Waltraud Ernst, Ilona Horwath (eds.)

GENDER IN SCIENCE AND TECHNOLOGY

Interdisciplinary Approaches

[transcript] Gender Studies

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Introduction

Waltraud Ernst and Ilona Horwath

What role does gender play in scientific research and the development of new technologies? This question has been asked from many different angles. This book provides methodological expertise, research experiences, and empiri cal results from a very dynamic and multifaceted field, feminist science and technology studies. In each of its chapters it connects, on many levels, in sights from gender studies and science and technology studies (STS). It aims to translate and link knowledge from gender studies produced in the humani ties, social sciences, and cultural studies to gender studies in the life sciences and material sciences as well as in mathematics and engineering. But more than this, the book seeks to enhance knowledge for the reflection and practice of scientific research and technological innovation by investigating its many gendered dimensions. It aims to show how reflecting upon gender in manifold critical ways can help to overcome gender hierarchies, exclusion practices, stereotypes, and other epistemic, ethical, and political problems.

For a long time, different groups of people have had mixed relations to technological developments and scientific advancements. For some decades the simple belief in the democratic purpose and use of science and technol ogy has been also questioned by historians of science, who pointed out the entanglements of scientific controversies with political struggles (see for ex ample Schiebinger, 1993; Serres, 1995). Moreover, sociologists of science and technology discuss the fundamental contextualization of scientific endeavor in social developments including complex structures of power (see for ex ample Jasanoff, 2003; Nowotny et al., 2001). They discuss the co evolution of science and society and demand socially robust knowledge in the sense that robustness is enhanced if research is improved by social knowledge (Nowotny et al., 2001: 167). But what is social knowledge? How can we differentiate

between social beliefs of scholars entering scientific theories, technological development or empirical research designs without further thought and knowl edge that has been systematically assessed in a collectively reflected and con trolled way? What is the relevant collectivity to decide on a certain set of questions (Longino, 1990, 2002)?

These questions become especially crucial when it comes to the field of gender studies. Because our culture has been structured for such a long time by this changing but powerful set of dynamics, there is a capacious mix of be liefs and interpretation practices about gender experienced by many scientists and engineers who are not necessarily aware of its impact on their practice of science and technology. This book was written especially for those students and scholars of science and engineering who are ready to confront unreflected assumptions about women and men and who want to learn about methods and strategies to develop research and innovation serving all genders and enable them to collaborate on equal terms. For this purpose, the book covers a range of theoretical insights from the construction of gender, sex, and sexuality to ap plications of gender in practices of engineering design and scientific reasoning.

Since the last decades of the 20th century, a field of knowledge has emerged that connects the interdisciplinary knowledge from gender studies with an other interdisciplinary field of knowledge, that of social and cultural studies of science and technology. In fact, these fields have been entangled from the beginning, forcing scholars to question undergirding theories in both gender studies and STS (Roy, 2008). This field of feminist studies of science and technology has grown rapidly as a discipline that transgresses disciplines as well as the barrier between social sciences, humanities, and cultural studies on the one hand, and life sciences, engineering, and material sciences on the other. This field has shed light on the entanglements of science and technology with gendered power relations and cultural constructions of femininity and masculinity. Although it has been quite controversial how to relate the critical insights in this powerful field of knowledge with potential participation neces sary to make changes, there was strong advocacy from early on that it is worth trying (see for example Haraway, 1991, 1997).

Since this time, feminist studies of science and technology have come a long way (Wajcman, 2008, 2010). Today, it is widely acknowledged to un derstand technology and gender relations as co constructions and as part of changing developments. The image of technology has changed from assumed betterment of life to a contested space and awareness that artifacts embody power relations. At the same time, feminisms have become just as multiple and

dynamic, especially concerning the insight that gender is connected to other constructions of power such as ethnicity, religion, sexuality, disability, and class. It is in this regard that today feminist technoscience investigates "tech nological change [a]s a contingent and heterogeneous process in which tech nology and society are mutually constituted" (Wajcman, 2008: 94) with gen der being understood as a performance or social achievement, "it is the product of a moving relational process, emerging from collective and individual acts of interpretation" (97). As a consequence, "the materiality of technology affords or inhibits the doing of particular gender power relations" (98). On the other hand Wajcman proposes that "the politics of technology is integral to a more just distribution of power in gender relations" (99). We want to contribute with our book to a better understanding of this complex relationship between gender, science, and technology.

The book emerges also from a specific local project: "For Future Innova tions: Gender in Science and Technology" was the title of a lecture series we organized in the winter term 2011/12 at the Johannes Kepler University Linz (JKU), Austria. Our aim was to show how gender becomes relevant in natural sciences, engineering, and technological development. This concern evolved in the context of our interdisciplinary work environment at the JKU, where a university wide development focus in the area of women's and gender studies promotes inter and transdisciplinary research cooperations with colleagues and students from technology and natural sciences. In this network we were able to observe an increasing interest in the role gender plays in scientific research outside of social sciences and how this category can be implemented in actual research and development processes: How can gender influence the shape of technologies at all, if these are fashioned on the basis of neutral prin ciples with regard to function and design?

The experts chosen for the lecture series at the Johannes Kepler University Linz in Austria and subsequently as authors for this volume work with a trans disciplinary approach. This means that they are familiar not only with theories and empirical results from the transdisciplinary field of gender studies, but also with those of the transdisciplinary field of science and technology studies. Nevertheless, although some authors have additionally had interdisciplinary training, all have a full scale academic background in one or more specific scientific disciplines. Coming from such diverse disciplines as media studies, computer science, social sciences, philosophy, mathematics, history, and biol ogy, the authors discuss how to ask questions about gender and give examples for their application in interdisciplinary research, development, and teaching.

The topics range from the design of information and communication technolo gies, epistemologies of biology and chemistry to teaching mathematics and professional processes of engineering.

The first section analyzes gender in the design processes of new technologies. The authors inquire how new technologies can be developed to foster equal opportunities for all genders. What role does cultural imagination play in in novation processes? In addressing these issues, the contributions do not focus on one best way to guarantee the best outcome but discuss different methods. The contributions show that there is also no 'one best way' for a feminist design of new technologies but that there *is* the possibility to take gender into account in a theoretically reflected and methodologically systematic way in order to counteract problematic gendering. Empirical findings from both analyses suggest that disregarding the category of gender does generally not lead to 'neutral' technologies but tends to reproduce gender hierarchies and stereotypes. The authors ask questions about the role of culture in technologi cal innovations and what kind of social experiences are involved in techno logical developments.

Concerning the design of technological artifacts in engineering as well as in information and communication technologies, Anne Balsamo promotes an understanding of design practices as a "process of technocultural innovation". As this process involves human beings, the gendering of the process happens by way of the participants' imagination concerning their own gender and that of others. Balsamo describes the interactive development of a multimedia de vice within the United Nations Fourth World Conference on Women in Bei jing, China in 1995 and discusses how technological innovation can foster feminist empowerment.

In her contribution Els Rommes focuses on design strategies of Informa tion and Communication Technologies (ICT) which explicitly aim to take gender into account. Drawing on gender dimensions proposed by feminist re search, she first develops a conceptual framework for the analysis of the gen deredness of ICTs. By distinguishing particular approaches of the application of gender, Rommes discusses how a feminist design could look like. Finally she explores empirical results on how 11 European companies studied in the SIGIS project (EU Strategies of Inclusion; Gender in the Information Society) actually took gender into account and elaborates the pros and cons of the most common design methodologies.

To provide a basic methodological framework for feminist design in com puter science is the objective of Corinna Bath. Based on empirical analysis of gendering processes in the development of new technologies she differentiates four main mechanisms that repeatedly lead to gendered computational arti facts. Drawing on the work of Judith Butler, Karen Barad, and Lucy Suchman, Bath develops a theoretical foundation for a "de gendering" in design pro cesses and proposes particular technology design methods for each of the four mechanisms to systematically avoid problematic ways of gendering.

Exploring the cultural history of masking and masquerade, Cecile Crut zen discusses what it means to negotiate humanity in confrontation with new capabilities for control by the developing information and communication technologies. She asks about the meaning of new opportunities of masking oneself within ICT. She describes our world as a mixed reality, of interaction between visible and invisible aspects of existence. The author concludes that understanding the "gender masquerades of past and present" can lead us to the disclosure of the masquerade of humans in robots.

The second section of the book discusses gender in epistemological founda tions of science and technology. Here, conceptual questions about how gender becomes a problem in scientific research are asked. How is gender framed as a phenomenon constituting epistemic problems to do research on? On which conceptual paths do cultural assumptions about women and men enter research on humans as well as on organic and non organic entities? How is it possible, as scholars and engineers, to analyze hidden assumptions about gender, to re flect on guiding norms and stereotypes as well as eventually redirect research questions, experiments, methodologies as well as methods of data interpreta tion? Can we invent gender differently? Can we think of gender and diversity in ways that enables scholarship and innovation efforts to lead to emancipatory and empowering effects for all genders in a democratic future?

Discovering the hidden assumptions about women and men in the organi zation theory of the brain, Rebecca Jordan Young analyzes the methodolog ical conditions and moves of experimental practices as well as the way of formulating research questions when it comes to studies of the relevance of hormones for the development of sex, gender, and sexual orientations from the 20th century to the present. She also reflects on practices of pathologiz ing non normative behavior concerning gender and sexuality in medicine, and combines her demand for better scientific practice with an argument for taking into account the social context of research.

Barbara Orland's contribution leads us into the history of science. She shows the conceptual moves in the discourse on motherhood and breast feed ing in the course of the nineteenth century. The author analyzes its relations to the practices of wet nursing and the innovation of artificial baby food in chem istry and its applications in the emerging sciences of medicine and pediatrics. She also discusses the link between scientific knowledge and the fast growing market economy. She shows how the negotiation of gender is always present in the debates on what is best for whom.

In her paper, Waltraud Ernst embarks on an epistemological discussion. She asks if it makes sense to understand gender as an apparatus (reading Ju dith Butler with Karen Barad), generating changing diffraction patterns in life sciences as well as material sciences. She explores the potential of conceiving and studying gender as diffraction patterns rather than differences between women and men or other organic and non organic material entities. Drawing on Butler's conceptualization of gender and Barad's theory of matter, the au thor searches for an epistemological foundation of feminist science and tech nology studies.

The following article by Lena Trojer connects feminist epistemology with the practice of scientific research, technological innovation, and institution building. She shows the implications of doing science and technology within a feminist framework of understanding technoscience as related to the social world of global power relations. She shows how to organize, institutional ize, and practice technoscience differently in order to attain knowledge and technologies which prove more suitable and therefore sustainable concerning equal opportunities for all genders in a global sense.

The third section is dedicated to reflecting un/equal conditions for participa tion in science and technology. How do traditional assumptions about women and men set limits to collaboration in fields of engineering? How do prevailing gender stereotypes influence the performance of individual women and men in science and technology? Which role do professionals play in this scenario and how can gender stereotypes be overcome in teacher education?

Based on an ethnographic investigation of engineering cultures, practic es, and identities, Wendy Faulkner explains, how the numerical minority of women in engineering cause an in/visibility paradox and associated gender in/authenticity dynamics that undermine their professional membership and progress in this field. According to Faulkner, efforts to improve the representa tion of women in engineering are substantially limited by these dynamics. To

overcome these limitations she challenges stereotyped dualisms about gender and engineering and the "pervasive (and comfortable) ideology of gender dif ferences", to create space for more plural versions of masculinities, feminini ties, and more heterogeneous understandings of engineering.

Ilona Horwath, Nicole Kronberger, and Markus Appel examine the com plex interrelations between cognitive abilities, stereotypes, and successful performance in the field of science and technology. The authors summarize the current state of research on gender specific cognitive differences and sepa rate empirical results from stereotypical interpretations. To transcend the con straints of common 'nurture nature' discussions, they suggest raising the ques tion of how cognitive skills can be developed and influenced. For this purpose they provide a comprehensive review of studies that shows how stereotypes about gender and prevailing assumptions about the nature of intelligence and talent can influence individual performance and success in science and tech nology.

Gender competence in mathematics teacher education is the issue explored by Andrea Blunck, Anina Mischau, and Sabine Mehlmann. Starting from the finding that the 'male image' of mathematics is at least partially created in school, they argue for an implementation of gender competence in mathemat ics teacher education in order to increase equal opportunities for pupils be yond gender stereotyped knowledge and interest domains. With this in mind the authors elaborated an exemplary course concept in their interdisciplinary research project "GenderMathematics" and tested it in several German univer sities. The article discusses the most important facets of 'gender competence' in teaching mathematics and provides an overview of the course concept.

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We are grateful to all lecturers and participants of the lecture series for hav ing joined this experimental project, some travelling from afar all the way to Linz, others willing to do some far reaching mind travelling. We would like to extend our special thanks to Nadia Alhasani, professor of Engineering and Applied Sciences and director of WISE, the Women in Science and Engineer ing Program at the Petroleum Institute in Abu Dhabi, United Arab Emirates, who made the effort to travel even several times to our university and not only gave a lecture about her success in recruiting and retaining women as students of engineering ("Balancing Gender Perceptions and Realities: The Case of

the Petroleum Industry in Abu Dhabi, UAE") but also brought her students to broaden our students' horizon concerning assumptions about gender and culture in most valuable ways. Unfortunately, we cannot present her contribu tion in this volume. Many thanks to all other lecturers for their contributions to this book. We also thank our former professor and initiator of the lecture series, Gabriella Hauch, and all our colleagues at the department of women's and gender studies at the Johannes Kepler University Linz for their support as well as the rectorate of our university for their far sightedness in this regard. We are also grateful for the financial support for our lecture series given to us by the Austrian Ministry of Transportation, Innovation and Technology, the Austrian Minister for Women and Civil Service, the Women's Department, and the Department for Education and Society of the state government of Up per Austria, the city of Linz as well as the Bureau for Women's Affairs of the city of Linz, the Austrian Center of Competence in Mechatronics and some private sponsors. Last but not least we want to thank Matthias Müller for his professional proofreading of the entire manuscript and Maren Lachmund for her marvellously thorough editing and careful layout of the manuscript.

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A. Gender in the Design Processes of New Technologies

Gendering the Technological Imagination

ANNE BALSAMO

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ABSTRACT

In her essay, "Gendering the Technological Imagination," Anne Balsamo describes the relationship between gender and the technological imagination by examining some of the myths that persist about women and technological innovation. She draws on insights provided by feminist epistemology to elaborate the nature of agency that unfolds during the process of developing technological applications. To illustrate how the methods of hermeneutic reverse engineering are deployed in practice, and to elaborate a reproductive theory of technology, she describes the development of an interactive multimedia documentary that was created for the NGO Forum held in China in 1995. (The NGO Forum was held in conjunction with the 4th U.N. World Conference on Women.) The multimedia documentary, called Women of the World Talk Back, served as a particular type of boundary-object that enabled the creation of several cultural constructs, including a set of identities for the designers and the audience members, as well as a set of counter narratives about the implications of the hardware and software that were used to create the work.

Feminist Interventions in the Design Process

Els Rommes

In this paper, I will first discuss what a feminist design of Information and Communication Technologies (ICTs) could look like. Is it enough to design products that include more women, or should feminist designs include efforts to provide for changes in gender relations? Subsequently, I will present results of an analysis of the design of, for instance, computer games, websites and mobile phones by eleven enterprises carried out as part of the large scale EU Strategies of Inclusion; Gender in the Information Society (SIGIS) research. All of these companies attempted to design in a gender inclusive way. I will discuss how the companies studied actually took gender into account: through designing from stereotypes, with the (reflexive) I methodology or through participatory design. I will discuss the pros and cons of each of these method ologies and conclude with some ideas on which interventions might be most effective in creating gender sensitive or even 'feminist' products.

In a large scale European research project called Strategies of Inclusion; Gender in the Information Society (SIGIS), we studied a large number of Eu ropean companies and organizations that designed ICTs either explicitly 'for everybody (including women)' or particularly 'for women'.[1] As we were in terested in inclusion of gender in the information society, we investigated the ways in which designers tried to design in an inclusive way. But what is it we

1 | In alphabetical surname order the 'we' are: Wendy Faulkner, Leopoldina Fortunati, Helen J. Gansmo, Deirdre Hynes, Aphra Kerr, Tine Kleif, Vivian A. Lagesen, Lisa Lee, Roberto A. de Luca, Carol MacKeogh, Anna Maria Mangelli, Hege Nordli, Barbara O'Connor, Ellen van Oost, Nelly Oudshoorn, Paschal Preston, Els Rommes, Marcelle Stienstra, Kristin H. Spilker, Irma van Slooten, James Stewart, Knut H. Sørensen, and Robin Williams.

actually mean with gender inclusive design? And are there design method ologies which will more easily lead to gender inclusive products than others? These questions will be addressed in this chapter.

Several researchers of gender and ICTs have been critical about the 'nor mal' design of ICTs. One of the main points of criticism has been that designers design for the masculine norm (Oudshoorn et al., 2004; Wajcman, 2004; Web ster, 1995). Hardware and software intended 'for everybody' were analyzed to investigate whether they indeed fitted the lives of 'everybody', or were in some ways more accessible to some groups (e.g. highly educated, middle class, self confident, able bodied, heterosexual white young men) than to others.

One way of analyzing the genderedness of ICTs employs the 'levels' or dimensions (structural, identity, and symbolic) in which society is gendered according to Sandra Harding as a systematic way of studying ICTs (Harding, 1986). In the structural dimension, questions are asked like who has access to the product? Which resources (e.g. financial, social networks) are needed to have or use the product? As Susan Leigh Star would say: question who is excluded and "cui bono?", who profits (Star, 1991: 43). Analyzing this di mension in a product means comparing features of the product with statistical knowledge on who is located where in society and who has access to which resources, such as social, economic or cultural capital (Bourdieu, 1984). In the identity dimension of gender, questions can be asked such as which skills and knowledge, which physical attributes, and which learning method should a user have to use the product? To analyze this dimension in the product, indi viduals with diverse preferences and skills can for instance be interviewed and observed while using the product, to see how well it matches their personal preferences and skills. In the symbolic dimension, questions can be asked like which aims and values (e.g. do products mostly have economic, virtuosity or user/need values which, according to Pacey, are the main values technologies can have (Pacey, 1983)) the product represents, whose metaphors are used, with which symbolic means the product is marketed, and which stereotypes are reproduced. To analyze this dimension, a critical feminist analysis of the product can be made to clarify which stereotypes and feminine and masculine connoted symbols it incorporates.

Analyzing a product with the help of these specific three dimensions of gender is just one shape a multi dimensional gender analysis can take. There are other ways of interpreting the three dimensions of Harding, as there are other distinctions between levels of gender in society, such as those offered by Scott and by Hagemann White (see Tonkens, 1998). The four 'inclusion

needs': access, motivation, capability, and various kinds of support we dis tinguished in our analysis of the case studies in SIGIS offer a similar kind of multi dimensional analytical tool (Sørensen et al., 2011, chapter 3). Each of these multi dimensional understandings of gender aims to offer a toolbox to give more encompassing insight into whose world is represented in a product. If this fits with the world of more men than women, a product can be regarded as designed for the 'masculine norm', it is gender specific, even if it is sup posed to be a 'gender neutral' or 'for everybody' product. In a similar way, other axes of inequality in society, such as class, age or cultural background can be analyzed, though which dimension is most important for (re)producing inequalities will be different depending on which social inequality category is chosen (see Verloo, 2006).

The point of this kind of research has rarely been to say that products which represent the world, including skills, preferences and metaphors, in which more men than women feel at home in present western society, ex clude all women. Women more often than not have resources, skills, and in terests which are associated with masculinity in society. More importantly, as researchers from the domestication approach have amply shown, users have considerable freedom to adjust the product to their liking and thus reconfigure intended practices and meanings of it (Berker et al., 2006; Oudshoorn and Pinch, 2005), although this freedom may again be unevenly distributed in so ciety. It is the intention of these kinds of studies, however, to say that it may be much harder, frustrating, and less interesting to use for people whose world is not represented in the product, and that some need to perform more 'inclusion work' than others.

In the following sections, I will first specify differences (and common alities) between gender sensitive and feminist products. Subsequently, I will describe the main design methodologies found in previous research by compa nies who attempted to design while taking gender into account. I will conclude this chapter with some speculations about what kind of relations might exist between these design methodologies and the kinds of products they produce.

Gender-inclusive or Feminist Products?

Whereas designs in which no particular attention is paid to gender easily run the risk of being in several ways gender specific and more directed towards men (Cassell and Jenkins, 1998; Wajcman, 2010), products in which specific

attention is paid to be 'gender sensitive' run the risk of being gender specific and directed towards 'women' or 'the feminine'.[2] This is what happened in several cases in the past in which, for example, attempts were made to develop a 'game for girls' (Jenkins and Cassel, 2008). Although this might be a way to (re)value the feminine and to offer a wider diversity of products in society, gender specific products may be problematic for the reasons mentioned above: requiring more inclusion work for some than for others. In itself, this is not such a big problem, as long as it is clear that it is a targeted product, rather than a product 'for all'.

There is, however, a bigger problem related to gender specific products, as they may reinforce sex stereotypes (see Rommes et al., 2010). The rein forcement of sex stereotypes is particularly salient if products are gendered in the symbolic dimension. Products which signify, for instance, with their colours, in their description, in the pictures of prospective users on the pack aging or in the way they are marketed that they are specifically aimed at one of the two sexes, reinforce stereotypes of what men or women are supposed to be, prefer, know, and are capable of. Indeed, a toy producing company in Sweden was asked by elementary school children and a marketing watchdog ombudsman to change their catalogue to present less sex stereotyped pictures of their prospective product users.[3] By changing these images, i.e. their gender specificity in the symbolic dimension, gender transgressive, or transforming products may have now been created: products which contain contradictory gender signifiers on one or all gender dimensions. Whether these product (im ages) will indeed have gender transgressive effects in society, for example in changing toy preferences in children and changing gender stereotypes in soci ety, remains an empirical question.

An important point of criticism of studies on the extent to which products are gendered or even gender stereotypical, is that they pay too little attention to transformations of gender. Although these studies claim to have a 'co con struction' perspective on gender and ICTs, closer analysis reveals that what is mostly analyzed is technology, and gender remains remarkably stable (Lag esen, 2005; Landström, 2007). Gender is regarded as static or even a statistical

2 | In theory, gender signifies men/masculinity and women/femininity, in practice, how ever, 'gender sticks more easily to women' (Berg), meaning that if particular attention is paid to 'gender' this is often understood as attention to women.

3 | See http://www.dw.de/neither good girls nor boys in sweden this year/a 16436045 (ac cessed 17 February 2013).

variable, and even in the symbolic dimension it is regarded as dichotomous and again stable. Various studies have accommodated these kinds of criticisms by focusing on the ways in which products themselves influence individual gender identities or performances of their users (see for instance Corneliussen, forthcoming, chapter 5; Lagesen, 2012; Lohan, 2001; Sørensen et al., 2011, chapter 5). It is, however, probably no coincidence that the dynamic character of gender in these studies is mostly located in the individual identity dimension of gender. Which kinds of performances and which kinds of research on these performances may show that gender is dynamic in the symbolic dimension and which of these evoke transformations in this and the structural dimension?

Moreover, these studies mostly focus on how gender is dynamic and open for transformations in people, or more often, in socio technical assemblages or cyborgs. Can gender as something dynamic and fluid also be studied as such in products? Are some products more capable of evoking transformations in gen der than others? This is a question not on how technologies can accommodate diversities in users, but rather a question of how technologies can contribute to the transformation of gender in society. Hence, it seems more appropriate to use the term feminist rather than gender sensitive for these kinds of products. These products could for example be technologies of which signifiers (color, material, costs, required skills) at different dimensions point in various direc tions and/or products which contain counter stereotypical images or stories.

In the SIGIS research, we found some examples of products with the po tential of being gender transgressive. Some Norwegian game designers, for instance, designed games that combined role playing and nice packaging, be lieved to be important to women, with action elements, believed to be impor tant to men. In our analysis of women's web magazines (Sørensen et al., 2011, chapter 4), websites were studied which were both 'technological' and at the same time were created as 'places for women'. These websites transmitted the message that women can simultaneously be computer competent and 'femi nine' in a traditional way. The image of women and femininities as including computer competence was constructed alongside more conventional percep tions of traditional femininities. They also challenged or loosened gender bi naries of women as being only interested in serious/functional use as opposed to men being geared towards fun and pleasure use, and binaries of women as connected with the private realm versus men as associated with the public area of Internet discussion forums. Arguably, these websites helped to reconstitute the Internet from a very masculine area (Hafner and Matthew, 1996) to the mixed place it is considered to be nowadays.

How can such gender transgressive, feminist products be conceived? And how should products be designed which aim to reach a diverse audience, or which even intentionally want to include more women as users without pro ducing gender stereotypical products? To answer these questions, I will now present some of the findings of the design methodologies we found in the SIGIS project: which design methodologies did these companies that tried to design 'for everybody' or even 'specifically for women' employ? The follow ing is a summary of the findings we[4] present more fully in Sørensen et al. (2011), chapter 6.

Gender-sensitive Design Methodologies in Practice

When designers make a new product or remake an existing one, they construct a script: "Technical objects define actors, the space in which they move, and ways in which they interact." (Akrich, 1992: 216) If this definition of actors, or the division of responsibilities between actors and the spaces in which the ob ject is supposed to act, is in any way gendered, we call this a 'gender script'. In constructing this script, designers draw on some representation of the intended users, on images of the presumed target group. This may happen more or less consciously, but one cannot really design a product without some idea about how it is going to be used, by whom, and for what purpose (Akrich, 1995). In the eleven companies we studied, we observed three main practices with respect to the construction of user representations, each with different implica tions for the way gender issues were approached:

- Designing from gender stereotypes.
- I methodology, where designers see themselves as typical users, and the reflexive I methodology, where companies deliberately chose to involve women designers.
- Participatory design, where potential users were directly involved in the design process.

4 | In this section I will use the 'we' form, as this part was written together with Wendy Faulkner and Knut Sørensen and based on the collective work of the participants in the SIGIS project.

In the following, we describe and discuss these practices in greater detail. In several companies, more than one of these approaches have been used in the same project.

Designing from Stereotypes

In the companies we studied, it was clear that many designers who aimed to include women as end users of their products saw it as important to define in what ways women or girls 'are' different from men or boys. Many were convinced, for example, that some features just 'belong' to women's or girls' products 'like fashion and beauty' as we saw in several of the designs for web magazines. How are such stereotypes chosen and invoked?

In some projects, the designers started with a literature study on gender differences, using books and reports that have in fact been extensively criti cized by feminists for the way they dichotomize and naturalize perceived 'bio logical' differences between men and women. In most of our studies, however, we found a more impressionistic approach. Designers looked at other 'typical' girls' products like girls' magazines, girls' books, or girls' favourite television programmes to get an impression of what girls and women would like.

Regardless of the source, the most common way of constructing an image of potential girl or woman users of a product was by thinking from stereotypes. To some extent, this reflected a felt need to construct an image of their future users as 'different' from the audience they had targeted before. Hence, no mat ter who actually were thought to be the precise target group adult women or girls, highly educated women or women living in disadvantaged areas the same general beliefs about what women want tended to resurface. Women were represented as neither interested nor skilled in technology and as prefer ring 'user friendly' (i.e. simplified) interfaces. Another widespread perception was that women were not into technology for fun but to gain from useful ap plications, without flashy pictures and such like. Contrary to our findings about the importance of having fun with computers and the Internet, it was widely presumed that women saw technology mainly as a tool.

In nearly all the companies we studied, such stereotypical ideas about how women 'are' or what they 'like', were important in guiding design decisions, if not exclusively so. Arguably, there is a positive and a negative side to de signers' interest in how girls 'are' different from boys. On the positive side, a focus on 'what girls want' may serve to strengthen and give value to skills and preferences considered feminine (Cassell and Jenkins, 1998) and it is a way

of creating a wider diversity of (gender specific) products with different target audiences. On the more negative side, by developing a product based on 'typi cal girls' interests', designers run the risk of reinforcing and re inscribing per ceived gender differences rather than challenging gender inequalities through efforts at transforming gender as a normative (social) construction. In other words, the stereotype approach may easily give rise to the design of products that are specific, e.g. pink websites with utilitarian aims focusing solely on top ics presumed to be of interest to women, or even worse, gender stereotypical, if such sites are explicitly addressed to women (see Rommes et al., 2010, for the different ways in which games can reinforce and re inscribe gender ste reotypes). Gender specific and especially stereotypical games may reinforce traditional gender practices and divisions of tasks (Corneliussen and Rettberg, 2008; Henning et al., 2009; Jenkins and Cassel, 2008; Kafai et al., 2009; Tay lor, 2006). Moreover, such designs run the risk of not being commercially viable, as we found in several companies. Designing from stereotypes should, at the very least, be considered a potentially risky business.

The (Reflexive) I-methodology

One of the most commonly used design techniques in ICTs is to make de sign decisions on the basis of designers' own preferences. This is frequent ly referred to as the 'I methodology', emphasizing the subjective aspect of formulating user requirements (Akrich, 1995; European Commission, 1998; Oudshoorn et al., 2004). The I methodology has been considered problematic in the context of gender inclusive design because most designers are men. Designers also tend to have a specific, 'insider' relationship with their technol ogy, which makes their world view different from that of many users of their product (Rommes, 2002). Hence, this design methodology may easily give rise to gender specific products targeting more men.

In most of the eleven companies we studied, some form of I methodology was practiced. However, the concern for gender inclusion made several com panies use what we consider to be an adapted version of the I methodology by explicitly making choices with respect to the sex composition of design teams or by stating up front that women ought to know what women want and need. This, we call reflexive I methodology. What kind of design practices did this refer to?

In feminist methodology, Donna Haraway (1988) has called for reflexive approaches to science and engineering, noting that such work needs to be situ

ated to be made understandable and that all perspectives are partial. Clearly, by adhering to these tenets, the I methodology may be used in a reflexive way. This requires that designers be aware of and take into account the ways in which their particular perspectives and situation make them similar to and different from the end users of their products. Of course, relying on stereo types is one way of dealing with the situatedness of designers in so much as it acknowledges that they are different from the intended users. However, to qualify as reflexive I methodology, designers need to pursue in much more depth the thinking and reflection about their roles.

What we observed in many of the companies we studied was anything but such an in depth reflexive approach. Instead, women were asked to join the design team to help create a product aimed at women. In all of these instances, it was assumed that women are necessarily similar to their target audiences of girls or women, and understand these potential users better than men designers would. In effect, they used the reflexive I methodology in an essentialist way. This said, even where women were involved positively in the design, their influence was often limited. Hence, if women are introduced in the design pro cess as a way of introducing a reflexive I methodology, their position within the organizational hierarchy and the division of labour will have a major bear ing on how much they are able to influence the ultimate design.

There remains the problematic issue of the implied essentialism in this version of the reflexive I methodology, the belief that every woman is repre sentative of women (or girls) in general. As indicated in the discussion about the I methodology, even in cases where women designers are similar to the potential users for instance, in terms of age, class, ethnicity, and interests the mere fact that they are part of a design team, have access to the latest technology, and are interested and skilled in the use of technology, makes their relation with technology different than that of most users. So, both versions of the I methodology need to be used with care. Moreover, because of the es sentialist tendency inherent in the observed use of reflexive I methodology, it is likely to lead to gender traditional products, as some of the developed web magazines and computer games we studied exemplify. This danger could be avoided if designers' reflexivity were based on efforts to find out about the complexity and diversity of actual people, their practices, identities, and the like, rather than on essentialist assumptions. One way of doing this is to access expert knowledge about gender, so that design teams can learn from previous research on the subject, and use this knowledge to identify relevant consider ations and refine their own understandings. Another way to find out what girl

and women end users want is to engage in participatory and interactive design techniques, to which we now turn.

User Testing and Participatory Design

As we have seen, both the stereotype approach and the reflexive I methodology in the form of deliberately employing women designers assume that there are differences between men and women and, consequently, risk reproducing these differences through the design of quite gender traditional and stereotypical products. Arguably, the most important alternative is the use of techniques such as the testing of products on potential users or participatory design. These techniques which have sometimes been called 'feminist' strategies (Balka, 2005; Cassell, 1998; Greenbaum, 1991; Suchman, 1991) allow potential end users some direct influence upon design, with the result that design does not rely solely on the ideas and beliefs of designers.

Several of the companies we studied invested time and energy in identifying representative end users and examining their preferences. Such user involvement in the design process seems to be the exception rather than the rule (European Commission, 1998; Haddon and Paul, 1999; Offenbeek and Koopman, 1996). Involvement of potential users in early phases of the design process is especially rare.[5] In this context, it is interesting to note the fairly widespread use of testing and some kind of user participation in the companies we have been studying in various phases in the design process. This suggests that concerns to include more girls or women result in greater than normal engagement with potential users possibly because of unfamiliarity with the target group. In addition, it seems clear that the Internet facilitates interaction with users and user input to design, which helped the companies we studied. New ways of user testing and getting feedback on designs have become available.

Although the interactive features of ICTs seem to be very effective in allowing users more influence, those users that give feedback in this way are a select group: more active, engaged, and articulate than ordinary users. By focusing solely on their needs and wishes, designers run the risk of ignoring those users who are less capable of articulating their demands, or of ignoring

5 | It is so exceptional that several authors have developed design methodologies that they consider to be innovative because of the early phases and the extent to which they involve potential users (see e.g. Fullerton et al., 2006; and Mackay et al., 2000).

potential users that are not yet using the product. This is a general problem with respect to participatory design strategies: how to achieve a reasonable degree of representativeness? The companies we studied could perhaps have been more concerned about these limitations. Again, the challenge is to find out about the multitude of actual and potential users, to become more sensitive to the diversity of wishes, skills, and preferences, which could enable their designs to include a wider range of users, in other words, to be more gender sensitive.

Which Design Methodologies Lead to Gender-sensitive Products?

After having looked at which design methodologies are most common for companies that seek to design products taking gender into account, the ques tion now is what can be said about the outcome of these products. It seems safe to assume that explicit user representation techniques will more easily lead to gender sensitive products, as producers of these products will have a more nuanced and diversified image of what their target group is interested in and prefers. And whereas the I methodology might give rise to gender specific products, the reflexive I methodology might at least create some awareness of this amongst the designers.

Nevertheless, it is not easy to predict to which kind of product a specific design methodology will lead. Although it seems logical to assume that the stereotype approach will more easily lead to gender specific or even stereo typical products, this is not necessarily the case. If designers (un)intentionally only change some aspects of their products, like some of the companies we studied as part of our SIGIS study, the result could just as easily be feminist products that transform or transgress gender. In several cases, stereotypically feminine elements were used to attract both girls and boys: for example, de signers would make a slightly pink product, incorporating several interests which they considered to be 'typically feminine', which they intended to mar ket to both girls and boys. Similarly, the web magazines which we discussed earlier were partially made with the design from a stereotypes approach, while they also represented masculine connoted interests and values like being inter ested in cars and in ICTs.

In a previous research on the development of games for children (Rommes et al., 2010), we did find that the 'feminist values' of those that are in charge of

designing products may affect the extent to which products are gender sensi tive or even gender transgressive, as Jenkins and Cassel (2008) also tentatively concluded. Those designers that believed that products could influence gender identity and behavior of, in this study, children, and who wanted children to behave less gender stereotypically, consciously chose to design more gender inclusive or even transgressive products. As to how interventions in the val ues of designers can best take place, more research is needed, but some sug gestions could be derived from work by Allhutter (2012). The main element behind the interventions Allhutter and others using similar methodologies sug gested, is to make designers aware of their own feminist or other values and of the potential consequences of these values, in the hope that this will affect designers' choices.

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Searching for Methodology

Feminist Technology Design in Computer Science

Corinna Bath

The objective of this article is to provide methods for technology design that avoid a perpetuation of the existing structural symbolic gender order. Moreover, by aiming for a systematic approach to conceptualizing and building computational artefacts, it seeks to identify a feminist methodology in the field of computer science. The core argument of the contribution is that methods for counteracting problematic gendering mechanisms need to be differentiated. Thus the main part of the article is arranged along an analysis of gendering processes.

Based on a review of existing science and technology studies (STS) research, four mechanisms are described that often lead to gendered computational artefacts: 1) the 'I methodology' that assumes technology to be neutral; 2) the inscription of implicit gender stereotypes and the gendered distribution of labor into computational artefacts; 3) the gendered technological concepts of human bodies and behaviors; and 4) decontextualization and disputable epistemological or ontological assumptions. For each of these mechanisms I will propose technology design methods adopted from the field of critical computing,[1] and outline in which way these methods can avoid problematic

1 | Critical computing refers to a field that can be characterized by the series of decennial conferences called critical computing (see Bertelsen et al., 2005), where researchers and designers from a variety of critical approaches to computing (e.g. participatory design, values in design or the German theory of computer science / 'Theorie der Informatik') meet.

ways of gendering. Finally, the potential and limitations of the methods and the methodology as such are discussed on the basis of feminist theory.

INTRODUCTION

During the last decades the corpus of knowledge about gender *in* technology has been growing continuously. Numerous case studies show in detail how gen der configures and is configured by the design of technology (see for example Archibald et al., 2005; Cockburn, 1986; Cockburn and Ormrod, 1993; MacK enzie and Wajcman, 1999; Oudshoorn and Pinch, 2003; Wajcman, 1991; Zorn et al., 2007). Though several comparative studies aimed at a critical review of the underlying theoretical concepts of gender in the gender technology lit erature, particularly in case studies (e.g. Faulkner, 2000; Gill and Grint, 1995; Wajcman, 2007) that have been conducted, there is still a lack of a thorough overview that focuses on the *processes* of gendering technology. A deeper un derstanding of the mechanisms that are at work when technological artefacts are gendered, however, is a crucial prerequisite for making suggestions for an alternative design that might be called feminist. In order to be able to change the design of artefacts and apply more appropriate design methods, designers of technologies need to know in which sense their artefacts might be problematic.

The gender category and, therefore, the gendering of technological arte facts is, however, a somewhat intricate subject. Some technology designers tend to ignore gender. For example, Anne Jorunne Berg (1999) pointed out that a designer of smart houses thought of the target consumers as 'everyone', while her study revealed that these artefacts were designed for the technically interested male user und not for supporting, for example, housework. Other technical designs such as lady shavers (Van Oost, 2003) or the Volvo concept car (Temm, 2008) explicitly take gender into account. This approach to de sign becomes problematic when gender stereotypes are built into technology, for instance when the design mirrors the assumption that women are techno logically incompetent,[2] while the assumption of gender neutral technology is

2 | For example, Van Oost (2003) shows in her historical study that Philips shavers were not only gendered by design (e.g. pink vs. black or metallic colors), but also by func tionalities. Whereas the Ladyshave can hardly be opened without destroying the device, men's Philishave has screws to open it and a display that conveys technical information to the user. Van Oost concludes that Philips shavers not only reflect the gendering of

particularly disputable, when it is assumed that the artefact addresses 'every one' without explicitly taking notice of gender and other differences. For the latter case it has been shown that gender is often an implicit element of the design process in the sense that certain user groups have to make a greater ef fort than others in order to access the technology or to make the use of artefacts meaningful for them (Oudshoorn et al., 2004).

These two forms of gendering were already well described by the concept of the gender script that distinguishes between explicit and implicit notions (see Van Oost, 2003; Rommes, 2002). Rommes, moreover, specified the mechanism behind implicit gender scripts. She pointed out that designers unconsciously base their design choices on their own preferences, interests, and competencies. Referring to Akrich's early use of the term, artefacts thus often become biased and one sided due to the so called "I methodology" (Akrich, 1995).

So far, the gender script concept and its related gendering mechanisms, stereotyping, and 'I methodology', seem to be a good starting point to un derstanding gendering processes in technology design. However, the existing 'gender in technology' literature provides insights also into other gendering mechanisms that defy explanation by the script concept. One gendered impact of technologies which the script concept can hardly describe are the substantial effects that some computational artefacts such as concepts of humanness in Artificial Intelligence (e.g. Suchman, 2007) or human like artificial characters (e.g. Weber and Bath, 2007) can have on the users' subjectivities. The gen deredness of these artefacts cannot be understood merely as a form of stereo types, i.e. an association of certain qualities and competencies with femininity or masculinity, since they tend to normalize gender and re establish the two sex system itself. Moreover, such effects are not necessarily related to the de signers' visions of use and users that are essential for the definition of the gen der script. By focusing on the designers' *user* representations, gender scripts can neither explain the gendering of human bodies and behavior, nor does it capture modelling methods such as object orientation, classifications schemes or dichotomies underlying technology designs. These artefacts, though, have been proven to have (gender) politics, too (see Bath, 2010; Bowker and Star, 1999; Crutzen and Gerissen, 2000). Hence, looking at computational artefacts, not in the narrow sense of technologies and products, but also including con

technological competence, they also construct and strengthen the prevailing gendering of technological competence. "In other words: Philips not only produces shavers but also genders" (Van Oost, 2003: 206).

cepts and material symbolic entities produced by those who work in com puting, raises the awareness for gender analysis in the field of technology. Extending the framework to gendered technological concepts and assumptions contributes productively to the search for a feminist design methodology, be cause counteracting the related gendering mechanisms might be even more effective and substantial than only avoiding gender scripts.

