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The gendered doing of physics: A conceptual framework and its application for exploring undergraduate physics students' identity formation in relation to laboratory work

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Abstract

In this licentiate thesis I explore undergraduate physics students' experiences of doing laboratory work in physics and, in particular, how this relates to the gendering of physics in relation to their formation of physicist identities. I outline a conceptual framework for exploring the gendered nature of learning physics in the laboratory setting, and in this framework situated cognition and post-structural gender theory are merged together. This allows me to analyze gender as an active process and to relate the dynamics of this process to the emerging physicist identities of the students. Thus, my conceptual framework allows for an analysis of the gendered learning experiences in physics that goes well beyond the usual 'women-friendly' teaching approaches. The conceptual framework has been developed 'in conversation' with an empirical study, where thirteen undergraduate physics students were interviewed about their experiences of learning from and doing laboratory work. I found these students to be constituting their physicist identities in relation both to different forms of 'physicist masculinities' and to what they characterized as 'normal femininity'. The results, which are described in-depth in the thesis, are given and illustrated both in terms of the conceptual framing and descriptions taken from the interviews. Further, the results show the importance for teachers to deepen their understanding of students' identity formation in order to improve the students' learning experiences in physics, in the student laboratory as well as beyond it.

List of papers and conference presentations

Danielsson, A. (2005). University students' experience of doing laboratory work in physics. Poster presented at the Junior Researchers for EARLI Pre-conference at the 11th European Conference for Research on Learning and Instruction, Nicosia, Cyprus, August, 2005.

Danielsson, A. (2005). Gender in the student in the student laboratory. An exploration of students' experiences of doing laboratory work in university physics. Poster presented at the Physics Education Research Conference, Salt Lake City, Utah, August 2005.

Danielsson, A., Lippmann Kung, R. & Linder, C. (2005). Female Physics Majors' Experiences of Doing University Laboratory Work. Paper presented at the American Association of Physics Teachers Summer Meeting, Salt Lake City, Utah, August, 2005.

Danielsson, A. & Linder, C. (2006). Gendered identities in the physics student laboratory. Paper presented at the Gender and Science and Technology 12 International Conference, Brighton, England, September, 2006.

Danielsson, A. & Linder, C. (in review), Learning in Physics by doing Laboratory Work: toward a new Conceptual Framework. Submitted to *Gender and Education*.

Contents

Prelude: Women doing physics in Uppsala around the year 1900

Kvinnor i Uppsala-fysiken omkring sekelskiftet 1900

> Herrar Filosofie Doktorer!
>
> I hafven nu inträtt i den akademiska lärdomens brödraskap…

Så inleddes promotors tal till de nyblivna doktorerna vid 1901 års promovering vid Uppsala universitet[1] - trots att en av de nyblivna doktorerna var en kvinna; Gulli Rossander, den första kvinnan att disputera i fysik i Sverige. Promotor hade dock helt rätt i att Uppsala universitet omkring sekelskiftet 1900 i allra högsta grad var en männens värld, ett lärdomens brödraskap. Kvinnorna hade visserligen fått tillträde till universitetsstudier år 1873, men det skulle dröja ända till 1923 innan kvinnor genom behörighetslagens antagande fick tillträde till högre tjänster inom universiteten.

Universitetet var alltså omkring förra sekelskiftet i allt väsentligt en manlig area. Kvinnor hade visserligen möjlighet att studera, men de allra flesta fortsatta karriärvägar var stängda, både inom och utom akademin. De yrken som ansågs lämpade för en utbildad kvinna var i första hand de där hon kunde få utlopp för sina ”vårdande modersinstinkter”, såsom läkare och lärare.[2] Ett inte försvinnande antal kvinnor valde dock att gå andra vägar; år 1910 hade sexton kvinnor disputerat i Sverige, varav fyra i fysik, ett av de ämnen som idag har allra starkast manlig kodning.[3] Först ut bland de kvinnliga fysikdoktorerna i Uppsala var alltså Gulli Rossander, hon följdes sedan av Eva von Bahr 1908 och Eva Ramstedt 1910 - sedan skulle det dröja ända till 1937 innan nästa kvinna disputerade i ämnet och det var Anna Beckman, som tagit sin licentiatexamen redan 1911. Den femte kvinnan att disputera i fysik i Uppsala var Ewelyn Sokolowski, år 1959. Situationen vid Stockholms universitet är den motsvarande, med Signe Schmidt-Nielsen, år 1907, som första kvinnliga fysikdoktor och Inga Fischer, år 1952, som den andra. Under

[1] UNT 17/6 1901
[2] Markusson [Winkvist] (2002) s. 105
[3] Kaiserfeld (1997)

en period på över fyrtio år, från 1910 till 1952, disputerade alltså endast en kvinna i fysik i Sverige.

Det låga antalet kvinnor kanske inte verkar alltför anmärkningsvärt, andelen kvinnliga fysikdoktorander är ju trots allt fortfarande låg[4], men det anmärkningsvärda ligger i att denna fyrtioårsperiod föregicks av ett decennium då fyra kvinnor disputerade i fysik.[5] Dessa kvinnor verkar dock inte uppfattat fysiken såsom särskilt manlig, ingenstans ger de uttryck för att ha gett sig in på ett manligt ämnesområde. Viktigt är i detta sammanhang emellertid att betänka den annorlunda ställning naturvetenskapen rent allmänt, och då fysiken i synnerhet, hade omkring förra sekelskiftet: år 1900 stod den klassiska fysiken på sin höjdpunkt, kvantmekanik och relativitetsteori hörde framtiden till, och ingen kunde ana på vilket sätt naturvetenskapen och dess teknologiska tillämpningar skulle revolutionera hela vårt samhälle.[6] Beryktat är lord Kelvins (1824-1907) uttalande år 1900; att man då visste allt och det bara fanns ett par mörka moln på den vetenskapliga himlen.[7] Fysiken var med andra ord omkring förra sekelskiftet inte mer ett litet universitetsämne, naturvetenskapernas maktpotential var fortfarande okänd och kanske sågs fysiken därför som inte så viktig för män och följaktligen möjlig för kvinnor.[8]

Vi ska nu bekanta oss lite närmare med en av de kvinnor som disputerade i fysik i Uppsala under 1900-talets första decennium och den enda gjorde fortsatt karriär inom Uppsala universitet; Eva von Bahr. Därefter kommer vi att se på vilken relation förra sekelskiftets kvinnliga Uppsalafysiker hade till den så mansdominerade universitetsvärlden.

