Chapter 5
Cultural Models of Physics

An Analysis of Historical Connections Between Hard Sciences, Humanities and Gender in Physics

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Culture is generally understood to be the values, beliefs and practices that we inherit and transform over time. At a deeper level it can be argued that values, beliefs and practices stem from cultural learning. Science has downplayed the influence of culture in its internalist self-understanding. In this chapter I argue that science is formed through cultural processes, which influence the selection of who are able to perform as scientists. I use a cultural-psychological theoretical framework to analyze how selections of physicists' works through implicitly learned connections, which are only recognized as cultural, when they are contrasted with other ways of connecting. Cultural learning processes form conceptual connections over time, which are too self-evident to be questioned. They are only challenged when they are confronted with amazingly different connections. For many physicists in western European countries it has come as a surprise to learn that female physicists are found in larger numbers in the Southern and Eastern parts of Europe than in the Northern parts. Many possible sociological explanations have been proposed, but none have provided satisfactory answers. The cultural-psychological approach I propose offers a new understanding pointing to different historical formations of connections between gender, physics and the humanities. These connections can be understood as particular organizations of knowledge captured as different "cultural models" of physics. In Denmark, a Northern European country, we find a shockingly low representation of female physicists. In comparison, the southern European country Italy has a much higher representation of female physicists. It is argued that the difference is due to the work of historically formed implicit connections of gender and humanities in relation to physics, which are made explicit when the conceptions of physics in Italy is contrasted with conceptions of physics in Denmark.

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O. Skovsmose et al. (eds.), *University Science and Mathematics Education in Transition*,

5.1 Challenging Internalist Science

In 1998 Sandra Harding posed the provoking question: Is Science multicultural? Internalist scientific epistemology rests on the central assumption that the internal features of science insure its success. Even when culture is recognized as an influencing factor on science this influence shall be weeded out. Society shall provide education and conditions for science, but not influence it.

> "When science progresses, at its very best, it shall produce nothing culturally distinctive to the representations of nature that appear in the results of the research. The aim is to produce scientific information in which one can find no culturally distinctive interests or discursive resources of the societies that have produced the research" (Harding, 1998, p. 3).

This would to a large extent be the internal tale of science, as it was told to Robert Merton back in 1942, where the ideal norms of science (the CUDOS-norms) explicitly state that anyone, regardless of gender, colour of the skin and family background has a right to do science.[1]

In the past 30 years Science and Technology Studies (STS) have discussed science *as* culture replacing the notion of a value-free objectivism with particular forms of reasoning which Karin Knorr-Cetina called "epistemic culture" (Knorr-Cetina, 1999). Many of these studies have undermined the internalist self-understanding, not least in physics.[2] In spite of these studies many scientists still want to believe that their world is basically culture-free. Though it is generally accepted that science plays an important part in forming society, it is much less accepted by scientific disciplines like physics that society forms science. In the words of the anthropologist Sharon Traweek, physicists belong to an "extreme culture of objectivity, a culture of no culture, which longs passionately for a world without loose ends, without temperament, gender, nationalism or other sources of disorder – for a world outside human space and time" (Traweek, 1988, p. 162).

As shown by STS-studies this is a false picture. Physics is not only a culture with internal cultural beliefs, values and feelings. Science *as* culture is imbedded in a wider national/western context: science *in* culture.[3] From postcolonial and cultural studies, we learn that science and society are co-constructing each other and they are

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[1] CUDOS stands for the four most important ideals identified by Merton: Communism (meaning 'communality' —science is not connected to any specific personal, corporate or state interest— it is common and therefore has an obligation to be public accessible knowledge), Universalism (truth is evaluated through impersonal criteria and stands as universal regardless of the cultural background of the scientific practitioners), Disinterestedness (science proceeds without being influenced by any personal interests of individual scientists) and Organized Scepticism (Science understands all truths claims to be provisional and open to critique (Merton, 1942).

[2] See for example Knorr-Cetina (1999), Pickering (1984) and Galison (1997).

[3] It should be noted that many physicists have actually welcomed this debate with the STS-people and seen it as an opportunity to expand the understanding of the relation between technology and nature, but these studies rarely include the psychological understanding of man's understanding of nature. Other physicists have entered the dialogue with the STS-people and some have countered their claims in the fierce debate called 'the science war'.

also co-constricting each other in an array of different ways. Science is heterogeneous and complex. Even within the same discipline a glance through the magnifying glass can dissolve what appeared on the surface to be a coherent whole into a myriad of cultural practices, or, in the words of Joseph Rouse: “The practices of scientific investigation, its products, and its norms are historically variant. They also vary considerably both across and within scientific disciplines” (Rouse, 1992, p. 60).

The studies of science *as* culture have challenged notions of value-free scientific objectivism in the production of scientific facts (Knorr-Cetina, 1999; Latour, 1987). The studies of science *in* culture, including the present chapter, have tried to find explanations for variations in the way science is practiced and variations in who does the practicing in different national settings. It is still not fully understood why we find cultural differences, their nature and their influence, in the practice of physics. To understand the implications of cultural diversity in science we need a comprehensive theory of culture as well as informed empirical material. Neither is easily obtained. In the following parts of my argument, I shall first present a theory of culture, which connects historic variability and culture. Next I present empirical data, which supports the assumption that historical variability creates cultural diversity in relation to who are regarded as “intelligible” physicists. This analysis will finally be used to discuss the cultural diversity, which appears when we address who it is that actually make gendered careers within the “same” discipline in different nation states.

5.2 Cultural Models

The understanding that science is embedded in a culture, which is not confined to the scientific practice itself, demands a theoretical framework, which can render it probable that science *as* culture is connected with science *in* culture. The problem is that culture is not easily discerned as an empirical object. What one person sees as culture another may see as perfectly normal everyday life. Culture is therefore not directly what we *see*. It always appears as a foreground to an implicitly background carpet. When we decide something is cultural we need to explain the processes behind the creation of what is termed culture. Cultural psychology offers a comprehensive approach to the understanding of the processes behind the complex concept of culture. It is a fairly trans-disciplinary theoretical framework, which connects practice with psychological processes (Cole, 1996).[4] It is not *one* coherent theory, but a ramified network of theoretical approaches combining insights from psychology, philosophy and anthropology. Within this framework culture can be understood as inseparable from human activity (Engeström, 1987) and broadly

[4] Cultural psychology first appeared as a theoretical framework in connection with a meeting in San Diego in 1980, between representatives from psychology and anthropology where the declared focus was to study the relation between cultural and psychic processes in real life activities instead of laboratory arrangements with the aim of bridging the gap between practice and cognition (Shweder & LeVine, 1984).

understood as the "patterns of beliefs, values, and practices that we both inherit and transform over time". Individuals "never share the complete culture of the group to which they are said to belong. At the same time, cultural practices are open or responsive to their ever-changing environment" (Gutiérrez, 2002).