In the remainder of this paper I will discuss four categories of computation al artefacts (and their related gendering mechanisms) that have been introduced so far: alleged neutral technologies for 'everyone', technologies for the female user, representations of 'the human' in IT and abstract concepts/basic research. This distinction will be explored further in the next section which argues that there is a strong relationship between the categories of artefacts chosen, a cer tain gendering mechanism and a certain strategy of counteracting this gender ing mechanism. In the main part of the paper each of the four categories is discussed in detail: it starts with the gendering mechanism that is likely to occur and gives examples from feminist STS research that illustrate this process. As a next step, a feminist political epistemological strategy is suggested that might avoid such a gendering. Finally, possible technology design methods borrowed from critical computing are introduced that appear suitable to implement the chosen strategy in a concrete design process. Taken together, these four sections aim at a methodological framework that integrates systematic gender analysis based on STS research with technology design into computer science. How ever, such a pragmatic approach can only form a complete methodology if it is reflected upon on the basis of feminist theory and politics. The potential and limitations of the technology design procedure suggested will be evaluated in the last section. The concepts from feminist research that are needed to give the approach a theoretical foundation are introduced in the following section.

De-gendering Computational Artefacts: Theoretical Foundations for Counteracting Gendering Mechanisms

The methodology proposed in this article aims at avoiding the reproduction of the existing structural symbolic gender order and rupturing its further stabili zation by technology design. I call this objective 'de gendering computational artefacts'. This term does not imply that there can be a gender free zone or a gender neutral artefact. Speaking with Judith Butler, entities like bodies

cannot escape ongoing processes of gender signification and resignification (Butler, 1993). Judith Lorber argues that using more than two polarized cat egories of sex, sexuality and gender makes research more accurate. The term '*de* gendering' refers to her political goal of going beyond binaries (Lorber, 2000, 2005). In this context it is rather meant as an attempt to challenge those designers who assume that their artefacts were gender neutral, because it pos tulates that technological artefacts were already beforehand in some ways gen dered. The term is also chosen as a counterpoint to some recent initiatives that intend to 'gender' technological artefacts by considering women's interests or demands in the design and thus producing a new essentialism (see e.g. Bührer and Schraudner, 2006). 'De gendering computational artefacts' is therefore an intervention on several levels. As such it requires a theoretical foundation.

It has already been mentioned that the gender script concept, which is of ten used to capture the concrete processes of gendering technology, is not suf ficient to describe certain gendering processes of computational artefacts. For instance, it cannot be applied to concepts of human behavior or ontological and epistemological assumptions in technology design, because of its focus on user representation. To understand the gendering of artefacts on such a conceptual level, I propose applying Barad's concept of 'posthumanist per formativity' (Barad, 2003). Barad describes posthumanist performativity as a materialist and posthumanist reworking of Judith Butler's notion of perfor mativity (Butler, 1990, 1993). Butler developed this notion within the context of feminist theorizing of the body by stating that sex is a materialization of gender norms that is contested at all times. Barad agrees to the procedural character of gendering and the relevance of existing social norms that change during the process. However, she criticizes that Butler understands matter (i.e. the body) as a passive product of discursive practices rather than conceiving it as an active agent participating in the process of materialization. By contrast, posthumanist performativity, is "a robust account of the materialization of all bodies 'human' and 'non human' and the material discursive practices by which their differential constitutions are marked" (Barad, 2003: 810). On this basis the gendering of artefacts can be conceptualized as a co materialization of matter (or computational artefacts, respectively) and gender. This concept allows for a description of the gendering of software applications, information systems, and user interfaces, but also the gendering of concepts and assump tions in technology design, modelling methods, and basic research.

In her concern to de emphasize the discursive and linguistic aspects within feminism and within STS research, Barad stresses the relevance of "taking

matter seriously" (Barad, 2007: 132). Posthumanist performativity is framed by her "epistem onto logical" theory of "agential realism" (Barad, 1996a, b, 2007) that she developed by drawing on as well as fundamentally criticizing and further developing the actor network theory, particularly the version of the feminist technoscience researcher Donna Haraway. Along this line of thinking, Barad conceives the relationship between humans and non human artefacts as a complex and heterogeneous network or hybrid, without presuming essen tial differences between humans and artefacts. However, she stresses to keep in mind that this relation between human and non humans is always asymmet ric. "Agential realism acknowledges the agency of both subjects and objects without pretending that there is some utopian symmetrical wholesome dia logue, outside of human representation." (Barad, 1996b) This would not mean that authorship lies in the hand of humans only, on the contrary: "the world kicks back" (Barad, 1998: 112). Agential Realism therefore concentrates on "real consequences, interventions, creative possibilities, and responsibilities of interacting with the world" (Barad, 1996a: 8).

Lucy Suchman (2007) translates Barad's account from physics to compu tational artefacts. Against the background of Artificial Intelligence, a field that she studied thoroughly, she also calls for acknowledging the specific agency of humans in processes of mutual configuration of humans and technologies, without reiterating traditional humanist notions of autonomous human agency, which essentialized differences between human and machines. Moreover, she takes Barad's concern a step further by emphasizing this notion of account ability that also includes boundary making between humans and machines. "The accountability involved is not, however, a matter of authorship in any simple sense, but rather a problem of understanding the effects of particular assemblages and assessing distributions, for better and worse, that they per form." (Suchman, 2007: 271) In this instance she refers to Barad: "We are responsible for the world in which we live not because it is an arbitrary choos ing, but because it is sedimented out of particular practices that we have a role in shaping." (Barad, 1998: 102) Suchman argues that an asymmetrically distributed agency between humans and the non human implies understand ing responsibilities as also being asymmetrically distributed. "Agencies and associated responsibilities reside neither in us nor in our artefacts, but in our intra actions. The question, following Barad, is how to configure assemblages in such a way that we can intra act responsibly and generatively with and through them." (Suchman, 2007: 285)

'De gendering computational artefacts' is based on this broad theoretical account opened up by Barad and Suchman. It aims at taking agencies and re sponsibilities in socio material assemblages of humans and artefacts seriously. 'De gendering computational artefacts' is inspired by Suchman's (2007) sug gestion of making 'accountable cuts' as a strategy of analysis and intervention. Choosing four characteristically problematic gendering mechanisms and their related artefacts as a starting point here should be seen as a form of preparation for cutting a concrete network of humans and artefacts in a responsible way. However, every design process requires a thorough analysis of the gender ing at work. The approach that will be proposed in this paper also applies the second strategy that Suchman (2007) suggests: 'expanding the frames'. While she proposes to disenchant the effects by zooming out to a wider view and explicating the hidden labor and contingencies, 'de gendering computational artefacts' aims to move forward from gender analysis towards feminist design. It is argued there that each category of artefacts not only correlates with a certain gendering mechanism, but requires a certain political epistemological positioning towards gender. This means that designers have to decide what kind of change in the structural symbolic gender order they intend to address when aiming to counteract the identified gendering in their designs.

My suggestion for this part is mainly borrowed from feminist theory and politics, which distinguishes strategies such as achieving gender equality, ac knowledging differences or deconstructing gender (see for instance Gill and Grint, 1995; Maass et al., 2007; Wajcman, 2007). While these approaches gen erally conceptualize gender or the gender technology relationship, my idea is to translate such strategies into technology design and its gendering. For instance, feminist theory interprets the gender equality approach (liberalism) as aiming to get more women into computer science and engineering, whereas I suggest analyzing whether artefacts should produce gender equality by de sign. Hence, I propose to determine a goal as a first step of a feminist (design) process. This goal, the envisioned outcome, should be situated and chosen according to the computational artefact in question. Considering the four cat egories of computational artefacts discussed above, there are several options as to what counteracting the gendering of computational artefact can mean: in the case of alleged neutral technologies that ignore certain user perspectives the best counter strategy seems to be that designers acknowledge differences between users. This means that these artefacts call for a gender difference ap proach, in order to provide equal access and meaningfulness. In the second type of technologies intended for women, it can be suggested that artefacts

should support issues assigned to the female realm as much as those tradition ally considered as masculine. This means that these artefacts call for a gender equality approach, in order to overcome gender differences and hierarchies. The third category of artefacts that contribute to identity building or even more changing subjectivities indicates that technology should enable users to question and reflect on the existing binary sex and gender system. Thus, a deconstructionist approach seems to be a good choice here, in order to avoid a further normalization of existing gender patterns. Many gendered concepts of the fourth category require a re contextualisation before critical and interven tionist strategies can be applied. It depends on the context revealed whether the alternate design should rather aim at changes in epistemological or ontological assumptions or both, and if this refers to one of the goals mentioned above.

In the following four sections the four categories of artefacts introduced are described in detail. For each gendering mechanism I will propose technol ogy design methods from the field of critical computing.

Alleged Neutral Technology and the 'I-Methodology'

Designers assume many technologies to be neutral, but a closer analysis re veals barriers in use. An example of these kinds of artefacts are early speech recognition systems in Artificial Intelligence that were said to not have been capable of recognizing female voices, since the designers did not think about the fact that adapting the technology to male voices could exclude female us ers. A more serious case study shows that even if designers explicitly aim to build technology 'for everyone', they are still in danger of excluding certain users by design. Els Rommes revealed the development of the Digital City Amsterdam as a design for hegemonic masculine interests (Oudshoorn et al., 2004; Rommes, 2002). She discovered that designers undermined their own agenda 'XS4all' (pronounced 'access for all') by using the 'I methodology' a form of implicit user representation. They unconsciously assumed that users would have the same technical equipment, knowledge and skills, the same preferences and interests, and thus, see themselves as representatives of the us ers. Since they often form a homosocial, predominantly masculine group, they actually inscribe this gendered background and knowledge, their concerns and attitudes into the technology.

The example of the early speech recognition systems refers to a (more or less) biological gender difference. It is argued that these artefacts could not be used by women, because of their higher pitched voice. Rommes, in contrast, draws on socio economic factors to demonstrate that the Digital City Amsterdam was gendered. Designers did not question essential, but gendered prerequisites, such as access to the latest generation of computers, a certain experience in the use of the Internet and the trial and error strategy. As Anne Jorunne Berg pointed out, such a structural exclusion of women and other 'others' from the use of certain technologies can already occur on the level of problem definitions that underlie technological solutions (Berg, 1999). Her study of smart houses illustrates that the designers were not aware of house work that is traditionally assigned to the female realm. The interviews revealed that they implicitly assume the customer to be a man interested in technology, not unlike the stereotype of the computer nerd.

All these examples illustrate the need for technology design method ologies that take into account a variety of users. Hence, the objective when facing alleged neutral technologies should be the inclusion of diverse users, equal access, and usability. The methodologies sought after should strive for the acknowledgement of differences, for example, physical and social gender differences, but also in terms of ethnicity, race, nation, class, age, and other categories.

Several subfields of computer science already have a long tradition of de veloping methods of technology design that aim to avoid the 'I methodology'. Ergonomics, socio technical systems design, and human computer interaction focus on getting to know the user, in order to build technologies for use and the real user instead of expecting that users will adapt to already existing tech nology (see for instance Dix et al., 1993; Nielsen, 1994). In the cases of the Digital City Amsterdam and the smart houses, designers could have conducted usability tests to realize that their products do not match the skills, interests, and preferences of the technology's envisioned target group (Oudshoorn et al., 2004). According to the field of human computer interaction, however, an alternative design should start with a thorough requirements analysis of the intended users not in the sense of allowing them only to test prototypes and end products, but involving them from the very start of the design process, which should to be understood as an evolutionary or cyclic user centred design (see for example Beyer and Holtzblatt, 1998; Preece et al., 2007). Although it has to be discussed which representatives of the users should be chosen, if the technology is meant to be used by everyone; particularly involving a diversity

of female users in the design process seems to be a way of preventing technologists from repeating the mistakes of the 'I methodology'.

Technologies for 'The Female User', Stereotypes and the Gendered Division of Labor

A second class of technologies contains those which are built for specific users, e.g. women as customers, or to support women in their workplaces, but which in effect codify gender difference and reinforce the traditional gender hierarchy. Examples of this kind are the round dialogue box for font selection designed by the graphic designer Aaron Marcus for white American women, which is built upon the assumption that females would prefer curvilinear shapes (Marcus, 1993), or the early word processing software Jeanette Hofmann analyzed, which assumed secretaries to be permanent beginners and by design defined them as technically unskilled users (Hofmann, 1999). Other case studies, for instance in the fields of nursing and call centre service work, show the lack of knowledge on 'invisible work', since these software systems were modelled in a way that fails to adequately support the workflows by technological means (for example Maass and Rommes, 2007; Wagner, 1993). Since 'invisible work' is often done by women (Star, 1991), it is particularly their work that remains undervalued, since designers either ignore its importance for the organization as a whole or its complexity.

Design for women obviously risks celebrating stereotypes about 'women', their preferences, skills and work, which should be avoided. A de gendering methodology, therefore, has to aim at attributing equal competencies to female and male users and upgrading women's work. Hence, designers should strive to inscribe gender equality into technologies, if they are designed for female users, for instance at women's workplaces as opposed to the case of technologies for general use, where they should become aware of gender differences and the diversity of users. As already mentioned, in the latter category of technologies user tests seem to be a useful tool for recognizing that software and user interfaces do not fit the intended real user. In the example of the round dialog box it was demonstrated that, regardless of the gender, all test persons preferred a squared and axially symmetrical layout of the dialog box and strongly disliked the 'female' user interface (Teasley et al., 1994). Thus,

the gender stereotype that women like curvilinear features, while men prefer squared ones, was clearly disproven.

However, if we want to move from analysis to an alternative design for the cases mentioned above, it is not enough to remain at the level of aiming to map social realities of work, life, and use as best as possible as it is often assumed in computer science modelling, since such approaches tend to re produce the existing structural symbolic gender order. Hence, if technologies need to be designed for a predominantly female group of users it takes more than only applying user centred design methods and evaluating usability. For a de gendered design of such technologies, an explicit political positioning for those who are structurally discriminated against seems necessary. The most well known research to support workplace democracy and establish better working conditions for workers and employees through the use of technology is the Scandinavian tradition of participatory design (e.g. Bjerknes and Brat teteig, 1995). Following this approach, a variety of methods were developed and tested such as future workshops, design games, and prototypes (see for instance Greenbaum and Kyng, 1991). The aims and guidelines to 'design for skill' and 'design for technical empowerment' were already successfully applied in women's workplaces such as nursing, office work or call centre service work (see Maass and Rommes, 2007; Wagner, 1993). Since strategies against deskilling, degrading or learning to adapt and to program software in certain contexts work against the traditional gender hierarchy, these partici patory design approaches can be regarded as de gendering methodologies, if they are enhanced by a critical awareness of the gendered patterns in society and symbolism.

Representation of 'The Human' in IT and the Perpetuation of Gender Norms

A third category of gendered technological artefacts include those that rep resent certain abilities, characteristics or even the nature of 'the human', but actually normalize gender stereotypical behavior. Persuasive examples are human like machines that explicitly display human bodies and human behav ior such as anthropomorphic sociable robots or emotional software agents. The bodily appearance of these artefacts, but also their concepts of action/behavior and interaction/communication were exposed as intrinsically permeated by gender stereotypes (e.g. Draude, 2005; Weber and Bath, 2007).

Against a further consolidation of these genderings, a de gendering meth odology should aim to de construct the binary sex and gender system. This might be accomplished by artefacts that offer users and designers the possibility to gain an understanding of gender (and technology) as social constructions and instable, constantly performed and negotiated categories. A design philosophy that "allows users to engender themselves, to attribute to themselves a gen dered identity of any one of a number of sorts, to create or perform themselves through using technology" (Cassell, 2003: 204) is 'underdetermined design'. While Cassell's ideas were primarily directed at encouraging gender identity formation in computer games for children that transcend gender stereotypes, "technology as experience" (McCarthy and Wright, 2004) is an experimental account addressing 'felt life'. Rooted in phenomenology, this theoretical ap proach serves as a basis for some broader design methodologies. 'Design for experience' (Sengers, 2004; Sengers et al., 2004), as opposed to designing ex perience into an artefact, focuses not only on the subjective experiences (e.g. sensual, emotional, compositional, spatio temporal) of the users, but also opens up space for potentiality and meaningfulness, i.e. a plurality of processes that construct meaning and which should not be closed or specified by design. 'Re flective Design' goes one step further in stating that "reflection should be a core design outcome of HCI[3]" (Sengers et al., 2005: 49). Reflection, in this case, is to be understood as critical reflection that renders users aware of unconscious aspects of experience. The methodology consists of principles and strategies which combine the analysis of the ways technology reflects and perpetuates un conscious cultural assumptions (such as the politics of race, gender, and econ omy) with the design, building, and evaluation of computational artefacts that reflect alternative possibilities. It aims at providing support for self reflection. To my mind, this approach could be productively used to raise an awareness of gender stereotypes internalized by users, designers, and artefacts.

Formalisms, Abstract Concepts, and Basic Research: De-contextualization and Objectivism

A fourth category of computational artefacts includes algorithms, formal ob jects, and conceptual approaches in computer science that can be said to have

3 | HCI stands for Human Computer Interaction.

gender politics. Abstraction, formalization, and classification produce the im pression of objectivity and a neutral research subject. Here, it seems problem atic that these processes inevitably entangled with computer scientists' work disguise explicit and implicit decisions made in the process of technology de sign, while they in effect establish hierarchies of knowledge, gendered clas sifications or dichotomies. Striking examples of this kind of gendering mecha nism are the mathematical tools used to transform raw data from a computer tomograph into colored pictures of the brain. It has been shown (Kaiser et al., 2004) that depending on the algorithm and threshold chosen gender dif ferences of the brain appear or do not appear. Thus, formalization is not innocent. A field where this has also been demonstrated is the representation of knowledge. For instance, CYC, a knowledge based system, which received a huge amount of research funding over 10 years during the 1980s in the US, aimed to codify common sense knowledge. However, only declarative knowl edge has been taken into account, whereas procedural knowledge has been ignored. Alison Adam and Catherine Sherron complain that the knowledge, which is excluded from formal representation, corresponds with the knowl edge that is traditionally assigned to the female realm (Adam, 1998; Sher ron, 2000). Moreover, CYC assumes a universal subject of knowledge. Con trary to feminist insights into the situatedness of all knowledge (e.g Haraway, 1988), it is taken for granted that all knowers share the same reality, "be they a professor, waitress, a six year old child, or even a lawyer" (Lenat and Guha, 1990, according to Adam, 1998: 85). Recent formalization projects such as the Semantic Web or Linked Open Data encounter similar problems (see Bath, 2013). Another exemplification of the category of formalisms, abstract con cepts, and basic research are dichotomies that underlie computational concepts that might be symbolically gendered such as the dualisms of mind and body or rationality and emotionality. Attempts to overcome these dichotomies, e.g. in artificial intelligence, often consolidate a new, but also deeply gendered symbolic order (see for instance Bath, 2010).

A de gendering strategy for these formal objects presupposes a re con textualization in use and in structural as well as cultural effects. It requires questioning assumptions, ontologies and epistemologies of technology design, and a dissolution of dichotomies. Since such gendering processes do not nec essarily refer to users and use, alternative technology design methods should mainly involve designers.

'Mind Scripting' (Allhutter, 2012) is an approach to identify presumptions and gender scripts in the process of designing technology. The technique is

based on Frigga Haug's "memory work" that uses one page long texts writ ten by group members to deconstruct shared experiences and assumptions re flecting societal structures (Haug, 1999). "Mind Scripting" transfers this idea, which originated in the consciousness raising groups of the 1970s, to present groups of technology designers (Allhutter, 2012). "Value Sensitive Design" (Friedman and Kahn, 2003) is a method that aims to inscribe certain desired values such as equity, diversity, and inclusion into technological artefacts. It contains three levels of inquiry: empirical, technological and, most notably, conceptual studies that are based on moral philosophy and ethics. However, the method was already applied to computer game design by feminist schol ars (e.g. Flanagan et al., 2007). Particularly in order to undermine or resolve dichotomies that are gendered in western traditional thought and connected to technology design, "Critical Technical Practice" (Agre, 1997) can be a helpful tool. This method suggests analyzing designers' discourses, in order to iden tify key metaphors and then to invert these terms. It results in bringing in the margin to the center of technology design. For instance, Agre and Chap man (1987) developed a system, in which the model of abstract cognition that was dominant in Artificial Intelligence during the 1980s was replaced by a situated action approach that implemented Suchmans' theoretical account. An other technique to question and change concepts of basic research in computer science are interventionist laboratory studies. As a form of anthropological inquiry commonly used in science and technology studies (STS) laboratory studies are interventionist as such. However, applied to the context of basic research in computer science, this method can be explicitly guided by feminist goals in design such as the ontological and epistemological 'de gendering of computational artefacts'. This has been explored by own research in the field of anthropomorphic software agents (see for example Weber and Bath, 2007). Hence, there are already a few techniques that seem promising to use, in order to re contextualize formal objects and replace questionable ontological and epistemological assumptions in basic research in computer science.

Critical and Feminist Re-reading of the Methodological Framework

The approach that has been roughly presented in the last sections aims at a basic methodological framework for feminist technology design in computer science. It provides a broad spectrum of methods helpful for 'de gendering

computational artefacts'. The suggestions are based on a thorough and system atic analysis of gendering processes. It can, however, only become a method ology, if it is critically re read from the feminist theory perspective introduced at the beginning and evaluated in practice. This section discusses theoretical traps and possible empirical improvements of the four strands.

When technologies are created 'for everyone', designers often inscribe their own mental models into the technology. To avoid a gendering of the arte facts resulting from such an 'I methodology' it was proposed to apply methods from user centered design. Such a de gendering strategy is based on a gender equality argument and aims at the inclusion of users. Therefore, this strategy tends to essentialize alleged differences between women and men. In order to accomplish that, diversity and particularly gender differences have to be recognized. Involving diverse users and considering intersectional exclusions might support avoiding such traps. A second argument that needs to be taken into account when applying user centered design for de gendering purposes to this type of artefacts is that the method only has the potential to adjust the technology to users by empirical means. If the users involved, however, per form and perceive gender in a very traditional way, for instance, strictly binary or stereotyped, this method cannot bring critical, deconstructive impulses to technology design. Therefore, the participation of different users might extend design perspectives for products that better meet the expectations of certain users. However, these methods do not necessarily bring a gender critical ap proach to design.

Inscribing gendered images of use, users, and the division of labor into computational artefacts was identified as a second gendering mechanism that often occurs in the design of technologies intended for female users. To coun teract stereotypes and gendered hierarchical patterns in such processes, partic ipatory design methods were suggested. Especially approaches from the Scan dinavian tradition appear to be appropriate here, since they challenge existing societal structures of inequality and, thus, avoid reproducing the structural gender order by technological means. However, these approaches sometimes imply a rather simplistic view in how far emancipatory ideals can be built into technology. STS and media studies views can help to correct such narrow interpretations. It can moreover be put forward that applying these techniques often means to aim at making visible and revaluing women's work and com petencies. From a feminist perspective this means that the strategy tends to re essentialize gender. It is also problematic, since it aims to make aspects of work visible that should rather be hidden from a political perspective (see for

example Bowker and Star, 1999). Thus, the participatory design approach, too, needs a second reflection when adapted for de gendering purposes.

The third de gendering strategy addressed representations of 'the human' in IT, which tend to normalize gender stereotypes. In order to deconstruct not only such gendered assumptions inscribed into the artefacts, but also the un derlying binary sex and gender system, it was proposed to combine 'reflective design' and 'design for experience' with insights of current gender studies. Both of these design approaches are based on a constructivist epistemology. They furthermore combine technology design with critical social theory. These methods can therefore easily be connected with current feminist theory and deconstructivist approaches. However, they have so far not been applied as de gendering strategies. Beyond that, it is an open question whether 'reflec tive design' and 'design for experience' can be applied to a broader scope of technologies. Since the first two types of artefacts discussed in this paper tend to essentialize gender, deconstructivist approaches might also be promising methods to avoid the gendering of such technologies. It has to be explored whether there are more suitable techniques to deconstruct the binary sex and gender system by technology design in these cases.

The methods proposed to avoid the gendering of formal objects and ba sic research in computer science need further empirical evaluation. Most of these methods require either a practical implementation to explore, whether they can serve as a de gendering strategy, or whether they were originally de veloped for guiding software development and not for revealing problematic presumptions in technological concepts. It is the question whether they can be transferred to formalisms, abstract concepts, and basic research, and what they can contribute to re contextualising artefacts, counteracting disputable epistemological and ontological assumptions in the design process or resolv ing traditional dichotomies in basic technological concepts. Particularly in this area there is need for further research on de gendering methods.

In summary, this paper introduced a systematic approach to feminist technol ogy design. It presented a starting point for a general methodology to coun teract the gendering of computational artefacts that goes far beyond existing suggestions, which so far have been either restricted to software applications or to problematic guidelines. The proposed de gendering approach takes into account the complex gendering processes, which might occur in the field of computional artefact design. It clarifies for what cases well known design methods from the field of critical computing such as participatory design are

likely to support de gendering processes. 'De gendering computational artefacts' furthermore suggests design methods for those artefacts that have rarely been addressed, in order to avoid gendering by earlier methods. In critically reconnecting this approach with feminist theory we should be cautious not use it as a simple recipe. It has been argued that analyzing the gendering and aiming at a 'de gendering of computational artefacts' needs a careful theoretical background, in order to avoid well known shortcomings such as essentializing gender or technology or falling into the trap of technological determinism.

Nevertheless, it requires further discussion whether the artefacts that have been developed according to the proposed methodology can, in the end, be 'better' or 'less gendered' than those developed outside of this framework. Why does design and particularly design for de gendering matter? Numerous STS case studies have stressed that designers' intentions do not necessarily result in a use that was intended. Users rather adopt technologies in their own way be it along designers' concepts and scripts or against them (see for instance Oudshoorn and Pinch, 2003). I would counter that these insights have already been included in the methodological framework theoretically, but also by the procedure: the concept of posthumanist performativity takes into consideration that gender signification and re signification is complex, situated, and historically continuously changing. The actual gendering processes are neither predictable, nor controllable for the future use of an artefact. Gender is as fluid and unstable as artefacts are. However, design is not arbitrary. On the contrary, it has as Suchman (2007) and Barad (1996a, b, 1998) emphasize 'real consequences' (see also Van der Velden and Mörtberg, 2012). On this basis, 'de gendering computational artefacts' calls for a responsible handling of the design situation, where the use of the artefacts created is not foreseeable. Since the future use cannot be empirically researched, it takes into account those gendering mechanisms that have already been identified in earlier STS studies and aims to avoid them in future designs. However, practically speaking, the approach proposed needs empirical examination. This evaluation might result in further refinement and enhancement of the methodology. Hence, the challenge is now to work with the methodological framework of 'de gendering computational artefacts' in order to gain more experience with it.

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Masks between the Visible and the Invisible

Cecile K. M. Crutzen

> "The world men are born into contains many things, natural and artificial, living and dead, transient and sempiternal, all of which have in common that they appear and hence are meant to be seen, heard, touched, tasted and smelled, to be perceived by sentient creatures endowed with the appropriate sense organs. Nothing could appear, the word 'appearance' would make no sense, if recipients of appearances did not exist – living creatures able to acknowledge and react to – in flight or desire, approval or disapproval, blame or praise – what is not merely there but appears to them and is meant for their perception."
> (Arendt, 1978: 19)

The words 'mask', 'masking' and 'masquerade' are metaphors for discussing, describing, and analyzing the visible and invisible acting of human and non-human actors. The mask has for a long time been a symbol for the interpretation and representation of the visible and invisible and is a powerful device for human experience and transformation in many cultures. It still lives strongly within our societies where the mixing of reality and virtuality will continue to increase.

Masks are devices for hiding, conserving, transformation, and mediation, giving humans the protection they need. Masks have become a dualistic means of concealment and hiding but also of liberation, disclosure, and revealment. They always offer the opportunity of unmasking, disrupting the mental invis-

ibility of our self, the others and the daily life we act in. In the masking, gender aspects play a crucial role.

Looking to the differences and resemblances with masking in theatre, in rites and in daily life I formulated questions like, "Who has the right to present masks and to turn others into an audience?" The conflict between aspects of authenticity and privacy will intensify because the masks in our mixed reality create fragmented, partial identities referring to human and non-human actors. As the masquerade becomes a stage for discussing femininity, the masquerade will give us the opportunity to negotiate humanity in confrontation with the super robots humankind wants to create.

Interaction

Interaction is an exchange of representations between actors. Speaking, gesturing, writing, making, designing are actions in which actors present themselves to other actors: both human and non-human. All acting of actors is a representation of themselves in a world of other actors and at the same time an interpretation of that world. Every interpretation and representation will influence future (inter-)actions. Not only the actual behavior but also the actions, which are not executed (actions in deficient mode), are presentable and interpretable because these absent actions also influence the process, since they comprise the possibility of being expected or missed (Crutzen, 2000: 40–107, 2003: 89–91).

Interaction is an ongoing process of mutual actions from several actors in a specific situation or a series of situations. It is a process of consciously and unconsciously constructing meaning through repeated interpretation and representation of the actors, which is always situated in the interaction itself, and it depends on the horizons and the backgrounds of the actors and their representations involved and the specific interaction. All actors, human and non-human, "are part of the world in its ongoing intra-activity [...] human practices have a role to play as part of the material configuration of the world in its intra-active becoming. 'Humans' are part of the world-body space in its dynamic structuration" (Barad, 2003: 828–829). The construction of meaning occurs in the dynamics of the actors' acting in their actions. Visibility and invisibility for each other will influence the borders and the materiality of the actors involved.

Visibility and Invisibility

> "Literature, music, the passions, but also the experience of the visible world are [...] the exploration of an invisible and the disclosure of a universe of ideas. The difference is simply that this invisible, these ideas [...] cannot be detached from the sensible appearances and be erected into a second positivity. [...] With the first vision, the first contact, the first pleasure, there is initiation, that is, not the positing of a content, but the opening of a dimension that can never again be closed, the establishment of a level in terms of which every other experience will henceforth be situated. The idea is this level, this dimension. It is therefore not a de facto invisible, like an object hidden behind another, and not an absolute invisible, which would have nothing to do with the visible. Rather it is the invisible of this world, that which inhabits this world, sustains it, and renders it visible, its own and interior possibility, the Being of this being."
> (Merleau-Ponty, 1968: 149, 151)

Visibility for humans represents everything that humans can, directly or indirectly, perceive with their senses: hearing, seeing, feeling, smelling, and tasting. Artificial actors have sensors and other input possibilities to simulate the senses of humans.

Humans have developed and used a wide range of visual, haptic, and acoustic instruments for attending a certain degree of visibility, such as microscopes, binoculars, and fire alarms. In the Greek theatre the mask was a tool to make the actors more visible to all of the audience and to make the actors' voices audible. The masks had a small megaphone-like contraption concealed in the mouth of the mask. The mask not only enhanced the sense of seeing a face, but also enhanced the voice (Vervain and Wiles, 2001: 255, 270).

Visibility of a human or artificial actor for its environment can be defined as the possibility of unveiling its interactions (Crutzen and Hein, 2009: 468). This unveiling does not necessarily need to be done by one person; it can also be achieved by social interactions in the interaction itself within human environments such as 'house', 'neighbourhood', 'work', 'homeland', and of course the theatre. Invisible acting in interaction with artificial devices occurs when users during the interaction do not perceive triggers for critically reflect-

ing and developing emotions about the ready-made artificial acting presented: "[...] Most of reality is hidden from direct sensory experience and must be adumbrated and conceptualized or imagined in our encounter with reality." (Laughlin, 1993: 5)

An artificial actor's invisibility for humans is unlimited. Marc Weiser (1994: 7) argues for an "invisibility of the tool", that it should "not intrude" into our "consciousness", that it should disappear from our awareness, the focus should be "the task and not the tool". A tool might be visible in itself, but it will be invisible "as a part of a context of use". This means that the activity performed with the tool should be obvious, the tool itself should not be the centre of our attention. He asks what kind of interface this tool should have and suggests "moving to full-body sensing and interaction" and "by maximally utilising all of our body's input and output channels" (Weiser, 1994: 8). So, according to him and those that share his view, the visibility of human actors to artificial actors should increase more and more. However, the interaction of humans with artificial actors should be mentally invisible for humans.

Mental, Physical, and Methodical Invisibility

Invisibility can be classified in mental, physical, and methodical invisibility (Crutzen and Hein, 2009). Physical invisibility of artificial actors for humans occurs because many distributed devices are hidden in our environment. A continuous process of miniaturization makes it impossible to recognize them. Not feeling their presence, not seeing their full (inter-)actional options, but only some designer-intended fractional output, makes it impossible to understand the complete arsenal of their possible representations. They can only be physically visible in the effects of their action, which can take place in our absence.

In our daily life a lot of things, tools, and even human actors are mentally invisible. Mental invisibility occurs when domesticated artificial products are taken for granted, when they are thought of as a natural part of our daily life and become a part of our routines. The evident and continuous availability of artificial products causes their disappearance in the complexity of our environment. The humans in such environments can also become mentally invisible if they act according to the expectations of designers and users inspired by the traditions and rules of our society. People observed by intelligent cameras are mentally visible for the artificial actor in the form of software only if they act outside the range of normal behavior.

Human actors can experience other actors as 'actable' if these actors present themselves in a way which is interpretable from their own experiences. That does not mean that this is the intended interpretation because each actor has a personal horizon of experiences and expectations. Physical visibility is a necessary condition of actability. So humans can perceive the performance of the non-human actor and humans can give meaning to them by drawing them into their interactions. A sound can be physically visible but until giving meaning to it, for instance as music, it will not be actable. Actability requires the mental visibility of an invisible meaning.

Usually humans cannot always say what they really do because it is unconscious – they do not reflect on it and cannot describe it. The details of everyday work become second nature and invisible (Beyer and Holtzblatt, 1993: 93). Mental invisibility is not only negative. Humans require a lot of obviousness in their living world in order to deal with daily life. That is precisely the way we love our environment, because our adaptation to our interactional worlds involves a lot of effort to make it work. Humans have to accomplish that adaptation. The evident and continuous availability of technology causes its disappearance in the complexity of our environment. Humans integrate the ready-made technological acting in their routine acting, accepting it without reflection and emotions. Mental invisibility can be seen as a precondition for the stabilization of use and the domestication of technology and harmonious living, but it should not be a frozen final state of the human actors in a community.

The physical and mental visibility of artificial actors to human actors is limited within the technical constraints of their construction, it can be determined purposefully by designers through the implemented data-models, processing functionality, and the chosen sensors and actors. In the future, our physical body representations and movements will be unconsciously the cause of actions and interactions in our technological environment. Technology resides in the periphery of our attention; artificial actors continuously whispering in our background, observing our daily behavior. People become the objects of the ongoing conversations of artificial agents that are providing us with services, without demanding a conscious effort on our behalf or without involving us in their interactivities. The artificial agents that humans are allowed to perceive will fake emotions and obviousness in their acting to seduce us into interacting.

Methodical invisibility and visibility appear through the assumptions of the makers embedded beforehand in the ready-made acting of the artificial

product. The interpretation and representation work has been accomplished partly before the product is ready made and the actions of the artificial actor take place. The way an artificial actor can interpret and represent depends not only on the activity from the human but also on the ready-made acting, which is constructed.

If people act according to a ready-made script within a prepared setting and frame, then their acting is methodically visible and becomes mostly mentally invisible for themselves; other acting possibilities are made invisible. This methodical invisibility shapes and limits the interactional spaces in which users can act and it will irrevocably make solutions unimaginable despite their makeability. This is even more true as this methodical invisibility is a mental invisibility on behalf of the makers of artificial products. Their scripts and assumptions are frozen in the structures of modelling methods that are embedded in their software development tools (Crutzen and Hein, 2009).

Based on my definition, visibility and invisibility of (artificial) actors are not oppositional, because every acting produces traces in our environment. The actors are not simply 'visible' or 'invisible'. Maurice Merleau-Ponty (1968) said there always stays something invisible in the heart of the visible. People need their senses and their body before arriving at a vision. Actable actors are always partly visible and invisible. However, the acting of human and non-human actors is mostly only visible in its effects; they act behind the scenes. We cannot see the artificial actor in a service call, however, by following the instructions we can get the information we need.

The space between the visible and the invisible is a dialogue space where human actors can design their own interpretations. It is a space of conflicts but also a space of adventures where humans can play with the contradictions of living in a world with artificial actors. According to Heidegger, the essence of technology is that it "unconceals" what became obvious, making it mentally visible and perceptible again (Heidegger, 1962: 12–13). In the interactions between human and non-human actors there is always a play in progress between visible and invisible.

Identity and Visibility

The *identity* of an actor presented to other actors is the meaning other actors give to the actor's performance. "Social interaction is a negotiation of identities between people in a given environment." (Boyd, 2002: 11) The meanings other actors give to the actor's performances constructs the social identities of

an actor. According to Danah Boyd, humans do a lot of self-monitoring and self-management to control "the impressions that others might perceive, to convey the appropriate information at the appropriate time". The identities of humans are always facets of the personal internal identities and public social identities they comprise; identity is a dynamic process anticipating and changing in their several interactional worlds. "As people engage socially, they project aspects of their internal identity into a social identity for others to perceive. Based on the situation, people only present a particular facet of their internal identity for consideration." (Boyd, 2002: 11)

Personal internal identity is not a closed decisive whole. Human identities are not fixed, they are "inherently unstable, differentiated, dispersed, and yet strangely coherent" (quote of Vicky Kirby in Barad, 2003: 828). In their interaction, actors can develop new identities, change their identities and alternate between them. Internal identities can be partly masked by the social identities humans present. However, the used masks will always in some way refer to and connect the internal identities and the social contexts. Humans cannot totally separate their internal identities from their social identities. Artificial actors can only present those facets of the inner self which are preplanned by the designers and only when they receive adequate inputs from their environment to do so.

Identity will always remain a very vague concept, but according to Anselm Strauss

> "identity is connected with the fateful appraisals made of oneself – by oneself – and by others. Everyone presents himself to the others and to himself, and sees himself in the mirrors of their judgments. The masks he then and thereafter presents to the world and its citizens are fashioned upon his anticipations of their judgments. The others present themselves too; they wear their own brands of mask and they get appraised in turn" (Strauss, 1997: 11).

In this sense, interactions between human actors and artificial actors can give the human actor a specific identity. We speak of users because of their specific interactions with Information and Communication Technology (ICT). Identity is not restricted to only human actors. We also speak of the identity of artefacts, companies, and communities. The social identity of artificial actors can be interpreted as their actable functionality. Their internal identity can be hidden by the surface of their appearance; the 'social and huggable' love-return-

ing pet robots have a face, they move their eyes, they make gestures, however, their internal identity is a machine executing a software depending on the input and the feedback the machine can receive with its sensors.

Identity as a Mask in the Theatre of Daily Life

The original use of the word *person* derives from persona – the masks worn by characters in Greek tragedies: "As a tool of impersonation, the mask is considered to be a convention which enables the actor to separate himself from a particularized communal identity in order to become a symbolic image of a more universal condition." (Mitchell, 1985: 7)

Goffman has used terms from the theatre context to analyze the identity concept: the visible human identity is a performance of everyday social activities, in which situationally appropriate behaviors are set up on the front stage, "[...] that part of the individual's performance which regularly functions in a general and fixed fashion to define the situation for those who observe the performance" (Goffman, 1959: 22), and situationally inappropriate acting will take place 'backstage', out of sight. At the front, human actors establish their social identity. At the front, the standardization of roles will make the person 'actable'. Other human and non-human actors can understand the individual's acting because of its normalized meaning. The self as a social identity is the mask the individual wears in social situations, but it is also the human being behind the mask who decides which mask to wear:

> "A correctly staged and performed character leads the audience to impute a self to a performed character, but this imputation – this self – is a product of a scene that comes off; and is not a cause of it. The self, then, as a performed character, is not an organic thing that has a specific location, [...] it is a dramatic effect arising diffusely from a scene that is presented, and the characteristic issue, the crucial concern, is whether it will be credited or discredited." (Goffman, 1959: 252–253)

Between a mask and its wearer there is a continuous interaction; the wearer animates the mask and the mask animates the wearer. Role playing is not masking the 'true person', but performances will transform humans into persons (Lawler, 2008: 105–106). According to Ian Hacking "the roles are not gliding surfaces that conceal the true person. The roles become aspects of the person, some more owned, some more resented, but always an evolving side of what

the person is. [...] Some roles become not only habitual, but almost an integral part of the body" (Hacking, 2004: 290, 299).