Eva von Bahr

Omvägen till universitetet

Den unga Eva von Bahr ger intrycket av att ha varit en pojkflicka; dockor och andra flickleksaker intresserade henne inte, och aldrig verkar triumfen ha varit så stor som när hon fick besegra en pojke. Hennes äldre syster Ellen lärde henne tidigt läsa och vid fem års ålder läste hon allt hon kom över. Eva började 1886 i klass fem i flickskolan, en klass hon egentligen var för ung för, men höll sig trots detta bland de främsta i klassen - utan större ansträngning, om vi får tro henne själv. Hon verkar dock ha upplevt skolan som

[4] År 2002 var drygt 20 % av de forskarstuderande i fysik i Sverige kvinnor. www.scb.se
[5] Dessa fyra kvinnor utgjorde tillsammans 10 % av det totala antalet fysikdoktorander under perioden, att jämföras med att andelen kvinnor som disputerat i fysik under perioden 1970-89 var 8 %. Benckert - Staberg (2000), s. 17
[6] Detta är också utgångspunkten i Thomas Kaiserfeld avhandling där han analyserar hur fysikens förändrade samhällsställning ändrade fysikernas karriärmöjligheter.
[7] Danielsson (2003), ss. 84-85
[8] Benckert (1997), s. 54

ganska tråkig, då hon inte fann uppgifterna utmanande nog. De enda lektionerna hon säger sig ha uppskattat var de i matematik och fysik.[9]

Efter att Eva von Bahr slutat skolan hade hon tankar på att fortsätta till studentexamen, men kände sig osäker då studentexamen för flickor var en sådan nymodighet och dessutom såg hennes far helst att hans döttrar stannade hemma. I Uppsala fanns dock ännu inte någon skola där flickor kunde ta studentexamen och Eva kom att ägna de följande åren i huvudsak åt dans och nöjen, men även vävskola och franskalektioner hanns med. Efter fem år som hemmaflicka började hon emellertid längta efter något annat och började, trots ett totalt ointresse för dylika göromål, vid en hushållsskola.[10]

De två följande åren tillbringade Eva von Bahr vid Uppsalas fackskola för huslig ekonomi, först som elev, senare som lärare. Matlagning intresserade henne dock inte alls och hon vantrivdes, även tyckte att det var roligt att undervisa. Detta till trots var hon också med om att starta upp ett skolkök i Uddevalla, men återvände därefter till sina egna studier; i november 1898 begav hon sig till Askov i södra Danmark för att studera på folkhögskolan där. Eva von Bahr blev dock tvungen att avbryta studierna i förtid då hennes syster Ellen hastigt avlidit, men folkhögskolan hade då, skriver hon i självbiografin, gett henne så mycket att hon beslutat att ägna sitt liv åt den. Efter hemkomsten från Danmark inledde hon därför studier vid Stockholms Högskola, för att skaffa sig kompetens för att undervisa på folkhögskola, till en början dock utan tanke på studentexamen då hon ansåg sig för gammal. Som genom en stundens ingivelse, åtminstone om man får tro självbiografin, ändrades emellertid detta och Eva von Bahr bestämde sig för att ta studentexamen och efter ett års studier examinerades hon vid Åhlinska skolan i Stockholm.[11]

År 1901 inledde så Eva von Bahr sina studier vid Uppsala universitet. Vid denna tidpunkt var de kvinnliga studenterna fortfarande få; men inte riktigt lika ovanliga som tidigare, under perioden 1901-05 skrev drygt hundra kvinnor in vid universitetet.[12] I synnerhet framstår nationsgemenskapen som kompakt manlig, för egen del verkar dock Eva von Bahr inte ha haft något större intresse av att delta i studentlivet, hon var trots allt ungefär tio år äldre än sina studiekamrater och bodde dessutom hemma hos sin mor. Den kvinnliga studentföreningen var hon dock aktiv i, under ett par år till och med som dess ordförande.[13]

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[9] von Bahr-Bergius
[10] von Bahr-Bergius
[11] von Bahr-Bergius
[12] Rönnholm (1999), s. 43
[13] von Bahr-Bergius

Docent Eva von Bahr

Av de tre kvinnor som disputerade under åren 1900-1910 var Eva von Bahr den enda som kom att stanna vid Uppsala universitet. Något som, om man får tro hennes självbiografi, berodde mer på tillfälligheter än ett aktivt val. I självbiografin lyfter hon gång på gång fram hur målet med hennes studier var att bli lärare på Brunnsviks folkhögskola. Hon erbjöd sig också att efter licentiatexamen komma till Brunnsvik som lärare, men fick ingen lärarplats då det redan fanns lärare i hennes ämnen. von Bahr stannade därför vid Uppsala universitet och inledde hösten 1907 sitt doktorandarbete. Om tiden som licentiatstuderande och doktorand saknas helt uppgifter i självbiografin och hon fokuserar istället på tiden som docent. [14]

I självbiografin ges alltså intrycket att Eva von Bahrs huvudmål med sina studier hela tiden var att bli lärare vid Brunnsviks folkhögskola – att detta skulle kunna vara en medveten eller omedveten efterkonstruktion sedan andra karriärvägar visat sig stängda är knappast någon omöjlighet, men liknade tankar finns även i ett brev till Gulli Rossander, författat 1909:

> …då jag ju i alla fall aldrig tänkt mig möjligheten att stanna här och aldrig studerat med det målet. Frestelsen blev emellertid för stark, inte frestelsen att bli docent, som var högst måttlig, men att få stanna och arbeta på den nya institutionen.[15]

Någon önskan att göra akademisk karriär fanns alltså inte hos von Bahr, vilket hon även poängterar i självbiografin:

> Kort tid före disputationen överraskade mig Knut Ångström med att fråga om jag inte skulle ha lust att stanna vid universitetet som docent. Det var något jag aldrig haft en tanke på. Jag hade ingen som helst önskan att kämpa mig fram till en professur och hoppades fortfarande på folkhögskolan.[16]

Därtill är hon osäker på sin egen förmåga, och upplever att Knut Ångström överskattat henne och gett henne ett alltför högt betyg på avhandlingen. Eva von Bahr var dessutom smärtsamt medveten om den press pionjärskap innebar och uttryckte oro inför att vara den första kvinnan att föreläsa på Fysikum:

> Då det var första gången en kvinna föreläste på institutionen var det ju också synnerligen viktigt att inte blamera sig.[17]

[14] von Bahr-Bergius
[15] Brev från Eva von Bahr till Gulli Rossander 7/2 1909, GP A10:6, GUB
[16] von Bahr-Bergius, s. 29
[17] von Bahr-Bergius, s. 34

I januari 1913 tog hon så tjänstledigt från sin docentur och begav sig till Tyskland för att studera, först i Freiburg och senare i Berlin. Där samarbetade hon med bland andra Lise Meitner, med vilken hon kom att utveckla en nära vänskap. När Eva von Bahr reste till en kongress i Göttingen, utan Meitner, kände hon sig dock ensam – att ta sig in i den i övrigt så kompakt manliga fysikergemenskapen var inte det lättaste. [18] Eva von Bahr reste hem från Tyskland i januari 1914, sedan hennes mor drabbats av en hjärnblödning och avslutade därmed sitt vetenskapliga arbete.