Within this wide framework the more specific theoretical approach of cultural models offers an analytical tool to capture both end-product (cultural models) and processes (the connections through which cultural models are formed). In these models, artefacts, discourse and activity combine to make a coherent whole (Holland and Cole, 1995). As an analytical tool cultural models aim to make implicit cultural organizations of knowledge explicit, exposing assumptions, tacit beliefs and connections (D'Andrade and Strauss, 1992). What we call cultural models are organizations of knowledge formed in practices and "doings", while they on their part give directive force to certain motivations, without making people "cultural dopes" (Holland and Quinn, 1987; Strauss, 1992). In this framework there is a strong focus on how different cultures seem to connect and organize local knowledge in particular ways, which implicates and directs certain practices (D'Andrade and Strauss, 1992; Holland and Quinn, 1987). It is through cultural models that our conceptions of the world are formed. Whenever we use a concept like "woman" or "physics" – or in one of the cases presented by Naomi Quinn a concept like "marriage" (Quinn, 1987) – we implicitly take a number of connections for granted.

Following a group of researchers working on parallel distributed processes, (McClelland et al., 1986) theories of cultural models use connectionism to explain how models are built up from everyday experiences. In connectionism, organization of cultural knowledge is learned implicitly in everyday practice. Contrary to classical theories in cognitive science the mind is not regarded as an information processor working on representations of the external world. Rather than making conscious association between otherwise discrete elements, the mind is considered a neural network. Whenever we experience the world around us, connections are made between neurons in the brain and when experiences are repeated the connections are reinforced (Strauss and Quinn, 1994). "Knowledge need not be explicitly learned or retained as explicit generalizations or formulae; instead regularities in behaviour reflect cognitive patterns extracted from repeated experience" (Strauss, 1992, pp. 11–12).[5] Cultural models organize the connections we make in relation to the categories we have learned mark the boundaries of the self-evident world around us.

The approach has, in my opinion, correctly been criticised for being overly mentalist and overlooking how actions and the body play a part in forming cultural organizations of knowledge. When the process is defined broader than connectionism, as a cultural learning process (Hasse, 2002), the body and its position in physical world become part of the process.

[5] The discussion of the formation of cultural models has often underestimated the importance of bodily presence for experiences, but in my understanding of cultural models they cannot be seen as inseparable from bodily presence in the world. It is our bodily movements in a physical world, which provide the experiences, which form the basis of connections.

What is relevant for my argument here though, is that culture in this theoretical framework is not explicitly learned as what we see, but what we see *with*. "Once learned, it [culture] becomes what one *sees with,* but seldom what one sees" (Hutchins, 1980, p. 12). In the process of forming cultural models, every kind of experience with discourse and artefacts takes part in the formation (Holland and Cole, 1995). We live in "naturalized" self-evident cultural worlds, where acts, artefacts and opinions around us are so well-known that we would not dream of questioning them. It is only when we meet with other cultural ways of life that we begin to question the naturalness of our own connections.

The problem with scrutinising this relation within the framework of cultural psychology is that when culture is what one sees *with*, how can a researcher, seeing with his or her own cultural connections, claim to detect what can be analyzed as the cultural models other people see with?

5.3 The Method of Culture Contrast

In the case of relations between gender and science, countries around the world seem to have surprisingly different cultural organizations of knowledge about how the female gender and physics are connected.[6] In countries influenced by Islam such as Turkey and Kuwait we find many female physicists (Megaw, 1991; Ebeid, 1998), where as we, with our western conceptions, would have expected the sharply divided gender roles to dictate that women stayed away from a "masculine" science such as physics. In countries such as Thailand girls are doing much better at physics and chemistry than boys (Klainin et al., 1989) and women seem to do much better in the "hard science" of physics in Eastern and Southern Europe (Barinaga, 1994).

When we regard this information as surprising we are using our implicit organization of knowledge. We perform an act of what Laura Nader has called "implicit comparisons". Cultural research is *always* comparative as the prerequisite for acknowledging culture (Nader, 1994). To find culture we need to select areas of contrast, which creates the effect that the culture we perceive is a precise inversion of our own self-evident culture. When in Western culture the Muslim culture is often perceived as repressive to women's rights, because women have to cover their hair and wear a chador, we in the same implicit comparison are seeing *with* a culture, which defines the western woman as free, because she can appear almost naked in public. Contrary to this what many Muslims see is a western culture that makes women into pornographic objects because they see *with* a cultural gaze, where a woman's sexuality should be covered in public.

When we find out girls are doing better than boys in physics in Thailand and that women do well in "hard sciences" in Eastern and Southern Europe, it is surprising

[6] Knowledge is in this theoretical framework more to be understood as embodied than propositional knowledge.

because in contexts such as the Nordic/Danish physics is associated with boys and careers in physics with male physicists.

If we combine the perspective of implicit comparison with cultural models, we can use the unexpected differences we find to tell us about the implicit connections we make ourselves in our own cultural models – and thus call forth explicitly the culture we see *with*. This is the aim in the method of culture contrast. The purpose is not to compare between two comparable objects, but to find connected to one object, what would be seen as the reverse in another context. This method opens up an analysis of surprising connections made between a science like physics and other culturally informed areas of life.