The Theatre as a Metaphor for Virtual Worlds

As Maggie Cooper and Ivor Benjamin mentioned already in 1995, the design of virtual worlds and the virtual world itself is analogous to a theatre and its creation:

> "A place where something will happen, and which must be designed and staged and peopled to suit that which will take place there. The design and construction of the inanimate elements of virtual worlds is then analogous to the design and construction of sets, scenery, properties; to the location and contents of an envisionment." (Cooper and Benjamin, 1995)

Brenda Laurel and Anna Swartling also compared the interaction between designers, users, and technology with a theatre play. Brenda Laurel focused on human interaction by comparing software with theatre:

> "In theatrical terms a program (or a cluster of interacting programs) is analogous to a script, including its stage directions. [...] Its interesting potential lay not in its ability to perform calculations, but in its capacity to represent action in which humans could participate. [...] functionality consists of the actions that are performed by people and computers working in concert, and programs are the means for creating the potential for those actions." (Laurel, 1993: 44–45)

In Laurel's concept of software there is the restriction of human actors to only play "in the interface" (Laurel, 1993: 4) in the same way as the non-human actors, determined by the formal software script:

> "In a theatrical view of human-computer activity, the stage is a virtual world. It is populated by agents, both human and computer-generated, and other elements of the representational context. [...] The technical magic that supports the representation, as in the theatre, is behind the scenes." (Laurel, 1993: 17)

Anna Swartling (2008) has used the theatre metaphor to make visible the ideological elements not only within information system acquisition but also within human computer interaction research. She presents theories, analyses and arguments in the form of a theatrical script. Her focus was on power structures and the ways common sense is constructed within the discourses of information systems development.

The stage theory of Goffman is often used to analyze and describe the interactions in social networks. Nikki Sannicolas sees the "... dramaturgy demonstrated every day within the on-line chat networks. Several scripts for the stage itself, being internet chat, have been written by the media, attracting different audiences and performers" (Sannicolas, 1997).

In my rewriting of the ontology of the Object Oriented (OO) approach in software design (Crutzen, 2000, 2003; Crutzen and Gerrissen, 2000) I used the theatre metaphor to give the software users a position of author and director in an artificial OBJECTs play. The OBJECT is the basic unit in a description of an OBJECT world, which functions as a SCRIPT for an 'interaction play' of cooperating OBJECTs. The OBJECTs are descriptions of ROLEs. A performance of an OBJECT world – the execution of a software program – is like the performance of a theatre play. The imagination of the authors of such Object Oriented theatre scripts comes to reality by creating ROLE- and ACTOR-types and by instantiating ACTORs which act according to their SCRIPT. The user, as a director or author, could create new ACTORTYPEs from the available present-at-hand ROLEs and by aggregation change the performance in new plays.

However, in the Object Oriented software the OBJECTs are mostly masked. The behavior of the OBJECT is contained in the methods of the OBJECTs. The covering up of data types and methods is called encapsulation. It refers to an object concept that is placed as an abstraction mask on reality. Through that mask we can see reality as closed units with hierarchical relations and planned interaction, where the user acquired the role of a chorus member with a standardized mask like the tragic chorus in Greek theatre (Mitchell, 1985: 6) and where the software designer has the power to look behind the mask of encapsulation. Susan Leigh Star has unmasked the making and modelling process of our technological environments by saying that these masks will temper "the clutter of the visible" and that the masks are abstractions "that will stand quietly, cleanly and docilely for the noisome, messy actions and materials" (Star, 1991: 82).

The Mask

Masks are and will be worn and used in our everyday lives, at the theatre, and in virtual life. The mask is a powerful symbol and device for human experience and transformation in many cultures. It still lives strongly within our current culture, and it will live in our future cultures and societies, where the mixing of reality and virtuality will intensify. In their functionality and appearances masks participate in a "chain of reference, which turns out not to terminate in some fixed referent". Every used mask "bears a series of imprints from previous maskings" and "seems to invoke an endless series of references that leaves a trace" (Wiszniewski and Coyne, 2002: 203). These traces are the opportunities to make the invisible visible again.

The masked performer goes back far earlier than anything recognizable as theatre. In rites the mask was venerated; it was and still is used for the embodiment of the spirit to be consulted and for the representation of desired events. Masks have the potential for the exaltation of the individual and the revealment of the power of the god captured in its very essence. The mask effects change

> "[...] not only within the wearer, but also outside – in the world he contacted. The primitive mask allowed one reality to be supplanted by another as it granted its wearer the power and freedom to perform unconventional acts. [...] As a device of transformation, it enabled its wearer to transcend one reality and experience another reality of his own creation" (Mitchell, 1985: 2–3).

The change of appearance by masking can have purposes of protection, make-believe, social acceptance, disguise, amusement, or religious devotion.

The Mask as a Hiding Device

A mask will always conceal; masking means cloaking or disguising. The meaning of masquerade in Computer Science in terms of communications security issues is a disguise. It is seen as an attack where the attacker pretends to be an authorized user of a system in order to gain access to it or to gain greater privileges than he is authorized for. A masquerade may be attempted through the use of stolen login IDs and passwords, through finding security gaps in programs, or through bypassing the authentication mechanism. Once

the attacker has been authorized for entry, he may have full access to the organization's critical data, and (depending on the privilege level he pretends to have) may be able to modify and delete software and data, and make changes to network configuration and routing information.[1]

A 'Trojan horse' is an example of software masked as a desirable gadget for the user such as a game, often a path for viruses or other malicious codes to be smuggled into a computer system. However, it actually hides a program to steal passwords and acquire remote access to the computer system and perform various operations.

Hiding has not always a negative meaning. We use several masks for protection such as the gas masks, virus and sun protection masks, sport masks, and so on. For users of commercial platforms masking has become a useful act to hide their identity: eBay account users are hidden behind the masks of their pseudonyms. "Most of these users buy and sell on eBay for fun. For them, it is just a new part of their life: a new partial identity. [...] the pseudonym is used to conceal the true identity of the person, i.e., it acts as a privacy enhancing tool." (Jaquet-Chiffelle et al., 2009: 78, 85)

The "bubbles" concept of Laurent Beslay and Hannu Hakala, a model for "informational immune spaces" with two-sided conditional borders facilitates the management of an appropriate informational distance from other humans and from non-human actors.

> "A bubble is a temporary, but well-defined space that can be used to limit the information coming into and leaving the bubble in the digital domain. [...] A bubble can be created whenever it is necessary for personal, community or global use. The bubbles can be shared between individuals or groups." (Beslay and Hakala, 2007: 71–72)

The bubble is a protection mask to realize the integrity of information inside the bubble.

The Mask as a Conservator

Masks acquire their meaning from their appearance and through the wearers' actions and through the actions they provoke. Masks are always fundamen-

1 | See http://searchsecurity.techtarget.com/sDefinition/0,,sid14_gci498695,00.html (accessed 12 September 2012).

tally double in function, signification, and experience, serving simultaneously as tools for disguise connected with positive and negative meanings but also as markers of identity. In the Roman theatre the mask was standardized to stereotypes: "It was a mirror for human foibles and peculiarities." In the Commedia dell'Arte the characters performed by the actors were called masks. In a mask-type, actors portrayed essential characteristic behavioral patterns as an abstraction from the behavior in real life (Mitchell, 1985: 17–18, 49).

Humans present themselves with formal masks, uniforms, robes and wigs to provoke a "preferred reading" (Hall, 1980)[2] of their social identity and acting. They act as mentally invisible persons. The barrister's and magistrate's robes transform a lawyer into an advocate, and the person behind that robe should become mentally invisible when doing the job. Such masks create methodical visibility and invisibility, too, because they inhabit an acting script.

The avatars and humanoid robots we are confronted with try to conserve human values. Even institutional actors mask behind screen-based humanoids, equipped with expression of 'simulated' emotions and empathy.

Some machines are masked as 'social and huggable' love returning pet robots. They have a face, they move their eyes, they make gestures. We hear a lot of artificial voices simulating that we are talking to real persons. In our reality we interact with animal-like robots for entertainment and therapy. We see standardized avatars in the web trying to over-trust us with a simulated care:

> "Humanoid social robots serve as 'prosthetic extensions' of human individuals by acting as their surrogates in social interaction. Standing in proxy for bank tellers, shop assistants, telephone operators, tour guides, housemaids and playmates, to name but a few, humanoid social robots interact with humans, as humans and on behalf of humans." (Zhao, 2006: 403)

2 | Stuart Hall (1980: 172) argued that the dominant ideology is inscribed as the 'preferred reading' in a media text, but that this is not automatically adopted by readers. In social situations where the reading takes place, people can "[...] adopt different stances. 'Dominant' readings are produced by those whose social situation favours the preferred reading; 'negotiated' readings are produced by those who inflect the preferred reading to take account of their social position; and 'oppositional' readings are produced by those whose social position puts them into direct conflict with the preferred reading" (Chandler, 2000).

In these interaction plays between humans and machines the visible cover of the robots and avatars mask not only the machine character of these things but they represent also the values of the habits of humans we like to interact with. They mimic the world we have lost. Eva Gustavsson and Barbara Czarniawska concluded that in "business on the net" a majority of the used avatars are females. Their job is "to assist customers by giving advice and delivering information". They are the mask of the business behind them, representing the business as caring and helpful. They fulfil not only the designers' dream but also that of the consumers:

> "Virtual women, much more than living models and machines, can be created according to their designers' wishes. And, even if designers are not always men, they tend to re-create the male dream of a woman. [...] a self-replicating circle seems to be in place: subsequent versions of Web Women perpetuate the same projection, and we perpetuate the same reciprocation, perceiving the companies that produce them as being insensitive and chauvinistic." (Gustavsson and Czarniawska, 2004: 666)

Fortunately there is also a counter-movement of transformation to this conversation masking.

The Mask as a Transformation Device

For hiding our identity and representing another identity the mask has become the symbol of transformation (Keats, 2000: 102). Masks give humans the opportunity to free themselves from their social identities. The mask confers the freedom of anonymity and of transformation. In carnival we use the mask to interact with other members of the society outside the bounds of identity and everyday convention:

> "The masks served an important social purpose of keeping every citizen on an equal playing field. Masked, a servant could be mistaken for a nobleman – or vice versa. State inquisitors and spies could question citizens without fear of their true identity being discovered (and citizens could answer without fear of retribution). The morale of the people was

> maintained through the use of masks – for with no faces, everyone had voices."[3]

Androgyne clowns like Pierrot represented a rebellion against society. "They blurred the reality of the division of gender and called into question all the attributes that were apportioned to what was male and what female." (Kreuiter, 2008: 2) The coloured balaclava masks, used by the female punk band Pussy Riot, have become the symbols for rebellion and a cry for transformation of society into a coloured society in which diversity is possible: "When I'm in a mask I feel a little bit like a superhero and maybe feel more power. I feel really brave, I believe that I can do everything and I believe that I can change the situation."[4] The Guy Fawkes mask, the icon of the Anonymous movement, associated with collaborative, international hacktivism is the symbol for the struggle between the visibility and invisibility aspects of the Internet and by hiding their personal visibility masks they start negotiation processes; making the invisible visible. According to Gabriella Coleman, Anonymous has succeeded in spreading its messages:

> "Although cloaked and veiled, many of their actions seek transparency from the state and corporations and also often strike at legislation – copyright statutes, surveillance bills – seen to threaten Internet freedoms. It depends on a spectacular visibility and invisibility; it is everywhere, yet difficult to pin down. It thrives off a dynamic tension between cool and hot, openness and secrecy, pranks and seriousness, and predictability and unpredictability." (Coleman, 2012)

Using the mask of a pseudonym was already practised in the 17th century. Readers of the periodical *Athenian Mercury*, which consisted only of anonymous letters of readers and the answers to those letters, could participate in debates through pseudonymous letters to the editor. Especially female writers of letters or poems could "bypass notions of middle-class propriety" behind this

3 | See http://www.maskitalia.com/maskhistory.htm (accessed 12 September 2012) and http://en.wikipedia.org/wiki/Venetian_mask#Venetian_carnival_masks (accessed 12 September 2012).

4 | A statement of Sparrow, a member of Pussy Riot, quoted in an article of Carole Cadwalladr, *The Observer*, 29 July 2012. Available at: http://www.guardian.co.uk/world/2012/jul/29/pussy-riot-protest-vladimir-putin-russia? (accessed 12 September 2012).

virtual mask: “The protection offered by a pseudonym [...] made them feel free to join in an uninhibited public discussion while they themselves remained safely hidden in their own private spheres.” It was also possible to advertise under a pseudonym for private or commercial transactions (Heyl, 2004: 561).

Behind the mask, humans are free to express joy, pain or anger without social restraints. With video games, humans can transform themselves into excellent sports persons, forgetting the physical constraints of their body. Masks are the attributes of the temporal reality in virtual worlds: “The performer is defined anew by the mask and is transformed into a deity, a demon, or some universal superhuman type, or, conversely, into an exaggerated representation of a sub-human impulse.” (Sheppard, 2001: 25)

In these virtual worlds masks create new forms of being with each other:

> “At the end of the course we had an informal social meeting in a virtual world called ‘The Virtual MIT House’. The two of us stayed and talked long after the others had left. We talked about very serious and personal issues, and felt comfortable in doing so despite the fact that we knew very little about each other. We attribute this to the way the avatar works as a mask that shields the person behind it and in this way tends to make the person more open.” (Jakobsson and Popdan, 2002: 5)

The virtual world Second Life has evolved from intimate explicit often pornographic expressions to “content that is merely intimate, romantic, affectionate, but not overtly sexual” (Bardzell and Bardzell, 2008: 15).

Gender swapping was one of the first phenomenons in the Internet. Amy Bruckman (1992, 1993) saw gender swapping as an identity workshop, in which the virtual role-playing was an opportunity to discover several aspects of one’s own identity. Already in text-based chat environments humans used nicknames to be released from their usual social identities and to pretend and perform to be another. It was the “paradoxical combination of both anonymity and intimacy [...] Some individuals are already living part of their daily life in these chat modes, adopting either a gender-free identity, or playing a role as a member of the opposite gender” (Danet, 1996).

According to Sherry Turkle, “the Internet has become a significant social laboratory for experimenting with the constructions and reconstructions of self that characterize postmodern life. In its virtual reality, we self-fashion and self-create” (Turkle, 1995: 180). She was in those early days also very doubtful about the significance of the Internet. In her opinion, the WWW was the

materialization of the postmodern wish for differences. She feared also the loss of the bodily experiences:

> "[...] Virtual experience may be so compelling that we believe that within it we've achieved more than we have. Many of the people [...] claim that virtual genderswapping [...] enables them to understand what it's like to be a person of the other gender, [...] But as I have listened to this boast, my mind has often travelled to my own experiences of living in a woman's body. These include worry about physical vulnerability, fears of unwanted pregnancy and infertility, fine-tuned decisions about how much make-up to wear to a job interview, and the difficulty of giving a professional seminar while doubled over with monthly cramps. Some knowledge is inherently experiential, dependent on physical sensations." (Turkle, 1996: 53)

Playing with identity using the Internet seems to be bodiless. However this forgetting of the physical body's existence occurred already in ancient Greek theatre. Masks were used for the portrayal of various stock characters, be it the Mischievous Slave, the Idle Son, or the Angry Father. They were not a disguise but a transformation tool. The actor on the stage expresses a character embodying the life and the related emotions of his mask (Maduram, 2002: 3). The bodies of the mask-wearing humans were only seen as instruments, acting like an internal clockwork: "To this extent, the mask and costume are the character, and the actor merely the mechanism that gives them temporary motion." (Mitchell, 1985: 11) Several characters were performed by a single actor; especially male actors could transform themselves into female characters. The wearers of the mask separated themselves from their known identity presented by their own body by the masks representing symbolic images with a universal character (Mitchell, 1985: 7). Hiding behind a mask gives humans the opportunity for "setting aside social taboos and freely participating" in interaction plays, questioning the rules and routines of society. So the "mask invites curiosity, providing occasion for the workings of seduction" (Coyne et al., 2000: 67–68).

So even in the function of hiding, the mask reveals as well as conceals: making the body physically invisible and making our daily acting mentally visible again. With masked interactions, humans transform themselves and the worlds they interact in. But in the mask itself a reference to a human body is mostly present; alternated or swapped.

The Mask as a Mediator

The mask is a mediator between the inner self of its wearers, the world they live in and the worlds they cannot reach. As the twentieth-century Scandinavian painter Egil Jacobson, famous for his mask paintings, wrote to his biographer Per Hovdenakk:

> "The mask has existed for millennia as an expression in many widely differing cultures. It can be primitive or sophisticated. All moods can be expressed through it [...] Whenever I think of the mask, it is not to conceal or to frighten but to express inner and outer experiences, and to free these experiences and pass them on. The eyes look inwards, trying to recognize something, and look outward to unite it with its surroundings. It is inward turned self-recognition and outward turned liberation for the Drama, seeking the whole, a poetic synthesis." (Mussari, 2004: 491–492)

In ritual performances the mask functions as a medium through which the gods can be invoked. It gives the invisible god an appropriate and available form for communication with humans (Sheppard, 2001: 26). In many computer games humans play god, heroes, and murderers, disguised as avatars, living a life very different from their daily life. On social networking sites like Second Life you can be rich and famous and have a marvellous body. The Rolling Stones fans on their fan sites can create the illusions that they are living in the community of the band or even be a band member (Baker, 2009). In their impacts, the virtual masks create consciousness for transitions and give us the Friends and Followers we need.

The Theatre and the Masks in our Virtual Worlds

The Masquerade World

If we define a masquerade world as a social gathering of actors wearing masks, then the integration and mixing of the virtual and real worlds are masquerades. We are living more and more in an artificial theatre play with planned scripts and human and non-human actors disguised behind masks. Actors are wearing

several masks, as already mentioned, for protection, for hiding and for representation. We are dealing with artificial actors wearing the masks of humans and humans wearing virtual and real masks. Reality is infiltrated with sensing, computing, transmitting, and acting hardware. The acting of people will be preceded, accompanied, and followed by the invisible and visible acting of artificial intelligent tools and environments – and their providers.

Mixed reality is a world of fragmented, partial identities referring to human and non-human actors. Persons can create many identities and identities can be shared by many persons or present a community of actors. Annamaria S. de Rosa calls this self-baptism (De Rosa, 2002). This ritual is the start of an adventure in which humans can discover that their body is 'one' but their selfs are fragmented as Vitangelo Moscarda, the protagonist in Luigi Pirandello's novel *One, None and a Hundred Thousand (Uno, Nessuno e Centomila)* discovered during an illness. After he was cured he was free from his past. He was no longer living in himself but in everything around and outside him. In this sense the usage of several identities in the Internet could be a disease that disrupts the image of our self – or are we already experiencing the healing?

In the mixed realities, interaction has become an interaction between masks:

> "On the Internet, it can be hard to know if the entity we are interacting with is of flesh and blood, or only digital. We are now facing a complex reality both in the 'real' world and in the information society. We have to deal with subjects acting behind masks." The masks are the actors in our mixed reality: "In front of the mask, we have the identity." (Jaquet-Chiffelle et al., 2009: 78, 82)

The play with identity in mixed reality has blurred the concept of an official, unique, and legal identity in the system of states and countries. In that system we are registered by our birth, marriages, sex, and death. Human actors can act only having these identity documents: Enter and leave a country, buy and sell, have a legal job. The official identity documents are transparent masks which refer to our official status and will link us with the activity of the past and the rights and duties of the present. However, the uniqueness of identity is dissolved by the use of electronic media: "People have many identities nowadays; and some identities may also be shared by different persons or even by things." (Jaquet-Chiffelle et al., 2009: 76) The state has already lost the exclusive power of registration and production of identity documents. It

only produces 'flesh and blood' identities linking them to a material body by enhancing the amount of biometrical data in the identity documents. So it can only tie rights and duties to that material body. State and countries are aware of this loss and are producing laws for unmasking the real and the virtual persons: forbidding the burka and the covering of head and face and encrypting Internet communication.[5] Humans will be confronted with questions like:

> "Are the masks in our mixed reality really representations of the devil as was thought in the Middle Ages? Should we listen to the authority like the clerical authorities in the Middle Ages, who want to forbid our mixed reality masks? Or are these authorities themselves the evil forces who want to posses identity and unmask our interactivities?" (Mitchell, 1985: 26)

Masking the flesh and blood will become one of the main strategies for hiding and protection. Altering fingerprints and wearing a cap and sunglasses in an environment with cameras is a protection against face recognition. Another strategy is masking the link between the body and our virtual interactions; reducing the amount of information that will be disclosed in our online interaction: e.g. sender anonymity (remaining unidentifiable to the communicating party) and unlinkability (the inability to determine that you are communicating with a particular receiver) (Romanosky et al., 2006: 7–8). However, can we avoid that in the future masks are interactive artificial intelligent devices linking themselves with the physical body of their wearers?

In these mixed mask worlds there will be a conflict between aspects of authenticity and privacy. At the end of the Middle Ages, according to Christoph Heyl (2004), the mask became in London a device for creating a private sphere in public. It was common for women to wear a mask in public as a protection of their privacy and reputation from uninvited eyes. The mask initially belonged to the winter accessories for protection of the face and became available at any time of the year to confer varying degrees of anonymity. Its size increased from the half-mask to a mask covering the entire face. Masks were worn in special places such as London parks and theatres. With the mask, women could escape from the role they played in everyday life. The semiotic

5 | See for instance the comment of Charlie Savage in the article "U.S. Tries to Make It Easier to Wiretap the Internet", *New York Times*, 27 September 2010. Available at: http://www.nytimes.com/2010/09/27/us/27wiretap.html (accessed 12 September 2012).

function of these masks was to denote that people might approach each other more freely than elsewhere:

> "The mask assumed a dialectic function of repellent and invitation, its message was both 'I can't be seen, I am – at least notionally – not here at all', and 'look at me, I am wearing a mask, maybe I am about to abandon the role I normally play'. One of the mask's paradoxical attractions was that it could both endanger and protect one's respectability. On the one hand, wearing a mask, one might allow oneself to do things which would otherwise be unthinkable." (Heyl, 2005: 134)

Encrypting textual actions in the Internet is a protection against unauthorized reading and infiltration. Humans in these mixed realities are overloaded with information and invitations to act. Creating mask filters such as 'People You May Know', and the 'News Feed' in Facebook are necessary survival tools for not drowning in this overload and not being seduced into undesirable involvements. The avatar masks humans use in social nets are mostly invitations to interact with each other in a specific way. Avatars can only present a selective part of the persons who have chosen these masks, but "they are rich as performed expressions of how users perceive themselves and/or desire to be perceived" (Bardzell and Bardzell, 2008: 12). Avatars connect the 'real actors' with the other masked actors playing on the stage of mixed reality, The avatars are active representations and should be understood as 'subjectivities', a "living force, an agent that both acts in the world and is constituted in the world through action. Because it is constituted through action or performance, it cannot lie; it is as it does" (Bardzell and Bardzell, 2008: 12).

The Audience of the Mask

In the theatre, the mask is not only used for an aesthetic transformation of the actors but also for the transformation of the audience when it decides to believe in that transformation. "By engaging with the mask performer, the audience shares in the transformation, and in this way is able to be transformed themselves." (Koerner, 2008: 25) A mask is actable because the wearer and the audience give meaning to the mask; it connects the wearer with its audience. Masking is in the theatre and in our mixed reality "[...] a socially constructed act. Masking will not work as discussed if there is no shared understanding [...] between the wearer and audience about what masking socially means" (Kim,

2004: 50). In that understanding, the audience can undertake a dominant, negotiated or an oppositional reading of the masked performance (Hall, 1980). The followers in Facebook are perhaps the passive auditorium for which the performance is actable in such a way that they undertake the preferred reading. A lot of commercial companies just for that reason 'mask and play' the role of a friend.

Do we have the freedom to choose our reading position? In the mixed masked worlds power relations will undeniably exist between the masked performers and the audience. A performance with masks can articulate an unequal relation between masked performers and audience. Hiding behind an avatar mask transforms an actor into an anonymous observer, a position which normally is reserved for the audience: "Freedom to gaze anonymously in a darkened auditorium. The masked performer is allowed to observe from behind a sheltering cover." (Sheppard, 2001: 25)

Ferdinand de Jong (1999) has analyzed the Kumpo mask performance in Southern Senegal. He mentioned that masking enables certain groups to exert coercive power on condition that the audience subjects itself to the capricious behavior of the mask. The Kumpo mask cannot exist without an audience and without playing its part in the performance. The mask comes to life by running around speaking or shouting and often threatening the audience. Mask performers are nearly always male and their identity is kept secret from women. The secrecy aspects imposed on the audience serves the purpose of exerting coercive power. Women, as part of the audience and excluded as wearers of the mask, are an integral part of the performance since the power of illusion and secrecy depends upon women playing the role of the non-initiated. Ferdinand de Jong concluded that by examining the social dynamics of mask performance the following question has to be asked: "Who has the right to present masks and to turn others into an audience?" (Tokin quoted in De Jong, 1999: 54) The player-audience relationships in the mask performance reflect or legitimize social relationships but also produce them. Anonymous and Pussy Riot produce visible audiences and engage them in their unmasking activities. "The right to present masks and to turn others into an audience is itself subject to negotiation." (De Jong, 1999: 54) However, as de Jong holds, the audience is mostly in the disadvantaged position of being unable to contest or question the player-audience relationship.

Masking as a Sign of Humanity

Joan Riviere described in her essay of 1929, *Womanliness as Masquerade*, a professional woman having success in her job. "This woman experienced anxiety after each public appointment, and sought reassurance from father figures among her colleagues, primarily through inappropriate flirting and seductive behaviour." (Riviere quoted in Robinson, 2006: 32) Riviere deduced: "Womanliness therefore could be assumed and worn as a mask, both to hide the possession of masculinity and to avert the reprisals expected if she was found to possess it." (Riviere quoted in Robinson, 2006: 32) This mask was used far more as a device for avoiding anxiety than as a primary mode of sexual enjoyment (Chowaniec et al., 2008).

Luce Irigaray saw the mask of feminity as a necessary key to enter in a world "of values that is not hers":

> "The belief, for example, that it is necessary to become a woman, a 'normal' one at that, whereas a man is a man from the outset. He has only to effect his being-a-man, whereas a woman has to become a normal woman, that is, has to enter into the masquerade of femininity. [...] and in which she can 'appear' and circulate only when enveloped in the needs / desires / fantasies of others, namely, men." (Irigaray, 1985: 134; Robinson, 2006: 33–34).

According to Luce Irigaray it is an alienated, false version of feminity, developed out of the awareness of women to comfort man's desire for her to be his other. The mask is the frame made by man's desire (Irigaray 1985: 220).

According to Rafael Capurro, robots can be seen also as a mask of human desire: "Our love affair with them opens a double bind relationship that includes the whole range of human passions, from indifference through idealization until rivalry and violence." Robots are the masks in which we can discuss "the humanness of humanity [...] robots are the bad and the good conscience of ourselves". In the robot mask, humans redefine our identity but also the identity of the human we want to possess and we want to be (Capurro, 2007). In that desire we go as far as possible, going into the creation of artificial humans. It is this same longing that the mask represents in the theatre in the tribal rites, trying to reach a god and even being a god.

There are already a lot of masked priests like futurist Ray Kurzweil, an advocate of the transhumanist movements, who have put on the masks of the god and given their vision of the future of humans:

> "A future period during which the pace of technological change will be so fast and far-reaching that human existence on this planet will be irreversibly altered. We will combine our brain power – the knowledge, skills, and personality quirks that make us human – with our computer power in order to think, reason, communicate, and create in ways we can scarcely even contemplate today. This merger of man and machine, coupled with the sudden explosion in machine intelligence and rapid innovation in gene research and nanotechnology, will result in a world where there is no distinction between the biological and the mechanical, or between physical and virtual reality." (Kurzweil, 2006: 39)

Of course, these predictions are overloaded by statements that technology "of course" will be for the benefit of human kind: "These developments will help over-come pollution and poverty, provide vastly extended longevity and enhance human intelligence." (Kurzweil, 2007: 76) However, he is preparing humans for living in a world that will not longer be theirs. The world could become occupied by super cyborgs in which human intelligence will be considered as subordinate to artificial intelligence.

Are the appearances of masks in our mixed reality signs of a masquerade of humanity? Are we comforting the wishes and desires of the technology shamans? Or are we healing ourselves from the traumas in real life? Emotionality and sociability are inappropriate qualities to attach to artificial devices. However, why are so many designers busy making models of human emotions to mimic them in robots and avatars? Is it the exclusion of human emotions in ourselves and other humans? Can we better deal with prepared controllable emotions?

Conclusion

The masking in mixed reality has already belonged to our culture for a long time. Humans need the masquerade for disrupting their mental invisibility because it

> "unsettles and disrupts the fantasy of coherent, unitary, stable, mutually exclusive divisions. It replaces clarity with ambiguity, certainty with reflexivity, and phantasmic construction of containment and closure with constructions that in reality are more messy, diverse, impure, and imperfect" (Tseëlon, 2001: 3).

Looking to the differences and resemblances with masking in theatre, in rites and in daily life, I formulated questions on the masking in our mixed reality by walking back on the traces of masks and looking at their imprints (Wiszniewski and Coyne, 2002: 203). I learned that humans have always lived in a masked society and that masking is an act in the space between the infinite and fictitious poles of total invisibility and visibility. "In this oscillation between a concealing and revealing, one can comprehend practical differences, which brings us closer to the nature of identity and community." (Wiszniewski and Coyne, 2002: 210) How and what the mask reveals, depends on the producer, the wearer, the audience, the interaction and the context situation the mask is used in (Gjertson, 1992: 1, 6–7). The gender masquerades of past and present can lead us to the disclosure of the masquerade of humans in robots and avatars in the future of mixed reality.

The phenomenon of the mask establishes an active field of play between notions of presence and absence, of invisibility and visibility. A mask has always two sides: the visible in the mask and the invisible behind the mask. The issues of visibility and invisibility are not only to ask who and what is visible but who sees what and who creates invisibilities in our daily lives, realizing that human and artificial actors wear masks to hide from unwanted interpretations and representations and to enhance specific affordances. Masks are the identities, ready-made for interpretation. We have to deal with human and artificial subjects acting behind masks. All these masks are interacting and demand for interpretation. Only in the complexity of their negotiations, conflicts, and agreements can we try to understand the interactions of masks, or in the words of Claude Lévi-Strauss, a mask exits not in isolation, there are always other masks by its side: "A mask is not primarily what it represents but what it transforms, that is to say, what it chooses not to represent. [...] a mask denies as much as it affirms. It is not made solely of what it says or thinks it is saying, but of what it excludes." (Lévi-Strauss, 1988: 144) Masks always give us the opportunity of unmasking, disrupting the mental invisibility of our self, the others, and the daily life we are acting in. And having a mask ourselves, it will give us the protection we need. Still we have to ask: Who are the providers of the masks and who will do the unmasking?

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B. Gender in Epistemological Foundations of Science and Technology

Homunculus in the Hormones?[1]

Rebecca Jordan-Young

How is it that we, as humans, come to be who we are? It is, of course, one of the most ancient questions, and it may signal a curiosity about individuality (How do I, in particular, come to have these ideas, skills, bodily traits, and desires?) as well as about groups (Why are these things living and those dead? Why are these beings human and those dogs? Why is *this kind* of human different from *that kind*?). Aristotle proposed that all living beings must have a "soul" – an active principle that animates and directs the development of the organism, without which the living being would be lifeless as a mineral. The soul gave both life itself, and the specific form of the organism. This explanation satisfied plenty of people for a remarkably long time. But during the seventeenth century, learned people became more and more likely to expect that theories about the natural world should be based on evidence, and the idea that development was directed by the soul created a serious problem. Namely, no one had ever seen a soul, nor had any idea where, specifically, it might be, nor how, exactly it might work. In short, the soul was too abstract and metaphysical an idea for the increasingly materialist beliefs of Western science.

And so, because no one could see how matter could take on new forms all by itself, the idea of preformationism began to take hold. In short, this was the idea that organisms develop from smaller versions of themselves. The fundamental form of the organism was always already there. The biologist/historian Clara Pinto-Correia (1997) has written a lovely history that fleshes out all the details of the interesting and still relevant history of preformationism, which she defines as "the assumption that the primordial organism already contains

1 | Based on a presentation delivered December 14, 2011 at Johannes Kepler University, Linz, Austria (Lecture series 'For Future Innovations: Gender in Science and Technology') and on Jordan-Young (2010).

inside itself all other organisms of the same species, perfectly preformed, miniscule though they might be". That idea now seems quaint, but it is not really so far removed from what she describes as "the more sophisticated version of the model", pre-existence, "in which the primordial organism contains only the basic blueprints of all the related organisms to come" (Pinto-Correia, 1997: xxi).

A big argument among preformationists concerned the role of eggs and ovaries versus the role of sperm and testes. 'Spermists' were certain that the rudimentary human could be found in sperm, and 'ovists' were convinced that the egg was the true address of the tiny pre-human. The famous naturalist Antoni van Leeuwenhoek, a spermist, famously reported how his microscope allowed him to 'see' these tiny creatures in sperm, and he called them "little men" (in Latin: homunculus). The homunculus is still with us, as it turns out. Scientists no longer 'see' them in sperm, or in ova – but I argue in this paper that a theory of development that is currently quite popular is a variation on the broad theme of pre-existence. This theory, brain organization, holds that 'sex hormones' transform the initially sex-neutral matter of the brain, causing the brain to take on traits that are timelessly masculine or feminine. Instead of literal 'little men', the entity that is now thought to be transmitted across time, from one generation to the next, is masculinity or femininity – a popular way of understanding fundamental categories of human nature. Rather than curled inside the sperm, as the 'spermists' believed, or tucked inside the ovum, as 'ovists' did, the imaginary timeless 'little men' and 'little women' of brain organization theory are encased in testosterone and estrogen.

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This chapter encapsulates the main arguments of my book *Brain Storm* (Jordan-Young, 2010), in which I present the first systematic and synthetic analysis of all the studies applying brain organization theory to humans from introduction of the theory in 1959 until the first decade of this century. I begin by explaining the theory itself and the basic study designs, and then describe my analytic method of using "symmetry principles" to evaluate how well the theory is supported by the evidence that has emerged from the many hundreds of studies in humans. To anticipate my conclusion, I argue that there are so many gaps and contradictions in the research on brain organization in humans that the theory is not supported by a coherent body of evidence. Current acceptance of this theory as a 'fact' of human development is at best premature.

For the purposes of this chapter, I present a very concise summary of the main types of human brain organization studies, five core assumptions that drive the research, and three fundamental ways that the overall evidence from research on brain organization fails to support the theory by conventional scientific standards. I conclude with a few notes about the different levels on which we can understand the discrepancies and gaps in brain organization research, especially considering whether it is necessary to choose between identifying scientific errors, or pursuing an analysis that demonstrates the fundamentally social and contingent nature of scientific knowledge. This tension poses a particular risk when I use other kinds of research on human sex-typed traits in order to contrast those with the vision of sex/gender embedded in brain organization theory. In *Brain Storm*, I used such contrasts in a variety of ways, chief among them to show that all evidence does not, in fact, converge in support of brain organization theory. I want to be clear here that it was never my intention to suggest that one of these *other* ways of knowing human sex/gender is in some way fully 'true' or can escape all the baggage of embedded gender ideology, incomplete modeling and data, and other flaws that bedevil brain organization research. Yet some research approaches do seem more promising than others to me. Everything in my own research on sexuality, my knowledge of history and feminist STS, and life experiences prepare me to see sexuality and gender as complex, contingent, and historically changeable – in short, not very likely to be the kind of phenomena that might be characterized as 'traits' that emerge out of masculine or feminine substances. So with that disclaimer out in the open, let's take a closer look at brain organization research.

The Theory of Brain Organization

> "If you're going to reproduce bisexually, you need different genitalia, you need different gonads, too, and you need different internal organs. But the brain controls these things, so you need – I think you need a different brain."
> Brain Organization Researcher ('Dr. I'), August 20, 1998

To examine brain organization theory, I analyzed all the human studies that scientists have used to test this theory, and I also identified the most widely-cited and influential scientists in the world who conduct such studies. My main interest was in talking to them about the technical details of their studies, but I

also I asked them to explain the theory in the most concise way they could, and I asked them what stimulated their initial interest in the theory. 'Dr. I' is one of those scientists[2] – a world-renowned neuroscientist who has been doing studies related to this theory for decades. The way he framed it, in a sexually reproducing species, the brain is a sort of accessory reproductive organ. To him, the existence of a male brain versus a female brain is not an open question that one should investigate, but is instead a logical requirement of sexual reproduction itself. Brain organization theory is appealing to 'Dr. I' and others who think like him because it has the characteristic of 'parsimony', meaning that it is the simplest explanation that covers a great number of phenomena. Brain organization theory is an excellent example of a parsimonious theory, because it builds a single unifying explanation of sex development, encompassing both behavior and the physical/physiological body. The key actor for both the body and behavior (via the brain) would be steroid hormones.

To skim quickly over a great deal of history that is covered nicely in many other places (e.g. Oudshoorn, 1994; Sengoopta, 2006; Van den Wijngaard, 1997), the first century of hormone research – predating both the term 'hormones' and the biochemical insights and technologies that would allow precise isolation and identification of these substances – was focused on questions of sex. The steroids that people still today tend to think of as 'sex hormones' were put together into groups based not on having similar chemical structures, but based on their abilities to affect characteristics associated with masculinity (the hormones classified as 'androgens') or those affected with femininity (the 'estrogens'). Nelly Oudshoorn (1994) has shown how a certain ideology of binary, oppositional sexes created a research framework that not only shaped the experiments in early endocrinology, but repeatedly blocked evidence that contradicted this ideology. Three major expectations included that: 1) these chemicals would be sex-specific (present only in healthy individuals of one sex or the other, but not both); 2) they would be antagonistic (androgens counteracting the effects of estrogens); and 3) they would be fundamentally 'for' development of sexual characteristics, as opposed to being involved in a wide range of functions for both sexes.

2 | Following standard ethnographic practice, in both the book and this chapter I refer to all scientists I interviewed by pseudonyms rather than their real names. I promised them confidentiality when I conducted the interviews, in order to make them feel comfortable expressing scientifically unpopular views, or critiquing colleagues or work that they wouldn't want to publicly oppose.

By the 1950s, experiments in developmental endocrinology had demonstrated that steroids play a very powerful role in the differentiation of reproductive and genital structures. It was during this time that more systematic experimental methods (e.g., using control groups as well as experimental groups) and advanced research techniques (e.g., the ability to conduct surgeries extremely early in animal development) allowed Alfred Jost and others to solve what had been a longstanding puzzle in sexual development: how do fetuses go from being sexually 'neutral' – that is, structurally indistinguishable by sex, from the macroscopic level, at least – to being visibly and functionally either 'male' or 'female'? Jost built on experiments going all the way back to the father of experimental endocrinology, the Viennese scientist Eugen Steinach, trying to show that steroids, and in particular androgens, seemed to play the decisive role. If any animal is exposed to a sufficient quantity of androgens during the critical period in its life when genital and reproductive differentiation takes place (a period that is the same for every individual in a given species), that animal will develop the reproductive structures of a male. In the absence of androgens, 'female' structures would develop. Jost concluded that the female pathway is the *default direction*, which happens in the absence of *any* gonadal hormones. This led Jost and others to assert that female development is 'passive'. This idea, which enjoyed an uncanny fit with social ideas about the assumed (proper and natural) passivity of women, reigned for nearly fifty years before developmental biologists came to their senses and apparently remembered that there is no such thing as 'passive' development: there are *always* mechanisms to be explained. It's simply the case that the developmental mechanisms for female reproductive structures seem to be somewhat different than for males – they aren't under the obvious control of gonadal steroids, and they may be more directly related to genetic mechanisms (see e.g. Hughes, 2004; Yao, 2005). And while it is true that 'androgens' like testosterone (especially after conversion to dihydrotestosterone) are crucial for development of male-typical structures, it's also the case that some aspects of male reproductive tract development are in fact controlled by estrogen, the supposedly 'female' hormone (for a review, see Vincenzo et al., 2009). This already shows that the Jost Paradigm is too simple in holding that with androgens, development is masculine, and without androgens, development is feminine.

In 1959, William Young and colleagues extended the Jost Paradigm to explain the development of masculine and feminine *behavior*, by suggesting that brain development follows a path that is basically similar to the development of genitals: the brain begins as sex-neutral in all individuals (regardless of

chromosomes), but it develops as either masculine or feminine depending on whether androgens are present during a critical period (Phoenix et al., 1959). They based their thinking on experiments in guinea pigs that had been castrated and treated with hormones at very early stages of life. Those animals who were treated with androgens, regardless of their chromosomal sex, were more likely to display 'male-typical' sexual behaviors, meaning that they would readily mount other animals. 'Depriving' developing animals of androgens during the same critical period resulted in a basically 'female-typical' pattern, meaning that they would more readily perform the arched-back lordosis response, and allow other animals to mount them. From the very first research report on brain organization, Young and his colleagues suggested that this same process could explain human sex-typed behavior.