Förutom osäkerheten på den egna förmågan och oviljan att göra akademisk karriär kan nog också Knut Ångströms död 1910 ha påverkat Eva von Bahrs beslut att lämna akademin, han var den som hade uppmuntrat henne att fortsätta inom akademin efter disputationen och de kom att stå varandra nära. Ångström efterträddes av den ökänt kvinnofientlige Granqvist och även om Eva von Bahr inte sade sig ha haft några större problem med honom, så hade hon svårt att finna sig tillrätta på Fysikum:

> Han [Knut Ångström] dog på våren 1910 och det blev mycket tomt efter honom. Undervisningen intresserade mig alltid, men eljest kände jag mig ensam på institutionen. Ingen visade mig ovänlighet, men de som arbetade där voro föga stimulerande.[19]

Eva von Bahr hade svårt att identifiera sig med den akademiska världen och att ta upp kampen mot systemet för kvinnosakens skull intresserade henne inte.[20] Hon sökte dock laboratorsplatsen efter Granqvist, ivrigt uppmuntrad av kvinnosakskvinnorna, trots att hon, om man får tro hennes självbiografi, inte var det minsta intresserad av platsen. Det var dock vanligt att man sökte enbart för att få meriten av en kompetensförklaring och von Bahr visste dessutom att hon inte kunde vara aktuell för platsen då även den mer meriterade docent Koch sökte. De sakkunniga förklarade också att von Bahr, på grund av grundlagshinder, inte kunde få platsen.[21]

Eva von Bahr lämnade alltså universitetsvärlden 1914 och arbetade under återstoden av sin yrkesbana på Brunnsviks folkhögskola, som lärare i matematik, fysik och kemi. Bland eleverna fanns bland andra diktaren Dan Andersson, han var dock ingen mönsterelev och särskilt matematiken intresserade honom inte. von Bahr befriade honom därför snart från de privatlektioner det var tänkt att hon skulle ge honom.[22]

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[18] von Bahr-Bergius, s. 37
[19] von Bahr-Bergius, s.31
[20] von Bahr-Bergius
[21] von Bahr-Bergius, s. 32
[22] von Bahr-Bergius. En varm och bestående vänskap kom senare att utvecklas mellan Dan Andersson och Eva von Bahr och hennes make Niklas Bergius och Dan Anderssons brev till Eva von Bahr finns samlade i Gunde Johanssons ”Hjärtans oro”.

Relationen till det manliga universitetet

I de kvinnliga fysikernas berättelser om sin tid vid Fysiska institutionen är det framförallt två män som ofta figurerar; professor Knut Ångström och hans efterträdare Gustaf Granqvist. Dessa två får också i många sammanhang stå som motpoler när det handlar om de manliga akademikernas inställning till sina kvinnliga kollegor; den stödjande Ångström mot den kvinnofientlige Granqvist. Sanningen verkar dock, inte helt oväntat, vara mer komplex.

Knut Ångström verkar till en början ha varit osäker på hur han skulle bemöta de kvinnliga studenterna. Han skriver i ett brev till sin hustru, med anledning av en ung kvinna som 1891 anmält sig till fysikkollegiet och som av i brevet beskrivs som ”af bländande skönhet och dertill otroligt kokett”:

> Jag undrar hur det ser ut i en liten hjärna, der egaren vet med sig att se så bra ut och dock vill ta’ filen [filosofie kandidatexamen]. Kommer den att fullfölja sin afsigt så borde det dock vara något med den flickan.23

Denna fixering vid utseendet är genomgående i de manliga akademikernas skildringar av akademins kvinnor, vare sig det handlar om att ge stöd för den allmänna uppfattningen att studentskor var manhaftiga eller att, likt Ångström, berömma deras utseende. De kvinnor som männen uppfattade som ”vackra” och som intog en mer traditionell kvinnoroll verkade utgöra ett mindre hot emot männen och accepterades lättare. De kvinnor som däremot uppfattades som ”fula” skilde sig tvåfalt från den accepterade kvinnobilden, dels genom sin belästhet, dels genom sitt utseende, och blev därmed ett hot mot manligheten.[24] I fallet med Ångström verkar han dock även vara intresserad av studentskans kompetens.

Professor Knut Ångström kom senare att samarbeta nära med Eva von Bahr. Hon skriver att hon trivdes mycket bra med honom och Ångström i sin tur verkar ha varit mycket nöjd med hennes arbete.[25] Det nära samarbetet mellan en manlig och en kvinnlig kollega verkar emellertid inte ha fallit i god jord hos alla, följande passage kommer från Anna Beckmans självbiografi:

> Ångström hade lagt bort titlarna med henne - annars förekom just inte titelbortläggning mellan manliga och kvinnliga kontrahenter. Eva hade vunnit hans hjärta. Vaktmästare Lans, som assisterade ibland, när prof. Ångström ordnade experiment talade med vämjelse om vilket oerhört ”Knutande och Evande det var”.[26]

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[23] Brev från Knut Ångström till hustrun Hélène 16-17/9 1891, citerat i Widmalm (2001), s. 343

[24] Rönnholm (1999), ss. 172-174

[25] von Bahr-Bergius

[26] Beckman

Vaktmästare Lans var dock inte den enda som retade sig på Ångström och von Bahrs samarbete. Laborator Granqvists förakt för studentskor var allmänt känt – bland annat drev den kvinnliga studentföreningen med det i ett spex – och enligt Anna Beckman ansåg han att Ångström gett Eva von Bahr fördelar.

Eva von Bahr skriver dock i sin självbiografi att hon aldrig haft några svårigheter med Granqvist.[27] Hon visar emellertid i ett samtida brev att hon är klart medveten om Granqvists kvinnosyn och kanske var det just farhågor om att möta ett större motstånd från honom än hon kom att göra som bidrog till att hennes förhållandevis välvilliga beskrivning av Granqvist i självbiografin:

> Granqvist är rörande hygglig, då man betänker, att han knappast var vidare belåten med att få en kvinnlig amanuens på halsen.[28]

Gulli Rossander, Eva von Bahr och Anna Beckmans självbiografiska texter är fyllda med berättelser om det anmärkningsvärda i förekomsten av kvinnliga akademiker. Gulli Rossander beskriver till exempel hur matematikdocenten Ernst Pfannenstiel mycket förtjust berättat för sina matlagskamrater om den ”märkvärdiga händelsen att han fått två kvinnliga kollegianter”.[29] Detta inträffade under Gulli Rossanders första år vid universitetet, alltså läsåret 1887/88, och man får väl ha en viss förståelse för Pfannenstiels häpnad, de kvinnliga studenterna utgjorde trots allt endast omkring en procent av det totala antalet studenter.[30] Ett tjugotal år senare, när Eva von Bahr under det tidiga 1910-talet undervisar på Fysikum, anses dock kvinnor ännu inte som en naturlig del av akademin:

> Och det visade sig till [laboratorns] stora förvåning att en kvinnlig assistent på laboratoriet inte åstadkom någon revolution utan att allt gick lugnt och bra. Visst märkte jag att en del av studenterna tyckte att det var en smula löjligt att bli undervisade av en kvinna och en och annan fanns som hade lust att skoja en smula. Men de funno snart att också jag tyckte det var ganska lustigt och så kom vi bra överens.[31]

Kvinnorna sågs alltså inte som en naturlig del i den akademiska gemenskapen. De arbetade visserligen tillsammans med männen i laboratoriet, men var utestängda från stora delar av den sociala gemenskapen, att delta i männens disputationsmiddagar var till exempel inte aktuellt.