A starting point for the method of culture contrast can be for the researcher to compare statistical numbers connecting science and gender, but to get deeper layers of surprises it is necessary to combine with other fieldwork methods: participant observation and in-depth interviews. Both these approaches have the advantage that they open up the unexpected in research and thereby provide the sought after challenge to what we see *with* in the method of culture contrast. Below I first present studies, that connect gender with science and challenge our self-evident understandings of how physics and gender should be connected as seen from a Nordic European perspective. Next I present a number of semi-structured interviews I held with Italian physicists in 2002–2003, and physicists from other nationalities made in 2004–2005. "As semi-structured interviews the questions follow a general script, but are basically open ended" (Russell Bernard, 2002, p. 203). It is this open-endedness, which allows for the surprises, which can be analyzed through the method of culture contrast. In these interviews with 11 Italian women and 14 Italian men, a completely new connection to physics appears, which can reveal my own Nordic/Danish cultural model of physics in contrast to an Italian one.[7] This connection apparently has nothing to do with gender. It rather concerns the relationship between humanities and natural sciences in a local, cultural-historically shaped context. However, in the end this culture contrast can provide a new insight in the gender differences found.

5.4 Women in Science

In general, natural sciences are encountering increasing problems with recruitment, especially of female physics students – and notably in the industrial North Western world (Sjøberg, 2000, 2004; Mejding et al., 2004). The few women who choose to study physics tend to disappear after graduation.

[7] I have made 55 semi-structured interviews with physicists in all, mainly from Denmark and Italy (but also with physicists from the United Kingdom, Sweden, the Netherlands, Senegal and USA); and also a number of interviews and focus group interviews with Danish and Italian physics students. The interviews were gathered in two interconnected projects: *Gender-barriers in the Becoming of a Natural Scientist* (1996–1999) and *The Cultural Dimensions of Science* (2002–2005) both financed by the Danish Research Council.

This lack of women at the top of academia is not unique to the discipline of physics, though. Well-qualified female scientists seldom reach top-level positions to the same extent that their male counterparts do and often leave the research system prematurely. This has been well documented in a number of studies, notably the SHE-figures, the Helsinki Group Reports, and the ETAN- and ENWISE Reports.[8]

The difference between the women and men entering science studies and the women and men obtaining academic positions in academic science institutions are illustrated by the so called scissors diagrams (TERSTI, 2003, p. 263; Osborn et al., 2000). Even if women and men start their studies on an equal footing, the closer one gets to the top-academic positions the more men (the upper blade of the scissor) and the fewer women (the lower blade of the scissor) one finds. From this scissors diagram – formed from huge collections of data on women, men and science conducted by the European Commission (EU) – we can see that women are not moving up through the echelons of scientific careers as much as their male counterparts.[9] This lack of gender balance can, to a greater or lesser extent, be found in all areas of the European countries surveyed by the Helsinki Group, who commissioned the study of these subjects. Another apt metaphor for the same process is the leaky pipeline, introduced by Joe Alper in 1993.The background for using this metaphor was highlighted in the ETAN report on women and science (Osborn et al., 2000). Whatever country or discipline we're discussing, whatever the proportion of women among the undergraduates and whatever equality measures are put in place, we still see a disproportionate leakage of women from scientific careers at every stage in the academic hierarchy. These numbers are in themselves a challenge to internalist and CUDOS-driven conceptions of science.

Yet, in a number of EU-surveys cultural differences have appeared on a very general scale and have complicated the pattern of general exclusion of women from scientific careers; as well as troubling even more the notion of a coherent scientific enterprise. Theresa Rees, conductor of the Helsinki Report on national policies on women and science in Europe, summed it up in this way:

> So what have we learned about women and science from such a diverse range of countries? The first point to emerge is that there is a huge diversity in the approach to women and science among these countries. (Rees, 2002b, p. 53).

If we take a closer look at the general figures the numbers are puzzling, according to expectations. Many statistics deal with general sectors–as HES (Higher Education Sector) and GOV (Government Sector). If for example we take a closer look at the

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[8] The reports can be found in Alper (1993), OECD (1996), Colosimo and Dewandre (1999), Osborn et al. (2000), Bebbington and Glover (2000), Laurila and Young (2001), Maxwell, Slavin and Young (2002), Rees (2002a), SHE-figures (2003), Blagojevic, Havelková, Sretenova, Tripsa and Velichová (2003).

[9] See for example the Helsinki report, the ETAN-report and the SHE-figures to mention a few (Rees, 2002a; Osborn et al., 2000; SHE-figures, 2003).

interesting pie charts presented by the Helsinki Group we find an almost similar number of women in HES in Denmark and Italy. In Denmark the percentage of women in HES is 27, 3%, whereas in Italy the number is 28, 4%. Rees (2002a, p. 38) says[10]:

> There is no significant difference between these numbers and that is a surprise in a Nordic context. You would have expected Danish women to have a higher share than Italian women. For one thing Denmark is a country with a long story of government supporting facilities easing women's work-life and women liberation. As it was stated in the Helsinki-report: "For more than 25 years there have been laws regulating equal rights between women and men within Danish society".

The first Danish laws on gender equality were passed back in the mid 1970s and even though in the past years we have experienced some setbacks (see Lykke, 2002, pp. 144–149), we are normally considered a paragon country when it comes to equality policies. We have in past years received much praise for the ability of the Danish State to supply assistance in childcare, kindergartens, maternity leave and so on. In politics, Denmark in 1999 had 37, 5% female members at the European Parliament, whereas Italy had only 10, 3%.

Italy, on the other hand, has only recently acknowledged the "women's problem". As it became clear at the European Conference on Gender and Research in Brussels in November 2001, Italy generally looked upon gender in this way: "as such, women's and gender studies were generally judged as an anomaly – which caused a delay in comparison with the situation of other European countries". (Cantú, 2002, p. 168)[11]. Furthermore, the female share of the workforce is 47% in Denmark and only 38% in Italy. In the "naturalized" connections we make in Nordic countries, we would expect to find that the percentage of women in HES-research in Denmark to be much higher than in Italy. But we find to our surprise, that even though women in Denmark have a much better foothold in the labour-marked in general, we are not performing better than Italian women in HES. When it comes to having gained a foothold in physics, Danish women perform worse. These kinds of puzzling differential patterns can be found not just in Europe between North and South – but also between East and West all over the globe.

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[10] From the Helsinki report on National Policies we know that in Italy (p. 106) there are 50.501 HES-researchers of which 14.332 are women and 36.169 men. In my recalculation this is 28.4% women. In Denmark (p. 100) we have 9,685 HES-researchers of which 2,645 are women and 7,040 men, which in my recalculation equals 27.3% women (1999-figures) (Rees, 2002a).