One of the most important things to understand about brain organization theory is that it cannot be tested experimentally in humans. Doing so would require interventions in human development that are not only unethical and against both international law and virtually all professional codes of ethics, but logistically so complex and expensive as to be utterly unrealistic. For example, to mirror even the most basic, early experiments on guinea pigs, scientists would need to perform surgery on human fetuses to remove the testes or ovaries during a very early period of development, and then randomly assign the pregnant women who were still carrying these castrated fetuses to receive standardized 'masculinizing' or 'feminizing' hormone regimens. Then these experimentally manipulated fetuses would have to be tracked all the way into adulthood to see how their gender and sexuality turned out – under 'blinding' conditions, of course, meaning that neither the scientists nor the families nor the experimental subjects themselves would know what kind of treatment they got. There's no need to go into all the other details of this nightmarish-fantasy research: it's an evil idea, and it's simply not possible. As a result, you can't look at the results of studies on brain organization in the same way that you would if they were experiments. You have to consider the evidence differently, and more holistically.

With experiments, scientists control the circumstances of knowledge production as much as possible, ideally varying just one thing at a time in order to observe how elements relate to one another. This is a rough, or idealized, description, but it works as a contrast to the sorts of studies scientists have to do when they can't experiment. Non-experimental studies are called 'observational research' or 'quasi-experiments'. In this sort of work, there is even more room for interpretation, and there can never be a single definitive study.

Instead, scientists have to piece together various studies that use different approaches, and therefore have different strengths and weaknesses. But in piecing together those different studies, it is important to pay attention to how the different elements that scientists are working with either line up (are symmetrical) or are different. That is how I conducted symmetry analyses of brain organization research. While the work of examining more than 300 studies in detail was painstaking, the idea behind it was rather simple: when scientists say that androgen exposures in early development lead to masculine gender and sexuality, what precisely do they mean by 'masculine gender and sexuality'? Do these things mean the same thing in various different studies? What about the other phenomena that scientists link to early hormone exposures, like heterosexuality or homosexuality, or 'sex-typed interests'? In my book, and in the few examples below, I show that the way scientists approach these phenomena are so profoundly different as to make the whole body of research extremely incoherent.

First, though, it's useful to understand the kinds of studies scientists have used to test the theory in humans. Their first strategy was to study people they considered 'experiments of nature': those who were known to have had hormone exposures that were unusual for their genetic sex. They studied people with intersex conditions in which either the level of exposure to particular hormones, or the way that the body responded to hormones, was not typical. The most common intersex conditions that scientists have studied include genetic females with the classical form of congenital adrenal hyperplasia (CAH), in which there is high production of androgens during fetal life; androgen insensitivity syndrome (AIS), in which a genetic male produces androgens, but the tissues do not respond to them; and 5-alpha reductase deficiency, in which an enzyme that is necessary for converting testosterone to dihydrotestosterine is missing, so that genetic males without this enzyme are born with ambiguous looking genitalia, but develop a much more 'masculine' physique at puberty. Once scientists have identified a group of people with intersex conditions to study, they compare this group with non-intersex people of the same assigned sex/gender (i.e. both intersex and 'control' subjects must be reared in the same gender). In epidemiology, studies that compare outcomes among two groups who have had different earlier exposures are called cohort studies, so that's the term I'll use to describe these studies.

By 1967, reports began to appear that suggested girls and women who had been exposed to a high level of androgens in the womb were, indeed, more 'masculine' than other girls and women (Ehrhardt and Money, 1967; Ehrhardt,

Evers, and Money, 1968; Ehrhardt, Epstein, and Money, 1968), and the researchers attributed this to the effects of 'sex hormones' on the developing brain (see Jordan-Young, 2010: 32–35 and 69–73).

A second research strategy was introduced in the early 1970s: start from the other end of development, by comparing people with patterns of gender or sexuality that scientists considered 'sex-reversed' to people that they considered 'normal'. This is a classic 'case-control' design, where scientists look at people with different outcomes and then look for some kind of evidence that the two groups have had different earlier exposures. Many studies along these lines begin by recruiting groups of gay men and heterosexual men for comparison. The scientists then take measurements of other physical or psychological traits that they believe are also affected by early hormone exposures – things like the relative length of different fingers, left- versus right-handedness, or personality traits that are considered masculine versus feminine. If they find that gay men and straight men are, on average, also different on any of these other traits, the scientists infer that early hormone exposures may have influenced both sexual orientation and the other trait(s) (see Jordan-Young, 2010: 38–48 and chapter 5, *passim*).

So to recap the two main sorts of studies, brain organization studies of intersex people group subjects according to the hormonal *inputs* into their development; studies of gay, lesbian, and trans people begin with developmental *outcomes* that scientists consider sex-reversed, then look backwards for evidence that their fetal hormone exposures were different than those of cisgender heterosexuals.

Though they are rarely, if ever, explicitly enumerated, it's worth identifying a number of underlying assumptions within brain organization theory research: 1) the brain is *(must be)* sexually dimorphic; 2) 'male' and 'female' are distinct categories; 3) 'masculine' and 'feminine' are sets of simple, common-sense traits; 4) since reproduction is the purpose of sexual differentiation, heterosexual desire and behavior is the aim of brain organization; and, it follows from the fourth assumption that 5) homosexuality is a 'cross-sex' trait which, above all other aspects of personality or behavior, indicates that brain organization is 'sex reversed' – meaning that it has taken a different path from the sexual differentiation of the rest of the body.

Even the originators of the theory were well aware that not all of these elements were true, especially in humans but even in non-human species. For example, the fact that there is some overlap in the supposedly dimorphic sexual behavior was the reason that they were so careful to use untreated control ani-

mals of both sexes (Phoenix et al., 1959: 182). That is, hormonally untreated, normal females of guinea pigs and the other small mammals will mount other animals to some extent, and males of these same species also allow themselves to be mounted. Young's team may not have been aware of the extent to which these behaviors varied, because exploring and documenting the phenomena related to animal behavior or human behavior was not their real interest. From the beginning, the things that interested biological scientists about sex were all 'how' questions, not 'what' questions. In other words, they were firmly focused on *how* sex develops, but did much less thinking about *what* precisely 'sex' is. As a result, they incorporated more or less wholesale the folk ideas about sex that were popular in the times and places where they have worked. While the details in these folk ideas have varied in interesting ways that turn out to be important for understanding how the research fits together over time, one of the most enduring assumptions in scientific work on hormones and sex development is that sex is binary (male versus female), and it is a 'package deal' – sex-linked traits of the body, all aspects of personality or behavior that are coded as 'masculine' or 'feminine', and everything about erotic desire and practice are all understood to *flow from* and also *reveal* a single underlying masculine or feminine nature.

In humans, the 'behavioral phenotypes' that are linked to this theory span virtually every domain that has been thought to differ between girls and boys in childhood, or men and women in adulthood. Sexuality was always of special interest, given the origins of the theory and the underlying notion that brain organization served the ultimate purpose of reproduction. The aspects of sexuality that scientists linked back to early hormone exposures included sexual orientation, libido, types of sexual acts, and patterns of becoming sexually aroused (e.g. Allen and Gorski, 1992; Ehrhardt, Evers, and Money, 1968; Kester et al., 1980; LeVay, 1991; McIntyre, 2003; Money, Ehrhardt, and Masica, 1968; Yalom, Green, and Fisk, 1973; see Jordan-Young, 2010: chapter 6, *passim*). They also linked what they called 'core gender identity' to hormones, meaning that they believed hormones to affect one's fundamental sense of self as male or female (or, as they sometimes acknowledged, as neither or both) (e.g. Berenbaum and Bailey, 2003; Ehrhardt, Epstein, and Money, 1968; Gooren and Cohen-Kettenis, 1991; Zucker et al., 2001; see Jordan-Young, 2010: 257–64 for an alternate reading of the evidence). Scientists have further asserted hormonal influence on 'gender role', a catch-all category that encompassed any behavior more common to, or thought to be appropriate for, one sex versus the other – things ranging from playing with dolls, building toys,

and love of sports to care in personal appearance, relationship ideals, hobbies and occupational aspirations (e.g. Berenbaum and Hines, 1992; Henderson and Berenbaum, 1997; Money and Ehrhardt, 1972; Pasterski et al., 2005; see Jordan-Young, 2010: chapter 8, *passim*). They also linked cognitive skills to early brain organization, and were initially confident that 'general intelligence' or IQ increased with androgen exposures (Ehrhardt and Money, 1967; Money and Lewis, 1966). Researchers dropped that claim fairly early, when it became clear that IQ doesn't actually differ between males and females, but continued to tie specific skills like mental rotation ability or verbal fluency to sex-typed hormone exposures early in development (e.g. Grimshaw, Sitarenios, and Finegan, 1995; Rahman et al., 2003; Sanders and Ross-Field, 1986; see Jordan-Young, 2010: chapter 4, especially 70–71, also 179–80).

Brain organization theory immediately transformed the research paradigm for sexual development, and hormones were thenceforth understood to play two distinct roles: an 'organizing' role and an 'activating' role. The organizing role, which hormones could only play during certain early critical periods of development, was about a permanent transformation of the brain from sex-neutral to either male or female, so that the behaviors that would eventually be expressed would consistently follow this sex-typing. The activating role, which circulating hormones play during puberty and adulthood, was about the specific timing and extent to which these 'latent' behaviors would get expressed. A good analogy is thinking about trains that run along particular tracks in the countryside. The 'organizing' force is like laying down the tracks, and the 'activating' force is akin to the power that makes the trains run. You can lay tracks allowing trains to pass through particular towns, but without power, the train will never get there. Likewise, all the power in the world will not make a train pass through a town that isn't on the rail route.

Many of the longstanding puzzles in hormone research stem from the fact that it is not possible, in either humans or experimental animals, to find consistent correlations between hormones and behaviors. For example, many scientists tried but failed to find a relationship between intra-sex variations in observable sex-typed behavior, on the one hand, and circulating hormones, on the other. It was also not possible to consistently achieve behavioral changes by manipulating circulating hormones. Unfortunately, the history of endocrinology shows many examples of scientists and doctors attempting to change men's sexual orientation from homosexual to heterosexual by giving them testosterone and other androgens, and these attempts are a part of the research tradition that fed into brain organization theory (for a review of many such

studies, see Meyer-Bahlburg, 1977). The 'organizing' hypothesis allowed an escape hatch from the difficulty posed by the failure of such interventions. Once the theory was introduced, the inability of scientists to show a correlation between behaviors or psychological traits and adult levels of circulating hormones could be dismissed as irrelevant. With the brain organization theory, scientists simply hypothesize that sex atypical traits or behaviors mean that something unusual *must have happened* with hormones in the early organizing period – even though that 'something' could no longer be directly seen or measured. This opened up a great many avenues for research designs that might yield indirect evidence of those earlier hormone effects. Scientists studied literally any aspect of behavior or psychology and temperament among intersex people, and if it seemed to differ from the non-intersex people to whom they are compared, then these differences have been overwhelmingly attributed to hormones. This continues to be the case in spite of longstanding arguments that the rearing experiences of intersex people are often dramatically different (Doell and Longino, 1988; Karkazis, 2008), that the medical and psychological interventions to which they are routinely subject are often traumatizing and in any case are certainly consequential (Jordan-Young, 2011; Minto et al., 2003; Morland, 2011), and that many other physical and physiological variables (like outward appearance, 'mood hormones', and metabolism) are also different in some intersex conditions, so attributing group differences to 'prenatal sex hormones' is an unacceptably narrow scientific interpretation of the data (see Jordan-Young, 2010: chapter 9, especially 240–57).

Within a few years it was not possible to even be taken seriously in the field without affirming the theory (Van den Wijngaard, 1997). As the 1970s rolled into the 1980s and beyond, though, this theory increasingly became regarded as a simple fact of development, folded into the background assumptions of research rather than being explicitly stated. This, of course, makes it all the more difficult, and all the more important, to step back and ask *how*, precisely, we know that this is the way things work? What is the evidence for this theory?

One way to answer this question is to approach it from a 'within science' perspective, focusing on methods and rules of evidential support. Elsewhere (Jordan-Young, 2010 and 2011), I have demonstrated three fundamental ways that the studies on brain organization in humans fail to provide convincing support for the theory according to the internal rules of science. First, many of the studies do not meet conventional standards of scientific research. For example, rules of statistical testing are routinely violated (e.g., by doing too

many comparisons in the same study, or by using the wrong kind of statistical tests for the study design). Another important violation of scientific principles is that studies that do not support the theory are routinely ignored in the literature, while those studies that strongly support the theory are cited very heavily, even though the latter are the smallest and least reliable studies. Collectively, such errors amount to what I have called "loading the dice" in favor of the theory.

The second major failure of brain organization theory is an interpretive problem: scientists routinely favor the explanation that hormones exert a direct organizing effect on the brain, which in turn directly affects behavior. Yet, as noted above regarding studies of people with intersex conditions, there are often many other (and, I would argue, more plausible) explanations for the small differences that scientists sometimes observe between people whose early hormone exposures have been different.

The third major failure is what I have termed a "lack of symmetry" between different studies of the same phenomenon. For example, dozens of studies that supposedly show how early hormone exposures affect sexual orientation do not actually add up to a coherent conclusion, because the studies use different and even outright contradictory definitions of and measures for sexual orientation. The same is true of studies that supposedly link early hormone exposures to other aspects of sex/gender psychology, such as 'feminine' or 'masculine' sexual styles, non-sexual interests (e.g., toys, occupations, hobbies), and personality traits that are supposedly gendered, such as aggression. Thus, I've argued that even from a strictly 'empiricist' or conventional scientific perspective, it's time to drop this theory and move on to more interesting and complex ways of studying human development.

CONCLUSION

The empirical critique – the part of my work that might understandably be mistaken for a sort of naïve feminist empiricism (Harding, 1993) – is only one facet of my analysis. In this project, I have tried to work on multiple analytic fronts simultaneously, in order to find points of connection with the widest range of readers, including everyone from the scientists who do these studies, to people who read about them in the daily news, to students of gender and critical science and technology studies (STS). In doing so, I know that I risk annoying readers from each of these groups by not directing myself more

fully or consistently to their interests and points of view. But I disagree with the notion that you cannot simultaneously be thoughtful about the adequacy of specific data and analytic methods for addressing particular questions, and at the same time maintain the perspective that *all* scientific knowledge is fundamentally social and partial (Haraway, 1988; Harding, 1993; Longino, 1990 and 2002).

Like all scientific objects, the human 'traits' that scientists study in connection with brain organization are contingent (Barad, 2007; Mol, 2002). The specific patterns of sexuality, cognition, emotion, and behavior that scientists 'know' through their research, and which their studies tie to specific kinds of hormone exposures, are not timeless, static, stable objects, but emergent phenomena, produced through the intra-action of the living beings who are studied, and the specific scientific practices that scientists employ in their research. These intra-actions characterize the psychology research that shows 'gendered' traits to be distributed in a mosaic way across individuals, rather than being actually sex-dimorphic, just as surely as they characterize brain organization research. Annemarie Mol and others who closely follow scientific practices (e.g. Franklin and Roberts, 2006; Martin, 1994; Murphy, 2006; Rapp, 1999) fracture the self-confident narrative of singular scientific objects and simple cause-effect relationships into "partialities, positionalities, complications, tenuousness, instabilities, irregularities, contradictions, heterogeneities, situatedness, and fragmentation – complexities" (Clarke, 2005: xxiv). Mol has observed that "this turns doing anthropology into a philosophical move" (2002: 32).

If I have not also turned the study of practices in brain organization research into a philosophical move, then I have failed in one of my aims. The point of delving into such detail into these studies, examining how the measures work, how the phenomena being examined shift from study to study, is precisely to highlight such contingencies. It is also to point out that there are different levels and degrees of multiplicity. Scientific standards such as those that suggest legitimate approaches to measurement, statistical procedures, and selection of experimental subjects and comparison groups cannot simply be thrown out because STS has already shown that science is contingent anyway. Most of us doing STS do it because of a healthy respect for, even a love of, empirical research. The most thrilling STS analysis doesn't consist in pointing out 'flaws' but in pointing out interesting and seemingly impossible inconsistencies in excellent, even brilliant work (see Mol, 2002 for what is perhaps my favorite example of such an analysis).

In the final chapter of *Brain Storm*, I looked beyond brain organization research and contrast the model of development implicit in that theory with other, more interactive and contingent, models of development. I also contrast the implicit models of femininity and masculinity in brain research with the models of masculinity and femininity that are found in other kinds of studies, such as social psychology, or research on learning interventions related to cognitive skills that show sex/gender imbalances. What is the point of contrasting brain organization research with other forms of research on sex/gender? It is not to assert that one form is clearly 'true': even controlled experiments, if they could be done on human brain organization, would not yield pristine and simple knowledge. On this point, I think my argument in *Brain Storm* was faulty, or at least insufficiently clear; in several places, I appealed to the evidence from other kinds of research as if that evidence were 'naked fact'.

So here I wish to be clearer: scientists' ideas as well as the concrete methods and tools that they use work together with their human subjects to produce particular versions of reality. In the end, it is necessary to notice but then move beyond the knowledge that different scientific approaches yield divergent information about the 'same' phenomena (say aggression, or verbal abilities, or highly specific skills like 3-D mental rotation). It is necessary, finally, to ask which kinds of interventions in the world do different research projects make possible, and what interventions do they preclude (Longino, 2012)? This makes us responsible for making much more explicit the connections between scientific projects and social investments, and it is particularly crucial when the subject of research is human differences.

What sort of interventions are made possible or precluded by the project of brain organization research? This question brings us back to the dear little homunculus, and it is why I closed my book with a call to turn away from research that seeks the cause of female or male 'essential natures'. Brain organization research is deeply invested in female and male as the 'basic' human division, not just for purposes of reproduction but in general. It enshrines a particular worldview that treasures the sex/gender binary, and invites interventions to further stabilize sex/gender as singular within individuals. It is basically a backwards-looking theory, holding the individual as a 'finished product' of sorts and seeking the seeds of the individual's nature in 'masculine' or 'feminine' chemicals at the right (or wrong) time and place. It is a research project that is persistently (some might argue obsessively) focused on 'deviations' from the supposedly correct and healthy masculine or feminine type, which is the most extremely stereotyped form. This research orientation blunts

interventions that might reimagine gender, or those that would refocus attention on other ways of understanding human traits and potential.

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Motherhood and Scientific Innovation

The Story of Natural versus Artificial Baby Food in the 19th Century

Barbara Orland

Science is said to deal with well-planned, systematic, and evidence-based knowledge, a knowledge that is capable of overcoming everyday experience. Epistemology teaches that the successful scholar even has to put aside his subjective everyday experiences in order to attain innovative knowledge. Everyday life and academia as well as common sense and scientific knowledge represent different worlds. However, this contradiction is put into perspective by newer approaches in science studies. Already in the 1930s Ludwik Fleck had pointed out that scholars have experiences in family, society, and politics that influence their work (Fleck, 1983; Orland, 1998). Not only do they continually subvert the difference between research and practice in medicine and health care because of the requirements of clinical therapeutic practice, progress in medical science can also be clearly linked to the everyday experiences of the practitioner. Research assignments are supposed to clarify a general physiological question and, at the same time, they are directly related to the task of healing a patient with an individual condition and history of suffering. Therefore, in clinical practice things are often done that contradict the general theory of medicine. Concessions have to be made with regard to subjective sensitivities and cultural traditions, which cannot be justified scientifically.

The debate surrounding the topic of *natural* versus *artificial* baby food illustrates this argument particularly clearly. During industrialization, breastfeeding and breast milk became a very powerful symbol and embodiment of nature in civilized society. It was elevated to the status of a 'natural' norm that

became particularly dogmatic in the public health discourse. However, whilst breast milk was propagated as the best nutrition for a baby, industry also developed mass-produced baby food. These products, which were based on the newest chemical knowledge, thus competed with maternal breast milk.

The controversies and conflicts which resulted from this contradiction shed light on a situation that is significant to the history of science. They bring to light the relationship between science, the market, and the public sphere, which had been changing primarily during the second half of the 19th century. Philipp Sarasin aptly described this as a "culture of knowledge" which "took the scientific rhetoric of 'facts' into the wider public sphere and brought all areas of life into a consultation relationship with individual medical, scientific and technical disciplines" (Sarasin, 2001: 130).[1]

On the other hand, and this aspect needs to be dealt with in more detail, controversies of the kind mentioned here make clear that in the political and economic arena the *scientific truth* is not always a sufficient resource that guarantees success. Theories come into conflict with societal conventions and, furthermore, there are a variety of disciplines on the market, which are in a competitive relationship with each other. What becomes established, taken for granted and thereby effectively practiced becomes *natural* and as such part of societal behavior. With respect to the sciences, controversies in concrete areas of research belong to the most productive factors in scientific development. Research creates problems, which in turn generate a new demand for research and the revision of consulting knowledge. For other market participants, however, this process is not always productive – mothers, in particular, were increasingly spoilt for choice.

THE NATURAL NORM: 'BREAST MILK'

The assertion that only a mother with her own milk can feed a child without any danger arose during the Enlightenment at a time when health, personal hygiene, and particularly the moral and character traits of the 'female' were being debated. Maternal love as a purpose of nature was discovered. Natural philosophers saw both, the female breast as well as the milk, as natural organ functions of the mother's (but not the woman's) body. Women do not have

1 | All quotes from German sources used in this paper were translated by Rebecca Carberry.

their "two milk vessels" in order "to lift them up artificially" and "use them for courting" but rather women develop breasts "as a highly important tool for feeding a child" (Osthoff, 1802: 375), doctors argued. Although they have been revered as fertility symbols since ancient times, breasts and milk had never before been so strongly maternalized (see Beier, 1996; Delahaye, 1990; Schiebinger, 1993; Yalom, 1997). The new conceptions of the 'anatomy and biology of the female' led many doctors to speak out against the widespread use of wet nurses and criticize the wet nurse milk as 'artificial baby food'. To them, it was the voice of nature that preached breastfeeding to mothers. One doctor for instance stated that current popular medical literature should no longer consider wet nurse breastfeeding merely as a moral sin, but as "a violation of laws of the living organism" (Osthoff, 1802: 378).

During the Enlightenment, maternal nurture was part of a political agenda for infant survival (see Fildes, 1988; Golden, 1996; Jacobus, 1995; Lastinger, 1996; Schiebinger, 1993). For the first time, philosophers, naturalists, and physicians turned their attention to the child as an object of scientific study, producing anatomical, physiological, and psychological descriptions of the child, elaborating debates on child-rearing customs, and generating a huge amount of advice and prescriptions on hygiene (see Benzaquén, 2004). Weaker than any animal, unable to move or make use of its organs and senses, the child was "an image of misery and pain", according to Georges-Louis Leclerc de Buffon (1707–1788), writing in 1749, in his *Natural History of Man*. Even more famous were the claims of Jean-Jacques Rousseau, who based his influential account of child-rearing in *Émile* (1762) on Buffon's work. Nature, he informed the enlightened public, produces strong and robust children "who are well constituted and make all the rest perish" (quoted in Benzaquén, 2004: 37). Far from being natural, the weakness of children is an instance of society's corrupting effect on human nature, complained the man who himself had placed his own five children in foundling homes. Returning to nature and its laws was the surest way to end corruption and regenerate society. *Émile* began this policy of regeneration by replacing the unnatural practice of wet-nursing with the figure of the maternal nurse, the guarantor of the family and of an incorruptible signsystem for the Republic of parents (see Jacobus, 1995: 209). "Let mothers deign to nurse their children", Rousseau preached, "morals will reform themselves, nature's sentiments will be awakened in every heart, the state will be repopulated" (quoted in Schiebinger, 1993: 70).

This new-found duty of mothering and breastfeeding, which featured – before Rousseau – in the relevant articles of the *Encyclopédie* in 1751, launched an unprecedented campaign against wet-nursing (Lastinger, 1996: 605). There can be no doubt that the ancient custom of employing a wet nurse for infant nutrition had increased enormously in the cities of the seventeenth and eighteenth centuries. Especially in France, wet-nursing was both a social institution and a state-regulated industry. Around 1780, fewer than 1000 babies out of 21,000 newborns in Paris were fed by their mothers; a further 1000 had a wet nurse in their parental home (from a population of 800,000 to 900,000) (Gélis, 1980: 164; see also Sussman, 1982: 22). All the other newborns were said to be given to wet nurses outside the city, in the peripheral areas and up to a distance of 200 km in Normandy, Picardy or Burgundy. A widespread feature of urban life, it was also popular in smaller towns and common among craftspeople, traders, members of the bourgeoisie, physicians, and even laborers. The silk workers of Lyons were said to have completely given away their babies. Only the poorest refrained from this practice.

At the beginning of the 19th century, mother's milk had already become an abstract biological norm, an anthropological model, which was the ideologically loaded basis of a variety of measures for health policy. Especially middle-class mothers were forced to breastfeed their own babies in order to contradict the "child-murdering practice of the aristocracy of letting their babies be fed by a wet nurse" (Frevert, 1984: 34; Frevert, 1985: 423). As Ute Frevert pointed out, women were regarded as the "extended arm of the doctor" to spread the message of the moral philosophers and medical experts. During the period of industrialization the call for breastfeeding developed into an instrument of middle-class health policy that was used in a variety of ways. Doctors, women's associations, health authorities, and local authorities intensified the breast feeding propaganda since the time when statisticians and social hygienists systematically investigated and wrote about infant mortality (see Stöckel, 1996). A soaring number of monographs and articles identified one cause in particular: "The deciding factor for an infant to thrive is first and foremost the type of nutrition and the other food. […] When children are regularly breastfed, infant mortality is low." (Prinzing, 1899: 578) No matter which social, economic or geographical factors were correlated, the maternal responsibility for nutrition and care of infants always occupied a prominent position.

The Need for Breast Milk Surrogates

Despite the unquestioned orientational function that the breast milk norm acquired in the everyday reality of the 19th century, the concrete practice of doctors regarding the breastfeeding question did not differ from that of mothers, midwives, and others who helped with pregnancy, birth, and confinement. In 1845, one doctor wrote that the "moral duty of the mother to breastfeed her infant herself is, however, not absolute" (Zettwach, 1845: 5). Medical literature recorded many reasons for not resorting to breastfeeding; these did not only include social reasons such as the frequently mentioned comfort of well-off women or that of the 'unnatural' wet nurse. There were a whole range of medical contra-indications (see Meissner, 1850: 12–18): a list of the year 1874 stated the following problems: age and constitution ("women who were weakened by worry and hard work"), anaemia, tuberculosis (consumption), scrofula, venereal diseases (syphilis, gonorrhoea), rachitis, osteomalacia (bone softening), feverish illnesses (confinement), cholera or dysentery (intestinal diseases), psychosis (hysteria), epilepsy, anomalies of the breast or inflammation of the breast, to name but a few (see Kehrer, 1874). Complaints about women's obduracy only rarely attributed it exclusively to a lack of understanding or willingness. The medical helpers stated just as often that mothers lacked the possibility of paying attention to their health and that of their children. For example, if the mother's social circumstances and lifestyle made it impossible for her to follow the necessary diet, her doctor would need to advise against breastfeeding (Weissenbach, 1825: 61). Doctors were often just as convinced by old practices as the mothers. Women over 35 were advised not to breastfeed, as "many children will not take the breast of an older woman" (Mauthner, 1853: 70).

Mothers certainly needed alternatives, a fact that was clear to every doctor. Furthermore, there were many uncared for infants in orphanages, foundling homes, hospitals, poor houses, and work houses whose nourishment was the responsibility of the institution's staff. Doctors who worked there were very often vehement advocates of wet nursing. In 1853, the manager of a Viennese children's hospital wrote:

> "It often breaks my heart when I see how a poor little mite whimpers and squirms, how it often screams with hunger until it is hoarse; how it is blue and stiff from an inner cold; how it is shrivelled like a mummy until it succumbs to the terrible suffering of starvation. […] For me,

> there is no greater joy than when I have used every possible art of persuasion and obtained a wet nurse for one of these poor mites and then see how it snatches the breast and then smiles and is revived after a few hours." (Mauthner, 1853: 71)

Justus von Liebig and the 'Soup for Infants'

The discourse on motherhood and the complex reality of infant feeding existed side by side, which is why, in 1865, the news that a chemist's laboratory had developed a formula for baby food did not cause a great stir. The then already famous Justus von Liebig wrote that his invention of 'artificial breast milk', which he called 'soup for infants', "was prompted by the fact that one of my grandchildren could not be fed by his mother and a second needed some more concentrated food alongside his mother's milk" (Liebig, 1866a: preface). The fathers of the children, both doctors, had suggested that Liebig should make the family recipe available to a wider public (UGL, No. 124).

It was in no way surprising that Liebig should turn his daughter's and daughter-in-law's problem into a scientific question – as a chemist, he had, after all, been dealing with food products for over twenty years and had the necessary laboratory facilities at his disposal. His meat extract was already a famous product that sold exceedingly well in the mid 1860s (Lewicki, 1982: 198, 199). This does, however, not permit the conclusion that it was Liebig's aim to create just another profitable food product. At this stage of his career Liebig was no longer concerned with increasing his reputation or income (see Munday, 1990; Finlay, 1991). Furthermore, the story of his baby food can hardly qualify as the history of a scientific breakthrough. Had he been primarily interested in finding the solution to a knotty question controversial within the world of chemistry, he presumably would have focused on the scientifically more gripping question of protein contents. Liebig had, after all, already done some groundwork on the primacy of proteins as a source of plastic and mechanical power, and producing scientifically engineered food that was rich in protein was very much en vogue. Yet it was other scientists that worked on the question of protein, which was particularly important in milk nutrition,[2] whilst Liebig turned his attention to the well-known fact that children have

2 | Also see the following paragraph.

no tolerance for preparations that included flour porridge.[3] He was not fundamentally opposed to flour porridge in baby food, because it was supposedly not difficult to calculate the correct mixture of cow's milk and flour that corresponded to the nutrients in breast milk. The main problem for Liebig lay in the fact that flour, which as such was by no means unsuitable for infants, was much less alkaline than breast milk and therefore reacted acidicly in the infants' stomach. Its transformation into soluble forms of sugar could, he feared, overstrain the little body's organism. It was precisely this problem that his formula aimed to avoid (see Liebig, 1866a: 8–11).

Liebig's idea was to use the mashing process that was already known from beer brewing as a kind of technological pre-digestion of the starch. This involved preparing a flour and milk porridge and then adding a mixture of barley malt and double carbonate of potash.[4] The warmed porridge had to rest for at least half an hour in order to obtain the desired effect of the mashing process. The whole procedure was not only inconvenient but also time-consuming. It took more than an hour before one could feed the child, and storage was not possible because the food contained milk.

Despite these disadvantages, chemists and pharmacists who were the first to hear of Liebig's laboratory experiments were enthusiastic about the idea. Liebig was obliged to speed up the first print of his work, because – as he informed his co-editor – the news was already spreading in pharmacist circles that there would soon be an efficient baby food formula on the market (UGL, No. 566). Indeed, after Liebig's work became known, he himself saw to its rapid dissemination. At the turn of the year 1864/65, Liebig had advised at least two pharmacists in different locations to make and sell his 'soup'. Amongst them were the Widnmann pharmacy in Munich and Savory & Mooze in London (UGL, No. 447). The latter publicized the promotionally effective

3 | Liebig knew that paediatricians saw flour porridge mixtures as a main cause for the early death of infants. He also wrote: "The doctors are aware of the harmful effect of the flour porridges that are so widespread in the country and in the city; one understands the fact that cow's milk is not improved by mixing it with wheat flour, rather it gets worse because wheat flour is a very incomplete food product due to its lack of mineral salts" (Liebig, 1869: 147).

4 | Barley malt was to be procured from a brewery, ground in an ordinary coffee grinder and then strained. The preparation of the potash solution was also described in detail. It was to be prepared using ordinary pharmacy potash (carbonicum depadurum) and preferably soft water.

message that even Queen Victoria gave her grandson prince Albert Victor the 'Liebig Soup' to eat. This, of course, flattered its creator (UGL, No. 304, No. 717), who reacted promptly by following up the first version of his work in the 'Annals of chemistry and Pharmacy' in 1865 with a separate publication a year later, which went to two editions in the same year.[5]

There was an obvious demand, and the innovator's famous name imparted credibility to the new food product even before it could prove its worth in the field. It was these circumstances and not so much the formula itself that led to the product's success. This becomes clear when taking a closer look at the work presented to the wider public in 1866: for the average lay person the theoretical derivation of the formula was not comprehensible. In addition, his general theory of nutrition also came under some criticism. However, neither the method's complexity nor the controversy were able to harm the 'Soup for infants'.

Remedy or Food Product: The Commercialization of Baby Food

Liebig was not the only one at the time to experiment with artificial baby food. A young doctoral student of obstetrics and gynaecology, Philipp Biedert, was also investigating the chemical differences between breast milk and cow's milk (see Vaupel, 1993). Like Liebig he conceived – based on his scientific findings – a food product and had it manufactured and marketed by a pharmacist.[6] Like Liebig's 'Soup for infants', *Biedert's Rahmgemenge* (Biedert's

5 | Supplements regarding the use of the product were published both in the *Annalen* and in *Buchners Neues Repertorium*, see Liebig (1865, 1866a, 1866b, 1866c).

6 | In contrast to Liebig, who investigated the digestion and reabsorption of carbohydrates and the reduction of starch production, Biedert concentrated on the metabolism of protein. He had built a small machine, a digestion machine, which simulated the digestion process of an infant. Stomach acid was added to various types of pre-treated milk and left to rest for a certain amount of time at 36°C. He was thus able to prove that breast milk not only contains less protein than cow's milk, but that it also curdles in a fine-grained way and thereby must be chemically different. This discovery was important for the production of a substitute in that it was not sufficient to merely balance "the percentages of casein in human and cow's milk" but to also replicate the chemical structure of breast milk proteins. Since this was not possible, Biedert concluded: "We therefore have no method

cream mixture) became known nationwide and was not only discussed in relevant chemistry and medical journals but also in daily newspapers, family periodicals and household and health advice publications.[7] However, both formulas shared the same disadvantage; they could not be readily prepared at home or in a doctor's office.

Thus for the time being they remained products that could only be bought at a pharmacy. In 1866 the pharmacy Pachmayr and Widnmann in Munich sold freshly prepared portions of 'Liebig soup' in various city pharmacies. They also sold a pre-prepared malt powder intended to facilitate preparation at home. Within eleven months (September 1866 to July 1867), Pachmayr alone sold 30,000 portions (see Pfiffner, 1993: 115). In 1874, *Biedert's Kindernahrung* (Biedert's children's food), later renamed *Biedert's Ramogen*, was the first tinned version to become available on the market and in 1880 sold for a price of 1.20 marks (Biedert, 1880: 271). Mixed with water and fresh milk, the contents were said to yield a food in every way comparable to the freshly prepared cream mixture. In 1892, the German dairy Zwingenberg i.H took over the production of the tinned butter-like substance. Despite the ever-changing views regarding the issue of fat, the product sold very well and was still on the market in 1937 (see Müller, 1937: 11).

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that really improves cow's milk; neither does goat's milk provide a better substitute [...] other types of milk are hard to obtain and anyway offer little hope of being more useful." (cited in Vaupel, 1993: 12) Biedert's substitute food aimed to make cow's milk more easily digestible by reducing the amount of protein and pre-curdling it. In a variation of a formula developed by his PhD supervisor, Biedert cooled fresh cow's milk for 12 hours and subsequently skimmed the fat off. The skimmed milk was laced with a liquid made from dried calf's stomach doused with vinegar. Roughly a teaspoon of this was to be added to a half a pint of milk and the entire mixture heated and filtered. Two parts of this whey where then mixed with one part cream.

7 | The family magazine *Die Gartenlaube (The Bower)* for instance, founded in 1853, regularly featured product advertisements from a variety of manufacturers. The time gap between the product launch and the first presentation in cookbooks decreased substantially when – as it later became common – editors and authors of cookbooks extended invitations to visit the manufacturing plants, organized cooking courses, and sent out free recipes. The famous cookbook author Henriette Davidis was a supporter of the various Liebig food products (see Teuteberg, 1990: 87).

It did not take long for countless imitators who had picked up on the potential demand to appear on the scene. The market now abounded with copycat products carrying names such as *Liebig'sche Suppe*, *Löfflund's Kindernahrung*, *Liebe's Nahrungsmittel* in direct or indirect references to the famous chemist (Gerber, 1877: 20ff).

In particular, so-called children's flours were sold, since their manufacturing process was comparatively simple. Most of the manufacturers were small or middle-sized businesses, whose owners were also the product's inventors (without author, 1892). As no particular qualification was required by the state to produce these products, it was only the sources of raw material that determined the access to the baby food market. Whether it was Zwieback (rusk) manufacturers, the soup industry (experienced in mixing diverse pulse flours with dried vegetables and seasoning), dairies or condensed milk producers, soon a wide range of manufacturers joined the pharmacies on a bustling market.[8]

While the effort in preparing various formulas was the initial reason that fostered the commercialization of baby food, it was the breastfeeding propaganda that was subsequently to affect the business. At first though, the market's euphoria over baby food prevailed, continuing into the 1880s. Many people at the time saw the commercialization of chemical knowledge as beneficial progress. Then, however, the radical politicization of infant mortality began to take effect. Paediatricians, in particular, came forward with their observations that the purchased products resulted in fatal malnutrition. A letter by a paediatrician from Darmstadt reveals who was held responsible: In 1907 Arnold Vidal asked the imperial health authority in Berlin for help

> "against a danger that threatens the infants in the whole of the German Empire […] I am referring to the advertising undertaken by various children's flour factories in a way that simply cannot be permitted. [...] Every attempt by doctors to spread the message about natural feeding and to steer artificial foods in the most rational direction is frustrated by unscrupulous advertising which more or less covertly casts suspicion on breast and cow's milk only to conclude by extolling children's flour. […] Some manufacturers were even so cautious as to exclude from

8 | This work gives a good overview of the various nutritional preparations before the Second World War: Reichert (1969). For the controversies over artificial baby food see also Apple (1987).

> their brochures anything directly controversial, in fact, to even partially recognize the usefulness of breastfeeding. The overall impression for the layman is nevertheless that nutrition using children's flour is best. [...] And experience confirms this: a common remark by mothers whose infant has become ill as a result of the food is 'but I did buy my child something good and expensive'" (Bundesarchiv Berlin, R86/2204).

The pressure from the public health discourse was such that it became vital to provide scientific proof of being able to perfectly replace breast milk. Otherwise one ran the risk of being seen as showing no concern for possible health damages. At the same time, the manufacturers could not give the impression of wanting to discourage mothers from breastfeeding. In this strange and conflicting situation, the manufacturers of baby food developed a unique marketing strategy. They advertised their products as substitutes. In their brochures, on advertising posters, and in newspaper advertisements they first praised breast milk and then, far more extensively, commended their product as a fully sufficient substitute (see Schmidt, 1888: 25; see also Bertling, 1881).

One result of this paradoxical situation of having to be as good as the natural archetype, but not being allowed to suppress it, was that the image of baby food products oscillated between remedy and food product. Only pharmacies could sell their products as remedies or medicinal products, only they could point to a professional relationship with medicine. However, the trade structure and the professional rules and traditions of the pharmacies gave the baby food manufacturers good reasons to avoid the medicinal market and to place themselves on the market as food product manufacturers. Pharmacists were inflexible, they were only allowed to work locally. As they were dealing with fresh milk, medical or children's milk establishments could only serve a small distribution area.[9] Nationwide ambitions could only be pursued as a food product manufacturer.

9 | The inflexibility of pharmacies was mainly caused by the concession system. In order to open a pharmacy it was necessary to obtain permission from the supervising authority. Between 1850 and 1900 there was a significant shortage of pharmacies in some towns and regions. While patent protection had gained in importance since the 1870s, there were strong restrictions against its application to remedies and medicinal products. In addition, in the 1880s there were a number of advertising bans by 'imperial decree' in force. See Ernst (1975: 173).

Supplying comparatively non-perishable and transportable products, condensed milk and children's flour manufacturers tried to bridge the gap between nationwide distribution and scientific legitimacy in their product branding and advertising. No one grasped this more quickly than Henri Nestlé who had a keen instinct for developing sophisticated marketing strategies. At a time when economics still spurned advertising as immoral deception and as a dishonourable action or declared it outright unnecessary, for Nestlé advertising already constituted the largest share of his overhead costs.