[27] von Bahr-Bergius, s. 29
[28] Brev från Eva von Bahr till Gulli Rossander 7/2 1909, GP A10:6, GUB
[29] Petrini (1937), s. 133
[30] Rönnholm (1999), s. 38
[31] von Bahr-Bergius

För en nutida läsare är något av det mest slående i Gulli Rossander, Eva von Bahr och Anna Beckmans skildringar av sin Uppsalatid den mycket ljusa bild de alla ger, diskriminering och underordning talas tyst om. Att förtrycket fanns där och att de tre kvinnorna var medvetna om det, är det emellertid nog inga tvivel om, även om de inte ville se sig själva som förtryckta på det individuella planet. Om inte annat så tyder ju deras engagemang i kvinnofrågor under studietiden i Uppsala Kvinnliga Studentförening och senare inom politiken på det. Det bör dessutom påpekas att det är mycket lätt att bli anakronistisk när man försöker sätta sig in i hur människor i en annan tid tänkte och kände, vi ser ett manligt förtryck när vi läser om förra sekelskiftets universitet, studentskan kanske såg en värld med större frihet än hon någonsin tidigare upplevt.

Käll- och litteraturförteckning

Källor

Beckman, Anna, *Annas minnen*, opublicerad självbiografi i datoravskrift av Olof Beckman. I familjens ägo.

Göteborgs universitetsbibliotek, Kvinnohistoriska samlingarna (GUB)
Gulli Petrinis samling (GP)

Petrini, Gulli (1937), Från de första kvinnliga studenternas tid i Thulin, Sven (red.), *Uppsalaminnen. Hågkomster och livsintryck av svenska män och kvinnor XVIII*. Uppsala.

Vetenskapsakademins arkiv (VAK)
von Bahr-Bergius, Eva, *Minnen från ett långt liv*, deponerad kopia av självbiografisk anteckning.

Litteratur

Benckert, S. (1997). Är fysiken könlös? Reflektioner kring ett universitet ämne. i *Makt & kön*. G. Nordborg, B. Östlings Symposion.

Benckert, Sylvia - Staberg, Else-Marie (2000), *Val, villkor och värderingar. Samtal med kvinnliga fysiker och kemister*. Umeå.

Danielsson, Ulf (2003), *Stjärnor och äpplen som faller. En bok om upptäckter och märkvärdigheter i universum*. Falun.

Kaiserfeld, Thomas (1999), Laboratoriets didaktik: Fysiken på läroverken i början av 1900-talet. i Widmalm, Sven (red.), *Vetenskapsbärarna. Naturvetenskapen i det svenska samhället 1880-1950*. Hedemora.

Markusson Winkvist, Hanna (2003), *Som isolerade öar. De lagerkransade kvinnorna och akademin under 1900-talets första hälft*. Eslöv.

Rönnholm, Tord (1999), *Kunskapens kvinnor. Sekelskiftets studentskor i mötet med den manliga universitetsvärlden*. Umeå.

Widmalm, Sven (2001), *Det öppna laboratoriet. Uppsalafysiken och dess nätverk 1853-1910*. Malmö.

Artikeln ”Kvinnor i Uppsala-fysiken omkring sekelskiftet 1900” har tidigare publicerats i Kosmos 2004 (redaktör Leif Karlsson) som en del i ”Kvinnor i fysik”. Vidare är artikeln baserad på min C-uppsats i historia, författad höstterminen 2003.

Lästips

För den som vill fördjupa sig i Uppsalafysiken omkring sekelskiftet 1900 rekommenderas Sven Widmalms *Det öppna laboratoriet. Uppsalafysiken och dess nätverk 1853-1910* (Malmö, 2001). Om de svenska fysikernas karriärmöjligheter 1900-1950 har Thomas Kaiserfeld skrivit i *Vetenskap och karriär. Svenska fysiker som lektorer, akademiker och industriforskare under 1900-talets första hälft* (Lund, 1997). För den som är intresserad av förra sekelskiftets kvinnliga akademiker rekommenderas Tord Rönnholms *Kunskapens kvinnor. Sekelskiftets studentskor i mötet med den manliga universitetsvärlden* (Umeå, 1999) och Hanna Markusson Winkvists *Som isolerade öar. De lagerkransade kvinnorna och akademin under 1900-talets första hälft* (Eslöv, 2003).

Populärvetenskaplig introduktion

Vad du nu håller i din hand är alltså en licentiatavhandling i fysikens didaktik – med andra ord kommer det alltså att på något sätt handla om lärande och fysik. Detta är något man kan närma sig på många olika sätt: Vissa forskare har intresserat sig för hur studenter förstår och/eller missförstår mekanik. Andra har undersökt vad studenter ser som bra fysikundervisning.

Fokus i denna avhandling ligger på hur studenter lär sig att bli fysiker, *hur de skapar sig identiteter som fysiker*. I synnerhet är jag intresserad av vilken roll kön spelar i detta identitetsskapande. Kön som analysvariabel blir viktigt dels till följd av den stora mansdominansen inom fysiken[1], dels eftersom det är en mycket viktig del i vår identitet.

Till att börja med kommer jag att diskutera två centrala begrepp vi alla har en vardagsförståelse av, men som i denna avhandling har mer specifika betydelser, nämligen lärande och kön. Jag arbetar inom en tradition som brukar kallas *situerat lärande*. Centralt inom denna tradition är att kunskap ses som konstruerad i ett socialt sammanhang. Lärande sker genom att man deltar i en *praktikgemenskap* (t.ex. fysikergemenskapen eller varför inte ett fotbollslag), endast genom att delta i praktiken kan vi lära oss den. Därför intresserar man sig snarare för hur studenter lär sig en viss praktik, t.ex. det att vara fysiker, än hur de lär sig specifika fysikbegrepp. Lärande brukar därför karakteriseras som en identitetsutveckling. Mer om detta sätt att se på lärande finns i kapitel 3.

