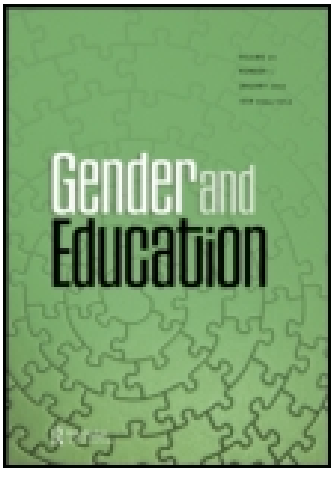

Gender and Education
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/cgee20

Exploring woman university physics students 'doing gender' and 'doing physics'

Anna T. Danielsson [a]
[a] Faculty of Education , University of Cambridge , Cambridge, UK
Published online: 28 Jun 2011.

To cite this article: Anna T. Danielsson (2012) Exploring woman university physics students 'doing gender' and 'doing physics', Gender and Education, 24:1, 25-39, DOI: 10.1080/09540253.2011.565040

To link to this article: http://dx.doi.org/10.1080/09540253.2011.565040

Gender and Education
Vol. 24, No. 1, January 2012, 25–39

Routledge
Taylor & Francis Group

Exploring woman university physics students 'doing gender' and 'doing physics'

Anna T. Danielsson*

Faculty of Education, University of Cambridge, Cambridge, UK

(*Received 26 August 2010; final version received 2 February 2011*)

This article explores what it can mean to be a woman physics student. A case study approach is used to explore how five women who are studying physics at a Swedish university simultaneously negotiate their doing of physics and their doing of gender. By conceptualising both gender and learning as aspects of identity formation, the analysis of the interviews with the five women offers insights into the nuances and complexities of how women relate to the gendered disciplinary culture of physics. This contrasts how research on gender and physics education has been predominantly concerned with comparisons of female and male students' attitudes and/or achievements. Furthermore, the analysis brings to the fore how it is not just the masculine connotations of physics that shape the experiences of the five women, but also the expectations on female physics students.

Keywords: physics; science; gender; higher education; identity; situated learning

Introduction

> I fell in love, simultaneously and inextricably, with my professors, with the discipline of pure, precise, definite thought, and with what I conceived of as its ambition. I fell in love with the life of the mind. I also fell in love, I might add, with the image of myself striving and succeeding in an area where women had rarely ventured.

In many ways, Evelyn Fox Keller's (1977) description of her experiences as a woman studying physics in the 1950s captures essential aspects of this article, both in regard to the motivations for the study and, as we shall see, in regard to the methodology. But that is stepping too far ahead in my introduction. This is an article about physics students and how they, in their learning to become physicists simultaneously, 'do physics' and 'do gender', as exemplified in Evelyn Fox Keller's narrative above. By all accounts, her story is a gendered story about doing physics; about how she constitutes herself as a particular kind of woman and a particular kind of physicist. Noticeably, how the words of Evelyn Fox Keller sharply contrast the usual portrayal – in education research and the public debate – of women and physics as 'incompatible' – regardless of whether this incompatibility is framed in terms of neurobiology and gender-related spatial abilities, or in terms of women's wish for a more socially relevant science. Seldom are the voices of women who have chosen to do physics heard. Instead, the discussion about 'women and science' has tended to be framed in terms of how to

*Email: atd32@cam.ac.uk

ISSN 0954-0253 print/ISSN 1360-0516 online

http://dx.doi.org/10.1080/09540253.2011.565040
http://www.tandfonline.com

recruit and retain women in science and technology, and this is also a major focus of educational research, formulating and evaluating supposedly 'women-friendly' approaches to science teaching. Reviews of physics education research (Danielsson 2010) and science education research (Nyström 2007) show a severe lack of critical, theoretically grounded studies of gender and science education. Notably, there is a dynamic tradition of research exploring women's experiences of engineering and engineering educations (see, for example, Faulkner 2007; Stonyer 2002; Walker 2001). Research on gender and physics education specifically, has spent considerable effort on exploring difference between men and women studying physics, in terms of, for example, performance, interests or attitudes. A common trait of many of these studies is that they treat gender as a stable category and focus on the differences between the genders rather than variations within each gender. In principal, the studies construct two different kinds of physics learners: male students who are interested in physics for its own sake and enjoy practical work and female students who want physics to be taught in a way they can relate to in their own lives and who have lower self-confidence, in particular in relation to practical work (Danielsson 2010). The starting point of this article is a different one; through five case studies I am exploring the experiences and negotiations of women who have chosen to continue to study physics in higher education. These are women who in various ways find pleasure in doing physics, but also struggle in reconciling the doing of physics with other aspects of themselves.

Returning to the introductory quote from Evelyn Fox Keller, it can also be seen as eloquently conveying, using only a few lines, how studying physics goes far beyond learning (or not learning) of the content matter. It is clear from her description that the learning of physics cannot be understood as an isolated activity, but needs to be understood in a broader personal and societal context. In the words of Brickhouse:

> Learning is not merely a matter of acquiring knowledge, it is matter of deciding what kind of person you are and want to be and engaging in those activities that make one part of the relevant communities. (2001, 286)

Therefore, a more complete understanding of students' learning of physics must expand the meaning of 'learning'; must dare to ask questions about what consequences the doing of physics has for a student's life outside the classroom; what identities are available for a particular student; how a student's participation in physics is intertwined with their participation in other social contexts; and what a student communicates by studying physics.

