do not know if you have inherited it, because it doesn't break out before you are 45-50 years old. Your doctor suggested a long time ago that you could take a gene-test and find out, but you did not want to, and after that you have almost completely suppressed it. No one else in the family knows how she died. They think she had a brain tumour. Lately, since there has been so much talk about the new baby coming, you have thought a lot about life, getting older, being a grandmother and your own mother. You are frightened when you think of the disease, but even though it is hard to think and talk about, you have decided that you should inform your children about this part of the family history.

Opening line: *How was your visit to the doctor's today?*

Role-card:

Your name is Gro, 22 years old and a nurse student. You have lived with Vegard for two years, and you are very happy about expecting a baby. You are 9 weeks pregnant and feel healthy. At the doctors today everything went as you expected, but you were given a dilemma that you want to discuss during dinner. The doctor asked if you wanted to participate in a European research project, mapping the outspread of different genetic features and diseases. You have mainly a positive stand to joining. As a nurse student you have a certain professional interest in the survey, and you are not especially afraid of the result because you know that statistically the chance of anything being wrong with the foetus, is very small. This little life is your child and no matter what is wrong with it you will take it and love it. You want to know everything about your baby, so whatever information you can get, you want to have. The only problem seems to be Vegard. He is not sure how he will react if there is something wrong with the baby. The doctor wants you to answer tomorrow if you want to join the survey, so you have to try and decide tonight.

Carrying a baby in your body makes you feel closer to your own mother, and it means a lot to you to get advice from her in this situation.

Role-card:

Your name is Vegard. You are 24 years old and have just started working as a teacher after your education. You have been living together with Gro for two years and feel very happy about having a baby. Gro is 9 weeks pregnant and by now completely healthy. You suppose that the pregnancy will be quite normal and OK, but you are glad that you will be able to have worked at school a year before the baby comes, because you reckon it will be hard being a parent for a small child.

Today, at the doctor's, you got a request about being in a big European research project where foetuses are tested for different genetic characteristics and diseases. At least as a starting point, you are a bit sceptical of joining. You do not want information about your child used as numbers in the statistics, and (and this is the real reason) you are afraid of the consequences if you get to know that there is something wrong with your child. You have a realistic feeling that an existence with a sick or functionally disabled child would be a hard ordeal for your relationship.

Role-card:

Your name is Tor(a). You are 18 years old and a student in upper secondary school. You care a lot about the environment and have joined the «Nature and Youth Organisation». You want to live and eat as healthy as possible. Lately you have been engaged in gene-technological issues. Planting gene-modified plants out in nature is something you oppose because we are too uncertain of the consequences for the environment. Generally you are sceptical to gene technology because you have the opinion that big capitalistic industries are behind, controlling the development. But you do understand the value of gene testing if it leads to a healthier diet and a reduction of the chance getting a disease you are genetically predisposed for, e.g. cancer.

It is exciting having a niece or nephew. The family's genes will be past on. Will the baby look like you? Surely, you are going to give Gro some good advice on diets for becoming mothers. It is a good thing she doesn't smoke!

The Region Hospital
in Nordenheim

12. August, 2005

Request to couples expecting children.

The region hospital in Nordenheim is participating in a research project financed by the European Communion. The project wants to map the distribution of different genetic characteristics and diseases in different parts of Europe. We offer you participation in this project, which implies a genetic test of your foetus.

After just a couple of week's pregnancy it is possible to find cells from the foetus in the mothers blood. The research only requires an ordinary blood test from the mother. The foetus-cells can be separated from the blood and sent for further inquiry. So the test does not expose either the mother or the foetus to any risk.

By examining the genes in the foetus-cells, you can, amongst other things, reveal if the foetus is suffering of a serious disease or is predisposed for a disease that can break out later in life. We have today quite a lot of knowledge about human beings' genes because of a successful accomplishment of HUGO (The Human Genome Project).