[11] That Denmark concerning gender policy really has experienced setbacks since the 1970s has been apparent. Not only in the political and academic unwillingness to earmark professorships for women (see Lykke, 2002), but also in the fact that Italy already in 1996 appointed a woman as Minister for Equal Opportunities for the first time, and she was responsible for important mainstreaming functions. (Cantú, 2002) In Denmark the first Minister for Equal Opportunities was appointed in July 1999 three years after Italy.

5.5 Surprises across the Culture Divide

In March 1994 the special issue on *Women in Science* in the *Journal Science* presented a "world map" of women in physics showing the percentage of women working in university physics faculties for 31 countries based on a questionnaire sent out to 1,000 university physics departments throughout the world (Barinaga, 1994; Megaw, 1991).

This study showed that the participation of women in physics varied dramatically among countries. Japan had the lowest percentage of women physics faculty (1–2%), with Canada, West Germany, Switzerland, Norway and U.K., all having less than 5% women physics faculty. At the other end of the spectrum, Hungary had 47% women faculty in physics. Thailand, USSR, Italy, Philippines and Portugal all have more than 25% female physics faculty – some a lot more.

Even though such cultural comparative studies are still few – they have been followed by further studies carried out by the physicists themselves (e.g., Ivie, Czujko and Stowe, 2002). These studies, as Carlson (2000) notes, begin to give shape and form to the underlying causes and contexts for the low participation of women in statistics and the sciences. It will be seen that it is not a uniform condition and we have much to learn from the varying realities across countries.

In Megaw's data a kind of pattern seems to appear. If you were to take a card over Europe and put a little green pin for every female physicist in Europe (member states and associated countries of the European Union) an ever more lush and green landscape appears the further South and East we go, where as the Northern and Western countries remain rather white and arid.[12]

The results were unexpected, as noted in the special issue of Science, which was termed "surprises across the Culture Divide" (Barinaga, 1994). The new map showed that some of the most industrialized countries had the smallest percentage of women physics faculty, and seemed to contradict stereotypes about national cultures and how they treat women. The ten countries with the *largest* female physics faculty percentage included three European Mediterranean countries (Portugal, Italy and Turkey, with Spain and France in 11th and 12th place), apart from Asian and Eastern Countries. Countries with large physics establishments, high levels of industrial development, and strong women's rights movements provided six of ten countries with the *smallest* female physics faculty percentage: Canada, Germany, Norway, USA, UK and the Netherlands.

Though Denmark was not part of the Megaw study, I can from my own data supplement his work and confirm that in Denmark the percentage of women physics faculty is also below 5% and indeed when I started my study on physicists in Denmark in 1996, it was below 3.5%[13].

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[12] Other surveys have found some differences from Megaw's very clear picture of the North/South-East differences, but the tendencies are more or less the same.

[13] As noted by Beverley Carlson, who finds the same puzzling dissimilarities within Women in Statistics, data like these clearly indicate that culture is a powerful influence on how well women do in science in general, as well as in statistics in particular. She notes that the Mediterranean phenomenon of much higher percentages of women in the scientific professions is also observed among the ISI members (Carlson, 2000).

These numbers are surprising and cannot be explained from an internalist view of physics. In their own self-understanding, physicists belong to a tolerant scientific community – only the explicit and official evaluation of scientific results matter. However, in practice their community is socially limited. Here some would argue that when we find more female physics students, we generally also find more female physicists. But as noted by Osborn (1994) there are places with up to 50% female university students studying science topics, but only 2–3% female full professors. Even if the numbers of physicist students followed the number of permanent staff more closely, it would still not explain why we find gender differences between the countries in relation to physics. In some countries it simply seems to be more feasible for females to study and make careers as physicists than in other national cultures.

According to internalist scientific epistemologies, the success of science is insured by its internal features (Harding, 1998, p. 2). However, the numbers suggest that physics, from the perspective of who gets access to study physics, is very far from the inherent ideals formulated by Robert Merton in the CUDOS-norms. According to these norms the evaluation of scientific results is based solely on impersonal and objective criteria. Nationality and gender are completely irrelevant when it comes to the evaluation of scientific expertise. If this was true we would expect either that male and female physicists or physics students were evaluated as equally competent no matter where they came from or we could expect a consistent pattern showing that male (or female) physicists or physics students were consistently better that their gender counterpart across national borders. Instead we find a complex pattern where girls can outsmart boys in physics in Thailand and the opposite is the case in Scandinavian countries. Female physicists apparently never outnumber male physicists when it comes to permanent positions. However, the share of female physicists fluctuates and we apparently find more of them the further South and East we move.

To understand the puzzling figures, we must first accept that knowledge about the natural world seems to be intertwined with knowledge about the social world (Harding, 1998, p. 11). When our knowledge about the social world changes, our knowledge about the natural world might also change. The very numbers in themselves dismiss the notion of an internalist understanding of science and cry out for more knowledge on consequences of cultural differences in gatekeepers (see Husu, 2003 for a discussion on gatekeepers) and recruitment policies to science and – from my point of view– most importantly: a better understanding of how cultural organizations of knowledge create cultural differences in practice.

5.6 Inconsistent Explanations

Several explanations of the numerical discrepancies have been put forward. In a special issue of *Science* in 1994, four discrepancies in particular were identified (Barinaga, 1994). It can be noted that these differences are on different levels of explanation:

1. Cultural differences in the economic development and the labour market
2. Cultural differences in perception of class
3. Cultural differences in perception of education
4. Cultural differences in state supported childcare.

At the most general level we can ascertain that in countries which seem in need of fast economic development (as the former communist Eastern European countries) women can make up to 50% of the scientific researchers, whereas in industrial countries with a long male dominated history of economic development (like USA and the Northern European countries) women's tenured participation in scientific activities can be as low as 3–5%. Connected to this argument is the point made about cultural differences in perception of class. In the Northern countries the pecking order has been considered by some to be organized by gender perception rather than class: rich men, poor men, rich women, poor women. Whereas in other countries, especially developing countries, the ordering principle has rather been economic wealth and the pecking order thus: rich men, rich women, poor men, and poor women.