Vad det gäller kön har jag funnit det mest passande att se på detta som ett dynamiskt görande snarare än något medfött och statiskt. Inom poststrukturell genusteori talar man om att ”göra kön”; istället för att se kön som orsaken till våra handlingar ses kön som ett resultat av våra handlingar. Jag lutar mig framförallt mot en teoretiker som hävdar att kön, alltså maskuliniteter och femininiteter, kan ses som praktikgemenskaper, av samma slags som t.ex. fysikergemenskapen. Se kapitel 1.3.4 samt kapitel 3 för en vidareutveckling av dessa tankar.

[1] Idag är ca en tredjedel av fysikstudenterna på grundnivå kvinnor, och ca sju procent av fysikprofessorerna.

Situerat lärande och poststrukturell genusteori är alltså den teoretiska bakgrunden till min forskning, men vad är det då jag gör? Min forskning tar sin utgångspunkt i intervjuer med tretton studenter på Naturvetarprogrammet, inriktning fysik, vid Uppsala universitet. Med dessa studenter höll jag intervjuer där vi pratade om arbetet i kurslaboratoriet, exempelvis vad de ser som viktigt att vara bra på och vad de ser sig själva som bra på. Mot slutet av intervjun pratade vi också om vilken roll kön spelar inom fysiken. Utifrån dessa intervjuer försökte jag sedan skapa förståelse för hur studenter skapar sig könade identiteter som fysiker – i relation till det rent handgripliga fysikarbetet i kurslaboratoriet. Med andra ord, hur studenterna gör kön samtidigt som de gör fysik. För att kunna analysera denna process av identitetsskapande har jag sedan konstruerat ett nyskapande teoretiskt ramverk. Detta ramverk utgår ifrån situerat lärande och poststrukturell genusteori. Att gå in på detta mer i detalj ligger utanför ramen för denna populära introduktion, och den intresserade läsaren hänvisas till kapitel 3.

Min forskning är vad som brukar beskrivas som *kvalitativ forskning* (i motsats till kvantitativ forskning). Kvantitativ forskning är som namnet antyder inriktad på kvantitet, eller antal, att genom mätningar beskriva vår omvärld. Kvalitativ forskning å andra sidan intresserar sig mer för underliggande processer, för att skapa förståelse för olika fenomen snarare än att söka mätbara fakta. Enkelt uttryckt kan man säga att kvalitativ forskning söker svara på frågorna *Hur?* och *Varför?*.

Resultaten av min intervjuundersökning presenteras i kapitel 6. Inte överraskade gör många av de intervjuade studenterna en tydlig koppling mellan fysik och maskulinitet. Vid en mer detaljerad analys framträder emellertid olika maskuliniteter i studenternas identitetsskapande; en fysikermaskulinitet fokuserad på analys och en fokuserad på det praktiska handlaget. Jag ger här ett exampel på hur en student, Ann, hanterar dessa olika maskuliniteter och vad hon beskriver som en ”normal femininitet” i sitt identitetsskapande. För fler exempel och en diskussion kring dessa hänvisas till kapitel 6.

Ann upplever fysiken som mycket ”öppen”, där en rad möjliga maskuliniteter och femininiteter kan finna sin plats. Ann är emellertid på det klara med att hon i sitt identitetsskapande strävar efter att delta i den analytiska fysikermaskuliniteten, hennes fokus i labbet ligger helt på analys – det praktiska arbetet ser hon sig själv som dålig på. Lika viktig som identifikationen med den analytiska fysikermaskuliniteten är för Ann motidentifikationen med vad hon karakteriserar som en normal femininitet. Hon återkommer gång efter annan till hur hon inte är som andra kvinnor. Denna motidentifikation kan förstås som ett sätt för Ann att hantera det att vara kvinna i ett traditionellt mycket mansdominerat yrke; genom att positionera sig som icke-feminin kan hon samtidigt positionera sig som fysiker.

Sammanfattningsvis kan man säga att kärnan i denna licentiatavhandling är det teoretiska ramverket i kapitel 3. Styrkan med detta ramverk är att det inkluderar genusteori i en lämplig teori om lärande och därigenom låter oss se kön som en aktiv process och vidare relaterar denna process till studenternas skapande av fysikeridentiteter.

1 Introduction

> To the great surprise of the associate professor it was clear that a female assistant in the laboratory caused no revolution; everything went smoothly and well. Sure, I noticed that some of the students thought it was a bit ridiculous to be taught by a woman and there were a few who tried to joke around a bit. But they soon realised that I thought it was quite funny as well and then we got along well.

The above quote comes from the autobiography of Eva von Bahr, one of the first female PhDs in physics in Sweden and the first women to teach physics at Uppsala University. The episode described took place around 1910, at a time when females were prohibited by law to be hired as, for example, professors. Those bans have long since been lifted, but physics is still a heavily male dominated discipline. For example, in 2005 only seven percent of Swedish physics professors were women (Statistiska Centralbyrån).

The female under-representation in physics is what triggered my interest in gender and physics in the first place and is also the background against which my research can be seen. However, my research is not concerned with the investigation of this ‘problem’ *per se*.

My focus is on how gender affects students learning experiences in their physics education. This will first and foremost provide insight into students’ learning of physics, but in the longer run possibly also help us to understand why so few women start studying physics and even fewer continue to higher academic positions. The starting point of my research is that physics, despite of (or rather because of) its perceived objectivity and gender-neutrality, has its own cultural features – what Traweek (1988) characterized as ‘a culture of no culture’. With this in mind I explore how the cultural boundaries of the discipline are experienced by the individual student when doing laboratory work in physics.

I have thus chosen to focus on one part of the physics education, the laboratory work. The primary reason for this choice of focus is how complex a learning situation the laboratory is.

Laboratory work is generally seen as an opportunity for students to learn problem solving and develop their understanding of physics as well as to understand how the science community works; to eventually be able to take part in the community themselves. Such a setting opens up an unparalleled opportunity to talk to students about how they experience learning the doing of science and how they relate this to what it means to become a physicist.

1.1 Research Question

The guiding question of the research presented in this thesis is:

How do undergraduate students in the context of laboratory work constitute physicist identities in relation to the cultural norms of the university-based physics community?

Underpinning this research question is a theoretical assumption that gender is something we ‘do’, by either maintaining or challenging gender structures. Thus, the research is centred around how students do gender simultaneously with their doing of physics. The focus of the empirical investigation presented in Chapter 6 will be on the questions:

- What are the gender manifestations underpinning students’ identity formation in the physics student-laboratory?
- How do different students experience themselves as constituting their physicist identities in relation to these gender manifestations?

1.2 Outline of the thesis

In the introduction a background to my research has been given, and the research questions presented. I continue introducing the reader to research on gender and science. Chapter 2 consists of a literature review, where an overview of previous research within physics education research is given, aiming to situate my study within this field of research. In Chapter 3 – the core of this thesis – a conceptual framework for investigating the guiding research question is developed. In Chapter 4 the research method is described. Chapter 5 reviews previous research on gender and physics, and in Chapter 6 an analysis of the empirical study is presented. The thesis is concluded by a discussion in Chapter 7 and a perspective on possible future research in Chapter 8. Finally, I share with you some afterthoughts in Chapter 9. In an appendix you will find a more popular introduction to gender and physics as well as my interview protocols.