The European Communion Project has chosen to test for the genetic characteristics described on the following pages. If you wish to be a part of the project you can choose the information you want to receive. In the research the foetus is tested for all the genes, but the information you do not wish, will be anonymised at once. It is therefore impossible to require other bits of information later.

Your decision about participating or not, will naturally not affect your treatment at the labour department at the hospital. All information will be treated confidentially. There will not be any risk of future misuse. The project is approved by the Ethical Committee and is watched by a special control commission from the Social Department.

Yours sincerely,

Birgitte Hansen
Researcher, cand.med.

Jan Olsen
Director of medicine, dr.med.

The Region Hospital
in Nordenheim

You are offered tests on the following characteristics:

- Alcoholism
- Cystic Fibrosis
- Huntington's Chorea
- Sex
- Manic Depression

Alcoholism

In this test we offer information on increased risk of alcoholism. Alcoholism develops according to a complicated pattern with both nature and nurture as components. In the research we only test for one gene (y-4kf). There are other genes that have an impact on the development of alcoholism, but y-4kf, has shown to have the greatest direct influence. Research gives a hunch that the presence of y-4kf quadruples the risk of becoming an alcoholic. Today 6 % of the population uses too much alcohol. But one must stress the fact that you can become an alcoholic without being carrier of the gene.

The knowledge of the gene y-4kf, gives parents a possibility to prevent alcoholism by drawing attention to healthy habits concerning alcohol when the child is growing up.

You find y-4kf on the Y-chromosome that the boy-child has inherited from his father. If the foetus is a carrier of y-4kf the father will have the same increased risk of developing alcoholism as the child.

Cystic fibrosis

When having cystic fibrosis the mucus-producing glands contain less water then normal. This has consequences for several body-functions. In the respiratory passage the viscous secretion give favourable conditions for the growth of bacteria, which often gives infections in the lungs. The intake of proteins and fat from the food is insufficient in the digestive system.

Patients with cystic fibrosis must have intensive treatment their whole life. The treatment consists of that the patient must inhale, several times daily, a mucus-resolving remedy and after that lung-exercises with help from a special mask. The patients must also eat pills with digestive enzymes so they can utilise the food. Because of the frequent lung-infections most patients must spend about 2 months a year in hospital.

With this test it is possible to determine with certainty if the coming baby will develop cystic fibrosis. We test for the gene 7-9kj. Cystic fibrosis is a recessive illness, which means that the foetus must inherit the gene from both parents to be ill. That makes the parents carriers of the gene - which means that they have the gene without having the disease. In the western world 1 of 25 people are carriers of the gene. 1 of 2500 new-born has the disease. Thereby cystic fibrosis is the most common inherited illness.

Huntington's chorea

Huntington's chorea can almost be characterised as a kind of disintegration of the mind. As a start the patients get strange involuntary movements with arms and legs and an unsteady way of walking as if one is intoxicated. The sick change their personality and become totally negative and uninterested in their surroundings. After 15-20 years they die, helpless and totally physically and psychic broken. There is no treatment. In most cases the disease breaks out at the age of 35-50.

Huntington's chorea is a dominant inherited disease. This means that it develops if the foetus has the gene 4-4tt, which also means that one of the parents also will develop Huntington's, chorea. The probability of the foetus having the gene for Huntington's chorea is indefinitely small if there is no known cases of the disease in the family.

Sex

The sex of the foetus appears in many tests that are offered pregnant women. Since the sex also is a characteristic in this test we offer you this information.

If, in your family, there are inherited diseases that are bound to the sex chromosomes, it can be of great value to you to know the sex of the foetus.

Some inherited diseases, like haemophilia and colour-blindness, appear mostly with boys/men. This is because the disease-gene is on the X-chromosome which men only have copy of and women have two. If a man has the disease-gene he will automatically have the disease. Women need two copies of the gene to have the disease. Also there are some diseases that are bound to the male's Y-chromosome.