By 1866/67 Nestlé had invented his children's flour, a mixture of Liebig's formula and condensed "first-class Swiss milk" as he never tired of emphasizing later on. In early October 1867 he tested his product on two infants. When word got round that they had reacted favorably to it, many mothers, midwives, and doctors flocked from near and far to purchase the children's flour. Nestlé deduced that "[...] if I can sell this at the same rate in the big cities, I will have to build a huge factory and will become a millionaire in no time" (see Pfiffner, 1993: 115). Within a year, production had started and Nestlé was proved right. In just seven and a half years from early 1868 to autumn 1875, he increased sales from 8,600 to 1,440,000 tins of children's flour. By 1874 the product was being sold in eighteen countries, with the highest sales in Germany, Switzerland, France, Russia, and Austria (in that order). The key to success, which continued to work after Henri Nestlé's retirement from active life in 1875 and the conversion of the firm into a limited company, lay in the combination of various marketing strategies. In order to set himself apart from the numerous imitations of Liebig's infant's 'soup', that advertised with Liebig's name with varying degrees of ingenuity, and disregarding the famous supplier of the idea, Nestlé tried from the beginning to associate the exclusivity of his invention with his own name. At a time when food products were usually sold open and were packed by the retailer and not the manufacturer, the Nestlé children's flour came on the market with consistently the same packaging and lettering and a logo that was designed quickly but is still used today. It was then, in fact, an infant-food product that launched the development of branding and corporate design.

On the other hand, due to the fact that, as mentioned above, advertising was considered deceptive and dishonourable, manufactures like Nestlé understandably sought a close association with pharmaceutical products and employed an advertising strategy that emphasized the public interest aspect or used moral arguments. Furthermore, it was crucial for these manufacturers to assert themselves in the health policy debates. For this reason, Nestlé used

authority-based advertising. Paid assessments by doctors or recognized forensic or research chemists and thank-you letters from doctors selected by the manufacturer were published in newspaper advertisements, newspaper supplements, on packaging, and on flyers.[10] Free trials for doctors were another strategy, since what could be more beneficial for a product than to be tested in the doctor's practice and then discussed in the relevant academic journals? Even paediatrics textbooks had served over the decades as product-testing platforms that cited individual products, manufacturers, and contact addresses (see Kehrer, 1874: 530ff; Kolisko, 1899: 249ff).[11] More importantly, Nestlé also negotiated favourable commission contracts with pharmacies, so that the packaging subsequently carried the notice 'Available in all (better) pharmacies'.

The Reaction of Paediatrics: Infant Physiology and Medical Nutrition Regimes

Paediatricians initially had as little experience with substitute food for infants as anyone else. Ironically, it was the commercialization of baby food that would expedite the forming of a separate discipline and its detachment from internal medicine. Medical historian Eduard Seidler put it this way: Baby food became a "vehicle for the establishment of paediatrics as a science, as a method that became theory" (Seidler, 1976: 288–302, 302).

Up until 1890, only a few individual paediatricians had conducted their own research. With the exception of Philippe Biedert, the majority had merely reacted to the aforementioned developments. Max Seiffert, a doctor at the University Children's Clinic in Leipzig, remarked in exasperation that instead of developing their own guidelines for food products, doctors were obliged to learn about the characteristics of the infant digestive system via reactions to industrially produced food products. In his criticism of the "excessive lenience towards incompetent reformers in the field of infant nutrition and milk treatment" he referred to the famous bacteriologist Carl Flügge, who had himself criticized

10 | A collection of reviews and analyses of the Nestlé children's flour can be found in the Archive Historique Nestlé in Vevey, AHN Cham, Dossier 192–200.

11 | A Bonn paediatrician for example devoted an entire book to the experimental comparison carried out in his own practice with purchasable children's nutrition products (Schoppe, 1894).

> "that in past years, with regard to the hygiene of milk, we have made the mistake of relying on the advice of men who are neither hygienists nor paediatricians but chemists, farmers and pharmacists, and that we have allowed ourselves to assume, almost without further verification, that everything the latter have provided us with in terms of milk preparations and theories and procedures of milk treatment is hygienically appropriate" (Seiffert, 1904: 256).

In a matter of a few years, research was systematically established at university clinics. The aetiology and pathogenesis of nutritional illnesses in infants remained the focal point of paediatric research for several decades (see Czerny and Keller, 1906/1917). Increasing significance was attached to the physiology of infants and the anatomy of digestion and the questions surrounding metabolism were investigated in detail.

What used to be described in colloquial terms as *a thriving* infant and one that *fails to thrive* was now defined scientifically and re-introduced into everyday practice as criteria for what should be considered *normal*. Mothers and manufacturers now had to bring their infant nutrition practice into line with scientific definitions of 'healthy' or 'pathological'. Measuring, weighing, chemical and physical examinations of metabolism and of the blood became regular techniques of paediatric diagnosis. The individual child was increasingly assessed and treated within the grid of statistical populations.

Around the turn of the last century, the kind of paediatric nutritional regimes in table form were developed that are still valid today and have long since gone beyond being exclusively applicable to sick children (see also Apple, 1987; De Knecht-van Eekelen, 1995). Ever since, the amount of milk or milk substitute consumed in relation to the child's body weight is recorded in minute detail. And after the medical research had got underway, it no longer seemed, from a paediatric point of view, neither theoretically nor practically scandalous to embark on experiments with baby food that contained no or very little milk. With time, this had its effect on the public perception of breast milk. As paediatrics were soon to find out, all the attempts to create an exact copy of breast milk would not have been strictly necessary. With the exception of the problem of sufficient milk hygiene, the infant organism proved to be more adaptable than previously thought. From a purely physiological point of view then, breastfeeding became practically superfluous and

paediatricians gradually relinquished their hostile attitude towards industrially produced baby food.[12]

Translated from German by Rebecca Carberry.

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12 | At least until new research results necessitated a reappraisal. The only finding that has stood the test of time is Biedert's notion of the chemical difference between breast and cow's milk. In the course of the 20th century other research results emerged, again assigning physiological importance to breastfeeding, as breast milk was proven to contain immunologically important substances for fighting infection that are not present in cow's milk (see Wachtel, 1990).

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Diffraction Patterns?

Shifting Gender Norms in Biology and Technology*

Waltraud Ernst

> "Not surprisingly, what is at stake in this dynamic conception of matter is an unsettling of nature's presumed fixity and hence an opening up of the possibilities for change."
> (Barad, 2007: 64)

Since the late twentieth century, feminist analysis of science and technology has been criticizing not only the absence of women as epistemic subjects and objects, but also their rather problematic presence as a stereotyped and devalued other. Studies show how prevalent gender norms impede people to develop technologies accessible to and profitable for all (Lerman et al., 2003; Sørensen et al., 2011). Studies also show how people find new ways to negotiate their gender identities within the materialized cultural space of normative assumptions about women and men (Kafai et al., 2008; Varma, 2007); and how people express gender in information and communication technologies beyond so-called natural or culturally desirable ways (Landström, 2007b; Wakeford, 2002). Therefore, feminist analysis of science and technology is in need of finding, first, innovative epistemic ways to empower those who are dis-empowered by gender hierarchies, racism, classism, homophobia, and other ideological conditions that classify persons in structural hierarchies. Second, feminist analysis can investigate the epistemic ground on which persons counteract those structural hierarchies. Third, I will argue that epistemological

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reasoning within feminist science and technology studies has to clarify the methodological and conceptual question of how to investigate gender in the life sciences and material sciences as well as in information- and communication technologies (ICT).

Feminist theories strive to understand how gender works. How does gender function as a social institution (Lorber, 2000) and as interactive iterative performativity (Butler, 1993)? How do narratives of identity acquisition interfere with a normative apparatus of gender (Kilian, 2004)? How do these narratives relate to gendered power relations (Castro Varela et al., 2011)? Finally, I will further elaborate the question of how can we practice gender studies within science and technology studies (STS) without reinforcing the binary of femininity and masculinity as the basis for gender hierarchies (Landström, 2007a). More precisely, I will explore what happens if we investigate gender, including sex and sexuality as diffraction patterns rather than as differences.

The chapter aims to contribute to a way of studying gender in technological processes and productions informed by a theory of gender that does not presuppose gender as a given binary or dichotomy. Drawing on the insights of Judith Butler's approach on performativity of gender (1993) and gender as an apparatus (2004), it will examine epistemic values for the discussion of gendered entanglements of scientific knowledge production. I will investigate whether – and if so, how – Butler's understanding of gender as an apparatus can be methodologically useful for feminist science and technology studies. A further point of discussion will be whether – and if so, how – Karen Barad's (2007) agential realist understanding of the apparatus as an epistemological concept can be applicable for gender studies beyond STS. With her understanding of matter as a dynamic intra-active becoming, Barad starts from the entanglement of matter and meaning to investigate innovative research methods for constructive interdisciplinary engagements between technosciences and humanities.

The paper will also debate the question whether this research perspective can be put to use for engineering design practices, as Lucy Suchman (2007) suggests. According to Suchman, the human-machine-interface is a dynamic process of materialization, in which meanings can change. This means that although newly developed technological objects need to be recognized in their envisioned cultural environment, they always carry the possibility of leading beyond the replication of established norms. From this follows that gendered subjects and objects can experience, in interaction, new practices and new meanings of themselves and the other, including their gendered meaning. In the area of biology, Anne Fausto-Sterling suggests an integrative, interdisci-

plinary and holistic model for the study of human sex, gender, and sexuality. This model includes questions about the cell, the organism, the psyche, person-to-person relationships, culture, and history on a larger scale (Fausto-Sterling, 2000). I will discuss whether her account on dynamic biocultural systems of reciprocally related processes can be put to use for the discussion of material and social aspects of gender, sex, and sexuality. In bringing these perspectives together, the paper claims that through the effort to counteract, to fit in or to perform along the norms produced by knowledge and ignorance of gender, sex, and sexuality, we all contribute to what counts as knowledge at any given moment. The paper argues for a relational epistemological framework and shows that not only our apparatuses and concepts shape the results, but that all involved "subjects, objects, humans and non-humans or inappropriate/d others" (Haraway, 1997) depend on each other, and thus mutually shape the understanding of each other and the world.

What is Diffraction? What is an Apparatus? What is Matter?

Diffraction is understood by Karen Barad in more than one way. The most important difference Barad makes is the one between diffraction and reflection. Reflection is problematized by Barad as an optical metaphor in representationalism, a widespread epistemological account in the philosophy of science. For Barad as well as for Haraway (1997), from whom Barad takes up the idea of diffraction as a useful concept for feminist epistemology, it is important to overcome reflection as an epistemological model as well as a means to understand difference – and thus as an ethical model – because it seems grounded in dichotomous thinking. In classical physics, diffraction points to an interesting picture:

> "Simply stated, diffraction has to do with the way waves combine when they overlap and the apparent bending and spreading of waves that occurs when waves encounter an obstruction. Diffraction can occur with any kind of wave: for example, water waves, sound waves, and light waves all exhibit diffraction under the right conditions." (Barad, 2007: 74)

This means that diffraction can be an outcome of an experimental setting in the laboratory as well as a natural phenomenon: "The ocean waves are thus

diffracted as they pass through the barrier; the barrier serves as a diffraction apparatus for ocean waves." (Barad, 2007: 74) – Later, Barad uses the example of two stones dropped into a calm pond simultaneously to illustrate the meaning of interference or diffraction pattern: "The waves are said to interfere with each other, and the pattern created is called an interference or diffraction pattern." (Barad, 2007: 77)

A shift in gender studies from a framework of reflection to a framework of diffraction could be interesting for the following reasons. Understanding gender in the framework of reflection seems problematic, because it supports a binary system of thought which envisages the Other as an opposite in front of the self, in a dichotomous model which excludes similarities. In the case of gender, the Other has often been schematized as the one of 'the opposite sex'. To think of gender in opposites, in turn, suggests to think of gender in dichotomous binaries as either women or men. Yet, this idea has proved insufficient to 'reflect' empirical reality, in terms of material bodies as well as in terms of a culturally or socially lived and represented reality. But more than this, to envision gender as an exclusive binary construction reinforces the idea that what is feminine cannot be masculine and vice versa, a powerful thought that has resulted in gender-segregated fields of work and pleasure and a devaluation of those fields associated with femininity (Hausen, 2012). Therefore, overcoming the framework of reflection seems to be a promising way to promote conceptual shifts in gender studies. These conceptual shifts might suggest investigating gender, sex, and sexuality along with concepts of similarity and plurality instead of bipolarity and dichotomies.

Following Judith Butler, Barad stresses the intra-active performativity of matter concerning gender, sex, and sexuality. She elaborates on Butler's famous statement that gender is not the cultural interpretation of sex but "the very apparatus of production whereby the sexes themselves are established" (Barad, 2007: 61). In the following, I will take a closer look at the connection between Judith Butler and Karen Barad and first elaborate on Butler's account on gender as a performative norm and an apparatus.

Judith Butler has argued that sex is always already gender, just because we cannot relate to our bodies and other bodies without the cultural framework or mindset we live in. In her book *Bodies that matter* (1993) she stressed that this does not mean to say that there are no bodies or that bodies are not relevant. On the contrary, as the programmatic title of her book suggests, living is a bodily matter in an important way for Butler. I conclude from this that the way how we are told about or able to relate to our materiality or to the materiality of oth-

ers is a highly contested field, precisely because it is so relevant for existence. In her book *Undoing Gender* (2004) Butler elaborates her theory of performativity of gender and relates gender as a norm closely to its bodily enactment:

> "In fact, the norm only persists as a norm to the extent that it is acted out in social practice and reidealized and reinstituted in and through the daily social rituals of bodily life. […] [I]t is itself (re)produced through its embodiment, through the acts that strive to approximate it, through the idealizations reproduced in and by those acts." (Butler, 2004: 48)

This means that, according to Butler, gender is neither something one has or is, but rather a normative regulation to which persons shape or reshape their bodies – not necessarily along established binary-gendered norms but in relation to them. From this follows that to understand how sex is related to gender one has to understand not only how the so-called social is related to the so-called natural or how culture is related to matter or the body, but also how femininities and masculinities are produced through these relations.

To understand the contingency of this binary and its applications in feminist studies of science and technology, I will subsequently discuss Butler's concept of the apparatus of gender in more detail. In the chapter *'Gender Regulations'*, she uses the concept of apparatus to describe the production and normalization processes in which different concepts delineate more or less bodily, psychic or social aspects of human personalities: "Gender is the apparatus by which the production and normalization of masculine and feminine take place along with the interstitial forms of hormonal, chromosomal, psychic, and performative that gender assumes." (Butler, 2004: 42) Here, her concept of apparatus clearly encompasses much more than a 'lens' or 'construction'. It points to a complex and multifaceted interaction between social norms and material-semiotic states of humans as diverse as hormonal levels, chromosomal activations, psychic interferences – or diffractions in the performative display in which gender is produced and enforced. On the other hand, she points out that gender exceeds its definition as a normative binary of femininity and masculinity:

> "Gender is the mechanism by which notions of masculine and feminine are produced and naturalized, but gender might very well be the apparatus by which such terms are deconstructed and denaturalized. Indeed, it may be that the very apparatus that seeks to install the norm also works

> to undermine that very installation, that the installation is, as it were, definitionally incomplete." (Butler, 2004: 42)

She suggests conducting research on gender that studies existing transgendered subjects and phenomena such as gender blending as ways of living beyond the naturalized binary (see also Halberstam, 2011). If we understand the more overtly existing transgendered subjects and phenomena such as gender blending or gender bending as shifts in the performative display of gender, will it be possible to develop research questions that relate these shifts to historical and current shifts of gender norms in biology and technology? Can these performative material-semiotic shifts be understood as diffraction patterns in Karen Barad's sense? And, if yes, in which sense can gender be understood as the very apparatus which produces these (and other) diffraction patterns?

In her book *Meeting the universe halfway* (2007), Barad elaborates on various manifestations of matter on the conceptual level, as if her conceptual approach itself figures as a barrier or a breakwater in the ocean or as the slits in a screen of a two-slit-experiment. The way she discusses material aspects of human bodies, of brittlestar species and of single atoms being object (or subject?!) of nanotechnological transition (manipulation) evokes quite special diffraction patterns in itself. As a quantum physicist, she plays with the ambivalence of wave and particle on the most fundamental level of light and atom. She employs this ambivalence as if one could discuss it in a similar way when it comes to living organisms.

Barad gives an interesting example for this approach. In connection with the description of various ways of mating, reproducing or multiplying, Barad introduces the brittlestar. The brittlestar, living in a deep and dark ocean environment, is a nice 'example of nature' of queerness beyond human ways of living. It was not for its queerness though that the brittlestar became famous. It was in projects of biomimesis, Barad explains, where its technique of seeing attracted the attention of research. The author thinks that there is more to the brittlestar: She asks crucial questions about bonding, belonging, and boundaries of material organic bodies. Interestingly, when it comes to the brittlestar the relatedness of a (singled out) body to the 'environment' surrounding it becomes blurred:

> "The brittlestar species exhibit great diversity in sexual behavior and reproduction: some species use broadcast spawning, others exhibit sexual dimorphism, some are hermaphroditic and self-fertilize, and some

> reproduce asexually by regenerating or cloning themselves out of the fragmented body parts. When is a broken-off limb only a piece of the environment, and when is it an offspring?" (Barad, 2007: 377)

She asks even more to the point: "Is contiguity of body parts required in the specification of a single organism? Can we trust visual delineations to define bodily boundaries? Can we trust our eyes?" Barad concludes: "Connectivity does not require physical contiguity." The crucial question seems to concern the relatedness in connection with the generation of organisms: "Is the connection between an 'offspring' regenerated from a fragmented body part and the parent brittlestar the same as its connection to a dead limb or the rest of the environment?" (Barad, 2007: 377) With the brittlestar, Barad does not only give a telling example of variations on the multifaceted ways sex, gender, and sexuality is organized in natural environments, but also provides fundamental insights to the various research apparatuses turning to it. It is also the most convincing example for Barad's claim for the intra-active becoming of matter within the world, which indeed goes beyond Judith Butler's focus on human interaction in the world. Moreover, her discussion of the brittlestar exceeds an understanding of organisms which presupposes solid boundaries. Barad thereby enlarges our concept of the organism in an interesting way from an entity with clear boundaries to something related to the environment within much less distinct limits. Here, Barad's description delineates an apparatus of research as an intra-active scenario of discerning and understanding empirical findings 'in nature'. It creates a shift in the understanding of matter within living organisms. It shows a diffraction pattern not only concerning the object of research but also concerning the epistemological frame which consists of, and constitutes at the same time, the epistemic subject.

Karen Barad suggests her approach of 'agential realism' as a new feminist epistemology to understand matter, including the gendered body, as a dynamic intra-active becoming. With this account she claims to go beyond Judith Butler's approach of performativity of gender, because she also includes non-human organisms and non-organic matter in these intra-active processes of becoming. Moreover, Barad questions the clear-cut boundaries between organic matter and non-organic matter, as well as those between the organism and the 'environment'. With this understanding of humans as just one curious organic entity between an indefinite number of others, she opens our eyes for a big variety of natural systems of reproduction as well as interactive or intra-active relationality and attachment. In this way, the current binary gender system,

which still seems rigorously binding for humans, might become contested in its exemplary function for nature as a whole.

I am not sure whether Butler and Barad use the concept of the apparatus with the same intention. Nevertheless, reading the two authors together is helpful for two reasons: one, for making Butler's understanding of gender as an apparatus methodologically useful for feminist science and technology studies, and secondly, for making Barad's agential realist version of the apparatus applicable as an epistemological concept for gender studies beyond STS. I think Butler introduces the term 'apparatus' to point to the fact that a specific or current normative understanding of gender is more material than the term 'framework' or 'interpretation' would suggest: "If gender is a norm, it is a form of social power that produces the intelligible field of subjects, and an apparatus by which the gender binary is instituted." (Butler, 2004: 48) The term 'apparatus' seems helpful for understanding the imperative character of gender as a valid social mechanism. At the same time, it helps to imagine the possibility to change certain aspects – parts or tools – of this mechanism, or even exchanging it as a whole. Since an apparatus is a complex instrument which is built and installed to achieve a certain goal, the term may help to understand the historical contingency of a certain gender regime. On top of that, an apparatus, if understood in its functioning as a technological device, might be transformed by subjects in ways which are not intended by other subjects in the first place. In other words, if we understand gender as an apparatus by which subjects are produced as incorporating a certain femininity or masculinity in present time in dominant cultures, those who do not fit in might be comprehensible as subjects who not only point to the limits of the apparatus at work and the need to change it. On top of that, they already represent subjects and objects of diffraction patterns of gender.

Butler and Barad both seem to understand an apparatus as provoking a certain set of material-semiotic practices. However, Butler's focus is on the constitution of gendered subjects through performative iteration, while Barad focuses on the constitution of (gendered) research objects and phenomena through intra-active becoming: "Apparatuses are dynamically made and remade through different kinds of boundary-making practices." (Barad, 2007: 449) Here it is important to note that in both accounts the clear-cut differentiation between subject and object is contested. Since the establishment of phenomena through research apparatuses is understood as material-discursive practices, an empiricist understanding of empirical research, also of experimental empirical research, seems impossible. For Barad, the research question is already part of

the phenomenon produced in the epistemic process as the apparatus is installed. Her understanding of matter is not limited to the empirical data which are collected or measured within a certain established apparatus, nor to the interpretation of these data. Maybe in a comparable way, Butler's account shows gender as performed by human subjects within, but not consistent with, the existing binary apparatus of gender. Precisely because the performance (necessarily) fails to conform to the established idealized binary code, the apparatus of gender is, as Butler points out, an elaborated institution and reveals its naturalizing and normalizing function. In a similar way, material phenomena intra-acting within the epistemic process in Barad's account are never fully calculable in advance by the apparatus of research. The uncertainty relation, brought forward by quantum physics, leads beyond the calculable predictability of material processes in experimental as well as in natural circumstances (as held, for instance, by classical mechanics). In both Butler's and Barad's accounts, it seems that a better understanding of the world is achieved precisely through the transgression of the envisioned or installed order of things (see also De Lauretis, 1990).

But does this lead to a *new feminist materialism* – as a new paradigm for gender studies? Since the material conditions in Karen Barad's account clearly exceed empiricist as well as marxist accounts, I consider the term *material feminism* more suitable (see also Alaimo and Hekman, 2008). For the following reasons: By understanding the materiality of human bodies and non-human nature as informed by the feminist constructivist idea of performativity rather than as an essential authority of authenticity, this materiality can be acknowledged as an active aspect in the production of knowledge without essentializing it. Barad gives the example of shop floor machinery in order to illustrate the productive role of materiality in different forms: "The material conditions of the shop floor performatively produce relations of class and other forms of cultural identity in the intra-action of humans and machines." (Barad, 2007: 227) A little later, she relates the term of the apparatus to this material-discoursive practice: "Importantly, apparatuses are not external forces that operate on bodies from the outside; rather, apparatuses are material-discoursive practices that are inextricable from the bodies that are produced and through which power works its productive effects." (Barad, 2007: 230) Therefore, Karen Barad's insights seem to point more to the notion that diffraction patterns help to understand the overlaps and shifts in an attempt to make sense of the world, not only concerning the constantly shifting materializations and discourses of gender norms, but also concerning the production of knowledge in general. Barad suggests that with the diffraction patterns of waves produced

by the two-slit-experiment, quantum physics provided a promising framework of understanding scientific knowledge production. She also holds that with the capability to locate and at the same time shift a single atom of a certain material or texture with the help of the technological device called 'scanning tunneling microscope' (stm) the 'second quantum-physical revolution' took place – as the basis for nanotechnology and biomimesis. In her account, these new technoscientific apparatuses of nanotechnology and biomimesis need to be investigated within a broader socio-political and natural 'environment', as they create through material-semiotic practices new – maybe precarious – relations between humans, other organisms, and non-organic matter. Therefore, on the epistemological level, Barad goes beyond Bohr's account in that she shifts the framework of relativity of knowledge production in quantum physics to a framework of relationality. With this move she connects the 'second quantum revolution' to feminist epistemology. If we understand the production of knowledge as the establishment of an apparatus of research, we might be able to analyze this very apparatus in order to deconstruct or shift the normativity of (gender) patterns it might produce. When doing so it seems important to reflect the limited access to knowledge of the world provided through even the newest epistemological and technological devices (see Jasanoff, 2006). Barad's account of 'agential realism' transcends the idea, still held by many scholars in technosciences, of processes, materials, and phenomena as segregated or isolatable in the research process. It enables the notion that processes, materials, and phenomena are linked in a complex and never fully apprehensible relationality, in which processes become activated through specific research, in a way that goes beyond the intentionality of persons and the calculation by machines. In order to discuss the entanglement of matter and meaning as innovative methods for constructive interdisciplinary engagements between technosciences and humanities, it seems important to investigate the shifting intra-activity of human-machine-interfaces. It seems that the access to the world through our machinery, the technological devices of contemporary knowledge production, also shifts our understanding of knowledge production itself.

Material Interrelations: Machines and Humans?

What happens between humans and machines when they face each other or interact? Humans don't merely use machines to do something. The machine and

the activity leave traces on and in humans and vice versa. Traces could mean to signify abrasion, wear and tear or attrition, but also empowerment, enhancement or other enabling aspects of this interaction. Neither is it just an interface – a touch screen or a contact area, because it is humans who must initiate contact to the machinery to start a process. It makes little sense to speak of machinery or technological devices as initiating encounters (at least until now), since even the most 'intelligent' devices do not act in a comparably intentional way as humans do. Intentionality might not be a necessary difference between humans and machines, because human agency is not always intentional, and automatic devices sometimes seem to initiate a certain process of interference. But intentionality seems to be a sufficient criterion of difference, because technological devices only simulate intentional agency. These simulations actually involve humans interacting with other humans through machines, in other words: by way of technological interference. The term interference points to impact, influence and manipulation, to impairment, intervention and intrusion, but also to merging and mixing as well as to overlap, overlay and superposition, and to disturbance, disruption and disorder. In Barad's use of the term, all these dimensions are evoked, although she uses the term synonymously to diffraction, as we have seen above.

Consequently, the human-machine-interface is a dynamic process of materialization, in which meanings can change. This means that although newly developed technological objects need to be recognized in their envisioned cultural environment, they always carry the possibility of leading beyond the replication of validated norms. The dynamic of the human-machine-relation is also a central result in Lucy Suchman's study *Human-Machine-Reconfigurations* (2007). Here, machines are not understood as finite objects: "Rather than fixed objects that prescribe their use, artefacts – particularly computationally based devices – comprise a medium or starting place elaborated in use." (Suchman, 2007: 278) In the same way, persons who are involved in human-machine-relations should not be understood as autonomous subjects: "The person figured here is not an autonomous, rational actor but an unfolding, shifting biography of culturally and materially specific experiences, relations, and possibilities inflected by each next encounter – including the most normative and familiar – in uniquely particular ways." (Suchman, 2007: 281) This means that gendered subjects and objects can experience new practices and new meanings of themselves, including their gendered meaning, through their interaction.

As a result, the production of technology shapes our culture, which in turn is structured by a gendered social order. Therefore, the way in which tech-

nological developments take place and the way technology is designed and produced, including each person involved in the process, is open to change.

BEYOND THE 'RODENT'S TALE'

How can gender in human and non-human organisms be investigated as a critical site where the material and the social interact? The biologist Anne Fausto-Sterling questions a reductionist view of functional principles on human sexuality in her celebrated book *Sexing the Body. Gender Politics and the Construction of Sexuality* (2000). Here, she traces the 20th century history of biological theories on hormones, genes, chromosomes, and of experiments to study the chemical physiology of behavior. She exposes the continuously changing perspective on the behavior of laboratory rodents in connection with hormonal treatment, which leads to quite curious and ever changing 'facts' through analogy inference about human sexuality.

For instance: in the mid-1940s, Frank Ambrose Beach developed a detailed theory of animal sexuality, as he observed "striking individual differences within each sex, among laboratory strains of the same species, and among rodent species". He consequently argued that neurologically, "all animals have a bisexual potential" (Fausto-Sterling, 2000: 207). By contrast, in 1964, informed by "the cold war ideology that praised heterosexuality and ranted about the homosexual menace", William C. Young proposed that "pre- or perinatal hormones organized central nervous tissue so that at puberty hormones could activate specific behaviors" and "injected pregnant guinea pigs with testosterone" (Fausto-Sterling, 2000: 214). As a result, "male and female rodent behaviors, as well as those of humans, for whom they served as a model, emerged as more stereotyped than they had previously seemed, and as more rigidly determined by prenatal hormonal environments" in Young's observational frame (Fausto-Sterling, 2000: 217).

Fausto-Sterling sees this as problematic, since there has been evidence that hormones should be seen merely as one component in an interactive development, together with neural components, living conditions, social rearing, and adult behaviors. "Hormonal systems, after all, respond exquisitely to experience, be it in the form of nutrition, stress, or sexual activity (to name but a few possibilities). Thus not only does the distinction between organizational and activational effects blur, so too does the dividing line between so-called biologically and socially shaped behaviors." She concludes that current bio-

logical theories about human sexuality "derived from rodent experimentation are inadequate even for rodents" (Fausto-Sterling, 2000: 232).

Anne Fausto-Sterling's question is whether and how neuronal systems and behavior develop as parts of social systems. She asks how social experience could change the neurophysiology (= sex?) of gender. To clarify this, the author quotes a neurobiological study which investigated paternal behavior of male mice working with such an interactive framework (Ehret et al., 1993). Male mice, which never had contact with their newborn offspring, did not care later if the baby mice fell out of the nest. However, as soon as the paternal mice were brought in touch with the newborns just for a few hours a day, they cared and brought the baby mice back. So, on the level of social behavior, the result was that social and personal experience has consequences for the social behavior of adult mice. But there was an even more striking result. The research group measured the estrogen receptor binding and discovered that it increased significantly in several parts of the brain when the paternal behavior was intensified. Hence, the experience of paternity had changed not only the social behavior of male mice, but also the brain physiology of the paternal brains. Because of the evolutionary kinship structures between the hormonal physiology between mice and humans, Fausto-Sterling infers that there could be mechanisms through which gendered experience also changes the gendered human body on the hormonal level (Fausto-Sterling, 2000: 239–40).

As a consequence, Fausto-Sterling develops an integrative, interdisciplinary and holistic model for the study of human sex, gender, and sexuality. It connects questions about the cell, the organism, the psyche, the person to person relationships, the culture, and the history on a larger scale. She considers these components as a dynamic biocultural system of reciprocally related processes (Fausto-Sterling, 2000: 243). This makes clear that to understand the nature and culture of gender, sex, and sexuality these conceptual fields have to be studied within an interactive framework. This could enable us to overcome naturalized narratives of gender hierarchies, heteronormativity, and sex binarism. We can see here how so-called material, natural or physiological processes are closely tied to so-called social and cultural processes. We are able to install experimental settings in which brain physiology does not function as an ultimate cause for social behavior, but instead as a correlating factor in reciprocal processes of material semiotic actors. Understanding sex, gender, and sexuality as a biocultural system does not provide easy answers, and it does not only necessitate an interdisciplinary approach. It needs transdisciplinary thinking to correlate different methods to research cells, organisms,

individual psyches, social groups, national histories and transnational cultures to overcome the binary categories of sex, gender, and sexuality.

CONCLUSION

The above analysis shows that new epistemological ideas enable new ways to investigate sex, gender, and sexuality without reinforcing binary gender norms. Feminist analysis of science and technology provides innovative ways for research to empower those who are dis-empowered by gender hierarchies, racism, classism, homophobia, and other ideological frames to classify persons in structural hierarchies. The discussion in this chapter suggests that it is challenging but worth attempting to study phenomena that transcend the normative apparatus of gender. We have seen that through the apparatus of research diffraction patterns of gender can be generated. If we follow Barad and understand the apparatus of research as a part of the phenomenon we are studying, it seems interesting to investigate if scientific claims confirming the normative gender binary are related to stereotypical assumptions about women and men, or whether they rely on insufficient sets of data (see Jordan-Young in this volume). It seems promising to analyze and deconstruct the very apparatus of research which produces the results. To quantify sex or gender in order to understand how sex or gender is relevant at a specific location at a specific time in a specific relation to a research question, might not always be important or helpful. We have seen that the two-sex-model bears as many shortcomings and misunderstandings as other numerical models, for example the one-sex-model, as Thomas Laqueur has shown in his conceptual history of the gendered body (Laqueur, 1990). It seems that the most important insight of gender studies lies in the understanding that cultural, scholarly models of 'nature' are better not confused with manifold natural and cultural realities as such.

The surplus value of feminist theories for biology and technology then, is to help to develop research questions on how gender stereotypes or gender norms obstruct equal opportunities for all persons to develop and act along individual inspirations or aspirations. The goal is twofold: to foster democratic developments in biology and technology as well as to contribute to democratic developments through biology and technology. Therefore it seems necessary to connect those individual inspirations and aspirations with each other, and to enhance an ethical and political discourse on questions of justice and equal share which encompasses not only all human beings, but also non-human

organisms and non-organic matter. As Karen Barad puts it: "The attending ethico-onto-epistemological questions have to do with responsibility and accountability for the entanglements 'we' are willing to take on, including commitments to 'ourselves' and who 'we' may become." (Barad, 2007: 382)

Feminist technoscience studies, therefore, need to pursue a deconstructive as well as a constructive direction. This means, first, that epistemic entanglements of current or historical apparatuses of gender with scientific theories and technological products can be analyzed. Second, ideally through the very moment of analysis the apparatus of gender becomes visible as a specific arrangement or normative frame of gender. Third, this can be understood as deconstruction or de-naturalization which opens the way for new material-semiotic practices in which an established apparatus of research as well as an established apparatus of gender are (ex-)changed and a new understanding of gender gets established. In other words, gender relations become diffracted in a new way through epistemic negotiation. Or, to put it another way, a change in the apparatus of gender shows new diffraction patterns. In this view, the understanding of gender within the growing and fast developing (trans-)discipline of gender studies is itself subjected to changing diffraction patterns. Understanding this change and variation as diffraction of the very apparatus of gender within gender studies is helpful in order to avoid a reinforcement of stereotypes about gender differences through gender studies. Changing the focus of investigation from differences between women and men to diffraction patterns of gender, generated through the intra-action of natural and cultural processes seems to be a promising path for gender studies. The phenomena under investigation in this approach would be both: the diffraction pattern of gender relations throughout history and the diffractions in play in the comprehension of gender inside and outside of scholarly investigation.

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Gender Research as Knowledge Resource in Technology and Engineering

Lena Trojer

Introduction – Science Creating Realities

Aspirations in gender research within technology and engineering have developed into a research-transforming activity focusing on societal relevance and engineering faculties. The conditions that are needed and created require epistemological pluralism. The gender research referred to here is also called feminist technoscience.

When discussing gender in sectors like technology and engineering, we often tend to count heads, i.e. how many women are present in which functions. By contrast, gender issues are much less seen as generating knowledge and technology in themselves. This chapter will illustrate what kind of added value certain academic activities starting in gender-related issues can have. Epistemological comments on feminist technoscience are presented as fostering and attempting to advance our understanding of knowledge production in technology and engineering.

In the last three decades the research-political debate on gender research in Sweden has moved back and forth. Major voices in the dominant academic discourse have rarely stressed the knowledge contribution made by gender research across all disciplines. Despite this circumstance, increasing numbers of scholars within gender research are finding their way and place at Sweden's universities.[1]

1 | See www.genus.se/meromgenus/forskningsmilj%C3%B6er/ (accessed 1 June 2012).

When it comes to gender research within the faculties of technology and engineering, relevant contributions from this research cause specific challenges, which have to be acknowledged. Why is that? One challenge is to have an understanding of gender research as actual research, in a situation where the obvious gender (non)equality issue is in the forefront, that is in a situation of imbalance in terms of the number of active researchers. Women are few and especially so among the professorial staff. The issue moves away from research to quantitative gender equality, which makes little sense when it comes to knowledge production within technology and engineering. The second and core challenge for academia is that gender research within technology and engineering does NOT primarily focus on gender – women and men. It focuses on technology. This means that gender researchers within technology and engineering quickly find themselves working with epistemological issues as the starting point for producing the technical knowledge, systems, artifacts etc. that are of relevance in the actual contexts of application and implication. The framework of theories and methodologies for this work is gathered from feminist research, nationally and internationally, as well as research fostering fundamental research transformations identified in society. This is what prompts me to use the concept of feminist technoscience instead of gender research within technology and engineering.[2] The concept of feminist research connotes change and transformation in a more explicit way than gender research, which is regarded as less provocative and not touching the raw nerves of academia.

Not only Donna Haraway but also scholars like Sheila Jasanoff, Sharon Traweek, and Elisabeth Gulbrandsen offer convincing arguments about research as reality-producing / world-making activities. Jasanoff (2003) emphasizes technologies of humility instead of technologies of hubris. I am particular inspired by Traweek's argumentation concerning detector building in particle physics laboratories and the reality-producing dimensions of the specific constructions of these detectors (Traweek, 1992a). Gulbrandsen was one of the first scholars to introduce Donna Haraway in the Nordic countries and her use of the reality-producing / world-making concept. Science is (co-)creating society and is thus political. That is why I also encourage researchers to concern themselves with the political aspects of their research. As a scientist I have to see myself as a producer of realities for myself and for all others in society.

2 | This is a concept inspired in particular by scholars like Donna Haraway, see e.g. Haraway 1991, 1997.

Anyone who finds this statement too abstract should just think of research in medicine or ICT. Particularly mode 1 researchers (Gibbons et al., 1994) feel provoked by this approach that rejects the dominant epistemology of neutrality and objectivity as well as discarding the God trick[3] (Haraway, 1991: 189).

In order to dissolve the rather categorical statement of feminist technoscience above, I will in this chapter give an example of a research project starting out with quite traditional gender equality issues which was found to bring fundamental reality-producing results in society. There are no cut-in-stone processes within feminist technoscience but a call for openness for what makes research relevant in society, robust and leading to more livable worlds not just for a few.

The aim of this chapter is to contribute to the recognition of feminist technoscience and its knowledge-producing values. Discussions of key understandings of feminist technoscience are illustrated by two cases and summed up by some closing remarks.

The Position of Feminist Technoscience – My Approach

As indicated above, I use the concept of feminist research synonymously with gender research and I use the concept of feminist technoscience almost synonymously with feminist research within technology and engineering. In my academic context I still have to explain why I am defining myself as a feminist researcher. When I started in the 1980s I thought it would be possible to "cleanse" the concept of feminist researcher from all strange associations people used to make (Wahl, 1996). This concept is still provocative (in Sweden) because it is a call for political and transforming actions regarding an academic discourse unwilling to transform. I should interpret this situation positively as it signals transformation of a second order (Ahrenfelt, 2001), which is what I am striving for. A second-order transformation refers to a more deep-going change in contrast to shallow activities of change which will keep the status quo intact.

Within international feminist research with strong links to the dominant technical fields of our age – information and communication technology (ICT), biotechnology, and material technology – there is a widespread under-

3 | "God-trick of seeing everything from nowhere."

standing of the production of knowledge and technology as processes taking place in distributed systems. In other words, knowledge is co-generated in the overlapping borderland of universities, companies, and other regional, national, and international actors. These processes are also apparent in my own region Blekinge and affect the way in which my university, the Blekinge Institute of Technology (BTH), is carrying out research and development, the R&D work. The term technoscience connotes this understanding of the production of knowledge and technology. The way in which technoscience is defined by scholars like Donna Haraway raises important questions about boundaries and transgressions between implosion of science, technology, politics and society, humans and non-humans etc. as well as implosion phenomena within the same spheres (Haraway, 1992).

One characteristic of technoscience is, as Gulbrandsen (2006) emphasizes, its reverse logic: knowledge has to be used in order to be tested. A classic example is reproduction technologies,[4] for instance where the practice of test tube babies has to be used in women's bodies in order to test this technique. This issue has therefore an important research-political dimension. In feminist technoscience, the research-political discussion is vital for the relation between research and politics, i.e. the reality-producing aspect of science and research.

Seeing ICT as a reality-producing technology rests on the idea that all of us, researchers in the field included, are enmeshed in development processes where no innocent positions exist (Flax, 1992; Haraway, 1997). ICT intervenes in and creates people's everyday lives. On the other hand, ICT is something developed and interpreted by people. The work of my colleagues and myself is inspired by this feminist technoscientific approach and aims to create both a theoretical basis and practices for development processes in ICT-related disciplines, as well as in the context of innovation systems. This is particularly relevant for our PhD students and colleagues coming from East Africa and Bolivia.

My concern is to open up for and foster epistemological pluralism[5] at faculties of technology and engineering in order to encounter complex realities in our research, encounter young people and their preferences in learning pro-

4 | From in-vitro fertilization to cloning see e.g. www.finrrage.org (accessed 17 February 2013).