Physics students spend a considerable amount of their time in the student laboratory, where they are expected to acquire a wide variety of knowledge and skills. Not only are they expected to acquire an understanding of theories and concepts, and develop a scientific approach to enquiry, laboratory work is also seen as a means to foster an understanding of the scientific community among students (Séré 2002). Hence, laboratory work is central to university physics education, in that it presents a unique opportunity to learn the essentials of scientifically based empirical activity; 'learning science by doing science' (Hofstein and Lunetta 2003). Further, while the laboratory teaching at the university in this study could be characterised as rather traditional it still presents greater opportunities for different ways of participation than many other learning contexts. All in all, it can be expected that the students in the context of laboratory work are able to construct a wide range of possible ways of being and becoming physics students. My explict focus on 'learning in the laboratory' is

thus motivated both by the centrality and the complexity of this learning context. Furthermore, my interest in laboratory work also stems from my own background in experimental physics, thus, this is a part of the practice of physics that I have extensive experience of and familiarity with, allowing me to explore it from the perspective of an 'insider'. The aim of this article is to explore what it can mean to be a woman physics student, in particular in the context of doing laboratory work, and how these women simultaneously negotiate their doing of physics and their doing of gender.

Theoretical framing

In a broad sense, the project is framed by a conceptualisation of both gender and learning as aspects of identity constitution, aiming to capture the complexity of the students' learning. In the spirit of situated learning theory (Lave and Wenger 1991; Wenger 1998), the interviewed physics students are understood as not only learning to do physics (in the sense of acquiring knowledge and skills) but also learning to become physicists. In the context of learning in the laboratory students can thus be understood as constituting identities as physics students (and possibly physicists) and also negotiating the norms of what it can mean to do physics. Further, by participating in the practice in their own particular way the individual student is also contributing to making the practice what it is. A fundamental building block in the theoretical framing of the analysis is, moreover, that the students are understood as not only 'doing physics' but also 'doing gender'. From a situated learning perspective participation in a practice is the key to 'being' and 'becoming', for example, a physicist – and what feminist post-structural theory challenges us to do is to think about gender in a similar fashion. Paechter explains:

> Identity can in this way be seen as being related to competent and convincing performance of a particular role; it is defined not just internally by the individual but externally by the group's inclusive or exclusive attitude to that individual … Thus, it becomes not sufficient to claim a particular identity; that identity has to be recognised by group members, which in turn reflects back on one's understanding of oneself. (2003, 74)

At the core of feminist post-structural theory is a 'troubling' of 'the very categories of male and female to make visible the way they are constituted and to question their inevitability' (Davies and Gannon 2005, 318). In short, gender is portrayed as something fluid, something continuously changing, not an inherent characteristic of a person. Hey explains that 'the central poststructuralist ideas that the subject is an effect rather than a cause is the key to Butler's theories of performative identities' (2006, 444). However, understanding gender as performative does not mean that all kinds of 'performances' are possible; subjects can only take up those positions that are available to them (Honan et al. 2006). Paechter clarifies: 'masculinities and femininities, while performative in nature, are not arbitrary; what can be performed is highly dependent on time, place and circumstances, including the power/knowledge relations in a specific context' (2007, 40). But, as pointed out by Davies (2006), it is important not to confuse the importance of external powers with a passive, deterministic shaping of the subjects. Subjectification, as conceptualised by Butler, involves a simultaneous imposition and active taking-up of available positions (Davies 2006). Hence, gender is conceptualised not as a trait of the individual but as something that is created and negotiated by the individual in response to a specific social setting. The aim of such a

post-structural analysis is, as argued by Davies and Gannon, 'not to document differences between men and women, but to multiply possibilities, to demassify ways of thinking about "male" and "female"' (2005, 319). Inspired by a post-structural understanding of gender I am in this article aiming to portray the nuances in the students' doing of gender.

Methodology

Setting and data collection

The case studies presented in this paper are part of a larger research project, which set out to explore university physics students' identity constitutions. The research took place at a well-established Swedish research university, where the physics research traditionally has primarily been centred around experimental physics. Among the physics professors less than 10% are women, in undergraduate physics education the percentage of women is between 10 and 30.

In total 22 university physics students were interviewed (12 women and 10 men), using semi-structured interviews. Out of these 22, five women have been chosen for this article. In a first round of interviews I interviewed 13 undergraduate physics students (six women and seven men), enrolled in different stages of an undergraduate degree programme. In a second round of interviews I interviewed nine graduate students, who were either just finishing their Master's degree projects or had recently begun their PhDs, and who considered themselves doing experimental physics. The selection of students for both rounds of interviews was strategic; aiming to reflect a diversity of students and possible identity constitutions. The same can be said for the five cases chosen for this article. At the start of all the interviews I introduced myself as a physicist, explaining that I am doing physics education research, but consciously stressing my background in physics. The construction of the interview situation as a 'physics community' contributed to a more nuanced exploration of how the students constitute their identities as physicists, and made their sharing of experiences related to the procedures and content of physics more meaningful. The interviews were audio-recorded and transcribed verbatim, but with little additional detail; longer pauses and obvious emotional expressions such as laughter have been marked. Interview excerpts used in this article have been translated from the original Swedish with the aim of capturing the meaning of the utterances rather than being literal translations and has been carefully edited to enhance the readability, removing false starts, repetitions and stuttering.