These explanations can, from the point of view of cultural models, be discussed as examples of different implicit connections made between gender and physics. In some countries physics is not strongly connected with gender, so when the economy demands "more hands at work" being female is not seen as an obstacle. From the implicit comparative point of view we could then argue that in a Nordic cultural model of physics we regard gender as so important that even when more hands are wanted in the economy (and the lack of "hands" in physics has been strongly underlined in the Nordic countries the past ten years), we "think gender" before we think "hands". Any hand in this context is a gendered hand: and the connection between physics and women is apparently difficult to make. This could be connected to the second explanation that class overrules gender in some countries in so far Nordic countries are perceived as countries which have levelled out class differences. But this is contradicted by the fact that Nordic countries are also known to have levelled out gender differences. These two explanations can, in other words, not provide satisfactory answers and the pattern becomes even more complicated when we include the last two explanations given.

The third and the fourth explanations concern how the state is, or is not, providing structures for education and childcare. Some societies use gender as an ordering principle for education in the sense that boys and girls are sent to different schools. In other countries (as in the former Communist countries and in the Scandinavian countries) it is underlined that boys and girls must follow the same path. Again these explanations can be seen as connections made between gender and science. The division in boys' and girls' schools should explain why we, in some countries, find a better representation of female physicists. Education (and therefore also science education) is related to gender in so far as male and female students are thought to disrupt each other's education in mixed classes. The assumption therefore is that when boys and girls are kept separate (when gender is made the overruling principle) then female physicists have a greater opportunityto develop themselves as proficient physicists. But again the pattern of connections is not consistent. In some countries, like the former Eastern European countries, we find many female physicists and yet the schools are in no way gender divided. In the Nordic countries the schools are similarly not gender divided and again we find a low representation of female physicists.

The fourth explanation claims that women are having a hard time making a career in science, because the state does not provide childcare. Women are thus connected more with childcare than men, and childcare is seen as something that excludes women from science unless they are helped by the state. Yet we find the lowest representation of female physicists in some of the countries with the highest amount of state provided childcare, like Denmark, and a much higher representation in Italy, where very little state child care is provided. The four explanations given are all contradicted when we compare the conditions in Eastern, Southern and Northern Europe.

The question remains: why do we find more female physicists in a country like Italy without much explicit gender policy than in Denmark with all the government supported facilities and a long history of women's emancipation? If we take a closer look at the particular science of physics in Italy and contrast it with Denmark, we find even more puzzling data from the Nordic point of view.

5.7 The Hard Science

If we start looking at the everyday life of a Danish female physicist, it is very likely that her early every day experiences were somehow affected by the gender issue. Not least because she was considered odd when she chose to study physics. In Denmark, according to the OECD-survey *Education at a Glance* (OECD, 1996), boys consistently outperform girls in physics. In mathematics, the gender gap in achievement is moderate – with a slight advantage for boys. In science, however, it is considerable. Boys outperform girls in Denmark with more than 30 points – almost one grade-year equivalent (see OECD, 1996, Chart R10.2). Are the gender differences observed at this age predictive of later stages and future career choices? Although this question cannot be answered directly, when it comes to the percentage of students in higher education in Denmark female students comprise around 25% for mathematics and the "hard" natural sciences, whereas in Italy we find 50% of the students are female in the same natural science and the percentage is almost the same in mathematics (Osborn et al., 2000, Fig. 2.2).

In Denmark physics seems to be gendered. It is generally known to be a subject that does not attract women. They prefer health-studies or human studies (Henningsen, 1998). Physics is considered to be a very hard subject, and only students with a background in natural sciences at a certain level, generally obtained through enrolment in a high school with an emphasis on mathematical and physics skills. In a study I did at the Niels Bohr Institute for Physics at Copenhagen University, it was obvious that the students considered physics a very hard subject to study indeed (Hasse, 2002).[14] Most girls drop physics modules in high school and choose the language lines, thereby excluding themselves from studying physics at university level and pursuing a career in physics – or at least making it very hard for themselves to catch up at a later stage to meet university requirements in physics.[15]

Once students are able to study physics at university level, they constantly talk about how hard it is, and that becoming a physicist is equivalent to becoming an elite scientist. Female students in particular, seem to completely loose their self-confidence in this elitist physics culture. (Hasse, 1998a).[16]

There seems to be a conflation in connecting physics with "hard science" and the fact that hard science is mostly sought after by male students. Conceptualizations of physics in Denmark come very close to what Carolyn Merchant (1990) and others have identified as inherently sexist science. In Denmark there is a commonplace connection made between physics as a hard science dominated by males and the humanities as soft sciences dominated by females

The politicians as well as the physicists have for a long period tried to attract more women to a career in physics. Among the administrative staff and the elder established female physicists, there is a lot of focus on gender and even a special organization for women in physics. Physics is generally regarded as a male domain, in which it can be very difficult for women to find a place. Therefore, something extra needs to be done to help females succeed in physics (Hasse, 2000, 2002). The cultural-historical conceptualizations of physics connect physics with being a hard "male" science that creates highly elitist, sought after scientists and where the gendered nature of physics is highly enunciated and discussed.

5.8 The "Classical" Physicist

In many Southern and Eastern European countries the view of physics is different – t is not considered especially hard, difficult or elitist. Nor is physics conceptualized as particularly masculine. These views are reflected in the number of women

[14] In a survey done among first year students most considered physics to be a hard subject to study (Hasse, 1998a).

[15] Until a few years ago there was a sharp division between mathematical-physical studies, classical studies and general language studies in Denmark. The division line was also generally considered a gender division line between females choosing languages and males math-physics. A new reform has in 2005 softened these division lines but the high school choice of subjects is still decisive for further education. There is no free uptake at university level. In study physics at university level a student has to have passed physics and mathematics at A-level and chemistry at C-level. As not enough students in general apply for this study the students are not competing on who have obtained the highest marks in the gymnasium. If one fulfils the general obligatory demands, students who want can study physics at university level (in sharp contrast with a lot of humanistic studies where students compete for the seats). From 2008 the formal demands are changed so you now have to have Danish at A-level, English at B-level, and mathematics, physics and chemistry at either A-AB- or A-B-A-level.