5 | In contrast to one dominant, singular epistemology e.g. the dominant western positivistic related epistemology.

cesses of higher ICT-related education as well as our cooperation partners in society both in the private and public sectors. We, who are working at faculties of technology and engineering, have to transform in more advanced ways than expected. One fundamental condition for the necessary transformation is to open up for and foster epistemological pluralism. With regard to this challenge Ina Wagner has contributed some essential understandings. She argues (Wagner, 1994) that the central idea of combining established forms of scientific inquiry with the social pragmatics of developing goals, methods, theories, and products can be realized by epistemological pluralism and partial translations between situated knowledges of different communities.

Fostering epistemological pluralism is a challenge at faculties of technology and engineering, whether young or long-established. When we have learned to spell the word epistemology, when we have acknowledged that we do research and teach by walking on a certain epistemological infrastructure, then it is high time to pose ourselves the question whether this infrastructure is relevant enough, whether it is appropriate for our identified needs.

Situated at a technical university with an explicit profile of applied ICT in close cooperation with university, industry, and government, epistemological openness is a huge challenge. The present knowledge and technology production occurs in situations that are far removed from what is identified as a traditional mode 1 university[6] (Gibbons et al., 1994) – the linear model university. These knowledge processes are my daily experiences at one of the campuses of BTH, more precisely at campus Karlshamn, which is integrated in an innovation node called NetPort.Karlshamn.[7] A too restricted and unreflected epistemological basis constitutes an impediment in our daily work.

What resources does an ICT researcher and member of the academic teaching staff have at her disposal in order to remain confident, future-oriented, and innovative? In the course of our now twelve years of development experience with so far good results in student recruitment, research, and campus building, the resources for the necessary epistemological infrastructures were found within feminist research developed within a faculty of technology – i.e. within feminist technoscience. It might sound strange that we have found relevance

6 | Some characteristics are disciplinarity, internally-driven taxonomy of disciplines, neutrality / objectivity / scientific discovery, hegemony of theoretical or experimental science, autonomy of scientists and their host institutions / the universities, sharp divide of basic and applied research.

7 | See www.netport.se (accessed 17 February 2013).

within feminist technoscience for the benefit of building a much needed epistemological pluralism. This chapter will provide arguments for the why and how.

FROM COUNTING HEADS TO RESEARCH TRANSFORMATION

As mentioned in the introduction, the history of feminist technoscience situated at faculties of technology and engineering has proceeded from the practice of counting heads (how many women) to fostering and advancing understandings and practices of knowledge production. This is not a linear process but more of a process in parallel. The gender equality work continues and is still far from reaching its goal in sustainable 40/60% representation of men and women at all levels. The academic story in Sweden within a time frame of more than 3 decades shows that we have moved from the gender equality question, to the woman question[8] to the science question. This refers to the Harding turn (Harding, 1991) moving from the question of what science can do for women to what feminists can do for science. There are no simple or self-acting links between these general phases.

During the last decades we have emphatically argued for the importance of perspectives from *within* (Trojer, 2002). This is a central condition for feminist technoscience to be relevant and useful at faculties of technology and engineering. Karen Barad has fostered this argument. She writes that "on an agential realist account of technoscientific practices, the 'knower' does not stand in a relation of absolute externality to the natural world being investigated – there is no such exterior observational point" (Barad, 2003: 828). It is not enough to do gender research of technology from the outside. It is equally important to be deeply involved in "the belly of the beast", a belly you are passionately interested in (Haraway, 1991: 189).

For the introduction of feminist epistemology into technoscience in practice at BTH, one statement of Donna Haraway has been especially important: "Technology is not neutral. We're inside what we make, and it's inside us. We're living in a world of connections – and it matters which ones get made and unmade." (Haraway cited in Kunzru, 1997) This quote was put up on the wall in the lunchroom at a research laboratory focusing on water jet tech-

8 | For instance developing cars or speech synthesizers suitable for women's bodies.

nologies close to BTH. Together with a colleague we were hired to integrate some kind of gender research perspective in a EU project at the laboratory mentioned. The Haraway quote was almost impossible to comprehend for the water jet researchers in our introductory discussions. But some of them took the initiative to copy it and put it on the wall for further internal debates. Almost a year after this event, we came back for continued collaboration and found the involved researchers appreciating the quote and all the discussions it had nurtured.

Co-evolving Processes

It is not by accident that feminist technoscience easily links up to and contributes to fostering co-evolving research processes within technology and engineering. As will be exemplified below, co-evolving processes are important where relevance and contexts of application and implication constitute the essential elements. The frame of understanding co-evolution includes the triple helix concept (Etzkowitz and Leydesdorff, 1997), which gives us some comprehension of the structure of the actors involved. The main actors are universities (knowledge institutions), industry (private sector), and government (on any level). But the triple helix concept does not contribute with the core answer to how the co-evolving / triple helix process is carried out. One answer to the 'how' question can be found in the research processes termed mode 2[9] (Gibbons et al., 1994).

The Swedish Council for Planning and Co-ordination of Research (FRN) initiated and financed a study that resulted in the publication *The new production of knowledge* (Gibbons et al., 1994), where the research process mode 2 was thoroughly described. Characteristics of mode 2 include for instance context of application, trans-disciplinarity, much greater diversity of sites of knowledge production, accountability / context of implication, novel forms of quality control, socially robust knowledge. The strong and hostile reactions from the dominant university (mode 1) representatives showed the mode 2 understandings were and are really touching the raw nerves of the existing academic discourse. These mode 1 representatives are protecting disciplinar-

9 | Some characteristics are context of application, trans-disciplinarity, great diversity of sites of knowledge production / research, highly reflexive / accountability, novel forms of quality control, socially robust knowledge, context of implication.

ity, internally driven taxonomy of disciplines, neutrality, objectivity, context of discovery, hegemony of theoretical or experimental science, a sharp divide of basic and applied research. But as Gibbons explained,[10] mode 2 knowledge productions have always existed and mode 1 is a very efficient specialization of knowledge production. This specialization finds its roots in the scientific revolution in the 1600s (Merchant, 1980).

The debates around the mode1 / mode 2 understandings concerns the twin notions of 'science speaking to society' and 'society speaking back to science'. In other words, 'society' is required to take part not only in the input phase but in the whole process (which more likely is non-linear) up to the output and outcomes of results.

We have experienced on a municipal level how society, represented by the local government, explicitly manifested the need in being involved in the whole input-operation-output process. The need for this involvement comes from the budgetary process in local government to have local tax resources approved for the input of research funds and infrastructure requests of universities. What the mayor and local government directors need are good arguments for the relevance of this 'investment' in order to convince the local parliament to vote in favor of it. For this argumentation to be successful, the mayor of Karlshamn clearly announced that "input is not enough".

THE CASE OF SWEDEN: NETPORT

The following case serves to illustrate co-evolution and research transformation processes in particular.

As mentioned above, the research division where I am academically situated has a specific history and obligation integrated in an innovation node called NetPort.Karlshamn,[11] hereafter referred to as NetPort. NetPort is co-owned by the university (BTH), the local government, and the industry in identified sectors (new media and ITS[12]). This relation of ownership constitutes a strong signal for putting triple helix processes in a real-life context. NetPort is not only a loose network of triple helix actors, but organized and jointly owned in a challenging and inspiring way.

10 | Interview at the HSS03 conference Ronneby, Sweden, 2003.

11 | See www.netport.se (accessed 17 February 2013).

12 | Intelligent transport systems.

The start of NetPort coincided with the start of a new university campus of BTH in Karlshamn. Developing a new campus at a technical university in a triple helix context needs at least 4 starting conditions:

1. Undergraduate students
2. Graduate students
3. Epistemological acknowledgement of mode 2
4. Tolerance towards resistance that is always appearing in development processes, especially internally at the university.

In the year 2000 the Vice Chancellor of BTH gave his approval for the department that includes the division of ICT and Gender Research at BTH to take the main responsibility of starting to develop the new campus. This task was supported by BTH with a centrally appointed project coordinator. The division had the authority and competence to initiate bachelor programs in media technology and was already running a PhD program with a number of doctoral students. The division staff was strongly motivated to embrace a triple helix collaboration practice i.e. to work in close collaboration between the university, local government, and industry.

For his approval the VC had become convinced of above condition Nos. 1 and 2. Condition No. 3 characterized the practice of the VC and seemed to be self-evident for him. The ambitions of the division to fulfill condition No. 3 were probably implicitly recognized by the VC, as explicit interest was demonstrated in cooperating with stakeholders outside the university, of which the local government of the campus city was the main partner.

Regarding condition No. 4 the experience of Bo Ahrenfelt (2001) proved to be of great help to the division in understanding different manifestations of resistance. Peter Ekdahl (2005) stresses that resistance in development and transformation processes is important and creates energy, even though resistance is momentarily experienced as destructive and energy consuming. A lack of resistance obstructs the possibilities for giving focus to the direction of one's development effort. In addition, resistance helps to clarify what kind of development and transformation conditions you need besides promoting dialogue.

Both BTH campus Karlshamn and NetPort started in the year 2000. NetPort Science Park was established in 2009. The status in 2012 for BTH campus Karlshamn included over 300 students in the bachelor programs Digital Visual Production, Digital Audio Production, Digital Game, Web Development plus an Introductory Year. The PhD program as well as the present research division is called Technoscience Studies and includes 4 profile areas namely

ICT4D, Design for Digital Media, Feminist Technoscience, Innovation system and Development.[13]

The research division is hosting an organization unit focusing on the development of clusters and innovation systems in collaboration with developing countries. This platform is called SICD (Scandinavian Institute for Competitiveness and Development).[14] The team working at SICD has long-term experiences with Sida (Swedish International Development Cooperation Agency), VINNOVA (the Swedish Governmental Agency for Innovation Systems), and BTH (Feminist Technoscience). The R&D projects in ITS are mostly conducted in NetPort projects with researchers from BTH.

The local government's involvement stems from the mutual 'project' NetPort of fostering sustainable development of (local) society. The prerequisite for this 'project' is a triple helix-like process, which in our case is nurtured by a constant, almost daily, dialogue. In this dialogue, which is a kind of agora, mutual understandings are supposed to find their expression in very concrete ways resulting in co-evolution processes. For us, who have been involved, we talk about an

> "establishment of the institution of a 'kitchen cabinet'. A generous, open, inviting, allowing arena had to be created for the construction of new questions and dreams …. We need a lot of 'kitchen cabinets' on campus to cater for the polycentric, interactive and multipartite processes of knowledge-making we may dream of. A vision that entails transformative processes, changing research cultures and 'teaching smart people how to learn'" (Gulbrandsen, 2004: 120; see also Argyris, 1991).

During the pioneer phase, the dialogue within NetPort was intense and relatively easy to keep going. There were always various kinds of challenges but they remained manageable, as the core group (kitchen cabinet) had an ideal number of members and it was possible to share the mode 2 experiences. As new colleagues and partners joined and the upscaling of NetPort activities continued, the kitchen cabinet became increasingly challenging to maintain. It is easier to prioritize time for the increasingly advanced development within each partner's areas of responsibility than to set aside sufficient time for the triple helix co-evolving process. The aspect of the co-evolving processes thus

13 | For more information see www.bth.se/tks/teknovet.nsf (accessed 17 February 2013).

14 | For more information see http://sicd.se/ (accessed 17 February 2013).

changes over time but the standpoint of keeping the main actors together is an absolute prerequesite for sustainability.

With this short summary of the case NetPort I hope to have illustrated how some fundamental concepts of feminist technoscience such as situated knowledges, transdisciplinarity, and co-evolution have been filled with substance for us active in the same professional environment.

The Case of Uganda: ICT Centre Arua

A radical change of context provides an opportunity to understand meanings of situated knowledges, epistemological pluralism, co-evolution processes, and the relevance of mode 2. The following case illustrates this.

Secondary schools in Uganda, except for some very few in the capital Kampala and its vicinity, have to cope with extremely scarce resources, like very few qualified teachers, no books, no laboratories, and poor electricity and Internet infrastructure.

A researcher at the Faculty of Technology, Makerere University (MAK) started a research project in 2004 investigating the reasons why there were so few female students at the Faculty of Technology at his university, why there were so few students at MAK coming from secondary schools in rural areas and how to change this situation (Lating, 2009). At that time, over 90% of the few female engineering students came from the 'elite' and advantaged urban schools located in Kampala and its surrounding districts of Mukono and Wakiso. The study's research questions were linked with the explicit dimension of gender issues, clearly in the more quantitative notion of gender equality but implicitly also in a qualitative sense, especially with regard to knowledge production at a technical faculty.

The study was conducted in Arua, which is a remote, poor, and unstable rural district of Uganda, 500 kilometers from Kampala in the north east of the country close to the borders of Democratic Republic of Congo and Sudan. Since the focus was on female students, two girls' secondary schools were chosen in the periphery of Arua town. The project was designed in such a way that boys and pupils in other schools would also benefit at a later stage in the research.

Hybrid e-learning tools were developed and implemented. Hybrid e-learning in the context of the project signifies a form of e-learning, where the main course delivery platform consists of interactive multimedia CD-ROM and is combined with traditional face-to-face classroom teaching. The development

part and the implementation of the project took place in a kind of parallel process that involved setting up an ICT Centre in the middle of Arua town. The main reason for establishing an ICT Centre (later on to become the ICT/GIS Research Centre) in the project was the financial situation in both secondary schools. Resources for the operational costs of sustaining Internet connectivity were not available. A decision was made to deliver content in CD-ROM format to the schools, but also to set up an ICT Centre with satellite Internet connectivity, VSAT, within the vicinity of the two schools for training and further digital resources.

In order to anchor the whole project in its starting phase, the researcher approached the local and district government of Arua and presented the project including the interest of the Faculty of Technology to develop an ICT Centre in Arua with the facilities of Internet connectivity. The response from the Arua government was very positive. They understood the potentials for the town and district and acted accordingly. They provided premises for the Centre in an old court house building, which they quickly repaired and upgraded with regard to security facilities. The Faculty of Technology, with financial support from Sida/SAREC (the research unit of Swedish International Development Cooperation Agency), equipped the Centre. Furthermore, the researcher approached the business community in Arua which agreed to use the services at the Centre to make it sustainable. A triple helix process was thus practised in the specific context of a rural district in Uganda with the main actors Makerere University, Arua local and district government, and the local business sector.

The girl students participating were enthusiastic, but a number of notable and sometimes critical situations occurred with the students and their teachers during the project.[15] As a very concrete result, the analysis of the research study showed that, for girls born and living in Arua, 41% of the final year (A-level) students passed[16] and were eligible for university admission compared to almost 0% before the introduction of e-learning tools. This was the result after only six months of girl students and their teachers using these tools.

The decision to establish an ICT Centre had a huge impact not only for the town and its surrounding district but also for municipalities on the other side of the nearby border with the Democratic Republic of Congo and Sudan.

15 | For more details see Lating, 2011.

16 | The school system in Uganda uses a national curriculum with nationally coordinated examination tests. The latter was used as indicators in this research study.

What started as an e-learning project in order to increase the number of female students at the Faculty of Technology, Makerere University, ended up as an ICT/GIS Research Centre in Arua facilitating 10 schools, district and local businesses and organizations, district and local governmental authorities, 2 hospitals, local authorities across the borders of Sudan and Congo.[17]

In 2010, the government of Uganda decided to establish a new university – Muni University – with the ICT/GIS Research Centre in Arua as its initial nucleus and including a Faculty of Technoscience.

The number of stakeholders is impressive and quite unique compared to a Swedish regional context. This is a strong signal from the stakeholders for the

17 | *District and local government officials:* Regional District Police Commander's Office; District Police Commander's Office; Chief Administrative Officer's Office; District Medical Officer's Office; District Forestry Office; Resident District State Attorney's Office; District Information Office; and District Engineer's Office.

Schools: Muni Girls Secondary School; Ediofe Girls Secondary School; Mvara Secondary School; Arua Public Secondary School; Arua Public Primary School; Uganda Christian University; Arua Campus; Arua Vocational Training School; Arua Core Primary Teacher's College; St. Joseph's College Ombachi; and Anyafio Role Model Secondary School.

Hospitals: Arua Hospital and Maracha Hospital.

Other governmental institutions: National Social Security Fund and Northern Uganda Social Action Fund.

Business sector: The District Chamber of Commerce; West Nile Rural Electrification Company; Uganda Breweries; Private Sector Initiative; Sumandura Construction Works; Boniface Television Networks; Nile Fm / radio station; Arua One FM radio station; Copcoot Uganda; Westnile Distilleries; Heritage Gardens – hotels business; Multitech Uganda – ICT training business; Kuluva Hospital and Marie Stopes Uganda –Reproductive health provider.

Non-governmental organizations and community-based organizations: Netherlands Development Organisation (SNV) Uganda; United Nations High Commission for Refugees; Cream Uganda (Community Based Organization); PAD (Community Based Organization); PRAFOD (Community Based Organization); CAFECC (A Sudanese Community Based Organization); World Vision Uganda; WENDWOA (A women's organization helping widows and disadvantaged children); NSEA / Needs Service Education Agency.

Others: travel agents; students from schools outside Arua District mostly during school vacations; community workers and the indigenous people mostly using the Internet for communication with their relatives and friends in and outside Uganda.

acknowledged relevance of the e-learning project, the triple helix collaboration, and its impact in a place like Arua District (Trojer and Lating, 2011). The researcher responsible for the project was collaborating with us at the Division of Technoscience Studies, BTH campus Karlshamn. Mutual learning and practice of its epistemological pluralism took place while the project was in progress. It is impossible to know at the beginning of such a project what will happen and how it will unfold. What is essential is to learn from one another, find situated solutions, and remain open for diverse understandings of knowledge.

Concluding Remarks

The Unknown, Unspecified, Uncontrollable

The case of Uganda presented above elucidates how boundaries between society and research are not straightforward and clear. That holds true for all our civilizations increasingly depending on research and knowledge. Helga Nowotny claimes that research and society are co-produced or co-evolve (Nowotny et al., 2001), which is a long way from the simple, linear understanding of this relationship that has for a long time dominated research in our traditional universities as well as in research policy. Gulbrandsen (2004) states that it is in the field of technoscience (such as information and communication technology, bio/gene-technology, and material technology) that scientists are most clearly pushing the boundaries between science and society, research and politics, and thereby underscoring the obsolescence of a linear understanding of knowledge production processes.

The increasingly acknowledged non-linear knowledge production processes stress the importance for us to assess the unknown, unspecified, uncontrollable, irregular in both research and political spheres. What follows for all actors is to admit there are limits to knowledge in research. Sheila Jasanoff emphasizes the practice of "technologies of humility" in favor of "technologies of hubris" in the dialogue between science and society. Jasanoff (2003: 225) addresses the driving force for society to speak back in stating that uncertainties and risks are "part of the modern human condition, woven into the very fabric of progress. The problem we urgently face is how to live democratically and at peace with the knowledge that our societies are inevitably 'at risk'." Appreciating technologies of humility brings me back to the typical characteristic of technoscience in the reverse logic. This means, as mentioned

above, that knowledge must be applied in order for it to be tested. The reverse logic as the 'collective experiment' has been explicitly discussed by Bruno Latour, where he states, that

> "all of us have become members of collective experiments on global warming, the influence of genetic engineering, conservation of species, demography, pollution, etc. Thus we have to practice something that, until recently, was the calling of very few specialists, namely science policy. Now everyone is led to practice science policy over a vast range of scientific and technical controversies. This has entirely modified the relations of the public with the producers of science and technology" (Latour, 1998: 7).

Increasingly open systems for knowledge production require a focus on the direct reality-producing effects of research – its context of implication (Nowotny et al., 2001). According to Donna Haraway there is neither time nor space to develop researchers' relations with society "… after all the serious epistemological action is over" (Haraway, 1997: 68). Neither sustainability nor other values that we would like to realize can be secured retrospectively. Our technoscientific research is positioning its projects and work to promote more complex and integrated understandings of the relationship between research and society in this grey area that Nowotny et al. (2001) interpret as a dedifferentiation of the social spheres of modernity.

Resources for What?

Trying out practices of feminist technoscience at a Swedish technical university as exemplified above has enabled us to formulate what kind of resources feminist technoscience can offer. Feminist technoscience represents resources to:

- expand the knowledge frames and practices for technology development in increasingly complex realities;
- open up preferential rights of interpretation in selections of procedures and standards, which are always reality producing activities;
- develop epistemological infrastructures relevant to a society heavily dependent on research and technology;
- establish new arenas for developing understandings of relations between research, the political sector, and industry;
- develop driving forces for inter- and transdisciplinary constellations.

Innovation Revisited

Situated knowledges is a cornerstone concept in feminist technoscience (Haraway, 1988, 1997) that also fosters our understanding of innovation processes. The term 'situated knowledges' was coined by Donna Haraway as part of her epistemological work to provide alternatives to "… developing at home that voice of entitlement, the voice of control, that accompanies the conquest of empires far from home" (Traweek, 1992b: 461). For Haraway, all knowledge is local. It is historically and culturally situated. It is problematic to argue for a watertight bulkhead between the researcher as a subject and the research object, between observing and changing, and between research and politics. The researcher is regarded as an active participant in the research process. She/he generates and organizes knowledge in an ongoing interaction with the reality she/he is researching. This notion of situated knowledges constitutes a vital part of the epistemological base for the case in Uganda as well as in Sweden as presented above.

The feminist technoscience I represent is deeply involved in innovation processes leaning on triple helix experiences and I wish to argue that feminist technoscience strengthens these processes by:

- process-oriented development through a broader understanding of transformation practices;
- enforcement and integration of situated knowledges and technology development;
- emphasizing the importance of power relations and their impacts, including complex understanding of gender structures (which is not explicitly discussed in this chapter but can be found elsewhere[18]).

For me, the innovation processes circle around the practices of situated knowledges, co-evolution, socially robust technology and knowledge, and technologies of humility. Nowotny has given an inspiring approach by stating that "innovation is the collective bet on a common fragile future and no side, neither science nor society, knows the secret of how to cope with its inherent uncer-

18 | For instance Birgitta Rydhagen's research project *Innovative clusters closing the gap between University and Society in East Africa. A living proof of Mode 2 excellence?* See http://www.bth.se/tks/teknovet.nsf/sidor/researchandprojects (accessed 31 January 2013).

tainties. It has to be done in some sort of alliance and a sense of direction which is shared" (Nowotny, 2005: 10).

The dominant discourse of innovation and innovation systems is focusing on the development of the market economy. In this context it is non-controversial to talk about sustainable economic development. But what I would like feminist technoscience to argue and try transformations for is innovation, in all its complexity, that creates sustainable conditions for a liveable world and life not only for me and other privileged people.

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C. Reflecting Un/equal Conditions for Participation

Can Women Engineers be 'Real Engineers' and 'Real Women'?

Gender In/Authenticity in Engineering

Wendy Faulkner

Introduction

A sociology student in one of my classes reported (unprompted) that men engineering students she knows describe the women on their course as either "ugly lesbians" or "pretty and only doing engineering in order to find a man". Threaded through the gross heterosexism of the engineering students' remarks is an equally worrying message about women engineers: women who are really into engineering are not 'real woman' and conversely 'real women' are not 'real engineers'. In what follows I will demonstrate how, in often subtle and taken-for-granted ways, this *gender in/authenticity* message gets reproduced again and again in engineering cultures, practices, and identities. I will argue that this is a crucial, but not widely understood, reason why the profession remains so resistant to gender change in most countries, in spite of concerted government- and industry-backed campaigns to recruit and retain more women engineers.

It is frequently claimed that women engineers have to "fit in to a masculine culture" (e.g. Carter and Kirkup, 1990), yet there is little systematic research on the subject, or any critical analysis of what is 'masculine' about the cultures in operating engineering. My evidence comes from a study, entitled 'Genders in/of Engineering' (Faulkner, 2006), which sought to bring a gender 'gaze' to an ethnographic investigation of engineering practices, cultures, and identities. The study combined interviews with observation through job shadowing in three companies: in software development (1 US workplace in 1998), in building design (2 UK workplaces in 2003), and in oilfield services (2 UK

workplaces in 2004). In total, 52 engineers (33 men, 19 women) were studied in these workplaces; a further 19 interviews were conducted with engineers from different disciplines and sectors. Analysis was based on repeated reading of extensive field notes, interview transcripts, and reports.

By using ethnographic methods, I hoped to document the more subtle gender in/exclusive dynamics which do not always register as such to participants. With notable exceptions (Hacker, 1989, 1990; Mellström, 1995; Tonso, 2007), ethnographic studies of engineers have not addressed gender; and most research into women in engineering has been based on interviews with women. By focusing on 'genders in/of engineering', I hoped to find out more about the men and masculinities of engineering in the belief that this is necessary if we are to understand the continuing poor representation of women in the profession. Gender in this framing is understood as multiple, fluid, and relational – not as fixed and time-less dualities of femininity/women vs. masculinity/men. I thus sought to investigate how genders are performed (see Butler, 1990) – how particular femininities and masculinities are actively constituted through social interactions and institutions – and, thus, how they may be changing and/or changed.

Two prior US studies informed my own. The first was a longitudinal, cross-sector study conducted by Judith McIlwee and Gregg Robinson (1992). They found that, although most women engineers occupied lower status positions than similarly educated men within ten years of graduating, they fared relatively better in some fields and organisations than in others. A key factor here was the existence of an 'engineering culture' which celebrates hands-on technical competence (even when the job does not require this) and rewards aggressive self-promotion. Thus, they conclude, "It is women's membership, not their competence, that is at question. They do not conform, or more accurately, do not *appear* to conform, to the culture of the workplace." (McIlwee and Robinson, 1992: 138) The second was an ethnographic study by Karen Tonso who, after 15 years work experience as an engineer, felt that "something about engineering seems to make it difficult for women to be thought of as full-fledged members" (2007: 2). She sought to investigate the process of 'becoming' an engineer by conducting extensive participant observation amongst college engineering students. As an insider/outsider, she was uniquely placed to observe various subtle ways in which the ability of the women students as engineers is often rendered invisible (see later).

Gaining relevant qualifications and technical expertise are necessary but not sufficient criteria for membership of an occupational community of prac-

tice; many other, informal mechanisms and criteria determine whether one is seen and felt to belong. In engineering, shared pleasure in technology (Kleif and Faulkner, 2003) is a common bond, as are shared approaches to thinking about problems and a shared humour about non-engineers' inability to see the world as 'we' do. Also crucial, in all occupations, are everyday aspects of what I am calling workplace culture, unrelated to the immediate demands of the job – such as how people interact with one another, topics of (non-work) conversation, what they find funny, and who socialises with whom. These things not only help oil the wheels of the organisation and get the job done, they also have a huge bearing on who is seen and felt to belong, and on who gets on. As numerous studies of workplace culture reveal, 'doing the job' frequently entails 'doing gender' (e.g. Acker, 1992; Collinson and Hearn, 1996; Halford et al., 1997).

My own fieldwork observations on engineering workplace cultures paint a mixed picture (see Faulkner, 2009a). Two workplaces provided extreme cases: in one UK oilfield engineering base, strong pressures to conform to a macho version of masculinity; and in the US software development department, a keen awareness of diversity politics. In general, the engineering workplace cultures I observed were respectful. Nonetheless, in all five workplaces I identified dynamics which tend to include some and marginalise others: most notably, the use of fraternal forms of greeting ('mate' or 'man') for which there is no feminine or gender neutral equivalent; a tendency to lean on topics of conversation stereotypically associated with men (e.g. football); and the existence of social networks of men whose masculinity is locally hegemonic and/or organisationally powerful. Such dynamics make it easier for (most) men than (most) women engineers to build and maintain working relationships and to progress their careers.

Underlying these dynamics is a phenomenon suggested also by Tonso's findings – a phenomenon I am calling the in/visibility paradox, whereby women engineers are simultaneously highly visible as women yet *in*visible as engineers. I believe this paradox is a key to understanding why women engineers struggle to belong in engineering workplace cultures. This chapter elaborates how the in/visibility paradox operates, and explores the related concept of gender in/authenticity. I initially coined the latter concept to capture *the apparent congruence or non-congruence of gender and engineering identities for men and women engineers respectively* – as in engineering is (felt and perceived to be) a gender inauthentic option for women (Faulkner, 2000a). It is a gender authentic option for men simply because the large majority of engineers are men; this is the statistical norm. Norms shape expectations; when people think 'engineer' most envisage a man. Women engineers are invisible, and surpris-

ing, as engineers for the same reason. They find themselves having to explain why they chose this career, where men who opt to be engineers are not remarkable, as men. With norms come normative pressures. Crucial amongst these, I believe, is the symbolic association of men/masculinities and technologies (Lohan and Faulkner, 2004), and the conventional gendering of the technical/social dualism evident in stereotypes like the asocial engineer. Even though actual people and practices are far more diverse than dualised stereotypes (Faulkner, 2000b), such symbols still perform work; they serve to normalise gender difference and inequalities. Accordingly, the term gender in/authenticity also serves to capture *the normative pressures of the way things are.*

INVISIBILITY AS ENGINEERS

Being seen to be professionally capable is naturally crucial to gaining membership in any occupational community of practice. That this is a particular struggle for women as engineers is evident at all stages of the career cycle. At university, men students are often surprised when the women start performing well academically. Even when faced with evidence to the contrary, there can remain lingering doubts about the women's ability (Dryburgh, 1999). Participating in student design teams, Tonso (2007) was able to observe subtle dynamics by which the contributions of very able women engineers were rendered invisible to faculty members. The men students involved were generally unaware of their part in this process, and the women were left wondering why they weren't getting good jobs.

Most women engineers have experienced being (quite literally) invisible as engineers – classically when they are mistaken for the secretary by outsiders. Arriving to do a presentation to a potential new client, building design engineer Karen knows she must immediately introduce herself and take a prominent role if she is to avoid this: "As a senior woman who is blond and girlie looking, there are people who don't take me seriously to start with. But once they realise I can do the job, it's over." It is a frequent lament of women in any occupation where they are in a minority that they have to work harder than the men to prove their ability. Yet none of the younger women engineers I interviewed voiced any concern that this might undermine their career. They tend to claim that any lack of credibility because of their gender is short-lived. Sadly, however, my findings indicate that doubts over women's engineering ability do not stop once they have passed the 'apprentice' stage. Even really

senior, older women engineers told me they have to (re)establish their credentials every time they encounter a new colleague, associate or client. So, having to demonstrate you can do the job constitutes an extra layer of practitioner identity work which women, and not men, have to do throughout their careers. A recent EU study, Prometea (Godfroy-Genin, 2010), found that this pressure is compounded by the (apparently widespread) perception that women engineers benefit from 'unfair' preferential treatment – that they 'got the job because they were a woman not because they were good enough'. This explicit questioning of the women's competence can be extremely undermining.

Various forms of labelling can serve to undermine the visibility and credibility of women as engineers. By no means trivial is the near universal use in the UK workplaces I studied of the generic 'he' to refer to an engineer who is not known, and the widespread use of masculine terms – 'men', 'boys', 'guys' – to refer to groups of engineers. There is little awareness of the impact of gendered language, even amongst engineers who support getting more women into engineering. But when a company director says "We put our key men forward" in bidding for a big design contract, he is perpetuating a tradition which makes it 'normal', even 'natural', to choose men for such jobs. At best, such statements render women engineers invisible; at worst, they render the very category woman engineer a non-sequitur.

Tonso (2007) asked interviewees to list and explain any terms they use to identify different types of engineering students. This yielded 36 terms in three categories: 'nerds', who were like design engineers; 'academic achievers', who performed best at the more abstract core of the curriculum; and 'geeks', who also performed well academically but were identified by their wider campus activities. Strikingly, only four of these 36 terms refer to women, all of them in the 'geek' category, so not defined by engineering performance. Informants simply didn't *see* women as being 'nerds' or 'academic achievers', even though many of their women colleagues would fit in these categories. As with the generic 'he', Tonso warns that such constructions of practitioner identities are consequential: "One cannot belong as an engineer if there are no recognised ways to belong as such." (Tonso, 2007: 255)

Perhaps somewhat less obvious is the implicit gendering of dichotomised categories used to describe different kinds of engineering work – hard/soft, concrete/abstract, practice/theory, technical/social. Gender hierarchies are often constituted through these dualisms – both symbolically and organisationally – albeit in contradictory ways (Faulkner, 2000b). The technical/social distinction surfaced repeatedly in my research, perhaps because it maps so

readily onto culturally available presumptions about masculine instrumentalism and feminine expressiveness. For example, many men engineers cleave to a 'nuts and bolts' identity: although this technicist identity is at odds with the profoundly heterogeneous nature of engineering practice, it converges with (and performs) available masculinities with which they are comfortable. The gender messages operating through these various mechanisms render women's membership as 'real engineers' more fragile than men's (Faulkner, 2007).

A crucial consequence of their fragile membership as engineers is its impact on the professional self-esteem and confidence of many women engineers, at various points in their career. Several younger engineers told me they unexpectedly experienced a sudden loss of confidence on entering university. I found this a shocking discovery, given the self-confidence required even to opt for a non-gender-conventional career, but Tonso's work signals the kind of identity and educational dynamics that might contribute to this. Both the McIlwee and Robinson (1992) and the Prometea studies (Thaler, 2010) encountered women engineers who reported a loss of confidence on getting stuck in dead-end jobs mid-career. Like Tonso, I believe many women engineers internalise a sense of their fragile status as engineers; it is *felt* as well as perceived. One older woman engineer recounted how, when she and other women engineers meet, they often "confess to feeling a fraud" after a few drinks together. Another told me that she and other women engineers who have been in senior management roles for some years tend now to introduce themselves to new acquaintances or associates as 'a manager' rather than 'an engineer', where senior men colleagues in these roles continue to refer to themselves as engineers.

We see very clearly here the sense of women engineers lacking 'authenticity' as engineers; indeed the strength of the evidence on this is a key reason why I have been unwilling to abandon the concept of gender in/authenticity. Shaky self-esteem and confidence can be insidiously undermining, with very damaging consequences for the retention and career progression of women in engineering. Whilst most women engineers are aware of their gender visibility and of the need for them to work harder than the men to prove their engineering credentials, few appear to be aware of the more subtle dynamics within engineering workplaces by which their professional self-esteem is undermined. Feelings of lack of confidence or authenticity are rarely voiced in public (in front of men). They tend to be seen as a personal failing rather than something for which the wider community and organisation bear responsibility, which is one reason why networks for women in technical occupations can be such an empowering mechanism for their members (Lee, 2011).

Several analysts have encountered a reluctance amongst (some) women engineers to see gender as relevant in their careers and workplaces, or to engage in collective feminist action. There seems to be a pervasive 'discourse of gender neutrality' – that everyone is being treated equally – amongst women and men scientists and engineers (Eisenhart and Finkel, 1993). In interviews with 15 women engineers (between the ages of 29 and 45) in the US, Jane Jorgenson found that "participants do not frame difficult episodes in their professional lives in terms of gender inequality" (2002: 350) and largely adopted a non- or anti-feminist position. Tellingly, Lisa Lee (2011)'s interviews with members of women's technology networks in Europe reveal a sensitivity that being 'feminist' implies a threat to the unity of the profession. Faced with challenges from feminists, the women students Dryburgh (1999) studied defended the 'play hard' culture of their men peers, even though they themselves rarely participated; and frequently dismissed any sexist behavior by men engineers as exceptional, even when presented with evidence to the contrary. She sees commitment to group solidarity as a key element in the socialisation of engineering students and concludes that learning to convey solidarity, like learning to convey one's competence, "requires extra effort [for the women] beyond what is asked of men in a similar position" (Dryburgh, 1999: 681).

We see again in these tensions the non-congruence of practitioner and gender identities for women engineers. It seems that, by refuting or playing down the significance of gender, women engineers are better able to strengthen or protect their fragile membership as engineers, while playing up gender and heightening their visibility as 'women' can be seen (and felt) to threaten their membership in the community of practice. Jorgenson suggests that women engineers' choice to distance themselves from feminist analyses and forms of intervention should be read as discursive positioning: it performs important identity work "consistent with assimilation strategies widely observed amongst female scientists and engineers to disqualify their femininity by muting their visibility as women" (2002: 169–70).

Visibility as Women

Whilst the invisibility of women engineers as engineers means they have to do extra layers of practitioner identity work, their visibility as women often means – paradoxically – that they also have to do extra layers of gender identity work. The point here is that women engineers tend to get pigeon-holed by

their colleagues into certain stereotypically feminine identities – most commonly as (hetero)sexually available or as mother – identities which have nothing to do with the job and which can be extremely problematic.

Of the labels used by Tonso's students to identify women engineers, only one (sorority woman) was respectable; the remainder characterised women engineers in terms of whether they were pretty and, by implication, sexually available to men (Betty, sorority chick/girl), or ugly and undesirable to men (engineering school woman). As in the remarks with which I opened this chapter, 'real woman' is defined in heteronormative terms: she is heterosexual and attractive to men. Being sexually visible brings the risk of predation. Most women engineers, unlike their men colleagues, have experienced unwanted flirting and/or sexual harassment from men colleagues or associates at some point. Young women are often ill-equipped to deal with this effectively. One oilfield engineer was sexually harassed by a client early in her career; with the benefit of hindsight, she says, "I should have reported him, but I didn't have the confidence, or the support." Some men are aware of these issues. Martin (also an oilfield engineer) told me, "I don't see my women colleagues as women", by which I later realised he meant he doesn't see them as sexual. Since he doesn't approve of sex between colleagues, Martin's intention here is supportive – as are the crewmen's who tell me they often 'protect' women on their team from sexual advances by other companies' crewmen offshore. But the equation drawn between 'woman' and '(hetero)sexually available' is striking.

Being visible as a mother can occur in two ways. One is a tendency to view *all* women as potential mothers – as when small firms refuse to employ a young woman in case she becomes pregnant, or when a lack of family-friendly provision is identified as *the* major reason for the loss of women engineers. The other occurs when having children is deemed to be the sole responsibility of the women. Thus, such family-friendly measures as exist in engineering workplaces are frequently viewed as 'for women', with scant awareness that more men engineers than women engineers are parents (in both absolute and relative terms). Little wonder that, in the absence of adequate support from either employers or partners, opting to have children is often a watershed in the careers of women engineers, the point when they get overtaken by their men peers. Those who stay frequently report that their visibility as mothers reduces further their visibility as engineers, where men with children continue to be taken seriously as engineers and are not defined by being parents (Lee et al., 2010).

There is evidence that becoming a mother shifts both the kinds of femininities women engineers perform at work and the career strategies they pursue.

From a study of women and men engineers in six organisations in Norway in the late 1980s, Elin Kvande (1999) identified four 'ideal type' femininities, split on two axes: (i) sameness or difference to men and (ii) proactive or not with respect to their careers. Younger women and women who opted to not have children tended to adopt a 'sameness strategy' whereby they sought to fit in and/or compete with the men on the men's terms. Like women in the studies reported earlier, they believed gender is not relevant at work, and tended to distance themselves from other women. By contrast, women with children pursued a 'difference strategy' because "By being pregnant, the women erase the idea of gender neutrality at the workplace." (Kvande, 1999: 307) They were unwilling to conform to the organisational norms and values, so either withdrew from the competition and prioritised family life or attempted to combine family and career by competing on their own terms.

The same/different choice of available femininities revealed here stands in some contrast to the fairly wide range of masculinities, some of them quite marginal, accommodated in the engineering workplaces I studied (Faulkner, 2009a). Kvande attributes this polarity to a 'dilemma of difference' whereby women have to position their gender identities in relation to the hegemonic masculinity/ies (see Connell, 1987) operating in the profession. This dilemma of difference is fundamentally linked to the non-congruence of gender and engineering identities for women engineers captured by the gender in/authenticity concept. If to be a 'real engineer' is to be a man, *and if 'men' and 'women' are necessarily different*, then women engineers have to play down their identity as 'real women' if they are to belong in engineering. Whilst women engineers are highly visible as women, they must also learn to, in some sense, become *in*visible as women. This is what Jorgenson (2002) means by "disqualifying their femininity", a perhaps superficial example being Kvande's finding that women engineers who "wear frills" or use make-up would not be taken seriously.

Jorgenson (2002) has challenged the tendency of the women in engineering literature to cast women as victims or (less commonly) resisters, arguing for a more nuanced and situated analysis; my own research supports this move. Certainly, my fieldwork identified pressures to become 'one of the lads' if they are to fit in to a workplace culture largely defined by and comfortable to men, where in some settings fitting in can mean sitting on the margins of conversations about football and families, going along with sexual humour or swearing, and so forth (Faulkner, 2009a). But my evidence also reveals a more complex and changing picture than is suggested by the 'disqualifying of femininity' conclusion of much earlier research. When I asked women engineers what

they felt about going into an occupation dominated by men, the first response of many was that they enjoy the company of men and have many men friends. Some relish the challenge this presents. Oilfield engineer Kathleen "liked being a novelty" and feels very proud that she "was good at the job and got noticed for it". Others are pragmatic, claiming that being visible as a *woman* engineer can work to their advantage: once their engineering credentials *are* established, colleagues and contacts remember them *because* they 'stand out in the crowd'. Yet others claim to be neutral on the subject. Kristin was initially the only woman in her oilfield base where now women are in the majority; "It doesn't bother me either way", she says.