Data analysis

The analysis of the interview transcripts was carried out in an iterative process, moving between the individuals and the complexity of their identity constitution and collective patterns found in the empirical material. In principal, the analysis was done in three stages, of increasing theoretical complexity. In the first stage of the analysis I kept close to the empirical material, read the interviews repeatedly and noted down common themes. Some of the themes emerging were the students' approaches to laboratory work, what they perceived as being desirable and undesirable approaches within physics and how they constituted the boundaries of physics. The result of this analytical stage was individual narratives of the interviewed students. In the second

stage of the analysis, the focus was shifted from the individual students to how they as a collective can be understood as constituting the practice of physics, described in part by the construction of Discourse models (Gee 2005). In short, a Discourse model can be understood as a stereotypical 'version' of, in my case, how to 'be' a physics student in the student laboratory, simplifying the complex practice of laboratory physics by focusing on some central aspects. Gee describes Discourse models as '"theories" (storylines, images, explanatory frameworks) that people hold, often unconsciously, and use to make sense of the world and their experience in it' (2005, 61). Thus, a Discourse model is a simplification of reality, embedding assumption both about what is 'normal' (for example, in terms of attitudes or ways of acting) and about what is viewed as inappropriate or atypical (Gee 2005). When constructing the Discourse models I worked with all the interviews in conversation with previous research about physics and engineering practices (such as Faulkner 2007; Hasse 2002; Mellström 1999; Wajcman 1991). The interview transcripts were read repeatedly, looking for what the students perceived as inappropriate/appropriate and typical/untypical ways of doing physics in the student laboratory. In the third and final stage of the analysis I returned to a thematisation that followed the individual students. Here, the individual narratives from the first stage of the analysis were combined with analytical insights from the second stage of the analysis as well as theoretical tools from situated learning theory, in order to deepen the analysis of how students constitute identities as physicists and how they negotiate the norms and boundaries of the physicist community. For example, in this stage of the analysis the Discourse models were used to explore the students' negotiation of their own and others' practice of physics and their related identity institution. Inspired by positioning theory (Harré and van Langenhove 1999), I also looked at how the students positioned themselves and other students/groups of students, e.g. in relation to the two Discourse models. Here it needs to be pointed out that the three analytical steps were not carried out linearly, but rather in a reciprocal fashion, where I, for example, allowed the third step of the analysis to influence and sharpen the Discourse models. The result of the third stage of analysis was theoretically deepened student narratives. It is such narratives that are presented in the next section of this article. A more detailed account of the theoretical framing and the analytical process can be found in Danielsson (2009).

When talking about the practice of the student laboratory the interviewed students were, as described above, interpreted as making use of two different, sometime conflicting Discourse models: 'the practical physics student' and 'the analytical physics student'. These have been described in detail elsewhere (Danielsson, forthcoming) and I will here account for them very briefly, as they are made use of in the case studies. 'The practical physics student' describes someone who in the context of laboratory work focuses on the handling of equipment. In this Discourse model practical skills are highly valued and it is not seen as necessary to read laboratory instructions, one should be able to figure out what to do intuitively. While analytical skills are not explicitly devalued, theory is seen as uninteresting and in the laboratory it is inappropriate to focus too much on the analysis, as this can prolong the execution of the experiment. 'The analytical physics student', on the other hand, views practical skills as unimportant and/or trivial and the primary focus is on physics reasoning and analytical skills. The experimental equipment is not seen as interesting for its own sake, but as a means to an end. Discussion, report writing, and collaborative skills are seen as important in the context of laboratory work.

Next the five case studies are presented.

Results

Mia and Ann – 'the anomaly of a woman in physics'

In both Mia's and Ann's identity constitutions the relation between gender and the participation in the physicist community of practice is central. Further, they both constitute their physics student identities largely by an association with 'the analytical physics student'. Unlike some of the other students in the study they do not, however, experience the boundaries of the physicist community coinciding with this Discourse model. On the contrary, both Mia and Ann do value practical skills in the student laboratory, even though they do not see themselves as possessing such skills in the context of laboratory work. When Ann talked about how she worked in the student laboratory she expressed the following:

> Ann: 'Cause most of the time I've been doing lab work with guys and then most often I've taken the female role, partly because I feel a bit slow.

In the interview, subsequent to this excerpt, Ann explains how this 'female role' for her is one of passivity, where she takes a step back and lets her laboratory partner take the main responsibility for the execution of the experiment. Thus, Ann associates 'the female role' with 'being slow' and passive; hardly sought-after characteristics in science, thereby constituting a boundary between science and femininity. This is a discontinuity that can be traced historically, as feminist philosophers of science have argued; what is seen as feminine and what is seen as proper science have ever since the Enlightenment been defined in opposition (see, for example, Fox Keller 1992; Harding 1986; Schiebinger 1991). For example, the science's ideal of rationality (an abstract, disembodied and distanced thinking) has historically been contrasted to women's embodiment and their presumed lack of rationality (Berner 2004). Further, Ann's use of the expression 'taking the female role' shows how this particular femininity for her is something she does, rather than something she is. Mia, on the other hand, draws on a discourse of gender as something biologically determined in her talk about gender and physics and is, from that standpoint, very explicitly expressing a discontinuity between femininity and the participation in the physicist community:

> I: It's mainly men who study physics – is that something you reflected upon? Why it's like that…?
> Mia: Yeah, that I also believe is, depends on the brain, on the female and the male brain. That it's easier for men, that's the way it is … I did the science programme in high school too, and the women were a minority and that's the way it is in most classes, or all I know about, so that's probably something that has to do with guys having an easier time with physics.