1.3 Conceptualising gender

The gender perspective employed in this thesis draws inspiration from two principal sources; research on gender and science (in particular feminist philosophy of science) and post-structural gender theory. Each of these sources will contribute with their own important insights for my research. In the following section I will first provide a brief introduction to the concept of gender and how my understanding of this concept has evolved. I will then move on to discuss how gender and science education has been conceptualised historically and also give an introduction to feminist philosophy of science. Finally, post-structural gender theory will be discussed.

I am well aware that some of these issues are repeated in later chapters, the reason for this is primarily that I want the chapters to be as independent as possible, allowing a piecewise reading of the thesis.

1.3.1 What is this thing called gender?

Gender is not easily defined, but it can be understood as socially constructed ideas of what it means to be male and female. It is a relational concept: what is seen as male or female receives its meaning in relation to the other. The characterization of the notion of gender used in this thesis will be further elaborated in section 1.3.4., where one perspective of gender – the post-structural one – is presented and argued for. A key notion in this perspective is that gender is taken to be something we 'do', not something we are born with. A very readable introduction to this view of gender can be found in, for example, Elvin-Nowak and Thomsson (2003).

One way of understanding the complexity of the gender concept is through Harding's (1986) portrayal of *individual*, *structural* and *symbolic* gender. *Individual gender* has to do with the individual's construction of their gender identity. *Structural gender* has mainly to do with the sharing of labour by sex. For example, most people working in physics, especially in more senior positions are men and the structural gender of physics can therefore be perceived as male.[1] *Symbolic gender* is constructed through language, by dichotomies such as subjective-objective, emotional-logical, where the latter word is associated with physics as well as masculinity.

To give you some idea of how my own view of gender has evolved I share an excerpt from an essay I wrote for a graduate course entitled 'Gender, science and education':

[1] One way the male structural gender of physics affects the female students in the field is through the lack of same-sex role-models; presence of female faculty can make female students more confident that they belong in their field of study and can succeed too.

My view of gender: A knowledge journey

I began the course with a rather unformulated and fragmentary knowledge about gender. My previous knowledge in the area consisted among other things of an introductory course to gender and science called ‘Kvinnor, män, naturvetenskap och framtid’[2], where we for example read some of Sandra Harding’s work. I had also met the concept of gender in my history studies, then mainly through Yvonne Hirdman’s texts. During my first six months as a PhD student I had also been reading particularly about gender and physics, on my own. I had a certain, but not so well supported, view of gender as something that is made by the individual rather than something inborn; that our gender identity is something created, something constructed. This was (is) a view that for me is just as much founded in thoughts about my own femininity and masculinity as in book-learned knowledge. To develop my knowledge of gender has for me therefore just as much to do with personal as professional development. My time as a PhD student has consequently for me to do a lot with personal development, but in the quest for knowledge there is also a political project. Seeing gender as something significant is for me a political, feminist statement and consequently I view myself as a feminist. Furthermore, this standpoint is something I believe is important to inform my future readers about; that my research, like any other research, has a political dimension.

During the course my earlier, quite fragmentary knowledge about gender – and in particular gender in relation to science – has been growing together into a more comprehensive picture, I have started to put the earlier pieces together, started to see the links. Above all I have begun to get an overview of how gender as a concept has developed since the beginning of the 1980s; to read Brian Easlea’s (1986) article from the early 1980s and be able to see his confusion about the concepts gender and sex was an ‘aha’ experience. The course’s historical overview might be what has mostly contributed to giving me a more consistent view of what gender is.

I first met the thoughts of Sandra Harding in the course ‘Kvinnor, män, vetenskap och framtid’ and I do believe that this could have been the first time I fully realised how the concepts of gender and sex differ, how gender includes so much more than the individual. Harding’s division into individual, structural and symbolic gender is for me one of the most important keys to understanding how something which is at first gender neutral (an academic discipline for example) can be seen as charged with gender – on a number of different levels. In my own research I focus very much on the individual, the particular physics student, and how their experiences of physics are affected by the gender of the discipline on a structural and symbolic level.

This knowledge journey, this development of my view of gender, is of course an ongoing one, which continues in this thesis.

[2] ‘Women, men, science, and future’

1.3.2 A brief history of gender and science education

The participation of women in science is a highly debated area and commonly the focus has been on how to attract more female students. There have been, and still are, however, several different ways to view ‘women and science’, or ‘gender and science’ for that matter. The most important shift was probably what Harding characterised as ‘from the women question in science to the science question in feminism’ (Harding 1986). In other words, instead of viewing women as the ‘problem’ that needs to be fixed, for example, that they need to learn to think more like men, it is science that is viewed as the ‘problem’, science itself needs to be critically examined.

Berner (2003) and Johnstone and Dunne (1996) examine the assumptions about gender and science that have underpinned discussions about a more inclusive science teaching. Johnstone and Dunne describe one type of research as centrally concerned with documenting differences in achievement or participation, sometimes seeking explanations for these differences in biology. Berner (2003) characterizes this research as ‘sex-roles research’ Another strand of research is seeking social explanations for gender differences, such as the effect of parental influence (Johnstone and Dunne 1996). What these perspectives have in common is an epistemological view that their findings represent the ‘truth’ about boys, girls, and science. Conclusions are of the type that girls, for example, prefer a certain kind of learning environment. From this perspective ‘a change in the situation, then, requires either girls to have experiences that compensate for their deficiencies or for the school learning environment to be altered to compensate for the learning styles of girls’ (Johnstone and Dunne, 1996, p. 58). Further,

> What must be recognised here is that the oppositions that are constructed, within both the research and the interventions which are developed from it, are constitutive of gender. They produce and reproduce the categories that they are assuming to describe. Ironically, in this production, the relationship that the research is seeking to challenge – the dominance of the masculine over the feminine – is reproduced through these oppositions. (Johnstone and Dunne, 1996, p. 59)

What Johnstone and Dunne (1996) are arguing for is research that engages with the dynamics of gender construction, that looks at how the dualistic gender relation is produced and reproduced in social practices, practices in which the said research is a part.

Berner (2003) describes how contemporary research more and more has turned away from the previous, often very passive view of female students as ’victim’, either of biology or of socialisation, and now instead focuses on their conscious choices. Gender is in this view seen as a question of choice and performance, rather than biological inherent behaviours or socialised norms. Here, focus has more and more moved towards looking at variations within the genders, their dynamics and diversity, not viewing them as a simple dualism. Furthermore, Harding (2005) points out that:

> Perhaps most illuminating has been the emergence of a critical focus on the masculinized culture of science and science education, and on how ‘doing science’ is a way of constituting certain kinds of social identity. (p 244)

It is within this last described development that I will situate my research.