Manic depression

Manic depression appears in periods that lasts from weeks to months and gives manias or depressions. Manic depression breaks out ordinarily at an age of 30-50 years, but it may happen both earlier and later.

In the manic periods everything happens in a very high tempo. The patient gets lots of ideas but is never able to realise them before an other exciting idea pops up. The patient nearly sleeps or eats, is exaggerate self-assure, lacks self-criticism and a sense of reality and does not look upon himself as sick, which makes the treatment difficult.

In the periods of depression the patient suffers of sadness and a total lack of courage to live. The patient's self-esteem and power of action is so reduced that even daily acts seem impossible. The patient wants to relief his anger by crying, but he can not. The muscles are flabby and movements are slow. Constipation can occur and women may loose their menstruation. Suicides occur frequently.

There is big variation in how seriously the patients are attacked by manic depression. Some only have simple depressions, while others get unaccountably many depressions and manias. The illness is treated with different kinds of medicine and in some cases with electro-shock, but it is impossible to prevent new manias or depressions.

Manic depression develops as a complicated interplay of inheritance and environment, where there also are many unknown factors. We offer to test the foetus for the gene 3-9sh. If the foetus has this gene the risk is 30 % of developing manic depression. In rest of the population, that does not carry this gene, that risk is 1-2 %.

Appendix 3

- the manuscript of *Gen-Gangere*

Gen-Gangere [Gene-Ghosts]

With liberty from Henrik Ibsen
and Eurobarometer 46.1

script made by
2MDD (*music, dance, drama*) and Per Arne Øiestad
(Translation by Marianne Ødegaard)

Characters:

Based on the following characteristics from research material about public understanding of biotechnology in Paper I, and on characters from Henrik Ibsen's dramatic works. (BT = biotechnology)

WOMAN IN GREEN – from *Peer Gynt*, negative, dangerous to tamper with nature, nature has value in itself, nature-mysticism, little education.

BRAND – from *Brand,* negative, like 'playing god', manipulating humans, selecting the people you want, does not trust scientists, educated.

HEDDA – from *Hedda Gabler,* negative, afraid of the consequences, has moral objections, what kind of a society will we get? Afraid of knowing too much, we know enough, but not enough of the consequences, nature might hit back on us, like Frankenstein, educated.

NORA – from *A Doll's House*, positive, naiv faith in technology, this new technology can solve many of our problems, has confidence in scientists, little education.

DR. RELLING – from *The Wild Duck*, positive, has knowledge about the new technology and sees the positive sides, has faith in the future, the world will be a better place to live in, BT is a good remedy for conquering hunger and diseases, educated.

DR. STOCKMAN – from *Enemy of the People*, neutral, tells about products we can get from BT, and what it may lead to, can have both a negative and a positive attitude, but chooses to tell facts instead of stating own opinion, educated.

HEDVIG – from *The Wild Duck*, neutral, explains what she thinks BT is, gives 'school-like', boring answers (maybe the ones she thinks are expected?), may or may not have education.

REGINE – from *Ghosts*, neutral, gives synonyms, alternative words, tries to say BT in a different way, or mentions the organisms used in BT research, little education.

OSVALD – from *Ghosts*, ambivalent, sees both the negative and the positive sides, often at the same time, sees the help it may provide, and imagines possible unfortunate impacts, has moral reservations, has knowledge and education.

PEER GYNT – from *Peer Gynt*, 'does not know', has not/ will not / can not answer, more negative than positive, indifferent, some education.

Scene 1.

EVERYONE: A-T-C-G-A-T-G-C-C-A-T-T-....

Gene. Gene. Gene...

Gene-manipulation, gene-mutation, gene-translocation, gene-splice, genetic variation, gene-modification, gene-transplantation, oxygen, genetic, general, legend, generator, agenda....

GEN-GANGERE! [Gene-Ghosts]

REGINE: "Gjengangere!" [Ghosts]

Scene 2.

OSVALD: Tell me, is there anything new under the sun?