[16] See also Hasse (1998b; 2001; 2002).

in physics, starting from the level of high school education. In Denmark female physicist students enrolling at university level comprise around 18–20% of a freshman group. In Italy female students comprise approximately 45%. During my fieldwork I asked Italian students questions about the oddity of a woman studying physics, but the students reacted with surprise. They expressed the opinion that they had never though of it this way. It was explained to me that “here in Italy physics is not a “gendered” subject” as it is in Denmark.[17]

On the other hand, in Italy physics is connected to something, which from a Danish point of view is very surprising, but rather self-evident for Italian students. In Italy, it is possible to study physics at university level with a background in the humanities. This fact was accidentally revealed through my interviews with Italian physicists. In these interviews I was surprised to find again and again that many of these physicists had apparently *not* entered physics from a background in a mathematical and physics oriented education. In a Danish context humanities and natural sciences are generally seen as mutually exclusive. The physics students I followed at the Niels Bohr Institute made this clear to me: the worse fate for a physicist was to be degraded to working with the soft humanities subjects (Hasse, 2002).[18] However, many of the very successful Italian professors in physics that I interviewed turned out to have entered their study with a high school background as classical studies. They were versed in philosophy and cultural history, studying Aristotle in Greek, reading Cicero in Latin and the like.[19] Through questions addressing why they began to study physics and general research biographies it became clear to me that the recruitment pattern differed substantially between Italy and Denmark. I was not aware of this when I planned the project in Italy and I did not select physicists to fit this pattern. This was something hat became apparent during my interviews. Apart from gender I selected the male and female physicists according to availability, geographic and topical interests. Even so 14% of the Italian men and 64% of the Italian female physicists I interviewed (or 7 out of 11 of the female physicists) turned out to have a background in classic language and philosophy.[20] From the perspective of someone familiar with the Danish culture of

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[17] Barbara Mapelli (2002) has argued that Italian girls have a real desire to do science. However, they describe a female scientist different from a male scientist, and they perceive science differently from boys (Mapelli, 2002). This does not mean that physics in Italy is gendered in the same way, as it is in Denmark, though, where the girls have no desire for science. The girls Mapelli spoke to, and the Italian university students I spoke to, did not consider the discipline of physics to be a primarily ‘male domain’ as such —but considered that there can be gendered ways of doing physics.

[18] New reforms have tended to blur this distinction, but the political pressure is more directed at underlining that physics has a humanistic value, than the opposite found in Italy, that languages and philosophy have something to offer to physics.

[19] These surprising findings led me to start searching for information on criteria for the intake of students and the group interviews with students with and without ‘classical’ backgrounds.

[20] One of these women actually did not have a background in classical studies but entered physics science with a ‘scuola magistrale’, a background with even less connection to physics than the classical educated.

science this is quite strange indeed – though not at all odd from the Italian perspective. What is even more astonishing from a Danish cultural perspective is that neither the male nor the female physicists (who had all done very well in physics and were now employed as full time professors) had found that the classical background had been clogging them during their university studies.[21] In fact, on the contrary: the more technically trained students had even admired classical students. In Italy having a background in classical studies was seen as an asset. As one professor in physics, coming to physics with a scientific background, explained:

> I myself have a background equivalent to a mathematical-physicist high school student in Denmark. But here in Italy it is rather an advantage to have a classical linguistic background, when you start physics studies at university level. The 'classical' students are simply better at analyzing. What we learned in science high school was to think much more 'mechanically' – to think in the correct answers. I have always believed students with a classical background are the most advantaged.

An Italian teacher of philosophy expressed the same opinion in a slightly different manner, explaining that the "classical" students become especially apt physics students because they, through their knowledge of philosophical and classical subjects, learn to think in the abstract lines of thought of importance to both the natural sciences and the humanities. She underlines that until 15 years ago is was not uncommon that most of the students matriculated at the physics institutes in Italy originated from the classical language line in high school – and thus did not have a scientific background.

> The high school in classical languages was simply the best at training students in reasoning, because such a systematic and profound study of classical subjects had a formative influence on the students' intelligence – especially their ability to think in abstractions and make inferences.

Furthermore this teacher underlined that a non-specialized education system like the Italian one does not make too hard a division between humanistic and natural sciences. And we do not find the same kind of gender divisions that we find in countries like Denmark, where girls and boys have had to choose between a humanistic or a scientific line – and where we find that the girls in much greater numbers have chosen the humanistic line just as the boys in much greater numbers chose the scientific line. This also conflates somehow with a more relaxed attitude towards science in Italy.[22]

What the Italian female physicists brought with them when they entered physics at university level was a rather prestigious background, giving them self-confidence, as one of them explained to me. And this could be part of the explanation as to why we find more Italian and maybe also Southern European female physicists

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[21] This was later confirmed in my study by young physics students from Rome with a classical background. They also claimed that they did not experience their classical background as particular cramming.

[22] Some might get the idea that Danes learn 'better' physics because it's considered a 'hard' subject in Denmark, but in the PISA survey Italy and Denmark score almost equally (Mejding et al., 2004).

than we do Nordic. Most of the Italian female physicists, just as their male colleagues, expressed satisfaction with their life as physicists. And even though many of them complained about problems with state support for childcare and maternity leave, they regarded these as problems belonging to the world outside of physics and many of them rejected even looking at themselves as "women in science". As an Italian physicist said:

> I do not want to speak of myself as a 'female-scientist' because I am a strange 'scientist-woman'. Why am I strange? We are alike. If I have a problem it' s because we do not have the kindergartens to bring the children to, but this is not a problem tied to the 'woman-scientist', this is a societal problem, where the Italian politics are failing.