The discontinuity Mia experiences between femininity and physics is possibly the most obvious in the laboratory setting, where it, according to Mia, gave rise to a particular division of labour between her and her male laboratory partner; he was handling the equipment whereas she was handling the computer. This discussion about their division of labour took place prior to my explicit introduction of issues of gender and physics into the interview. When asked why they had this division of labour Mia says that it is 'in the genes', thereby referring to a biological discourse about gender.

Further, Mia is in her constitution of her identity simultaneously reinforcing a boundary between physics and mathematics, a boundary that according to her is

gendered. Women have, according to her, more aptitude for logics and mathematics whereas men have more aptitude for what she sees as 'physics'. She also frames her own participation in science in terms of a participation in such a localised femininity, characterised by an aptitude for logical thinking and mathematics.

Returning to Ann, it can be noted that even though she at times has taken up the 'female role' in the student laboratory, it has been primarily from a different perspective that the perceived discontinuity between femininity and physics shapes her identity constitution. In the interview, Ann talks about herself as different from 'normal' women and repeatedly comes back to how she is more 'comfortable among guys' than in woman-dominated environments. Thus, Ann can be understood as positioning herself as a non-participant in 'traditional femininity'; a positioning that makes a simultaneous positioning as a participant in physics possible. This kind of a positioning as a non-participant in traditional femininity is well-documented in earlier research, which has shown that women within science and technology often construct them themselves as 'one of the boys' in order to be able to position themselves as scientists/engineers (see, for example, Henwood 1998; Hughes 2001; Walker 2001).

In their interviews both Ann and Mia are positioning themselves as associated with 'the analytical physics student', or more precisely by negotiating a participation in physics that draws on characteristics that are simultaneously associated with femininity and with this Discourse model. Mia describes a localised femininity that she associates with an aptitude for logic and mathematics. Ann refers to characteristics that are commonly associated with female science students, such as being well-prepared and wanting to reason and discuss. For example, throughout her interview Ann returns to how it is the discussions about the laboratory exercise, the prolonged engagement with the content, that she finds useful, not the laboratory work as such. Thus, both Ann and Mia are describing a doing of physics that integrates characteristics commonly associated with female students, something that could be interpreted as a negotiation between a simultaneous participation in physics and in an expected femininity.

In the interview with Ann the complexity of 'doing gender' in the participation in physics is very explicit; she describes herself as taking on 'the female role' in the laboratory and describes her practice in the laboratory in terms of characteristics commonly associated with female students. Ann does this while also positioning herself as being different from 'normal women'. Further, Ann is also distancing herself from a particular kind of technological masculinity, focused on practical skills, represented both by the men at her earlier workplace and by certain physics coursemates. Such a technological masculinity has been argued by Wajcman (1991) and Mellström (1999) to be particularly prominent and highly valued by working-class men. However, Robinson and McIlwee's (1991) study of male engineers showed that they also often celebrated the hands-on technical competence and were keen to demonstrate that they had this competence, even when their jobs did not require it. By distancing herself and physics from the kind of technological masculinity that characterised her previous workplace, the electrical workshop, Ann is constituting a discontinuity between her previous workplace and the university-based physics community. This perceived discontinuity is perhaps not surprising, but in sharp contrast to how another of the interviewed students is able to constitute a continuity between industrial work and the physics laboratory, by claiming that what attracted him to experimental physics was that it is 'so close to working in a workshop'. Ann further describes her previous workplace as very 'laddish' and is letting this workplace represent 'masculinity' in a broader sense. Thus, for Ann, the somewhat less man-dominated physics

does not come across as particularly masculine, thereby demonstrating the relational nature of gender. However, Ann stresses how physics for her is a 'very open' community, wherein a multitude of different people and different ways of participation can be included. For example, she is positioning her course-mate Mats (who for her represents 'the practical physics student') as 'fitting' in the student laboratory:

> Ann: Mats, he's an experimentalist! He's so much fun to do labwork with, 'cause he really gets, he might not understand the theory at all and hasn't done anything and is tired and hasn't slept and he sure starts to tinker kind of! He's so very different [from me], he really fits in a lab!

This shows how multifaceted and complex the practice of the student laboratory is. But, this interview excerpt is also interesting because of the different possible interpretations that can be given to it. How Ann turns Mats' lack of preparations and poor theoretical background, which could easily have been viewed as inappropriate in a student laboratory, into something positive, can be understood in several, possibly complementary, ways. Firstly, by describing Mats as a tinkerer, someone who does not need theoretical knowledge to deal with laboratory equipment, Ann is attributing him with a natural flair for experimental physics. This positioning of Mats as someone who fits in a laboratory is most certainly made possible by Mats being a man, and as such, fulfilling the gender-norms of physics. Consequently, it is possible for Ann to interpret Mats' possible 'shortcomings' as suitable, or even desirable, qualities in physics. But, secondly, Mats' doing of a practical, technological masculinity is also a 'doing of class', one that Ann not only recognises from her previous experience of working in a workshop, but also values, and to a certain extent identifies with.