PEER: I don't know.

OSVALD: Imagine a sky without birds. Super-humans that ravages the grounds. But also wheat and food for everybody...

PEER: I can not remember what I never have known.

OSVALD: Is there anything new under the sun?

PEER: I don't know.

(They start to fight.)

Scene 3.

DR. RELLING: "OK, Gregers" he said. "Now I'm relieved of this stifling debit item" – At least he had when he received my help to get an overview. And he thought that was good.

NORA: (dreaming) Now be my little skylark, as usual... Oh, sit down and play for me, dear Torvald; correct me, guide me as you usually do.

DR. RELLING: But he said I shouldn't use the foreign word: ideals, while we have the good Norwegian word: lies. You have much of the wild duck in you.

NORA: Because I think that genetic engineering can help and guard us against diseases. After all the age of data is blooming, and if I was to have children at my age, I would like to know if it is healthy.

DR: RELLING: Now we can change man's genes to avoid diseases or defects.

BRANN: I am a priest, but I hardly know if I'm a Christian. I am a stranger to them. The truth lies in genetic engineering, but what is the price for such truths? We will end up worshiping ourselves as gods.

THE WOMAN IN GREEN: My father says, "Troll, to thyself be-enough". So you should not tamper with nature, should we? Because then we will get cows so big that their legs will break and with so much milk their udders will burst.

HEDDA: …and then he said to me; "Imagine that – Hedda…" To me? What do you give me? Humans should not rule over nature? We know enough now! Who knows what the consequences will be?

HEDVIG: That poor wild duck! He can't see it before his eyes anymore. What if he feels like twisting his neck?! You could make giant animals if you use gene manipulation. Would he then transform the wild duck into a swan?

DR: STOCKMAN: "Dr. Stockman, you can not say things like that.", they said to me. But I want the liberty to speak about all affairs in the world; both giant tomatoes and meters of cucumber.

REGINE: Osvald, are you mad? Engstrand said; Regine, devil eat me! What is the Mrs's will? But damn, I don't care. Pied de mouton. Cloning and stuff, removal of deformed babies. Test tubes… eh.. research?

Scene 4.

(Creation)

STORYTELLER: Once upon a time. But now it is long ago. Once upon a time when the heartbeats were a song, and when the voice rippled over laughing words.

God saw that it was good. Because there were fishes in the sea and birds under the sky. There were wild animals and crawling creeps of all kind, scattered amongst growing green herbs and trees bending by fruit. God saw it was beautiful. God saw what he had done and said: "See, it is greatly good!"

A young body rejoiced itself. An Eve it was in the Garden of Eden. A dancing tender woman. With delicate skin.

And beside his beloved was Adam. From the mold of the earth he had raised when the spirit of life was blown into his nose, and he become a living soul. God created them both in his image. Blessed by him they were to be fertile, and become many!

Shall I tell you more?

("The Fall of Man": Eve gives Adam a genetically modified tomato, and a dance about eating the forbidden fruit follows.)

And God saw what they had done.

The Lord chased man out of his garden. The Lord put thorns and thistles on their backs.

Never again will you rejoice like Eve in the Garden of Eden, because you are now tamed by learning. You shall crush the serpent's head. But it shall crush your heel.

And the Lord God said: "If only he doesn't reach out his hand and also picks from the tree of life and lives until eternity!" Then God put guards round the tree of life, and showed them out of the Garden of Eden.

Scene 5.

THE WOMAN IN GREEN: Do you know my father? His name is King Brose.

PEER: Do you know my mother? Her name is Queen Åse.

THE WOMAN IN GREEN: Black it seems white, and dirty seems clean.

PEER: Big it seems little, and ugly seems fair.

THE WOMAN IN GREEN: But the kid, you'll have to raise, you light-footed tramp.

PEER: You devil's mare!

DR. RELLING: We can save the people!

PEER: I only want to save myself.