Dress is one of the ways in which gender identities are, rather literally, performed; and it is an area in which women generally have more discretion than men. In all four UK engineering workplaces, where almost all the women engineers are in their 20s or 30s and not mothers, a higher proportion dress 'up' for work in conventionally 'feminine' ways – including high heeled shoes, 'pretty' tops, even dresses. This indicates a shift from the 'no frills and make up' norm reported by Kvande. I sense that many of these women enjoy the perceived dissonance between a 'girlie' gender identity and their identity as engineers. This surfaced humorously on the occasion of oilfield engineer Laurie's birthday, when she wore a dress and a cream shawl to work (which shocked me, I must confess). She tells her colleague, Kristin, "I was getting my nails and hair done on Saturday", to which Kristin quips "And you an engineer!" and Laurie responds "Only from Monday to Friday!"

I suggest there is something more complicated going on here than a simple sameness/difference choice. Rather, I found a double paradox with respect to women's gender in/visibility in that, alongside the pressure to become 'one of the lads', there are also pressures not to 'lose their femininity'. Women engineers are expected to 'blend in' but, at the same time, *not* to behave like men in certain areas. The dividing lines are often only obvious when crossed. Women engineers offshore are judged badly if they aren't willing to 'have a go' at physically demanding jobs like turning valves, but they are expected to demure to men over heavier lifting work. Similarly, when building design engineer Alison cracked a sexual joke, the consternation of her men colleagues made it clear she had broken tacit norms about appropriate behavior for women: it is OK to laugh at sexual jokes but not to make them.

In negotiating and performing gender identities which are comfortable for them but also admissible within the workplace culture, women engineers occupy a rather ambivalent space. Leila is a case in point: "[Engineering] Being

male-dominated doesn't bother me. I always had more men friends than women. Many women are too girly. I think I have managed to stay very feminine; men comment on it. Some [women engineers] have lost it a bit because […] it starts early." References to women engineers who have 'lost it' were common in the oilfield engineering company. This underlines the thread running through the literature, that simply by being a woman in a man's job, women engineers jeopardise their status as women. But notice the delicate juggling act: Leila is 'very feminine' but not 'too girly'. Similarly, Léa told me she tries to find "a medium place between 'girls with nails' and 'feminist'". So what we see here is a tension between two gender messages: one which says, 'To be a woman engineer is to be somewhat less conventionally feminine, or more masculine, than most women' (several of the women software developers I interviewed made comments like this about themselves); the other which says, 'To be a "real woman" – or in my terms, to preserve one's gender authenticity – one must conform to stereotypes of femininity.' That the required stereotypes remain heteronormative is evident in Leila's reference to men as the judging audience for 'staying feminine', and in the concerns of men offshore to 'protect' their women co-workers from undue sexual predation and hard labour.

Conclusion

Gender in/authenticity and the in/visibility paradox create issues for women engineers which men engineers, by virtue of being men, rarely have to experience. Through numerous subtle and not so subtle dynamics, women engineers are perceived, and can feel themselves, to be not quite 'real engineers' *or* 'real women'. Men engineers belong more 'naturally' both professionally and in terms of gender, whilst women have to do additional identity work on both fronts if they are to secure their membership in, and so stay and progress in, engineering. The cumulative impact of these in/visibility dynamics on individual women engineers can be insidious and undermining, throughout their careers – a 'dripping tap' effect. Studies and policy recommendations on the retention and progression of women in engineering (e.g. European Commission, 2006) typically foreground structural factors, like the lack of flexible work practices and the norm of long working hours. Significant though these issues are, however, my research demonstrates how subtle, 'taken-for-granted' gender dynamics in workplace cultures also have a huge bearing – and so also need to be tackled.

For some, the language of gender in/authenticity implies a worrying essentialist judgement – about 'real' women, etc. The point for me is that it signals *real membership*, of engineering and genders. The deeper I reflected on my evidence, the more I realised that it is precisely the shocking quality of the term that gives the concept salience: it signals how consequential it is to be an 'exception to the norm' – and conversely, how much easier life is for those who conform to the norm. It would be wrong, however, to view genders in/of engineering as monolithic and unchanging. My evidence on the in/visibility of women engineers is mixed, as it is on other gender dynamics in/of engineering workplace cultures. This complexity allows us to consider the second aspect of the gender in/authenticity concept – namely, the normative pressures of the way things are – and to pose the question, how might gender change happen/be happening in engineering?

In this connection, I have found it useful to resurrect the dual meaning of norm: as statistical norm and as sociologically normative pressures. It seems to me that both are operating in engineering workplace cultures. Thus, comparison of the different workplaces I studied (Faulkner, 2009a), reveals that engineering workplace cultures are more comfortable for (most) men than (most) women to the degree that (i) men outnumber women and that (ii) narrow and locally hegemonic gender norms are operating. In general, the largest cultural group will tend to set the tone in any workplace, leaving any minority groups to adapt and 'fit in'. This is what Vivian Lagesen (2007) calls the 'strength of numbers' phenomenon. The greater the relative numbers of men to women, the greater the normative pressures and the more tenuously women belong. At the same time, women's membership and career progression in engineering are stronger where organisations work to nurture more inclusive workplace cultures. So the impact of relative numbers can be obviated to some extent, through instruments like strong team management and diversity training.

Rosabeth Moss Kanter's pioneering study of women entering the sales force of a large US corporation (1977) identified three common experiences: they felt highly visible as women and under pressures to perform better than the men; they felt isolated from the men's informal and professional networks; and they felt trapped in gender-stereotyped roles. These findings have been echoed in numerous subsequent studies (e.g. Padavic, 1991). Of particular note here, in/visibility dynamics and pressures to perform gender difference are almost invariably experienced by women in occupations dominated by men. Kanter attributed this to the numerical gender imbalance of an occupation, but in a persuasive critique, Janice Yoder (1991) demonstrates that gender

hierarchies, segregation, and various forms of sexism are also critical. This concurs with my conclusion that relative numbers *and* normative pressures in the wider gender order both work to reproduce stability.

Critical amongst these normative pressures is the tendency to see women as necessarily different from men, which so readily constrained the gender performances I observed. Judith Butler (1990) argues that this ideology of gender difference is a crucial symbolic aspect of heteronormativity, that most people have an investment in policing boundaries around what is admissible for women and men (e.g., by 'protecting' women from heavy work or swearing). She further argues that the performance of difference occurs through 'stylised repetition of speech acts' (e.g. the generic 'he'). It is common to find that actual people and practices are diverse, while people's accounts of them tend to dualise. For example, one frequently hears that women engineers have better 'people skills' than men engineers, but I found no empirical support for this in any of the workplaces I observed (Faulkner, 2000b). The repetition of such presumptions serves to reproduce the man engineer as the norm and the woman engineer as the invisible non-sequitur.

The upshot of this analysis is that we need to tackle both the wider gender order and the numerical gender imbalance if we want to achieve gender equality in engineering. Put another way, we need to normalise the woman engineer – both in the statistical sense, that the numbers of women become closer to those of men, and in the normative sense, that engineering becomes as 'gender authentic' an option for women as for men. This means that, as well as recruiting more women into engineering, its workplace cultures have to be made much more welcoming, comfortable, and supportive places for women in order to avoid losing or under-utilizing their talent.

The Prometea study found that, whilst most large engineering organisations across Europe now have policies which seek to improve the retention and progression of women engineers – addressing family-related issues, work-life balance, and career development – the uptake and the impact of such policies is generally limited or uneven (Lee et al., 2010). Moreover, few do anything to address gender dynamics in the workplace culture. There is a crying need for sustained 'culture change' to 'win hearts and minds' behind equality and diversity programmes at all levels of organisations (see Liff and Cameron, 1997). Such culture change requires time and commitment. A central element has to be raising awareness of in/visibility and other gender dynamics in the workplace. This is especially challenging, not only because of hostility to feminism and perceptions of 'unfair treatment', but also because many exclusion-

ary practices and cultures are so taken-for-granted they appear 'normal'. They persist because that they are not *seen* as exclusionary, even by members who care deeply about gender equality and who actively support women engineers (Tonso, 2007; see also Frehill, 1997).

This very taken-for-granted-ness is a key reason why gender inclusive efforts to date have had only limited impact. There may be promise, however, in my finding that in/visibility dynamics are far less prominent in women's individual interactions with close men co-workers than in group situations and encounters with outsiders (also observed by Padavic, 1991). With careful work on diversity awareness, such men could become agents of gender change – challenging the tendency of other men associates to ignore, undermine or stereotype their close women colleagues – so taking the pressure from them to do all the fighting or demure (Yoder et al., 1998 provides a compelling example of how this can be achieved).

I believe the other reason why gender inclusive efforts have had only limited impact to date is that so many cleave to the ideology of gender difference which underpins perceptions of gender in/authenticity. Crucially, following the argument developed here, we need to challenge stereotyped dualisms about both gender and engineering. In the words of physicist Evelyn Fox Keller (1992), we need to learn to 'count past two' – to create space for more plural versions of masculinities and femininities, and to foreground heterogeneous rather than dualised understandings of engineering (Faulkner, 2007). There remains considerable resistance to 'counting past two' amongst women into engineering practitioners as well as engineers. Many liberal feminists appeal explicitly to the conventional gendering of the technical/social dualism, in their attempts to attract more women (Lagesen, 2007). The ideology of gender difference is so pervasive (and comfortable), it can feel like 'tilting at windmills' to suggest this approach is counterproductive. But efforts to improve the representation of women in engineering will continue to flounder unless we succeed in getting this message across.

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Similar But Different?

Cognitive Differences in the Discussion of Women in Science and Technology

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Introduction

Recent years have seen a growing interest in increasing the proportion of women in science and technology (see OECD, 2008), motivated by economic considerations and/or policies to promote gender equality. A recurring topic in pertinent discussions has been the question whether gender differences in cognitive skills could be a reason why women, despite numerous initiatives, continue to be underrepresented in technical fields – certainly a very sensitive issue.[1] While some condemn the question itself as outrageous, others ask why women should be "pushed" into fields that do not appeal to them. In line with Ceci and Williams (2009) we think that there is a need for a more sober discussion that takes into account the impressive body of research that accumulated over recent years.

These discussions often focus on the question of whether gender differences actually exist or not. As we will show, the results of numerous studies on cognitive gender differences are multifaceted and highly nuanced. Thus, it is not hard to find studies that can be cited to support any given standpoint, and the discussion quickly starts going in circles. Furthermore, a politically

1 | A well-known example is a 2005 speech by the then-president of Harvard University on the underrepresentation of women in science and technology, which created a worldwide stir. His elaborations on ability differences among top achievers provoked a storm of indignation, but they also launched more nuanced efforts to address the issue (see, for example, Ceci and Williams, 2007; Nature Neuroscience, 2005).

motivated point of view often in many ways hampers a sober assessment of the results. Especially in recent years, though, we have witnessed the emergence of interesting research results in several respects. In particular, the publication of meta-analyses that summarize and evaluate the results of many studies, new studies in the field of stereotype research, and the consideration of new issues (such as whether gender differences in the cognitive area are stable or subject to change) have delivered new impetus to the discussion.

Even if the empirical findings continue to indicate a complex pattern of similarities and differences between men and women, we endeavor in this paper to summarize the research results in a kaleidoscopic way. We begin by questioning the role of competence for the stereotypical perceptions of men and women, and discuss what this means with respect to questioning women's aptitude for technical fields. We then survey the current state of research on gender-specific cognitive differences, taking into account various interpretations offered for the results. Finally, we shift perspective away from considering whether there are gender differences in cognitive abilities and raise the pragmatic question of whether cognitive abilities can be influenced and, if so, how. We strongly favor fostering this perspective shift in the discussion as a whole. We are convinced that this can save energy, prevent frustration, and create a constructive climate among the various protagonists.

Stereotypes about Women in Science and Technology

What stereotypes exist?

> "It seems to me that in the beginning women are always grossly underestimated." (Female student)
> "Even before I started, they said: A woman in computer science, forget it." (Freshman coed)

These quotes from a group discussion we conducted for our study[2] illustrate how female college students perceive the assessment of their competence. An

2 | In TEquality – Technik.Gender.Equality, we investigated factors that influenced whether students were successful in or dropped out of the computer science and mechatronics programs at a Middle European University. On the basis of our findings, we de-

openly articulated, universal denigration of women has now become generally unacceptable (Eckes and Six-Materna, 1998); nevertheless, stereotypes about the purported nature of gender differences – e.g. that men have superior mathematical-technical abilities – tenaciously persist.

Gender stereotypes are cognitive structures that convey socially shared assumptions and/or a culturally shared understanding of characteristic qualities of men and women (Eckes, 1997). As recent stereotype research shows (e.g. Cuddy et al., 2008; Fiske et al., 2002; Glick and Fiske, 2001), attributions of particular abilities or the lack of them constitute a substantial portion of many stereotypes. Viewing prejudices as exclusively negative judgment passed on a group usually misses the mark by failing to take into account the fact that the powerful influence of many stereotypes in everyday life is due precisely to the fact that they combine positive and negative views of a group.

Two dimensions are especially significant in connection with group stereotyping: In addition to the matter of competence, the ascription of social warmth (in the form of friendliness, helpfulness, a caring nature) also has particular significance. The combination of these two dimensions makes it possible to differentiate among four groups of stereotypes, each one of which elicits specific prejudicial dynamics and is also connected with specific feelings and behavioral options (Cuddy et al., 2008). This differentiation highlights that a particular stereotype does not necessarily apply to all women, and that they are frequently confronted by ambivalent stereotypes that combine positive and negative attributions (competent-but-cold versus warm-but-less-competent). The competent-but-cold ascription is often accompanied by clear antipathy, whereby certain groups of women are considered to be a real threat (e.g. they are said to be able to or want to control men). Attributing social warmth and simultaneously reduced competence, on the other hand, is usually paired with a paternalistic attitude (Glick and Fiske, 2001). In our study, we were able to observe that successful female students were said by their fellow students to be less socially warm and less attractive in a feminine way but extremely ambitious. It is alarming that these women experience a lower degree of social ac-

veloped recommendations designed to improve conditions for students and increase the proportion of women among them (see www.tequality.at and Horwath et al., 2006, 2007). Data collection comprised both group discussions with current and former students of computer science and mechatronics and a questionnaire to survey everyone who had registered for either of these two programs between 1993 and 2006.

ceptance and feelings of belonging in the academic environment (Kronberger and Horwath, forthcoming).

The paternalistic attitude is significantly more socially acceptable, since women are thereby portrayed as wonderful beings (possibly with social, cultural, and artistic gifts). The fact that this – at least implicitly – goes along with negation of their competence is something of which both sides are often not consciously aware. But this is precisely why this subtle form of prejudice can be so insidious. People who think this way are usually convinced that they are positively disposed towards women (subjective benevolence), and women who are confronted by this attitude often do not even perceive it as sexist or discriminatory. Rather, studies suggest that women usually have a hard time categorizing these attitudes; they find them somewhat perplexing (Rudman and Glick, 2008). When implicit denials of competence are expressed in combination with praise, this can have a disarming effect.

Many of the women we surveyed in our study also maintain that they have hardly experienced open discrimination and sexism. More frequently, they report experiencing implicit denials of their competence, more often expressed in deeds than in words – for instance, when women relate that men in their age group are quite helpful and gladly provide explanations about course material; conversely, these women are also aware that men – even younger men – hardly ever approach them with questions. Are they not considered likely to know the answer? Women also report experiencing denials of their competence cloaked in a compliment:

> "It's like, when people come to me and say 'Hey, you're a woman and you're studying computer science. Wow, super achievement!' … Men study mechatronics or computer science and that's just normal, but in my case it's an outstanding accomplishment. And I get this kind of funny feeling, because no way is that a real compliment. It's sort of a mixed message, both positive and negative." (female student)

Of course women feel flattered when they are praised as extraordinary; nevertheless, this praise is also confirmation that the 'women are not technically gifted' stereotype is still very much alive, whereby it must also be emphasized that women, too, not infrequently share this view.

The paternalistic approach of bringing goodwill to encounters with women while subtly disparaging their capabilities is also referred to as benevolent sexism (Glick and Fiske, 1996). For the recipients, this ambivalent attitude is

considerably harder to interpret than open deprecation and/or sexist hostility. Naturally, it might seem more pleasant to be confronted by benevolent sexism than with its antagonistic counterpart, but studies indicate that a denial of competence in the form of benevolent sexism can have a particularly deleterious effect on women's performance. In a series of experiments by Dardenne et al. (2007), for example, female jobseekers, prior to taking a test, were confronted by sexist remarks of either a benevolent or hostile nature. Although the benevolently sexist statements were not perceived as sexist by most of the women, four experiments indicated poorer performance under conditions of benevolent compared to hostile sexism. Women who encountered benevolent sexism had to struggle with confusing thoughts about their own competence. This brings us to the question of how stereotypes and the expectations of competence associated with them actually work in everyday life.

How do stereotypes work?

> "The feeling for technology that you get from your parents as part of your upbringing is what they (women) actually lack. And this is a bit of a shortcoming." (male student)

Many studies examine the question of how expectations of parents, caregivers, and teachers influence children's behavior and performance (see Lloyd and Duveen, 1992; Tiedemann, 2000). That such influences exist was highlighted long ago by Rosenthal and Jacobson's influential 1968 study on the Pygmalion Effect. This study showed that when teachers are told that some randomly selected students would soon excel, these students' performance (as measured by objective tests) indeed improved more than other students' performance. Later research on the relationship between expectation and achievement is more controversial but it is interesting to scrutinize the literature for gender issues.

For example, Ziegler et al. (1998) found that 27% of mathematics teachers and over 30% of physics instructors rated boys as more gifted than girls. Accordingly, there is a relatively high probability that a girl will encounter a teacher who attributes less talent to her than to a boy. An older study by Roloff and Evertz (1992; see Roloff, 1999) shows how girls' chances to succeed in physics and computer science are utterly thwarted by teachers' implicit conviction that this subject matter will not be used on a highly qualified level in these girls' lives, and how identical behavior by girls and boys in classroom situations is variably interpreted in accordance with the stereotype 'boys are

good; girls are diligent' (on the subject of this interpretational pattern, also see the meta-analysis by Swim and Sanna, 1996). A similar pattern of competence ascription was also sketched by Menacher (1994), whereby mothers attribute their daughters' good grades in mathematics to studying hard, whereas their sons are said to have obtained good grades because they are gifted. Crowley et al. (2001) observed parents and their children in museums and discovered that scientific objects on display were explained three times more often to boys than to girls.

But parents and educators are not the only ones who influence youngsters; young people make a major impact on each other. Even children regard mathematics as masculine (J. Steele, 2003), and girls are less frequently encouraged to participate in scientific activities by their peers than boys are (Stake and Nickens, 2005). Hyde et al. (1990) report that young people as well engage in such ascriptions. A meta-analysis of gender-specific attitudes towards mathematics reveals that boys tend to attribute success to their capabilities whereas girls are inclined to attribute their success to hard work or luck, and claim their failures are the result of lower mathematical aptitude. For girls, these are unfavorable ascriptive patterns that influence their further motivation and can act as a self-fulfilling prophecy.

Our study also presented accounts of scant support and encouragement (Horwath et al., 2007). Whereas the proportion of men and women surveyed who felt that their father had nurtured their interest in technology was about the same (45% versus 51%), 38% of men but only 23% of women said the same about their mother. Women report much less frequently of having had great opportunities to get technical experience, and their retrospective estimation of the contribution made by their school and teachers in fostering their interest in technology is truly alarming: 46% of men but a mere 27% of women claim to have received support and encouragement from teachers, and 14% of women even state that teachers curbed their enthusiasm (versus 3% of men).

The differential perception and treatment of women not only plays a role in upbringing and education; it continues on in occupational life. Discrimination against women in hiring decisions is often the result of unthinking, cliché-based modes of perception and behavior. A good illustration of this is the study by Norton et al. (2004, Study 1). The subjects were assigned the task of selecting, from among five persons, the most qualified for a construction engineering job (whereby the individual should possess a good educational background and work experience). Of the five applicants, two were shortlisted: Person A had better training (certificate in addition to a college degree) and had 5+

years of career experience, whereas Person B had only a college degree (no additional certificate), but 9 years of career experience. In the control group, the candidates were identified only as Person A and Person B, and 76% of the participants in this group selected Person A as the more qualified applicant. To the members of a second group, Person A was presented as a male and Person B as a female, and here as well 75% of the participants assessed Person A as better qualified for the job. Finally, in a third group, Person A was presented as female and Person B as male, the upshot of which was that only 43% of the participants now felt that Person A was the right one for the job. The results of this study show how stereotypes influence thinking. Men conform to preconceptions of what a good engineer is like better than women do, regardless of how much education or experience they have.

Discrimination is often based on relatively small effects, which raises the question of whether a little bit of discrimination can also be relevant. This question was investigated by Martell et al. (1996) with the help of a computer simulation. The authors simulated an organization with an eight-level hierarchy (500 persons on the lowest tier; 10 at the top) and the same number of men and women on each level. Then, a slight promotion bias in favor of men was introduced, and two simulations compared the effects of small degrees of preference/discrimination (5% versus 1% variance in the promotions). Following 20 rounds and as the outcome of minimal discrimination against women, the top level of the institution was staffed by 71% and 65% men respectively. This means that even slight bias can engender significant inequality over time.

The findings sketched above make it clear that stereotypes develop a certain momentum and can become self-fulfilling prophecies. Nevertheless, the question of whether the divergent representation of men and women in science and technology can also – or even primarily – be explained by divergent cognitive skills cannot be answered in terms of the above-described ways that stereotypes are operational in everyday life. Thus, we now turn to the question of whether gender differences with respect to cognitive skills can be identified. What generalizations are permissible according to the latest research?

Are There Cognitive Differences between Men and Women?

Relevant criteria for an assessment of the findings yielded by studies of cognitive skills are the questions of which skills are being measured, how are they

measured, and when (at what stage of the lifecycle) are they measured. The results of these studies are complex and sometimes ambiguous, which is why meta-analyses in this area are enlightening. These meta-analyses scrutinize how pronounced a difference is (mostly measured by the effect size *d*; Cohen, 1988[3]) over a number of different studies. The effect size is computed according to statistical formulas; however, this does not indicate when a difference is substantial enough in everyday life to be relevant. That, in turn, is a matter of interpretation and the subject of a controversial debate (for an overview see Ceci and Williams, 2007; Ceci et al., 2009; and Halpern et al., 2007).

First of all, meta-analyses permit the generalization that the cognitive profiles of men and women are largely similar but differ in some areas (Hyde, 2005). In detail, results show that, with respect to general intelligence, no gender differences can be established – i.e. women and men are equally intelligent on average (Halpern et al., 2007). Whereas there are no differences in the mid-range of the performance spectrum, there are differences at both extremes (Hedges and Nowell, 1995). Males display more heterogeneity – i.e. there are more men than women among both the lowest performers and the highest performers. The reasons for this are unclear (Halpern et al., 2007; Lubinski and Benbow, 2007).

Furthermore, meta-analyses indicate differences in the average skill profiles of men and women for certain types of cognitive abilities, whereby these differences vary with the subjects' age. We will now take a closer look at three such areas that can be considered particularly relevant for technical careers: verbal and mathematical capabilities and spatial thinking. Verbal skills are significant because superior performance in technical fields calls for the ability to communicate effectively and to understand abstract ideas. It is important to be able to communicate clearly, understand complex texts, and work together with other people. Verbal skills are an advantage in all academic areas. A perusal of the literature on this subject shows that numerous studies indicate a small to medium gender difference in favor of women (Halpern et al., 2007). Some but not all verbal tests reveal that women have a slight advantage here (see the meta-analyses by Hyde and Linn, 1988; and by Hedges and Nowell, 1995).

3 | The effect size *d* can range from -3 to +3, with a value of 0 indicating that there is no difference. A value of 0.8 is considered a large, 0.5 is a medium, 0.2 is a small, and <0.2 is a negligible difference (Cohen, 1988). By convention, negative values are used for higher values for women and positive values for higher values for men.

With respect to mathematical skills, the results are less clear. In this area, the one in which gender stereotypes are most highly defined, empirical findings reveal the smallest and the least stable differences in capabilities (Halpern et al., 2007). Thus, an analysis of 100 studies of mathematical skills involving more than 3 million participants indicated no gender difference (d = -0.05) for samples of the general population; men performed better in 51% of the studies, 6% found no difference, and women outperformed men in 43% of the studies (Hyde et al., 1990). In other words, it is not hard to find one or more studies that support one's view. In contrast to what the stereotype suggests, there is little evidence that boys are generally more gifted mathematically. Hyde et al. (2008), for example, analyzed standardized testing data of more than 7 million pupils across all grade levels in 10 U.S. states. Of the 66 reported effect sizes (10 states; 11 grades), 21 indicate better performance by boys, 36 indicate better performance by girls, and 9 indicate no gender differences. All effect sizes are smaller than 0.10, which means that the differences can be considered negligible. While the available meta-analyses all indicate that the effect sizes for gender differences in math achievement generally are negligible or very small, they also show that gender differences increase with age (favoring males), particularly at the top performance level (Else-Quest et al., 2010; Hedges and Nowell, 1995; Hyde et al., 2008; Hyde and Mertz, 2009; see also Hyde, 2005).

The last cognitive area we want to consider is spatial abilities. This is a key skill for a wide range of occupations, including architects, surgeons, artists, taxi drivers, and engineers. Many occupations call for the ability to visualize objects from different perspectives, such as for example, while in motion. There are comparatively large and consistent gender differences with respect to this ability, particularly for mental rotation tasks. Again, gender differences in the performance of mental rotation tasks are more apparent among adults than among children. Even if the effect sizes vary considerably across different spatial tasks, men consistently outperform women (see, for example, the meta-analyses by Linn and Petersen, 1985; and Voyer et al., 1995; see also Hyde, 2005).

On the basis of reported research on gender-specific cognitive differences, the following interim conclusions can be drawn. There are no average differences between the sexes with respect to general intelligence, although numerous studies indicate that there are small average differences in the cognitive profile of men and women as measured by standardized tests. The pattern of gender differences is more nuanced than is often assumed. Performance by men seems to be more dispersed than that of women. Gender differences mani-

fest themselves above all in performing verbal tasks (higher average values by women) and spatial tasks (higher average values by men). They often emerge only at a certain age and/or manifest themselves differently in different age groups. As a rule, performance differences can be identified only beginning at adolescence, especially among the highest performers. The differences vary depending on the particular area being considered. The biggest lead by boys emerges at about age 15 in certain spatial tasks (Halpern et al., 2007). Attributing superior mathematical skills to men is hardly tenable. Attributing verbal skills to women and math skills to men is likewise erroneous since both sexes exhibit strengths and weaknesses in particular sub-tests. In most areas, when differences between the genders can even be registered, they are small (Hyde, 2005). The meaning and practical relevance of such differences is less clear.

A pertinent question, of course, is whether the greater heterogeneity on the part of men (at the top and bottom of the performance spectrum) leads to their more frequent professional involvement with science and technology. Since, by definition, only a very small proportion of the population are top performers, there must also be many men employed in technical fields who are not in the top 1% of the performance spectrum. And in the top 5–10%, gender differences are already minimal. It is also important to note that women engaged in technical occupations are underrepresented at all performance levels and not only in the top 1% (Halpern, 2007). Also of interest in this connection is a study by Benbow et al. (2000) that investigated which professions were chosen by men and women who, at age 12, had been classified as highly gifted (top 1% of their cohort). Only a relatively small proportion of the boys were working in a scientific or technical field at age 33, and the proportion of gifted girls was even smaller. It should also be mentioned that, for gender differences in the highest performance group, ethnic differences were identified. In the group of U.S. pupils of Asian descent, for example, there are no gender differences in the highest performance group with respect to mathematical tasks (Hyde et al., 2008).

Cultural and Social Influences on Differences in Cognitive Performance

Performance differences between boys and girls are also culturally dependent, since tendencies are not identical in all countries. The 2009 PISA Study that tested the performance of 15-16-year-old pupils provides a few indications

here. In the area of reading skills, girls performed significantly better than boys in all OECD countries, where, on average, girls lead by 39 points, which corresponds to more than half a competence level/school year (Schwandtner and Schreiner, 2010; OECD, 2010). In Austria, girls outperformed boys by 41 points, in Germany by 40, and in Switzerland by 39; girls had significantly less of a lead in the Netherlands (24), the U.S. and Great Britain (25), whereas they were far ahead in Bulgaria (61), Lithuania (51), and Finland (55). This means that girls' reading skills as measured by the PISA Study were superior in every case, but the extent to which they outperformed boys varied considerably from country to country.[4] Furthermore, socioeconomic status had a greater influence on reading skills than gender – i.e. the score difference between the top and bottom quartiles of the pupils' socioeconomic distribution. Among OECD countries, Hungary (118) displayed the greatest difference, and Iceland (62) the least. The OECD average was 89 points, with Austria (102), Germany (105), and Switzerland (94) coming in above average (OECD, 2010).

With respect to mathematical skills, gender differences are less pronounced. In the OECD, boys average 11 points higher than girls.[5] In 35 of the 65 participating countries, boys outperformed girls. In Austria and Switzerland, the boys' lead was 20, in Germany 15 points. Among Austrian pupils surveyed, the boys' average score (506) topped that of girls (486); nevertheless, in such countries as Korea (544), Finland (539), and Switzerland (524), girls finished first (Frey et al., 2010).

These elaborations show that both the extent and the direction of gender differences vary from country to country and across ethnic groups, a finding also highlighted by recent meta-analyses (Else-Quest et al., 2010; Hyde and Mertz, 2009). Moreover, the influence of the respective school system and the extent to which it provides equal opportunity education can amplify or diminish performance differences. Equal opportunity manifests itself in endeavors to minimize competence differences between socially privileged and disadvantaged youths. In all participating countries, social background influenced pupils' achievements, though the strength of the interrelationship between socioeconomic status and competence differs among the individual countries. In Finland, for instance, pupils' achievement hardly correlated with their family's socioeconomic status; in Austria, it did to a considerable greater extent,

4 | The range is 22-55 difference points in the OECD member states, and 9-62 difference points in the partner countries.

5 | OECD mean, girls: M=490, SD=0.6; boys: M=501, SD=0.6 (Frey et al., 2010).

whereby this applies especially to those whose immediate family migrated to Austria (Schwandtner and Schreiner, 2010).

Gender-specific performance differences are neither immutable nor indispensible, and the differences between the genders are often less than the differences between the countries. The factors underlying national differences are multifaceted. Naturally, a country's economic strength and the quality of its educational system are key variables. The degree of gender stratification in a society also seems to play a role. Baker and Jones (1993) analyzed the international pattern of gender differences in mathematics achievement and discovered that there is a correlation with the proportion of women in the workforce ($r = -.55$). In other words, the more women are engaged in gainful employment, the less there are gender differences in mathematics achievement. An interrelationship between gender differences as established by PISA 2003 and four indicators of the social role of women in various countries was also reported by Guiso et al. (2008). The analysis reveals a tendency whereby gender differences in mathematics are considerably smaller – or even vanish altogether – in those societies that display a high degree of gender equality (see also Else-Quest et al., 2010; Hyde and Mertz, 2009). For spatial abilities, a study by Hoffman et al. (2011) showed for two tribes of comparable genetic background in Northeast India that the gender gap disappeared when moving from a patrilineal society to a matrilineal society.

In addition to international differences, those within a particular society are relevant too. In a study of children from economically less-well-off families, Levine et al. (2005) found no gender differences in tasks involving spatial thinking, whereas there were marked differences among children of middle- and high-income families. These findings can be viewed as an indication that training cognitive skills – just like development of spatial thinking by boys – depends on the experiential opportunities made available to a child (e.g. computer games, jigsaw puzzles, sets of building blocks, etc.).

Finally, it should be mentioned that gender differences in cognitive skills have also changed considerably over time. The differences established by numerous – though not all – tests have diminished (see the review by Hyde, 2005 that considered 46 meta-analyses). The difference between women and men in the top performance sector has also decreased (Halpern et al., 2007; Wai et al., 2010). The proportion of female college graduates has risen sharply, and the probability that a woman will graduate college is significantly higher today than it was 30 years ago. The graduation percentage of women is greater or equal to that of men in 21 of 27 OECD countries (OECD, 2004).

On the Interpretation of Cognitive Gender Differences

As already implied in previous sections, the interpretation of the results plays a decisive role in discussions of cognitive skills. For example, schoolchildren in the U.S. have been doing poorly in comparison to their peers abroad in tests on scientific-technical subjects for years now, but this hardly leads to the presumption that Americans have less of a chance to succeed in science (Hines, 2007). The question of whether the low proportion of women in science and technology can be explained by gender-specific differences in cognitive skills essentially asks whether women are less talented or less suited to technical occupations than men. It attributes certain cognitive deficits to women, even if it does so indirectly and sometimes even in a benevolent manner. The question is additionally problematic in that it proceeds under the implicit assumption that a single talent or ability makes for success, that standardized tests can measure this talent or ability, and, furthermore, that talent and ability are stable and thus unalterable (Valian, 2007). But the paths from skills to careers are subject to numerous factors. Even if certain abilities seem to be required for success in technology and science, there is often no objective standard of how much of a skill is necessary for students to become good technicians or scientists.

It seems even more characteristic that, in discussions of cognitive differences, this matter is often reduced to the question of whether this is biologically determined or due to socialization (social class phenomenon, attributable to the influence of parents and peers, or a consequence of how much effort went into nurturing interest in science and technology). This frequently observed (implicit) act of equating inborn/acquired with immutable/mutable nevertheless proves to be essentially problematic since biology is not necessarily an eternal fate. Otherwise, many health initiatives would be in vain – think of surgical interventions or lifestyle modifications such as a better diet and exercise to lower the risk of heart disease or diabetes. In many other spheres of life, biologically-caused conditions most certainly are considered alterable, and no attention is paid to differences in people's biological makeup (grey hair can be dyed, illnesses medicated, etc.). And, after all, the educational system would be obsolete if it were predetermined at birth who would later develop which abilities and be suitable for which occupation. In the cognitive area as well, people in modern societies use medicine, technology, and training all the time to influence their abilities.

The lifelong process of developing cognitive skills is carried out in an environment in which biological, social, and cultural influences constantly interact and reciprocally affect each other. Capabilities are nurtured by means of learning processes that likewise display biological, social, and cultural facets (Halpern et al., 2007; Halpern, 2004). Accordingly, people have to be considered biological and social beings in equal measure. It should also be kept in mind that there are maturation processes – for example, if differences emerge only at a certain age, this can mean that a differentiation is biologically determined to occur in a particular phase of life, or it might mean that the difference takes place at this time due to socialization. Therefore, so-called inborn gifts can only mean a potential more or less available, a predisposition that, in a setting that fosters its development, is highly cultivated or not.

The interplay of biological and social influences also manifests itself in reciprocal interaction of brain structures and experience. It is not only so that biology influences behavior; human action can also have an impact on biology. Studies of London taxi drivers by Maguire et al. (1997, 2000) created quite a stir in this connection. In comparison to a group of adults whose occupations did not call for spatial skills, the cabbies exhibited an enlargement of the right front area of the hippocampus. Furthermore, there were indications of a correlation between the number of years of taxi-driving experience and the size of that part of the brain. In another study, Draganski et al. (2004) found that practicing juggling for three months produced a thickening of the grey substance in the lateral prefrontal cortex, the region of the brain presumed to control such movements. Here as well, scholars proceed on the basis of a direct connection between behavior and brain morphology. Studies of piano players show that those who were already intensively practicing ambidextrously prior to age 6 displayed more symmetrical handedness as adults, as well as a thicker corpus callosum than musicians not trained to be ambidextrous (Jäncke et al., 1997; see Schlaug et al., 1995). These studies show that biological differences can also result from different experiences (also see Jordan-Young in this volume).

In the 19th century, American scientists believed women and Black men to be less intelligent because they have smaller brains, and German scholars felt superior to their French colleagues on the basis of the same assumption (Gould, 1981). Scientists no longer pay much attention to brain size; they attribute greater importance to how the various regions of the brain function, but here too the interrelationship with cognitive skills remains unclear (Halpern et al., 2007). For example, research is being done on whether the same areas of the brain are activated when men and women perform identical tasks (for an

overview, see Haier, 2007). These researchers have found that when men take a mathematics test, the greater the activation of the temporal lobe, the higher the test score. As for female test takers, there was no connection between activation of a region of the brain and the score achieved (Haier and Benbow, 1995). These results are interesting because they show that women and men can perform comparable cognitive tasks by using different areas of the brain. Findings of research on the function of brain regions also shows a relationship with an individual's previous experiences – for instance, among speakers of a second language, a different area of the brain is activated depending on whether the second language was learned before or after four years of age (see Wattendorf et al., 2001).

A currently very widespread hypothesis on biologically determined gender differences has to do with sex hormones, but here as well in the area of cognitive skills we have to proceed on the basis of complex reciprocities. In the brain, there are gender differences that are induced by hormones, but the brain's development is simultaneously influenced by experiences. Hormones undoubtedly influence behavior, but at the same time hormonal secretion varies depending on environmental influences (Halpern et al., 2007). Performance differences seem to correlate with fluctuations in hormone balance, but these fluctuations can be triggered by such influences as stress, weather, diet, and psychological burdens.

Thus, the common simplification that equates biological with unalterable and social with subject to modification is untenable. Social experiences and circumstances influence biology just as, conversely, biological influences play their roles in conjunction with modes of social behavior and cognition. As interesting as these results might be with respect to the question of whether differences in cognitive skills can explain women's lesser degree of representation in science and technology, this nature-versus-nurture discussion does not get us very far. Accordingly, we now turn to the question of whether existing cognitive skills can be influenced and changed, and if so, how.

Can Cognitive Skills be Influenced?

The question of whether cognitive skills can be influenced brings out divergent preconceptions since it implies that capability can be understood as both a stable characteristic as well as one that can be influenced over the short or long term. This differentiation is revealing from a theoretical point of view and is also im-

portant for designing measures to ensure fairness with respect to gender. In the following section, we will first look into whether situative determinants (such as updating stereotypes) can influence performance by men and women. Then, we will report on research findings as to how preconceptions of what skills can have an impact on cognitive performance. Finally, we will address the question of whether cognitive skills respond to long-term training and, if so, to what extent.

Situative Suggestability and Stereotype Threat

> Female student 1: Does he tell jokes that demean women during the lecture?
> Female student 2: Yes!
> Female student 3: Before an examination.
> Female student 4: Yes.
> Female student 3: If he only wants to start at quarter after and not at five minutes after, he says: "I'll tell you a quick joke …"

This exchange took place during a group discussion in conjunction with our study. The female students are obviously trying to come to terms with experiences they have had as women. A misogynistic joke is not usually regarded as seriously offensive but it is nevertheless disconcerting for these female students. What are we to make of an instructor like the one mentioned above who, right before a test, tells a joke that demeans women? Can this experience influence the performance of those who were the butt of the joke?

Insights into this issue are provided by numerous studies conducted in connection with the so-called stereotype threat approach (for an overview, see Inzlicht and Schmader, 2012). The phenomenon of stereotype threat was described in order to explain performance differences between men and women as well as between White and Black students. The first published study had to do with performance differences between Whites and Blacks in the U.S. (C.M. Steele and Aronson, 1995). Study participants who are Black and, prior to being administered a test, were asked to specify whether they are Black or White, got significantly lower scores than Black participants whose attention was not directed to their skin color before taking the test. Stereotype threat thus refers to the experience of threat that a person's performance might be interpreted in light of his/her membership in a negatively stereotyped group. Negative performance expectations with respect to one's own group can lead

to situative stress, which is detrimental to performance. The mere awareness of the existence of stereotypes can lead to a performance decline, so it is not even necessary to put credence in the stereotype. In other words, when an individual is tested in an area associated with a negative stereotype about the test taker's own group, then a subconscious "threat in the air" (C.M. Steele, 1997) can be operational and, like a self-fulfilling prophecy, lead to poorer performance.