Klara and Hanna: becoming a physicist – or not?

Klara and Hanna are both Master's students in the same research group, working with somewhat similar projects. However, their educational backgrounds are quite different. Klara is enrolled in the Engineering Physics programme, a programme Hanna decided against because she perceived it as too difficult and was unsure if she could cope with. Instead Hanna chose a more interdisciplinary engineering programme, also motivated by its possibilities to combine mathematics and physics with broader societal perspectives.

Despite the many similarities of their Master's research projects, Klara and Hanna are positioning themselves very differently. Klara is positioning herself as a physicist, a positioning that was largely made available to her through her prolonged engagement in a community where 'everyone' is a physicist:

> I: Do you see yourself as a physicist?
> Klara: I think I've started to do it, now.
> I: When did you start doing it?
> Klara: Well, yes. After a while when I had started the Master's research project.
> I: Ok.
> Klara: You are … We have been a group where all are physicists and that … We are physicists. So then I started, I'm probably a physicist too. [we're both laughing]

Hanna, on the other hand, is not positioning herself as a physicist. In her interview she explains that for her to gain access to the physicist community not only a PhD in physics is needed, but also some years of working experience after that. Hanna's lack of

identification with the physicist community is also intertwined with a perceived inability to negotiate what it means to be a physicist. She says that she finds it difficult to say much about the characteristics or experiences that are useful for a physicist (or an engineer):

> I: What is important to be skilled at then, as a physicist or engineer or whatever you're on your way towards?
> Hanna: …Well, it's kind of to be able to like be independent or … be, critically examining … I don't know. Erm.

So, from Hanna's perspective the boundaries of the physicist community are tightly set and gaining access and legitimacy is difficult. Further, from her perspective the boundaries are diffuse, and perhaps also moving, being defined by 'experience', rather than being defined by an explicit marker of membership, such as a degree.

In relation to doing laboratory work as an undergraduate student Klara talks about herself in terms of the Discourse model of the analytical physics student; she was not very interested in doing experiments but describes herself as having more aptitude for theory. During her Master's research project she describes this as having changed markedly; she says that she currently has much more self-confidence in the laboratory, as she during her Master's research project has had the opportunity to try things herself, without the pressure of time she experienced in the student laboratory. Consequently, during her Master's research project Klara could be said to have increased her repertoire of skills in the laboratory to include aspects of both the physics student Discourse models, thereby also increasing her repertoire of possible ways of participating in the laboratory practice. Interesting to note, however, is that she makes no claims about whether she perceives one of the Discourse models as more highly valued. Her distancing of herself from 'the practical physics student' is explained not by a view of 'handling of equipment' as lesser valued than 'handling of theories', but because she did not feel comfortable with the laboratory equipment. Further, Klara points to the time aspect as one of the main differences between the student laboratory and the research laboratory; in the student laboratory time was always sparse and she says that she was not able to develop the kind of independence she currently experiences in the research laboratory. Klara also talks about a certain continuity between the student laboratory and the research laboratory, in terms of the student laboratory helping her to get accustomed to certain kinds of equipment, but there are also prominent differences:

> I: Is there a difference in the purpose in the laboratory you're working in now versus in the student laboratory? Or maybe rather, what are the differences?
> Klara: Yes, there's a difference. Now I'm studying something to see what I get kind of, but then it was, then it should … Yeah, what should I say. Then it wasn't exploring in the same way, then it was more about confirming what we already knew. And now it's more research. So to speak.

Overall, there is a clear sense of progress in Klara's narrative. She was attracted to the Engineering Physics programme because of a rather idealistic interest in space research, an interest that along the way has transformed into a more focused aspiration to work with applications of radiation. Further, while recognising a certain continuity between the student laboratory and the research laboratory, she is also reflective about the differences and about her change from student to physicist and her associated

increased repertoire in the laboratory. All in all, Klara could be understood as being on an inbound trajectory in the physicist community of practice.

Hanna also describes her approach to laboratory work as an undergraduate in terms of 'the analytical physics student', with a particular focus on thoroughness. Thus, Hanna's approach to laboratory work can be described as being located in the overlap between 'the analytical physics student' and characteristics often associated with female students. Noticeable in Hanna's talk about working in the student laboratory versus working with her Master's research project is how little distinction she makes between the practices; when asked directly she does mention that the Master's research project is less premeditated than exercises in the student laboratory, but the clear sense of progress that characterises Klara's narrative is lacking. When you are doing your Master's research project you are 'nothing' Hanna says, neither physicist nor engineer or anything else. When Hanna started her Master's research project she thought of it as 'simple', something anyone could do:

I: What has changed during the course of the Master's research project then?
Hanna: Mmm … It might be that to begin with I thought that what I'm doing is so very simple and…
I: What do you mean by that?
Hanna: Well, easy. I sit here and simulate small things.