BRANN: You have to separate light from dim, living is an art.

DR. RELLING: Inherited diseases invades us like ghosts.

BRANN: You learn that the biggest victory is defeat.

DR.RELLING: We can feed the hungry.

BRANN: Life all in one it is.

HEDVIG: Dad says I am not his. He says he wants to be tested. Tested for what?

BRANN: God day, fare well, my time is short.

HEDVIG: Mom, just sits and cries. Whole day long. Everything is my fault, but what have I actually done wrong?

DR. STOCKMAN: What should I choose, I ..or we? Your own conscience and above all the truth, or society's future? Or do I have to live behind the lie the rest of my life? The lie is the serpent in Paradise. You do not see it, but you know it is there in the wet grass. The truth will come forth a beautiful day… or… There will not be a beautiful day. The day the truth comes forth perhaps the birds will be dead, children will cry because they are cold. Parents will sit and look down in their hands and think about the eternal dilemma of truth.

HEDDA: I decide for myself! Still in their power. Dependent on their demands and will, but do they think it will not be discovered? Man can not create the perfect human, though Tesman should be said to be correct in all ways. Oh.. I will come to an end in all this!! But as you nest, you lay, - I near said. I'm bored. I'm bored, do you hear!!

NORA: Now, be my little skylark…. Oh, sit down and play for me, dear Torvald, correct me; guide me as usual. I am a bit confused, and what do I know, what have I known or not known. I can really not say. That we could be so clumsy, Dr. Rank. Now that everything was so good.

REGINE: As me, he has always seen the sun, but he picked it down so it only was to shine for him.

OSVALD: And I tasted the sweetness. And enjoyed the pain while the flames raged over my tongue and down the inner of my throat.

REGINE: But now… now like a tumor it eats into the mind… Ravaging, while it beats like a false heart filled with the world's forgotten tears.

OSVALD: Like it has eaten into Regine from the moment I gave her my seeds.

REGINE: So tell me why you never warned me.

OSVALD: But I never knew.

Scene 6.

GIRL 1: Look at Regine! See how ugly she is! Look at the clothes she is wearing! And that body!

GIRL 2: Regine, she is pregnant. It does not surprise me. Heh, she is something! Isn't she? Little tart!...

GIRL 3: Regine,... that one! She is a big common hole. Real easy. By the way I've heard that she has been going out with you too... (points at one in the audience)

GIRL 4: So you think you are somebody, but you are wrong. No one here likes you, anyway. And Osvald. He is supposed to be of upper class, but he is no better than she, that ugly skit bitch.

GIRL 5: Regine Engstrand is actually an illegitimate brat too! So it is probably in her genes to be vulgar. Hey you! Have you heard that her father is a grouse old itchy-fingered bum?!
(raw laughter)

Scene 7.

REGINE: I'm looking forward to having the baby. It will change my whole life, but in a positive way. Osvald is also looking forward to it. It will be nice to have a family together.

All of a sudden today someone came and asked if I wanted to have a genetic test of my baby. I don't want to test my baby? No one is going to know anything about it before it comes. It will be allowed to come as it is! No test will make me decide whether I want my baby or not, even though, it would perhaps be OK to know, whether my kid has ordinary feet or 'pied de mouton', that is sheep feet.

But shit, it's all the same. Osvald agrees, but it doesn't matter for him. He lets me take the decision. I think what I do is right. Osvald, he is gorgeous.

Scene 8.

POSITIVE: Let us use a child as an example.

NEGATIVE: Why a child?

POSITIVE: This child is possibly a carrier of a lethal disease, and this 'possibly', can be revealed by a test!

NEGATIVE: A test! How ridiculous. We think that we can find the answer to all problems in the world with the help of tests!? (To neutral:) What do you think?

NEUTRAL: I do not care all that much. To test or not: Whatever, the child has a right to choose whether it wants it or not.