This attitude is considered very problematic from the feminist point of view of making gender problems visible in Italy, but most Italian women I spoke to did not want to connect their career-paths in physics with gender.[23]

This classical connection to the humanities clearly influences female physicists' career paths. In 2000–01, 23080 students were enrolled in physics studies at Italian universities. Of these 43.9% were women and of that percentage more than a third had a humanistic background, whereas only less than a tenth of the men had such a background.[24] The requirements for physics studies at university level are very different from Denmark, and this seems to open up new possibilities especially for female students with a degree in the humanities – often in classical languages and philosophy. In interviews female students with a "classical" background also expressed very clearly that they do not experience this starting point as being set back, but rather an advantage.[25]

Whereas in Italy female physicists do not identify themselves as "female" and refuse to see their gender as connected to career problems, it is no problem in the Nordic countries to find female physicists who links career problems to being female. Even though I also spoke to some feminist oriented Italian physicists I heard none of the real horror stories about being a *female* physicist that I heard from their colleagues in the Northern part of Europe. My interviews with Danish, Swedish and English female physicists showed a much more problematic relationship between being female and being a physicist. I shall in the following refer to them as "Nordic" – because the patterns are more or less alike in the three countries – but also to protect the women telling sad stories about not being recognized. Many of the women belong to the same age group as the Italian tenured female professors, but have never had a permanent position. They were interviewed because we find so few women in permanent positions in the Nordic countries. When I interviewed these women a substantial number expressed real bitterness

[23] Here we find a curious continuation of the pattern found on large scale at the European map of gendered physics. In the Southern part of Italy female physicists are more satisfied than in the North.

[24] The numbers were collected from the Ufficio di Statistica, Rome, in the summer 2003 by my assistant Ketty Mazzara.

[25] I made group interviews with four groups of male and female students in Rome, La Sapienza and in Catania.

over their academic life stories. Their whole career they had felt like outsiders. One of the Nordic female physicists told a terrible story of being a male professor's assistant on his project for more than 25 years. When he died she had never had tenure, and proposed that the institute should finally employ her. Her colleagues looked at her in bewilderment: "But did you ever publish anything on your own?" they had asked. She was very hurt, she explained in the interview. They were simply not aware that even as the professor's assistant she had been able to make independent research and had published over 100 renowned articles within her field. Even so she never got tenure as a physicist researcher.

Another female physicist from a different physics institute in a Nordic country also expressed how she always felt like an outsider, though she had been connected to her physics institute on a more or less yearly renewal base for over than 30 years.

> I have never been taken seriously as a colleague, when they talked about opening up for new tenure positions at the institute[...] I have very strongly been made to feel I am not one of them [even though] I am specialized within the broad research profile of the institute.

This woman had attended a girls'-school before studying physics and she was regarded as being really bright. According to this woman it was in no way a help to her when she entered the physics labour market that she had had excellent marks and had always received praise for her work as a Ph.D. student. She had achieved her Ph.D. in another country at a university were four women dominated her rather small institute: one professor, one lecturer and two PhDs. They had all attended all-girls-schools and she was certain that this had something to do with the relaxed atmosphere around doing physics. She had simply not been aware that physics could be considered a "hard" subject until she returned to her native Nordic country and got a part time contract.

Even so, in her Nordic country, her colleagues passed her by again and again as an almost invisible person –until a certain episode. At this time she was a very renowned researcher within her field of particle physics, abroad. But among her own colleagues she was not regarded as an equal partner when it came to tenure. She explains how it really hurt her feelings when, after many attempts, she applied for a job, which everyone agreed that she was obviously qualified for.

> It was a very ugly story. Even though I was declared obviously qualified, one of my closest collaborators said I was unqualified [...] they had decided someone else should have the position. The head of the department became the Chairman for the re-evaluation committee. I could do nothing.

She did not get the job and she explains it this way: "I think he had a problem with me being a woman. He felt it as a threat, I think. And I have no mentors here".

5.9 Cultural Knowledge of Gender and Physics

Intelligibility is important for cultural studies of science (Rouse, 1992). What I argue is that the cultural organization of knowledge, the cultural model of physics, makes different connections between gender and physics intelligible. In Italy gender and physics are simply not strongly connected to the extent they are in Denmark (and the Nordic/Western countries).[26] In the Nordic cultures everybody has, through everyday experience, learned to reinforce connections between physics and "hard science". "Hard" connects to "male" and "elitist". Girls who want to perceive themselves as girlish, should, in other words, stay away from physics, which threatens their identity as female: thus connecting physics with terms such as "not-female" and "gender-segregation" in the educational system. With this cultural perception it is very surprising that someone could even think about considering a background in classical studies to be an asset for a physicist.

In Italy physics is easily connected to humanistic studies – studies of philosophy, Greek and Latin[27] – and far from seeing the "humanistic" background for physics studies as disadvantage it is seen as advantageous, because classical education is considered to be of a higher status than physics. Women in no way lose their female identity by studying physics, though all physicists might be considered to be on the boring side of the job-market. However, physics is generally considered a good education for earning money later in life – much more than an elitist education aimed at "lofty science". It is not the case that Italian physicists are less respected or considered less competent than their Nordic colleagues, who stress the "elitist" aspect of physics.[28]

There is a link back to the four reasons given in the special issue of Science (Barinaga, 1994), which make it possible to understand the conflicting explanations in a new manner. In Denmark and other Nordic countries physics is, from the outset, gendered (as physics has been connected with "hard science" and "hard science" with being male). Any woman, who chooses to study physics, has to overcome the inherent cultural knowledge that she is entering a masculine domain. She also enters with the culturally organized knowledge that this discipline is not only masculine, but "hard" and "difficult". In Italy, which is much more of a class society than Denmark is, being a classical student has always been connected to being "posh" and from the upper classes. This connection between classical studies and class makes classical students attractive to all kind of studies – and here physics is no exception.

Cultural conceptualizations and what can be analyzed as "cultural models" do not appear out of the blue. They are never simple, but rather complex. They are emerging in everyday life as historical processes.[29] Culture as cultural conceptualizations is never at rest (Hasse, 2002). Human science thinking has been almost

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[26] This could also explain why much critique of natural science as androgynous comes from North-Western feminists.

[27] It can be noted here that the students Barbara Mapelli (2002) spoke to both connected physics with philosophy *and* to being a down-to-earth science that has practical implications for mankind (Mapelli, 2002). In my empirical material the women did not connect physics with more philosophical subjects, but I found the same connection with physics as a down-to-earth-science (Hasse, 1998a; 2002).

[28] Female PhD's in physics in Denmark often come from Italy, and Italian female physicists are highly respected in international collaborations in topics such as high-energy physics.

[29] In Denmark the first women graduated in physics in 1892. Italy has, on the other hand, a long history for women in science with the physicist Laura Bassi (1711–1778) as the most noteworthy. She was appointed to the Faculty of Physics in Bologna as early as in 1732.

completely excluded from physics in Denmark, but in both Italy and Denmark there are signs of new interrelations. In Denmark the Institute for Natural Science Philosophy has been placed at the Natural Science Faculty of Copenhagen University and in Italy the ministry of education is increasingly denouncing Italy's ongoing support of classical studies, which historically has been connected with a pride of the "Roman past". History and culture moves on, and physics *in* culture moves along with it.