1.3.3 Feminist philosophy of science

Feminist philosophy is philosophy conducted from a feminist perspective, but given the multitude of different feminist perspectives (see, for example, Gemzöe 2003) there is no such thing as a single feminist philosophy and consequently no one feminist philosophy of science. However, one of the key ideas in feminist epistemologies is a questioning of the traditional ways of knowing in science. Further, it is often brought to the fore how women’s voices and perspective traditionally have been ignored within science. Central to feminist science philosophy is the concept of the situated knower; how what is known reflects the perspective of the knower (Haraway 2003).

I will come back to this kind of critical examination of science in Chapter 5, where I discuss how the physics community can be seen as being influenced by gender. In the following I will introduce some of the ideas of two of the more well-known feminist philosophers of science; Evelyn Fox Keller and Sandra Harding.

Analysing the sciences in terms of gender has been, and can still be, highly controversial, something Fox Keller (1992) extensively discusses in her ‘Secrets of life. Secrets of Death’. Here she brings to the fore as a possible reason why such analysis can be problematic; that the scientific mind is at the same time viewed as masculine and disembodied. She strongly rejects the notion that women should do a different kind of science. This idea and its claim be feminist is in her view one of the great misconceptions about the goal of feminist critiques of science. Instead, she points to the liberating potential of feminism for both female scientists and for science as such:

> Despite repeated attempts at clarification, many scientists (especially, women scientists) persist in misreading the force that feminists attribute to gender ideology as a force being attributed to sex, that is, to the claim that women, for biological reasons, would to a different kind of science. The net effect is that, where some of us see a liberating potential (both for women *and* for science) in exhibiting the historical role of gender in science, these scientists of-

> ten see only a reactionary potential, fearing its use to support the exclusion of women from science. (Fox Keller, 1992, p. 20)

The insight that it is not the female scientists as such, but what can be learned from the feminist critique of science, that will change physics is central to my reading of Fox Keller's text. Here the focus is moved from women and their possible shortcomings to physics and its shortcomings. In a not too radical interpretation this could mean that physics, as it looks today, does not have a fundamentally mistaken worldview – it is just limited. It is therefore not about excluding the virtues of science in terms of objectivity, rationality and so on, but about being open to the idea that these can never give a full view of the world and that it is for the betterment of science and its development that one has to allow an inclusion of other qualities.

Harding (1991) makes a distinction between *bad science* and *science-as-usual* a distinction that can help to promote appreciation how gender in different views of science can be understood as influencing science. Bad science is here taken to mean activities and thinking that cannot be said to be scientific in any traditional sense. It can, for example, be about basing generalizations on a sample consisting only of males. If only bad science is viewed as a problem, the value neutrality of science becomes something highly desirable – whether it is positivism that could provide this value neutrality is, however, far from obvious.

Harding (1991) questions the fruitfulness of limiting the critique to bad science and describes the critics of bad science as caught between two loyalties. She argues that this leads to an attempt to stick to the dogma that good science can be produced without referring to its social origin, but at the same time believe that the women's movement could lead to better science. She argues that the critical examination of bad science, at best, could give a consciousness about equality to the science community and possibly clear away some sexist language without having the ability to add something fundamentally new to science's descriptions and explanations of the world. The critique of science-as-usual goes further than this with the epistemological claim that comprehensive, value neutral knowledge cannot exist. With inspiration from Marxist epistemology it is claimed that a hierarchical society can never reach complete knowledge since each person can only contribute with a knowledge perspective based on his or her place in the hierarchy. Whereas the critics of bad science strongly oppose the notion that women could do another kind of science the critics of science-as-usual suggest that women, in their role of being women, have the potential to bring powerful new resources to science. Only by working with (and against) science is it possible to make its character visible, that is, the sources of its power as well as its surprising weaknesses. An important tool in this work is women's experiences of being just women, mirrored in feminist theories. From this perspective, having a theory of science becomes absolutely crucial in order to make good science. In contrast to the views of Fox Keller (1992) women in the role of women can here contribute to the change and progress of science.

To summarize one can say that the goal of Harding's feminist critique of science seems to be to take science – and in particular physics – down from the pedestal that it has been placed on ever since the Enlightenment. Instead of physics, the critical and reflecting social sciences are seen as the desirable model for all sciences.[3] Moreover, one of the cornerstones in this argument as I see it, is Harding's proposition that science is impossible to separate from the society that creates it. This is based, among other things, on the fact that science and technology are mutually dependent on each other in order to make progress.

1.3.4 Post-structural gender theory

The concept of gender can be conceived of in a multitude of ways, but detailing all of these is beyond the scope of this thesis (for an informative introduction to gender see, for example, Connell 2003b). This is, after all, a thesis in PER, not gender studies – the difference being that whereas gender studies are concerned with the *development* of gender theories, researchers, like myself, who apply a gender perspective within a different area *make use of* gender theories. The gender theory I have found most appropriate for my research purposes is post-structural gender theory. In particular there are two aspects of this theory that I view as informative in the investigation of my research question. Firstly, gender is here seen as a process, something that is done, rather than a predetermined categorization label. Secondly, multiple gender manifestations are taken into account in that there is no single way of being a man or a woman.

Sowell (2004) makes a distinction between materialist and discursive accounts of gender, where post-structural gender theory belongs to the latter. Materialist accounts of gender view it as 'not an essential property of personality, but a structure that runs through the institutional, international, and individual spheres of life' (p. 25). Discursive accounts of gender, on the other hand, 'examine how individuals, within specific social settings, *create and negotiate gender*' (p. 26, emphasis added). Considering that the focus of my research questions is on individuals' identity formation, the discursive understanding of gender is arguably particularly appropriate. I find Butler's (1999) theory of performativity to be central to this understanding of gender;

[33] Here it can be added that today it is probably a somewhat old-fashioned idea to think that one kind of science – whether it is physics or the critical social sciences – can function as the role model for all research. Harding's thought is nevertheless an interesting starting point for further discussion.

here gender is portrayed as something fluid, something continuously changing, not an inherent characteristic of a person. Hey describes (2006) this as follows:

> The central poststructuralist ideas that the subject is an effect rather than a cause is the key to Butler's theories of performative identities. Deconstruction is thus a form of critique focused on examining the role of discourse in asserting forms of identity. (p 444)

Butler (1999) herself elaborates:

> In this sense, gender is not a noun, but neither a set of free-floating attributes, for we have seen that the substantive effect of gender is performatively produced and compelled by the regulatory practice and gender coherence. Hence, within the inherited discourse of the metaphysics of substance, gender proves to be performative – that is, constituting the identity it is purported to be. In this sense, gender is always a doing, though not doing by a subject who might be said to pre-exist the deed… There is no gender identity behind the expressions of gender; that identity is performatively constituted by the very 'expressions' that are said to be its results. (p 33)

To illustrate what performing of gender can mean in practice I borrow an example from Ambjörnsson (2004). She has studied how gender (as well as sexuality and ethnicity) is done by girls in secondary school; this is one way they can perform a certain kind of femininity:

> To walk down the school corridor with your book pressed against your chest, sit down at the bench next to another girl and giggling lean your head towards hers, are thus actions that in themselves create gender. However, it is not enough to once and for all giggle with girlfriends, dress in a skirt and put up your hair in a pony-tail. Gender has to be recreated continuously in order to be convincing. And it is this recreation – this eternal repetition – that means that gender not can be viewed as a static state. Rather it must be viewed as a verb, a continuous present tense – a process (Ambjörnsson 2004, my translation from the original Swedish).