Since the inception of this concept, there have been many studies on stereotype threat in the context of women and mathematics/technology (e.g. Dardenne et al., 2007; Good et al., 2008; Inzlicht and Ben-Zeev, 2000; Quinn and Spencer, 2001; Spencer et al., 1999; see Nguyen and Ryan, 2008 for a meta-analysis). Typically, a test is administered to male and female students, controlling for prior capabilities. One group is told in advance that in the past, the test results revealed gender differences (whereby men scored higher than women) and a second group is told that no gender differences are expected. And indeed, in the first group, women did score lower than men, whereas no performance differences were observable under the second set of circumstances (Spencer et al., 1999). It is interesting to note that it is not even necessary to directly point out the expected gender differences to the test takers, as in the above-mentioned study, in order to achieve this effect. Subtle and situative allusions such as the proportion of men and women in the group taking the test can also trigger the effect (i.e. women in the minority have a higher risk of suffering diminished performance than women in a group that is balanced with respect to gender) (Inzlicht and Ben-Zeev, 2000).[6] If a stereotype is sufficiently well-known, then it evidently suffices to merely remind the test takers – explicitly or implicitly – of the fact that they belong to this group. Many women are well aware of the stereotype that women are less gifted than men in mathematics, so that this can result in a real diminishment of their performance.

Stereotype threat represents situative performance pressure whereby women are made to feel that they have to refute the stereotype that they are less mathematically or technically inclined than men. But it is precisely this high-

6 | In such cases, individuals are often not even aware that the stereotype is having a deleterious effect on them. Blascovich et al. (2001) administered a test to Blacks and Whites, and confronted test takers with the stereotype that Blacks' test results were expected to be lower. Blacks reported that, in the stereotype threat condition, they did not feel more anxious or impaired due to the stereotype; nevertheless, their blood pressure was significantly higher, which can be interpreted as an indication of tension attributable to the stereotype.

pressure situation that actually does impair their performance. Ironically, the strongest stereotype threat effects manifest themselves on the part of individuals who are particularly gifted and highly interested in the respective subject matter (Aronson et al., 1999) – i.e. in the present context, vulnerability to such stereotyping is greatest among women who strongly identify with mathematical and technical content. The effect is also stronger among those who identify with their own group (Schmader, 2002) – i.e. women for whom being female is an important part of their identity. These people are particularly concerned with disproving negative expectations. Furthermore, the effect has the strongest repercussions when the individual faces a daunting task. If the assignment is easily completed, then the motivation to refute the stereotype does not hinder coming through with flying colors; in fact, putting in a bit more effort – summoned forth by the desire to lay a stereotype to rest – can even lead to performance enhancement (O'Brien and Crandall, 2003).

It is important to emphasize that stereotype threat is defined as a cognitive mechanism that does not spare White men either. For example, Aronson et al. (1999) conducted a study in the U.S. that confronted White men with a stereotype that is very widespread in that country – that Asians are more gifted in mathematics than other American ethnic groups. In comparison to the control group that was not confronted with this stereotype, White men that were confronted with it actually did suffer a significant decline in performance on a mathematics test. In such situations, men as well are susceptible to stereotype threat effects due to social stereotypes that predict inferior performance – in the realm of emotional sensitivity, for instance (Leyens et al., 2000).

This research approach thus shows that performance differences in tests can be caused not only by cognitive differences but also by situative factors. Nevertheless, it must also be pointed out that cognitive differences between men and women are not attributable solely to the impact of stereotypes (Sackett et al., 2004). Rather, the results of studies on the subject of stereotype threat show that the activation of stereotypes can overlay and further enlarge existing differences. Important in this context is that stereotypes constitute significant sources of stress for members of stereotyped groups, and can cause real diminishment of performance.

Concepts of the Changeability of Intelligence

If stereotypes actually can lead to performance impairment, then what can be done to prevent this? A casual remark that a test is gender-neutral and not

designed to detect gender differences might be all it takes to provide relief to those troubled by stereotype-related fears (Spencer et al., 1999; Quinn and Spencer, 2001). But stereotypes are operational not only in test settings but also in learning situations in which individuals are confronted with new material (Appel and Kronberger, 2012; Appel et al., 2011) – for example, at the beginning of undergraduate study.

Such situations can often be distressing since, when people begin an effort to learn something new, initial failure to comprehend it is less the exception than the rule. Indeed, the significance of this essentially normal situation should not be underestimated. The participants in our study (Horwath et al., 2007) discussed this problem of their initial inability to understand course material and the accompanying feeling of self-doubt.

Long-term studies (summarized in Dweck, 2007) suggest that women have particular difficulty dealing with such perplexity – in fact, the brighter they are, the harder it is. Intelligent boys, on the other hand, are often spurred on by failure to understand. Thus, this is actually a matter of how students deal with experiences that cast doubt on their abilities. Of key importance here are concepts of what an individual's capability actually is: an inborn endowment or an acquired skill? If one considers one's capability as a gift, then a setback can quickly lead to a loss of motivation to stick to it (since the failure is interpreted as a lack of talent). If, on the other hand, one is convinced that achievement can result from hard work and determination, then there is a higher probability one will display resilience in upsetting situations.

Grant and Dweck (2003) surveyed freshman studying chemistry at Columbia University. Women who interpreted their ability as a talent did comparatively worse; they considered their abilities as given and unchangeable. On the other hand, the performance of women who were convinced that practice makes perfect was as good as that of their male classmates. These results illustrate the fact that all women are not equally at risk of getting discouraged by disturbing situations. Their vulnerability rather depends on convictions (that can be inculcated) (Dweck, 2007).

What makes the capability-as-inborn-gift mentality so dangerous is its inherent implication that we can ascertain in advance who is talented and who is not (according to the stereotype regarding technical fields: men have the right stuff; women have less of what it takes). Accordingly, women who consider their own high performance as a gift are susceptible to setbacks. Bad grades, for instance, can easily lead to frustration. If, on the other hand, the message is

conveyed to students that hard work leads to success, then this has an encouraging effect on both genders.[7]

Now, teachers who wish to encourage women could wait for situations in which a woman does a great job and then praise her for her talent, but, paradoxically, this is precisely the problem. A series of investigations by Mueller and Dweck (1998), for example, show that praising students' talents (even in response to a performance that actually was outstanding) can have undesirable side-effects. It can induce students to hesitate to embark on tasks in which there is an intrinsic risk of failure. So what can be done? Dweck and her colleagues proceed under the assumption that the point is to influence convictions about what talent actually consists of (also see Aronson et al., 2002). Over the long term, imparting the idea that intelligence is subject to modification and development yields the highest probability of having a heartening effect. In concrete term, teachers should instill the conviction that capabilities can be upgraded through indefatigable effort. Thus, via an encouraging, supportive attitude, they can help women and men learn to overcome frustration and not to give up prematurely when a situation induces self-doubt.

Long-term Influence on and Training of Cognitive Skills

Calling upon educators to teach that capabilities are assets subject to enhancement raises the legitimate question of the extent to which capabilities actually can be modified. By way of example, we want to focus on the above-mentioned area in which the most pronounced gender differences have been established – spatial abilities. Marulis et al. (2007) presented a meta-analysis of the trainability of this skill; they come to the conclusion that both children and adults can train and improve this skill by engaging in a series of activities such as task-related practice, musical exercises, and computer gaming. A meta-analysis by Baenninger and Newcombe (1989; cf. Newcombe, 2007) also found that spatial abilities can be trained, and that both men and women

7 | Consider as well the open letter that Harvard University physicist Howard Georgi published in the school newspaper in January 2005 in response to remarks made by President Larry Summers. Implicitly, Georgi also made it clear that achievements in physics are not to be understood only as the result of innate talent but of continuous hard work too (Available at: http://www.thecrimson.com/article.aspx?ref=505377 (accessed 12 February 2013)).

benefit from such training. Repeated training sessions constitute the key to enhanced performance (e.g. Cherney, 2008). Sorby and Baartmans (2000) set up a course for freshmen at Michigan Technological University in which spatial conceptual abilities were trained. The evaluation showed a significant improvement in performance by men and women, and even lowered the drop-out rate. Gerson et al. (2001) used multimedia software to train freshmen's spatial abilities, resulting in a reduced drop-out rate among female engineering students.

On the whole, the literature on training mental skills shows that abilities certainly can be developed, and some studies suggest that gender differences can be reduced (e.g. Feng et al., 2007; Spence et al., 2009; Tzuriel and Egozi, 2010). In a critical analysis of the training literature, however, Ceci and Papierno (2005; see Voyer, 1995) point out that training need not necessarily erase gender differences. Sometimes those with better skills also benefit more from training, increasing rather than weakening existing gender differences. Overall it seems that women largely benefit from training, even if they do not necessarily benefit more than men. More important than the question of whether or not women can 'catch up' seems to be the insight that abilities can be successfully developed. The training studies show that the average improvement in performance is often greater than the gender differences and if a certain performance standard is set, both sexes can be trained to meet it.

Conclusion

Important for the issue under investigation here is recognizing that cognitive skills can be influenced both negatively and positively. A comprehensive review of research shows that we have a lot to learn about the influence of stereotypes on individual performance, that prevailing assumptions about the nature of intelligence and talent ought to be subjected to critical scrutiny in child rearing and education, and that relevant skills can be considerably enhanced via practice and perseverance. This leads us to conclude that there are both similarities and differences in the average profiles of men and women with respect to cognitive skills. Furthermore, these capabilities are by no means fixed; rather, they must be seen as constituting developmental potential that can certainly be nurtured. In any case, cognitive differences in the average profiles of men and women can hardly be singled out as the only reasons for the lower proportion of women active in technology and science.

Science and technology education are contexts in which equality and difference between men and women are both discussed, organized, and produced. This is why discussions of gender justice and cognitive abilities are of essential importance here. Our analysis shows that the question of whether there are cognitive differences between women and men is not easy to answer. As we have endeavored to show, fixation on this question can also frequently lead to a dead end since the key would be to know what practical relevance possible differences have in everyday life. As far as educators' ability to intervene, the question of how men's and women's cognitive skills can be influenced seems to us to be especially important. Here, researchers have been very active and produced impressive empirical results that permit concrete insights into the practical implications of moving towards gender justice. This paper has presented and discussed current scholarship on these issues.

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Gender Competence in Mathematics Teacher Education

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Introduction

In Germany, the prejudice still exists that 'girls aren't good at math'.[1] The 'male image' which mathematics has in society is at least partially created in school. In order to change this gendered image of mathematics, but also to increase equal opportunities for pupils beyond gender-stereotyped knowledge and interest domains, it is necessary that mathematics teachers act in a gender-competent way. Indeed, some research indicates that mathematics – beyond a relevant school subject and scientific discipline – is also a 'core discipline' for the field of natural sciences and engineering (see DMV et al., 2007; Heine et al., 2008). Thus, in the long term, gender-competent mathematics teaching could also help to diminish a gender-based choice of fields of study and occupation, and to promote equal opportunities for men and women in the labor market. However, in Germany's 'mainstream debates' within the current process of professionalization of academic teacher training there are few indications for the existence of a gender perspective, and gender competence is hardly ever included in the relevant curricula (see Langfeldt and Mischau, 2011).

Our interdisciplinary research project *GenderMathematik*[2] ('GenderMathematics') constitutes a first step towards the integration of gender competence

1 | This prejudice also exists in other countries, e.g. the German speaking countries Austria and Switzerland.

2 | The project 'GenderMathematik: Genderkompetenz als innovatives Element der LehrerInnenausbildung für das Fach Mathematik' ('Gender Mathematics: Gender competence as an innovative element of the professionalisation of teacher training in mathematics') was funded from 2008–2010 by the German Federal Ministry of Education and

within teacher training in Germany by developing an exemplary course for mathematics teacher training. In this paper, we will first present the background of the project, in particular the underlying definition of gender competence, and then give an overview of the designed course (see also Langfeldt and Mischau, 2011; Mischau and Mehlmann, 2011).

The Project *GenderMathematik* ('GenderMathematics')

One starting point for the project was the observation that in many countries international standardized assessment tests like PISA or TIMSS have shown discrepancies between girls and boys concerning their achievements in mathematics and their mathematical self-concept. In Germany, statistically significant gender differences in favor of boys occur regarding achievement and mathematical self-concept, which are in most cases even stronger than in other countries and the OECD average (see Bos et al., 2008; Mullis et al., 2000; OECD, 2004, 2010). Thus, in Germany, mathematics can still be regarded as a typical 'boys' subject' or 'male domain', where gender differences in mathematics already become apparent at the end of primary school, entrench themselves in the course of secondary school education and later on become manifest in a gender-based choice of fields of study and fields of occupation.

One of the essential reference points of the project were results of empirical research, which show that gender-stereotypical attributions play an important and problematic role in the processes of teaching and learning mathematics at school, as they reproduce gendered images of mathematics and gendered school subjects (see for example Bos et al., 2008; Zimmer et al., 2004). In order to break the 'vicious circle' (Ernest, 1995: 456) thus created, researchers within gender-oriented didactics and educational science have emphasized that besides the implementation of gender-sensitive didactics at school it is also necessary to make mathematics teachers aware of their impact on creating and reproducing gender stereotypes and gendered school subjects (see Curdes, 2007; Fischer and Rustemeyer, 2007; Jungwirth and Stadler, 2005a; Keitel, 2010). Together with other elements, the teachers' gender stereotypes about

Research. The project was a collaboration of the universities of Bielefeld, Gießen, and Hamburg. See http://www.uni-bielefeld.de/IFF/genderundmathe/index.html (accessed 20 February 2013).

the learning of mathematics, mathematical skills and achievement, as well as their potential lack of gender competence, can be identified as fundamental reasons for gender biases in the development of young people's interests and competences with regard to school subjects (see Jones et al., 2000; Jungwirth, 1991; Keller, 1998; Ziegler et al., 1998). Therefore, (prospective) teachers need to acquire gender competence with regard to didactics and subject-specific contents in order to overcome gender-specific biases within school subjects.

Within our project, *GenderMathematik*, we developed a gender competence course for teacher training in mathematics. The interdisciplinary course format combines results of gender studies from various disciplines like mathematics, didactics of mathematics, educational science and social sciences. With regard to the various gender theory approaches, the concept of the course relies upon a constructivist perspective on gender, i.e. gender differences are seen as effects of social practice and the related exclusions, and social hierarchies are seen as products of gendering processes (see for instance Wilz, 2008: 9f).

In the first step of the project, we conducted an inquiry into the status quo, hoping to find best-practice models. We discovered that gender competence with respect to mathematics teaching is not implemented as a mandatory course in the study and examination regulations at any German university. Some of them occasionally offer elective courses related to gender and the teaching of mathematics, but not regularly. These courses are, however, highly dependent on the commitment of individual lecturers. In the second step, we merged the relevant gender-oriented constructivist research on school and teaching from educational and social sciences with gender-oriented discussions in mathematics and mathematics education. The third step of the project consisted of discussions held with expert groups focusing on central topics and issues concerning the possible contents, methods, and design of a gender competence course in maths teacher training.

Based on the results of the preceding steps, we finally designed the curricular, didactical, and methodological concept of our course in the light of a further developed, multi-dimensional concept of gender competence which we used as a theoretical framework (see Langfeldt and Mischau, 2011; Langfeldt et al., 2012; Mischau et al., 2009, 2010).

A first version of the gender competence course 'Mathematics – School – Gender' was taught during the winter term 2009/10 at eight German universities.[3] The course was offered mainly for bachelor students, but also for master

3 | Augsburg, Bielefeld, Bremen, Gießen, Hamburg, Ludwigsburg, Lüneburg, Potsdam.

students, and was taught by cooperation partners of the project within their didactics of mathematics programmes.[4] Prior to the course, the lecturers had been trained in a workshop and had received a CD-ROM containing the course manual, teaching materials and a list of selected literature for the reserve shelf. In total, 160 students participated in the gender competence course, whereby 26.9% were male and 73.1% were female students.

At the end of the term the first version of the course, as it was taught in the exemplary teaching, was evaluated at seven universities.[5] This extensive formative and summative evaluation comprises two standardized questionnaires filled out by the students (one at the beginning, capturing, among other things, their gender competence before the course and expectations related to the course, and one at the end, measuring such features as satisfaction with the course and their gender competence after the course), semi-structured qualitative interviews with the lecturers, and semi-structured (self- and external) observations with some central questions concerning every single session, which the lecturers had to answer parallel to the course. Results of the evaluation can be found in Mischau et al. (2010), so at this point only a few brief comments should be given concerning the 'students' evaluation'.

The surveys conducted at the beginning and at the end of the course revealed that the course widely meets the students' demands and expectations concerning a gender competence course. At the beginning of the course, nearly 85% of the students mentioned a personal lack of didactical and methodological knowledge in dealing with gender (differences) as well as with other aspects of diversity at school and therefore professed a keen interest in innovative and differentiated teaching methods. About 50% of the students also reported having little competence and experience in self-reflection and a fair amount of uncertainty as to their future role as teachers. After attending the course nearly 80% of the students declared that particularly their ability to reflect on their own gender-biased views and attributions and their awareness of the influence of teachers' gender stereotypes on the pupils' achievements and self-concept had increased. In addition, about 68% also declared that their knowledge of how to plan mathematics lessons with gender-sensitive educa-

4 | Only in Hamburg the course was offered as a mathematics seminar (taught by project member and mathematician Andrea Blunck). In the Bielefeld project, member Anina Mischau co-taught the course with a colleague from mathematics education.

5 | At PH Ludwigsburg the course was taught in a modified way, so for comparability reasons the evaluation was not carried out there.

tional materials and methodological and didactical approaches had increased, as well as their knowledge on concrete gender-sensitive teaching and learning methods that foster a bias-free environment. 60% of the students stated that the theme 'gender' should become an integral part of didactics of mathematics at university and nearly 49% requested more gender-sensitive pedagogical contents in mathematics teacher training. One reason for this might be the opinion that dealing with gender themes is of great importance for later practice; this opinion was shared by 60% of the students.

Especially the semi-structured qualitative interviews with the lecturers but also their reports about their observations during the course conveyed helpful ideas for an optimization of the course structure, contents, methods, and materials. Based on the evaluation, the initial course concept was revised. In particular, the connection to professional practice was highlighted by introducing the distinction between the teaching framework and the classroom interactions (see Mischau et al., 2010). The revised concept is presented below.[6]

The Course Concept

The gender competence course was developed for primary and secondary teacher training in mathematics and comprises 14 lessons.[7] The first lesson is an introductory one which presents the course programme and, in addition, also describes formal conditions like examination modalities. The final lesson gives the students the opportunity to review what was learned. This lesson can also be used for a course feedback. The main part of the course consists of twelve lessons, which are divided into five blocks of two or three lessons each.

In the course manual provided for lecturers the description of each lesson is organized as follows: 1) Short introduction to the topics and issues of the respective lesson, 2) Overview of related state of research, 3) Proposal for methods to be used, 4) Learning goals, 5) Schedule of the lesson, 6) Outlook for the next lesson. Moreover, there is an overview of the whole course in order to provide the reader with a 'red thread' to follow. The course manual

6 | It should be pointed out that the revised course was taught only after the end of the project and that it was not evaluated. Some experiences with teaching the revised course are described in Mischau (2012).

7 | At German universities a term usually comprises 14 weeks, and a seminar usually consists of one lesson (90 min) per week.

is supplemented by a collection of teaching materials used in the course. The main contents, goals, and methods of the course are described below.

In the project, we formulated a definition of *gender competence* as an occupation-related key qualification (see Bremer and Mehlmann, 2006; Metz-Göckel and Roloff, 2002; Rosenkranz-Fallegger, 2009) which is fundamental for the course. According to this definition, gender competence comprises four aspects or dimensions: professional competence, methodological and didactical competence, interactional competence, and self-competence (see Langfeldt and Mischau, 2011; Langfeldt et al., 2012).

Professional competence comprises basic and specialized knowledge in the field of gender studies, in particular about socio-cultural constructions of gender and their impact on societal structures, institutions, and individuals, as well as about the development of gendered disciplinary cultures *(dimension of gender knowledge)*.

Methodological and didactical competence signifies competence with regard to a gender-sensitive arrangement of teaching and learning processes *(dimension of the teaching framework)*.

Interactional competence means competence in creating a gender-sensitive teaching culture *(dimension of classroom interactions)*.

Self-competence consists of the ability to reflect on one's own gendered biography, gender-based views and assumptions, social norms, stereotypes, and the ability to reflect gender-based attributions, expectations, and evaluations *(dimension of self-reflectivity)*.

Gender competence in this sense includes sensitivity for the mechanisms and consequences of gender-stereotypical attributions for the reproduction of gender-based domains of interest and knowledge. Moreover, it includes the knowledge of theoretical concepts as well as didactical and methodological approaches which should enable (prospective) teachers to offer gender-sensitive mathematics lessons and open opportunities for pupils to learn mathematics beyond gender-based restrictions. Finally, gender competence includes the ability to critically reflect one's own gender-based views and attitudes as well as on institutional frameworks like curricula or teaching material, the ability to reflect (and – if necessary – to change) one's own professional ways of acting, interacting and communicating with respect to – possibly unintentional – gender-stereotyping effects (see Mischau et al., 2010). As the four dimensions of gender competence described above systematically intertwine, they have been integrated – with varying degree of concentration – in the learning goals formulated for each lesson.

According to our definition, gender competence cannot be regarded as 'formula' knowledge. The basic methodological concept of the course relies on the idea of teachers as 'reflective practitioners' (see Adler, 1991; Schön, 1983), who reflect and continually refine their skills through a rigorous process of self-reflection while acting in the classroom. (Prospective) teachers should therefore be instructed to identify traps of co-construction in their own attributions, forms of teaching structures, patterns of interaction, etc., as well as to question their own performance with regard to possible (unintended) gender-biased effects, and to develop strategies to change their behavior (see Mischau et al., 2010).

The methods applied in the course are quite different from those that German mathematics students, studying to become teachers, usually encounter in their university seminars. A seminar in mathematics usually means that each week a student presents a mathematical topic by giving a talk and writing accompanying notes on the blackboard. A seminar in educational science or pedagogy means reading, presenting und discussing papers. For our course, however, using a variety of methods is a fundamental part of the didactical concept. One reason for this is that variation of methods is suggested by mathematics experts with regard to 'good' and 'gender-sensitive' mathematics teaching at school (see Jahnke-Klein, 2001: 229; Leuders, 2001: 63; Meyer, 2004).

The concept of our course follows the 'didactical-methodical double-decker' approach ('didaktisch-methodischer Doppeldecker'; see Wahl, 2002; Mischau et al., 2010). Thereby, besides phases of individualized work, the students experience within the course various forms of cooperative and research-based learning methods, which are also used at school and which are suitable for developing gender-sensitive mathematics lessons. Among other things, we, for example, use jigsaw puzzles ('Gruppenpuzzle'), think-pair-share ('Ich-Du-Wir'), and learning stations ('Stationenlernen') (see Barzel et al., 2007).[8]

In order to increase self-reflectivity, the students have to work on a portfolio throughout the course. This portfolio is used for documenting and reflecting results, but also for recording experiences, feelings, ideas, problems, and personal impressions. Furthermore, the portfolio is used to write down and reflect upon a student's insights and problems concerning the subjects as they were discussed from the point of view of the four dimensions of gender competence. Portfolios are also used at school (Barzel et al., 2007; Zwölfer, 2006), so this can also be seen as a part of the 'didactical-methodical double-decker'. Moreover, if neces-

8 | A description of these and many other methods can also be found in K. Reich's 'Methodenpool' (method pool): http://methodenpool.uni-koeln.de/ (accessed 20 February 2013).

sary, we suggest using the portfolio as course work that will be graded at the end of the course. In the following, the topics of the course blocks and the main thread running through the entire course are described (see also Langfeldt and Mischau, 2011; Langfeldt et al., 2012; Mischau and Mehlmann, 2011).

Main Contents, Goals and Methods of the Course

Sensitizing the students for the problematic effects of gender-stereotyped attributions by teachers and pupils in regard to the subject math in general and mathematical aptitude in particular is a central focus of the course. This includes dealing with one's own experiences and ideas of mathematics, which were chosen as a starting point of the seminar.

The introductory session of the seminar introduces the thematic field 'Mathematics, School and Gender', and opens up the different dimensions of gender competence as a professional key qualification for (prospective) maths teachers. This is followed by the first block which examines *'Images of Mathematics'* and their connections to the category gender in respect to their implications for the later school practice of the students studying to be teachers. As a preparation, the students are given the task to write their 'mathematical autobiography' (see Scharlach, undated) for the 'reactivation' of their own experiences with math and the images of math. In subsequent sessions, students go back to their mathematical autobiography to connect and illustrate scientific knowledge with subjective experience.

For the first block session we chose an intuitive introduction based on emotions and experiences. In a PowerPoint-presentation, the students are shown images of mathematics and/or of the teaching/learning of mathematics in different contexts. The students are given the task to choose the image that most corresponds to their own idea of mathematics or the teaching/learning of mathematics, and then reflect on their choice. The subsequent discussion in the course creates mutual understanding for the diversity of the images of mathematics the students have, and at the same time reflects the underlying attitude towards mathematics and learning and teaching it.

The students' reflection on their own image of mathematics is something that usually has no space in university courses for prospective mathematics teachers. However, such a reflection is important, because the beliefs about mathematics influence the way one deals with mathematics (Curdes et al.,

2003: 23). So the students' beliefs will have an impact on the way they will teach mathematics later on. Moreover, reflecting on mathematics and on the preferences for or aversions against certain aspects of mathematics might help the students studying to become teachers – who often have problems with the abstract 'university mathematics' – to (re-)gain a positive attitude towards their subject.

Finally, the students' subjective assessments are related to empirical results of research on mathematical beliefs (see for example Blömeke et al., 2008; Grigutsch et al., 1998; Stipek et al., 2001), which underline the influence of convictions about the structure of mathematics and the genesis of mathematical competence for teaching and learning mathematics.

The second block session subsequently focuses on the connection of mathematics and gender. An introductory exercise via the method of 'gender cards' on the one hand aims at a critical look at gender-stereotyped attributions rooted in everyday knowledge, and on the other, at increasing the awareness for the students' own – possibly unconscious – stereotyped ideas in regard to mathematical aptitude. The main focus of the second session therefore lies in the historical-cultural derivation of the question why mathematics is still seen as a 'male domain' by the majority of people in our culture. The 'gendering' of mathematics is thereby systematically unfolded from different points of view with respect to the category of gender: Besides dealing with gender-stereotyped attributions regarding mathematical aptitude, which are, among others, reproduced and popularized via pictorial representations, the stereotyping of mathematics as a 'male domain' based on current gender relations data are examined more closely, also from a historical perspective regarding the exclusion or marginalization of women in mathematics as a 'male discipline'. Aided by the method of learning stations, the students are encouraged to explore the aspect of a subject's gendering, mostly disregarded in the didactics of mathematics, and to show its implications for mathematics lessons in a self-directed and individual manner by means of prepared materials.

The first block primarily aims at sensitizing the student's self-awareness and triggering in particular the necessary processes of reflection on the implications of their own image of mathematics and the stereotyping of mathematics as a 'male domain' for the teaching and learning of mathematics with respect to the students' future professional practice.

The comparative analysis of findings of different assessment studies about *'Gender Differences Concerning Mathematic Achievements and Mathematical Self-Concept'* comprises Block II of the gender competence course. As a

contrast to the widespread gender-stereotyped assessments which attribute an inferior mathematical aptitude and thus lower performance in this field to girls and women, both sessions of the block take a closer look at the empirical findings regarding gender difference in the subject mathematics in the context of an international comparison. The students access these empirical findings by way of example via a secondary analysis of selected results from PISA 2000 to PISA 2009 and the elementary school study TIMSS 2007 (Bos et al., 2008; Martin et al., 2008; OECD, 2001, 2004, 2007, 2010). The main results are that gender differences in mathematics performance in general and with regard to mathematical content areas, competency clusters, or grades vary considerably; in addition, they vary between countries. The differences are not always in favor of boys, and sometimes they are not present at all.

The first session involves an examination of initially gender-based differences in mathematical performance – by means of a jigsaw puzzle. This includes integrating into the analysis findings about the mathematical performance overall, in relation to performance on different competence levels, as well as in terms of different mathematical content areas. The block's second session focuses on the selected results regarding gender-based differences in so-called student characteristics, which were surveyed in the context of PISA and TIMSS in terms of individual learning abilities, and which are being discussed as possible influencing factors for mathematical performance. The exemplary analysis comprises, for instance, the interest in mathematics, fear of mathematics, the positive attitude towards mathematics, as well as the mathematical self-concept, and takes place in partner and group work settings. In general, in the OECD average and in almost all countries, boys have more interest in and less fear of mathematics and their mathematical self-concept is significantly higher than that of girls. In Germany, these differences are particularly pronounced.

A close look at the data illustrates the simplicity of many explanations, especially found in the media, which attribute the different mathematical performances between the sexes to 'nature'. However, gender-bias assertions such as 'girls can't do mathematics and boys can't read' ignore the fact that the assessment studies do not show a uniform picture of gender differences in pupils' performance in reading, mathematics or natural sciences. In contrast, students should recognize that a correct and critical interpretation of the statistical data provided by international studies demonstrates a wide variation of gender differences in mathematical achievement among countries, mostly, but not exclusively, to girls' disadvantage. At the same time, students should realize that

the forms of gender-based differences in the examined student characteristics also vary between countries and respective characteristics, but that, overall, these gender-based differences, in comparison to those in mathematical performance, clearly prove to be rather more homogeneous and stable over time.

The aim of this detailed examination of the empirical findings in question is on the one hand to problematize the – still existing – gender-based 'knowledge and interest territories', as well as to sensitize the students for the issue of possible socio-cultural framework conditions and/or influencing factors regarding their formation and reproduction.[9] Both aspects underline not only the need for action regarding a change in lesson design for the subject mathematics, but also a reflection on one's own role as a (future) teacher in creating and overcoming gender differences in mathematics. On the other hand, it creates the prerequisite for a critical examination of the various explanatory approaches, which are covered in the next block, and which are to be questioned for the plausibility and scope based on the empirical findings.

The question about the reason for the detected gender differences in mathematical performance and in the mathematical self-concept forms the centre of Block III *'Explanatory Approaches to Gender Differences in the Subject Mathematics'*, which, just like Block II, accentuates the dimensions of gender knowledge.

The first session of this block focuses on the knowledge base of the students themselves. Using the 'think-pair-share' method on the basis of quotes taken from mathematics students, ideas (affected by everyday theory) and convictions about aptitude theory, as well as the students' scientific knowledge base in the field of mathematics are tapped and made accessible for critical examination.[10] In this context, a distinction is introduced by differentiating between the nature and the nurture perspective, which permits a first systematization of the spectrum of the scientific explanatory approaches at hand. In light

9 | Students should be made to realize that gender differences in mathematical performance and self-concept are neither inevitable nor a 'natural' outcome of differences between the sexes, but rather that factors such as the broader socio-cultural context (for example the formation of societal gender stereotypes and gender inequality) as well as gendered images of mathematics or educational policies and practices influence and reproduce gender differences (see Coradi Vellacott et al., 2003; Else-Quest et al., 2010; Guiso et al., 2008; Nosek et al., 2009; OECD, 2009).

10 | The interviews were carried out in a research project on doing gender in mathematics (see Mischau et al., 2004).

of the persistence of gender-stereotyped attributions regarding mathematical competences, which are based on 'natural' differences in aptitude, one of the focal points of the session lies in the critical examination of biological explanatory approaches in the context of the nature perspective. These approaches consider for example genetic, hormonal, and cerebro-physiological factors as a cause for gender differences in mathematical performance (for an overview see for instance Biedinger, 2008; Tausendpfund, 2007).

The second session is dedicated to a closer look at explanatory approaches of the nurture perspective. Here, the main focus is on socialization-theoretical approaches which assume that cultural gender-stereotypes and the stereotyping of gender as a 'male domain' – communicated via gender-based attitudes, expectations, and attributions by parents, peer groups, and teachers – have a significant influence on the observed gender differences regarding the subject-related self-concept, and thus also on mathematical performance (for an overview see for example Budde, 2009; Coradi Vellacott et al., 2003). A differentiation between 'internal' and 'external' factors, originally introduced by Coradi Vallacott et al. (2003), and further developed in this project, serves as a basis for opening up the spectrum of relevant influencing factors. As a preparation for the session, the students are given the homework assignment to work on excerpts which examine the individual aspects of this systematization on the basis of key questions. In the session itself, the students' work results are gathered and the respective influencing factors are reviewed in regard to their importance and their interactions. Concerning the relevance of influencing factors in school, the discussion will also in particular focus on key findings regarding attitudes, expectations and attributions by teachers, as well as towards learning materials, forms of teaching and learning, and also interaction patterns between teachers and pupils in math lessons. These are further examined in the subsequent blocks *'Teaching Framework'* and *'Classroom Interactions'*.

Regarding the students' subsequent professional practice, block III explicitly explores and reflects upon the implications of the respective explanatory approaches for the design of teaching and learning processes and its possibilities, as well as one's own understanding of one's role and profession. It does so by examining one's own (everyday) knowledge base, as well as by working with the research results at hand regarding the genesis of gender differences in the subject mathematics.

The fourth block's central focus comprises selected aspects of designing mathematics lessons, which may contribute to the reproduction of gender-

based knowledge territories. In content, the three sessions, united under the headline *'Teaching Framework'*, connect to the research results regarding forms of teaching and learning and lesson materials as 'external' factors for the development of gender differences in mathematical performance and in the mathematical self-concept, outlined in the second session of block III. Following the problematization of the implications of the 'developing-by-questioning' math lessons for the pupils' classroom participation, the first block session focuses on a critical examination of the books used in math lessons and the gender images they convey. For this, the students analyze excerpts from school books used in different grades; they do so in individual and group work settings. The task lies in inspecting the selected examples to see if and in what form gender-stereotypes are still reproduced today in texts and images. A further aim is to examine whether, in the selected topics and task contexts, the fields of interest and experiences of male and female pupils are equally considered, or, preferably, whether these are equally appealing for both male and female pupils. Analyzing and subsequently sharing their work results in the group will help to sensitize the students for the necessity of a conscious utilization of lesson materials under gender aspects.

The two following sessions in this block have the goal of developing alternative courses of action for the teaching framework. The second session mainly focuses on the development of criteria for gender-sensitive planning of math lessons based on existing didactical approaches for gender-sensitive math lessons. As a reference point for the development of such a set of criteria, the concept of 'meaningful mathematics lessons' by Jahnke-Klein (2001) as well as the suggestions presented by Schlüter (2001), Curdes (2007), and Bartosch (2008) are utilized for gender-sensitive lessons in mathematics and natural sciences, and worked on in more detail. In particular, gender-sensitive math lessons are characterized by a well-balanced combination of different forms of learning and a diversity of methods in order to address pupils with different learning and communication styles. The exercises used in such lessons permit individual learning and differentiation and incorporate the interests and everyday world of both boys and girls. Moreover, they take into account the diversity of mathematics and its historical development. Thus, gender-sensitive math lessons are also 'good' math lessons as discussed by researchers from didactics of mathematics (see for example Büchter and Leuders, 2005: 12f).

The third session, finally, introduces and discusses the different methodological instruments which make it possible to design math lessons in a way that is equally interesting for male and female pupils and that leaves room

for finding one's personal access to mathematics and gaining experience in acquiring subject-related competency. Considering the key importance of methodological diversity in math lessons, this session also features partner and group work not only with gender-sensitive lesson materials (see Eckelt, 2005; Schätz and Eisentraut, 2003) but particularly with methods for individualizing and differentiating lessons that seem especially suitable for gender-sensitive classroom work. Some of these methods, such as jigsaw puzzles, learning stations, think-pair-share, placemat (Barzel et al., 2007) have been applied in the seminar itself, much in the sense of the 'didactical-methodological double-decker'. The methodological instruments of the learning diary and the notebook entry (see Zwölfer, 2006), as well as 'Learning Mathematics with History' (see Jahnke and Richter, 2008) are also introduced.

In regard to our definition of gender competence and in view of later professional practice, block IV puts a special focus on relaying didactical-methodological competences for a gender-sensitive design of teaching and learning processes.

Block V *'Classroom Interactions'* addresses especially the third (interactional competence) and fourth dimension (self-reflectivity) of gender competence and focuses on the interactions between teachers and pupils. Here the main focus lies, on the one hand, on gender-based differences in the interactive behavior of teachers and their influence on the reproduction of gender differences with respect to the pupils' mathematical self-concept and mathematical performance (see for instance Coradi Vellacott et al., 2003; Ruppen et al., 2009; Rustemeyer and Fischer, 2007). On the other hand, from the perspective of 'doing gender', it is more closely examined how and in what way gender differences with regard to dealing with mathematics are 'created' in the interactions between teachers and students (see for example Faulstich-Wieland et al., 2009; Jungwirth, 1990, 1991, 2005; Jungwirth and Stadler, 2005b).

As the first session's main focus the students are required to examine in detail the research findings regarding gender-based distributional differences of the attention and feedback pupils receive from their teachers. The second session deals with the consequences of teachers' feedback on performance and their underlying gender-based attribution of aptitude as well as pupils' self-attribution of success and failure which are important for their self-assessment and their striving for good performance. In both sessions, the main thematic focus areas are developed on the basis of video footage and a verbatim transcript of two lesson sequences taken from a math lesson which are analyzed by the students in group work settings.

The third session of this block introduces the approach of 'doing gender', which looks at the construction of gender differences regarding mathematical competences in, or caused by, classroom interaction in math lessons, involving both teachers and pupils. The materials used for examining this perspective on such interactive events are drawn from lesson transcripts of math lessons in Austrian grammar schools (Jungwirth, 1990, 1991; Jungwirth and Stadler, 2005b). The students analyze them – again in a work-sharing group work setting based on key questions – for an implied gender-based 'positioning' (comp. Jungwirth and Stadler, 2005b) of the pupils with regard to their aptitude for the subject mathematics.

Similar to the procedure in block IV, block V also deals with alternative courses of action and possibilities for intervention. Re-attribution training, for instance, is something that is suggested as a suitable and appropriate pedagogical possibility to intervene in favor of encouraging self-worth and motivation-promoting attribution styles in pupils (see for example Budde, 2009: 44f.).

Regarding the relaying of interactional competences emphasized in this block, the main goal is to sensitize the students for problematic gender-based patterns of interaction and the gender-based expectations, attributions, and assessments that produce them, and to create an awareness for the need to continually reflect on one's own lesson practice.

In the final lesson, the students are invited to reflect on what they have learned based on key questions. In doing so, the students will recapitulate their respective learning experiences on the basis of their portfolio along the four dimensions of gender competence (professional competence, methodological and didactical competence, interactional competence, and self-competence), which were introduced in the introductory session. Furthermore, the students are encouraged to each give their assessment of the relevance of gender competence for teaching and learning mathematics and for their future role as teachers, and subsequently discuss these with each other.

Future Perspectives

To date, the revised course has been successfully taught five times.[11] The publication of the course manual is forthcoming (Mischau et al., 2013), so that

11 | By the head of the project, Anina Mischau, as a visiting professor at the FU Berlin (summer term 2011, winter term 2011/2012 and winter term 2012/13), by Renate Motzer,

in the future the course can also be taught by other lecturers. Thus, more universities will get the opportunity to offer the gender competence course in their teacher training in mathematics. The course's modular design principle permits individual blocks to be also used independently and integrated in other courses.

From the point of view of the project, it is necessary to implement gender competence as an occupation-related key qualification within teacher training in mathematics. Although important institutions of the higher education system in Germany (see HRK, 2006; Wissenschaftsrat, 2001) recommend a) implementing better praxis-oriented modules in the curricula of teacher training (at university) and b) conveying more key competencies, we see various problems concerning a sustainable implementation of our gender competence course (see Langfeldt and Mischau, 2011).

In particular, modularization within the latest reform affecting teacher training at German universities in the course of the Bologna process led, in many places, to inflexible curricular structures that impede the integration of new courses. Our experiences show that a gender competence course for (prospective) mathematics teachers can most easily be implemented in modules of didactics of mathematics programmes that are open with regard to contents, like 'special aspects of didactics of mathematics'. But respective modules are not available at all German universities.

Another problem is to find lecturers in mathematics or didactics of mathematics who have specialist knowledge on gender and are able and willing not only to teach mathematical contents with gender aspects, but also to adopt an interdisciplinary perspective and to perform in a gender-sensitive manner. The course manual is designed to help lecturers acquire the necessary background knowledge. Nevertheless, the necessity to train (potential) university lecturers themselves in gender competence remains, but so far German universities lack suitable higher education didactic qualification programs.

Even if the path to attaining the goal may be a rocky one, the systematic and sustainable integration of gender competence into the teacher training in mathematics forms an essential building block in professionalization, scientificity, and the strengthening of abilities, as well as quality assurance of a professionally-oriented university education of mathematics teachers: Teach-

a cooperation partner at the University of Augsburg (winter term 2011/2012), and by Claudia Lack, a cooperation partner at the Justus-Liebig-University Giessen (summer term 2012).

ing experiences thus far have shown that students who take part in the gender competence course profit in several respects regarding their future professional life and their own understanding of their profession (see Mischau, 2012). This offers cause for hope that an increase in gender competence in (future) mathematics teachers will actually break the 'vicious circle' of reproduction of gender-related knowledge domains.

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