Reflecting about the Master's research project in the interview situation she does, however, with hesitation, voice how she, after all, has come to make 'valuable' contributions. Nonetheless, the contrast to Klara is striking. Whereas Klara's clear sense of progress has opened up an inbound trajectory in the physicist community of practice, I would argue that Hanna, at most, can be understood as being on a peripheral trajectory.

Finally, it can be mentioned that in contrast to Mia and Ann, gender is not an explicit theme in either Hanna's or Klara's narrative. Hanna even very adamantly rejects that the gender issues should be of any importance in the physics community and talks about it as unusually gender neutral, where experience and knowledge is all that matters:

Hanna: It's what you know! Or, experience. It feels like it's the way you get, that you are something, it's not so much regarding gender.

In part, I would argue that this discourse of 'gender neutrality' (Magnusson 1998) is tied to a general academic ideal of individuality and independence. In this sense Hanna's utterance about how what matters is experience and knowledge, that within the physicist community people are judged by what they know, not who they are, is very much in line with what Eduards (2007) argues to be the self-image of the entire academia as an extremely individually oriented system. However, the description of how physics as 'unusually gender neutral' could also be a reflection of how physics is constructed as a science that produces universal, value-neutral and objective knowledge, independent of societal factors (Schiebinger 1991).

Cecilia: the experimentalist

Cecilia strongly identifies, not only as a physicist, but more precisely as an experimental physicist. Central to her participations in the practice of the student laboratory is an unproblematic association with 'the practical physics student'. Cecilia talks about

how what attracted her to experimental physics was its connection to 'reality', the possibility to solve problems in reality and not, as she expresses it, 'in the world of the formulas'. But whereas Tor, another of the interviewed PhD students whose descriptions of himself as a physicist in many ways resembles Cecilia's, describes his practice more towards the professional end of the spectrum, Cecilia's approach is more of the 'playful' kind. Tor talks about learning to handle equipment, in a progression from simple instruments like voltmeters to more advanced ones; Cecilia talks about playing around with the equipment until it works. Both thus focus extensively on the handling of equipment in their description of their practice in the student laboratory, but from different perspectives. Despite Cecilia's strong association with 'the practical physics student', it can also be noted how aspects of 'the analytical physics student' are present in her talk; when Cecilia is asked to characterise the physicist she says:

> Cecilia: Well … analytical … logical … Erm, what's it called, creative. Erm … what else can you be. It's a clear advantage if you're pedagogical, but you don't need to be.

Furthermore, Cecilia confidently answers 'yes' to my question about whether she recognises herself in the attributes she associates with 'the good physicist'; being analytical, logical and creative. She does not, however, seem to notice that her description of 'the physicist' differs markedly from her description of her own practice as a physicist. Cecilia is thus very explicitly bringing out aspects of both physics student Discourse models, thereby constituting her physicist practice as a highly versatile one. Cecilia's willingness to describe the physicist can further be interpreted as her experiencing herself to be in a position where she has legitimacy to describe and define norms of the physicist community. In other words, the identification with and the negotiation of the physicist community are tightly interconnected.

Cecilia's 'playful' approach to doing physics in the physics laboratory is also interesting from a different perspective – how it is intertwined with her doing of gender. In Hasse's (2002) anthropological study of Danish physics students she found that a playful approach to physics in general and laboratory exercises in particular was something that was limited to a group of male students, none of the female students in her study participated in this playing activity. While Hasse's results of course cannot be claimed to be 'generalisable' to a different context, it is still noticeable how Cecilia's approach to laboratory work is so very different from all the women in Hasse's study. Further, female physics students are often described as being diligent, neat and closely following the prescribed assignments (see, for example, Lorenzo, Crouch, and Mazur 2006; Robertson 2006; Williams et al. 2003). This is a picture that is far from Cecilia's description of her participation in physics, her talk about her practice in the student laboratory was very much focused on her confident handling of the laboratory equipment:

> Cecilia: I really sucked at preparation, it was always the last minute to read stuff through, just before … 'Some preparatory assignments, yeah, it was, damn.' So it was always the last minute. Erm, the laboratory report I sucked at in the beginning, was good at when I finished [the education] or I didn't suck, but … quite bad. When I look at my first labs, then just, erm, 'god how awful'. But … just passed like that. Erm, and then I was skilled at … well, when I'm doing laboratory work I'm good at daring to press all the buttons, kind of, if you have an oscilloscope 'I haven't used an oscilloscope in two years, turn a bit here, turn a bit here, damn, look, picture!'

In fact, I would argue that Cecilia's talk about her practice in the student laboratory as being characterised by inadequate preparation and unafraid tinkering with the equipment, in part needs to be understood as a reaction towards the norm for female science students. Thus, in her identity constitution as a woman in physics Cecilia not only has to relate to the masculine norms of the physicist community, but also to the expectations there are on female physics students.

But not only is Cecilia rejecting the rule-following approach to laboratory work commonly attributed to female students, she is also rejecting a 'traditional femininity' in more general terms, for example, by pointing out how she was a typical engineering student who 'drank beer and sang indecent songs'. Her rejection of 'traditional femininity' is also explicitly expressed through repeated descriptions of herself as 'laddish'. On the one hand, this non-participation in traditional femininity serves the same purpose as for Ann; by drawing on a discontinuity between traditional femininity and physics they are able to position themselves as non-participating in one and participating in the other. But not only that; through her participation in physics Cecilia is also able to participate in a particular kind of masculinity. Thus, by her participation in physics she simultaneously constitutes her own gendered physicist identity and the community of practice as gendered. This may not challenge the masculinised gender norms of physics, but it most certainly challenges the norms for female physics students. Finally, it should be noted that Cecilia's rejection of traditional femininity is not a rejection of gender as important in the physicist community; Cecilia is reflective and well versed about gender issues.