5.10 Towards a New Humanistic Physics?

Cultural diversity challenges the notions of internalist physical science along with "ready made" stable categories of gender. Contrasting field-findings suggest that in the Nordic countries male gender and physics are linked whereas physics and humanity cannot be connected in general conceptualizations. Physics is considered masculine and incompatible with human science. The discipline is placed in an untouchable ivory tower of "hard elitist science". In the Southern part of Europe general cultural conceptualizations of physics seem much less connected to gender. Physics is more integrated with the general cultural history and is not seen as a particularly "hard" discipline.

In this analysis of cultural models we have to find and connect the pieces of the puzzle which seem to be the most important for the discussion at hand, but any cultural model is also an analytical construct constricted by the researcher's research and limited imagination. Even so from this perspective it seems that we can discuss the influence of the cultural models of physics in two ways. One points to an interesting discussion of how tacitly learned connections can influence women's (and men's) career possibilities and create gender segregated research fields, such as the field of physics, in a wider national cultural context. The other is a more speculative discussion concerning whether social epistemology in general can influence scientific epistemology *in* physics culture. In both cases questions are raised about an internalist notion of science.

In the first case it seems as if the very enunciation of gender, emancipation and gender policy in the Nordic countries could be followed by an engendering and segregation of science as a reaction to the strong focus on gender in society in general. Physics could, in this cultural context, be seen as the "last bastion" for men in a world where women seem to take over public space.[30] We find a pattern of women in human sciences and men in the natural science.

In Italy we find that women place a lot more engagement in areas like "hard" industries involved in physics, engineering and IT as well (Colclough, 2004). This can lead to the suspicion that gender segregation stems from a focus on gender and a substantial amount of women in the workforce. Gender barriers, in what is in Nordic

[30] The frequent newspaper statements underlining this point support this thesis.

countries typically considered “male domain”, are not so explicit in Italy, where women’s participation in the working market is more recent than in the Nordic countries. This supports the thesis that the higher the employment rate of women, the more gender segregated the labour market (Colclough, 2004). Our findings could further imply that the higher the educational level for women, the higher the disciplinary gender segregation. so for however we lack the reseach to confirm this thesis.[31]

In the present argument cultural models of science can be influenced by an integration of gender into the model. A Nordic cultural model of physics makes it difficult for women to be motivated to engage with “masculinized” domains, because it might mean a loss of identity as “female”. The more women who enter the public arena, the more important gender as an ordering mechanism seems to become society – in education as well as work. Emancipation might historically have opened a lot of public doors to women in Denmark, but the price might have been a high degree of being connected as women the public arena. Some areas are easily connected to women (especially areas dealing with childcare, care of the elderly and the sick); others are more readily associated with men in this gender-segregated society. When a woman crosses a border into male “territory” she is risking her gender-identity. The result is that cultural models can force Nordic women to choose different career paths to Italian women if they do not want to be seen as “masculine women”.

In Italy gender is not connected to physics in the same way, so female physicists do not perceive themselves as women-in-physics.

Contrary to Merton’s ideals gender does seem to matter in the selection of those who get pass the intelligibility gates into the culture of physics. From a cultural-psychological perspective we can open the discussion of how differently connecting cultural models of physics and gender might influence scientific epistemology. For many scientists gender studies in physics are of no importance what so ever to internal science issues. In the so-called “science war” scientists such as Steven Weinberg, Paul R. Gross and Norman Levitt have attacked studies on the social practice of science. Feminist contributions to science studies from Sandra Harding and Donna Haraway have also been attacked (Parsons, 2003). For these opponents science/gender studies say nothing substantial about science even though they might say something on social relations. In the internalist science perspective a lack of women in science is a social problem, which does not concern science epistemology. On the other hand, even though it is not easy to determine exactly how different cultural models of science could have serious consequences for notions of internalist science, we also have some indications of how different cultural models of science with or without “masculinization” might influence science epistemology. We can clearly claim to find a pattern of a closer connection between humanities and conceptualizations of physics in the Italian case, but no research is available which could confirm or reject a direct link between the acceptance of “classics issues” in the practice of

[31] In the IT-area we find the same tendency as for women in physics. Women are severely under-represented in the IT-sector in Denmark and England, where they, according to 2001-figures, only comprise 26% and 24% of the employed. In Italy 38% of the employed in the sector are women (Colclough, 2004).

physics and the number of female physicists. It would be difficult to argue in any simple way that more women are equal to a different kind of physics, but it *has* been claimed that scientific knowledge is intertwined with social issues such as gender (Rolin, 2001). Gender ideologies can either restrict opportunities for scientific dialogue or distort the evaluation of scientific competence, as argued by the philosopher Rolin (2001). The strong opinions about women in physics in Denmark might influence evaluation of the work of female physicists.

In both models (the Italian and the Danish) connecting physics with either gender or classical studies could be of epistemic significance. This raises a number of questions about the relation between gender, science and the cultural recognition of excellence, following up on studies on gender bias and the mechanisms that appear to prevent women scientists from achieving excellence (Al-Khudhairy et al., 2004; Brouns, 2004).

It could be argued, that if natural sciences and their preoccupations in reporting on nature are embedded in and are complicitous with social projects, then a causal, scientific grasp of nature and how to study it must be embedded in (be a special area of) causal scientific studies of social relations and how to study them (Harding, 1991, p. ix). Not least because: adequate social studies of the sciences turn out to be the necessary foundations upon which more comprehensive and less distorted descriptions and explanations of nature can be built (p. 15).

Once it is acknowledged that there is no isolated internalist science, but a physics culture influenced by cultural-historical changes, we must start thinking about these studies of science and the practice of doing science in new ways. The physicist Karen Barad has, among others, encouraged readings of science and technology studies in physics classes and in general called for at more responsible natural science, which implies thinking about the nature of scientific practices and its relationship to other social practices (Barad, 2000, p. 246). Whether this approach will, in the future, show that there is a connection between many female physicists and a more responsible and more humanistic oriented science remains to be seen.

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