BRANN: Every day our own mask of carelessness is stupefying us. The truth leads us towards again eating new fruits from the tree of wisdom, which all in all was the start of the sin. Osvald, the truth is starring in your eyes; Let us see it with you... Come, and let yourself be tested.

Scene 9.

(Dramatic testing scene.)

BRANN: Osvald, you carry the rare gene of a heritable and lethal disease. Where did you get it from? Is this the 'fall of man'? How can this be punished? You must not spread your seeds. Lock him up!

Scene 10.

POSITIVE: Parents has a duty to know on behalf of the child! Just as the child has a right to know id it is doomed or not!

NEGATIVE: So hypocritical! In this case it is absolutely clear that the parents has a duty to not inform the child! The child has a right of *not knowing*, a potentially positive test result will burden the child through the whole childhood!

NEUTRAL: We have three possible outcomes. For the first: The child might have a disease. Secondly: The child has *not* a disease. And thirdly: The child might carry the gene of a disease. But all the same: We are obviously arguing as night and day, friends. Let time help us, and we will see the outcome.

POSITIVE: But that is also wrong.

BRANN: All wounds must be ripped up over and over before they can be healed for their sin. Regine, who is your child? Who is Osvald? The truth will be revealed by genetically testing your fetus. Regine, you have no choice. It is for our common good.

(Regine is tested)

BRANN: Regine, your child is not only a carrier of this lethal disease! No, it has the disease fully and wholly! – Regine, who are you? Your child shall die and its father is your own half-brother! How big can the sin grow?

Scene 11.

STUDENT 1: The seventh day. God looks upon his creation, the garden. Adam and Eve are playing naked amongst leaves of gold. God closes his tired eyes for a moment.

STUDENT 2: The eighth day. The serpent takes his place in Paradise. Hidden by the grass he regards Adam and Eve with a curious look. And Eve eats of the tree of knowledge, and gives the fruit further to Adam. God sees with terror that his own has turned from him.

STUDENT 3: Sex is clothed by leaves. The serpent disappears from the humans' field of vision, into their own hearts' inner being. God cries. Heavy tears fall from heaven and hit the humans like nails of steal. Never shall they return to Paradise. The serpent strikes at the human heart with curved teeth.

STUDENT 4: The ninth day. The all-knowing human holds God responsible for the lost sight of Paradise. With his hands he puts stone onto stone, builds a tower, to reach the Masters own kingdom. God shall with power be forced to re-open the gates of Paradise. But the tower collapses under God's almighty hands, and the stones pull the human down in the abyss. The serpent smiles.

STUDENT 5: The tenth day. The human has its value according to its rank in society. Gun shots bang, hands are reached towards heaven. Shouts resound in stationary air. But from above there comes no answer.

STUDENT 6: The eleventh day. The human creates his own life. Touches everything he approaches. Cities crawl up the hills. Cars drive aimlessly around with lit lights. Ships ravage the harbors with sad thumps from the machines. Alone stands the human.

EVERYONE: God is gone.

SERPENT: But in the day I stand. And I smile.

STUDENT 7: The twelfth day. The human positions himself above God, and honors himself with own life. What is hidden by the shadows of science, is disclosed. Genes are discovered. Genes are mapped. Genes are changed. Qualities are trashed and disappears. The original human is replaced by copies.

The birds disappear from heaven, the air is no longer shaken by rushing wings. Everything can be bought. Everything can be consumed.

STUDENT 8: The thirteenth day. The humans crawl over each other to breath. The oceans are emptied. Brooks and streams go dry. Heaps of litter grow like the tower of Babel towards Gods kingdom. Cities become ruins.

SERPENT: And in the human hearts I smile. Because what the human never understood, was that they eventually as they stepped into the absolute light, I stood in the shadows of death on the side, and cut over the threads of life. One after one after one. I, the serpent, the knowledge. Always a step ahead, at the same time as I unexpectedly breathe in their necks. I, the tempter, the lover. The one that gives humans the bittersweet off taste of eternal life.