Discussion

The five case studies in this article all represent women studying physics at university, and whilst there are similarities, there are also striking differences. Even Klara and Hanna, who superficially share many commonalities as Master's students in the same research group, are on very different trajectories in the physicist community. It can also be noticed that whereas gendered negotiations are a major theme in the narratives of Ann, Mia and Cecilia, this is not the case with Klara and Hanna. All in all, the case studies show numerous different ways in which women engage in physics studies, illuminating the variation and diversity of women's doing of physics. In this article, to focus solely on women has for me been a way to avoid comparisons between women and men, comparisons that often tend to establish the doings of the male students as the norm in physics, and give rise to generalisations about men and women. The common portrayal of women as physics learners in previous research incorporates elements such as being diligent, neat, thorough and rule-following, often taking on the secretarial duties in the laboratory and being intimidated by and/or unskilled in the handling of equipment. Often such characterisations have been taken as the 'truth' about woman students; have been interpreted as the way they 'are'. I would, however, like to offer a different reading, arguing that such characterisations play a key role in the shaping of women's educational experiences, in the sense that teachers (and sometimes researchers) attribute these traits to the female students. Thus, the masculine norms of physics are not the only gender norms which female physics students may have to relate to; there are also norms for how to be a female physics student. Thus, not only are the female physics students relating to masculine norms of the discipline, they may also have to deal with the norms and expectations about how a woman is supposed to be in a physics and engineering context.

Several of the women in the study negotiated a potentially disempowering participation in activities associated with female students (taking on the secretarial duties in the laboratory is not likely to give one status) by tying them to aspects of the high-status Discourse model of the analytical physics student. This meant that they could constitute a strong physicist identity without having to distance themselves from the norms and expectations on female science students. A somewhat unexpected negotiation of these norms was also exemplified by Mia, who was able to constitute a comfortable physicist identity by drawing on a discourse of women as having a natural aptitude for logic and mathematics. However, there is also the possibility of a positioning that strongly challenges the norms for femininity within science. Amongst the students interviewed, Cecilia was probably the woman with the most outspoken resistance towards these norms. Not only was she resisting the traditional portrayal of female physics students by describing an unstructured and unprepared approach to the student laboratory, thereby challenging disciplinary gender norms, she was also resisting femininity in more general terms and repeatedly referred to herself as 'laddish'. She also pointed out how this 'laddishness' contributed to it being easier for her than other women to fit within the boundaries of physics. Such a distancing from a traditional femininity among women within science and technology as a way to fit into a man-dominated discipline is well documented in previous research. However, a counter-identification with traditional femininity is often interpreted in negative terms, either as a failure to challenge dominant gender norms (Henwood 1996, 1998) or even as an approach forced on to the women (Kvande 1999). While I do not oppose these interpretations I would like to use the case of Cecilia to give nuance to the picture: What happens if we interpret Cecilia's choice of physics and her approach to laboratory work in terms of doing of a female masculinity (Halberstam 1998)? If we understand Cecilia's participation in physics as enabling a simultaneous participation in a desired female masculinity? These are questions that may provide a novel entry point into the exploration of women's constitutions of identities as physicists. From this perspective Cecilia's counter-identification with traditional femininity may not challenge the masculine norms of physics, but it does challenge heteronormative understandings of all men as desiring to be masculine and all women desiring to be feminine.

Gender issues are not a major theme in either Klara's or Hanna's narratives, at least not explicitly. Instead, in particular Hanna constitutes both physics as a discipline and academia in general as gender neutral. In part, this is done by stressing the importance of individual characteristics and abilities, disregarding the impact of structural forces. This exclusive attribution of academic achievement to individual skills and motivation was also identified by Erwin and Maurotto (1998) in their study of female science undergraduates; even when the students did acknowledge structural forces these were constructed as obstacles that could be overcome, given enough effort and motivation. Erwin and Maurutto further concluded that a consequence of this individualistic discourse was that 'few [of the interviewed women] appeared to know strategies, other than those involving self-improvement, that would help them cope with the barriers and problems they confronted' (Erwin and Maurotto 1998, 60). Considering this lack of strategies among many female science students for making sense of their participation beyond an individualistic discourse, I believe that theoretically informed narratives such as these presented in this article could be illuminating and empowering for the individual physics student on very concrete terms, giving them tools for reflecting on their own experiences and impressions.

References

Berner, B. 2004. Ifrågasättanden. Forskning om genus, teknik och naturvetenskap. Linköping: Linköpings Universitet.

Brickhouse, N.W. 2001. Embodying science: A feminist perspective on learning. *Journal of Research in Science Teaching* 38: 282–95.

Danielsson, A.T. 2009. Doing physics – doing gender. An exploration of physics students' identity constitution in the context of laboratory work. PhD diss., Uppsala University, Uppsala, Sweden.

Danielsson, A.T. 2010. Gender in physics education research: A review and a look forward. In *Never mind the gap! Gendering science in transgressive encounters*, ed. M. Blomqvist and E. Lindsmyr, 65–83. Uppsala, Sweden: Centre for Gender Research.

Danielsson, A.T. Forthcoming. 'Discourse models' as an analytical tool for characterising the practice of physics as enacted in university student laboratories. *Nordic Studies in Science Education.*

Davies, B. 2006. Subjectification: The relevance of Butler's analysis for education. *British Journal of Sociology of Education* 27: 425–38.

Davies, B., and S. Gannon. 2005. Feminism/poststructuralism. In *Research methods in the social sciences: A guide for students and researchers*, ed. B. Somekh and C. Lewin, 318–25. London: Sage.

Eduards, M. 2007. *Kroppspolitik. Om Moder Svea och andra kvinnor.* Stockholm: Atlas Akademi.

Erwin, L., and P. Maurutto. 1998. Beyond access: Considering gender deficits in science education. *Gender and Education* 10: 51–69.

Faulkner, W. 2007. 'Nuts and bolts and people': Gender-troubled engineering identities. *Social Studies of Science* 37: 331–56.

Fox Keller, E. 1977. The anomaly of a woman in physics. In *Working it out*, ed. S. Ruddick and P. Daniels, 78–91. New York: Pantheon Books.

Fox Keller, E. 1992. *Secrets of life. Secrets of death.* London: Routledge.

Gee, J.P. 2005. *An introduction to discourse analysis. Theory and method.* 2nd ed. New York: Routledge.

Halberstam, J. 1998. *Female masculinity.* Durham, NC: Duke University Press.

Harding, S. 1986. The science question in feminism. Milton Keynes: Open University Press.

Harré, R., and L. van Langenhove, eds. 1999. *Positioning theory: Moral contexts and intentional action.* Oxford: Blackwell Publishers.

Hasse, C. 2002. Gender diversity in play with physics: The problem of premises for participation in activities. *Mind, Culture, and Activity* 9: 250–69.

Henwood, F. 1996. Wise choices? Understanding occupational decision-making in a climate of equal opportunities for women in science and technology. *Gender and Education* 8: 199–214.

Henwood, F. 1998. Engineering difference: Discourses on gender, sexuality and work in a college of technology. *Gender and Education* 10: 35–49.

Hey, V. 2006. The politics of performative resignification: Translating Judith Butler's theoretical discourse and its potential for a sociology of education. *British Journal of Sociology of Education* 27: 439–57.

Hofstein, A., and V. Lunetta. 2003. The laboratory in science education: Foundations for the twenty-first century. *Science Education* 88, no. 1: 28–54.

Honan, E., M. Knobel, C. Baker, and B. Davies. 2006. Producing possible Hannahs: Theory and the subject of research. *Qualitative Inquiry* 6, no. 9: 9–32.

Hughes, G. 2001. Exploring the availability of student scientist identities within curriculum discourse: An anti-essentialist approach to gender-inclusive science. *Gender and Education* 13: 275–90.

Kvande, E. 1999. 'In the belly of the beast' constructing femininities in engineering organizations. *The European Journal of Women's Studies* 6: 305–28.

Lave, J., and E. Wenger. 1991. *Situated learning. Legitimate peripheral participation.* Cambridge: Cambridge University Press.

Lorenzo, M., C.H. Crouch, and E. Mazur. 2006. Reducing the gender gap in physics education. *American Journal of Physics* 74, no. 2: 118–22.

Magnusson, E. 1998. *Vardagens köninnebörder under förhandling.* Umeå, Sweden: Umeå University.
Mellström, U. 1999. *Män och deras maskiner.* Nora, Sweden: Bokförlaget Nya Doxa.
Nyström, E. 2007. Talking and taking positions. An encounter between action research and the gendered and racialised discourses of school science. PhD diss., Umeå University, Sweden.
Paechter, C. 2003. Masculinities and femininities as communities of practice. *Women's Studies International Forum* 26, no. 1: 69–77.
Paechter, C. 2007. *Being boys. Being girls. Learning masculinities and femininities.* Buckingham, UK: Open University Press.
Robertson, L.A. 2006. Why are there so few female physicists? *The Physics Teacher* 44: 177–80.
Robinson, J.G., and J.S. Mcllwee. 1991. Men, women, and the culture of engineering. *The Sociological Quarterly* 32: 403–21.
Schiebinger, L. 1991. *The mind has no sex? Women in the origins of modern science.* Cambridge, MA: Harvard University Press.
Séré, M. 2002. Towards renewed research questions from the outcomes of the European project Labwork in Science Education. *Science Education* 86: 624–44.
Stonyer, H. 2002. Making engineering students – making women: The discursive context of engineering education. *International Journal of Engineering Education* 18: 392–9.
Wajcman, J. 1991. *Feminism confronts technology.* Cambridge: Polity Press.
Walker, M. 2001. Engineering identities. *British Journal of Sociology of Education* 22, no. 1: 75–89.
Wenger, E. 1998. *Communities of practice. Learning, meaning and identity.* Cambridge: Cambridge University Press.
Williams, C., M. Stanisstreet, K. Spall, E. Boyes, and D. Dickson. 2003. Why aren't secondary students interested in physics? *Physics Education* 38: 324–9.