In other words, it is only through a 'successful performance' that a person can attain the identity in a given context as man or woman. Further, the view of gender as performative is for Butler (1999) a way to break down gender binaries, to allow for a wider variety of possible ways of doing gender:

> The reconceptualization of identity as an *effect*, that is, as produced or generated, opens up possibilities of 'agency' that are insidiously foreclosed by positions that take identity categories as foundational and fixed. (p. 187)

In going beyond the dualistic view of gender as masculinity versus femininity the notion of multiple masculinities and femininities becomes important (Connell 2003a). Here Connell notes that even the existence of the terms masculine and feminine indicates that we do conceptualize gender as a range of practices, otherwise we would not need these terms and would only need to talk about men versus women, or possibly male versus female. Furthermore, I think it is the realisation that gender can be performed in a variety of ways that is able to open up a way for us to move away from a rigid dualistic view of gender.

Moreover, West and Zimmerman's (1987) notion of 'doing gender' can be seen as an enrichment of Butler's theory of performativity. They view gender as something that is done in social interactions and above all they emphasize the context dependence of this doing; how gender is done differently in different social contexts. They elaborate on this as follows:

> When we view gender as an accomplishment, an achieved property of situated conduct, our attention shifts from matters internal to the individual and focuses in international and, ultimately, institutional arenas. In one sense, of course, it is individuals who 'do' gender. But it is a situated doing, carried out in the virtual or real presence of others who are presumed to be oriented to its production. Rather than as a property of individuals, we conceive gender as an emergent feature of social situations: both as an outcome of and a rationale for various social arrangements and as a means of legitimating one of the most fundamental divisions of society. (West and Zimmerman, 1987, p 126)

For me, West and Zimmerman's characterizing of gender first and foremost serves as a reminder that the performativity of gender is a situated activity, which needs to be understood within a specific social context – in my case the university based physicist community.

2 Literature Review

2.1 Physics education research

Prologue

In physics education research we use a multitude of different theories and approaches to research[4], the more prevalent of which will be presented in the literature review that follows. I will here give a very broad overview of how (some) people within physics education research (PER) think about their research and how I have situated my research within that community.

I like to, in a broad sense, situate my own research within PER by using a *what* and *how* divide. First of all, one could say the physics education researchers are interested in both *what* students learn (the experience of the content) and *how* students learn (the experience of the form of teaching), with no absolute distinction between the two. Dealing with what students learn some researchers focus on students learning of specific concepts, whereas others focus on how students perceive physics and how they relate to the culture of physics; learning to think and act as physicists. When it comes to how students learn, physics education researchers tend to, very generally, either focus on how knowledge is constructed by the individual student or in the social interplay between students or between students and teachers. My research is about how students through the social interplay (in the student laboratory) learn to become physicists.

[4] Unlike physics, physics education research, is firstly a much younger science and secondly a science dealing with much more complex systems (students trying to learn physics!). It should therefore not come as a big surprise that physics education researchers are far from reaching a consensus on the most appropriate theoretical frameworks for their science.

2.1.1 Introduction

In a broad sense much of the existing physics education research (PER) deals with students' understanding of physics and is aimed at informing teaching and curriculum design for improving learning outcomes (Redish 2003; Thacker 2003). This interest stems from both a concern that traditional teaching methods might not be the most effective for teaching physics to an increasingly diverse student body, as well as concern about the decline in students choosing to study physics at university level (van Aalst 2000; Thacker 2003). Early work in PER grew out of university physics; concerned by the fact that many physics students seemed to emerge from physics teaching with substantial gaps in their understanding of physics, physicists began to conduct studies of the teaching and learning of physics. These studies were, due to the researchers' background in physics largely a-theoretical (McDermott and Redish 1999). Later, with inspiration from studies in general science education as well as fields such as ethnography and psychology more theoretical developments within PER started to emerge (see, for example, diSessa 1993 and Redish 1999). Outside of Germany, most PER has been empirical, and has included qualitative as well as quantitative studies. Methods used have been typically questionnaires and/or interviews (van Aalst 2000).

McDermott (1991) wrote that PER's most significant impact on instruction came from the need for a greater focus on the student in both teaching practice and curriculum design. In particular, transmission-based epistemology and its associated practice have been shown to be relatively ineffective for optimizing learning. Building on forms of constructivism it was argued that students need to construct their own knowledge and in this construction it is important that the knowledge the students already have is taken into account. While this still is very much the case it is important to remember, as pointed out by Heron and Meltzer (2005), that PER has also advanced well beyond documenting the shortcomings in student learning and of traditional methods of instruction – as the following literature review will show.[5]

2.1.1.1 Outline

The first part of this literature review consists of a (relatively chronological) overview of physics education research. The focus of this overview is on research trends and theoretical developments rather than on outcomes of individual studies, aiming to illustrate how PER over the years has progressed and broadened – a broadening that I argue this thesis forms a part of. Following the general PER overview a more focused introduction is given to

[5] Additional references, to the ones mentioned in this literature review, can be found in the PER resource letters by McDermott and Redish (1999), Thacker (2003) and Falk et al. (in review).

physics education research closely related to my research question, namely research within the areas concerning gender and laboratory work. In the final section I situate my thesis in relation to previous research traditions.

2.1.2 Students' conceptions

One of the major trends in PER has been the investigation of students' so called naïve understandings of the physical world and how those understanding differ from those of the physics discipline. These student understandings have been characterized as, for example, misconceptions, alternative conceptions and alternative frameworks. The more systematic investigations of students' 'misconceptions' in physics began in the late 1970s; Warren (1979) summarized some difficulties student had with understanding the concept force and also suggested some pedagogical implications. Later Helm (1980) described a number of 'misconceptions' in various fields of physics among South African students. Two early seminal papers dealing with students' understandings of Newtonian mechanics are Clement (1982) and McCloskey (1983). Clement was able to show how many physics students possess stable conceptions regarding the relationship between force and acceleration. His conclusion is that, 'apparently one cannot consider the student's mind to be a "blank slate" in the area of force and motion' (p. 70). McCloskey (1983) carries the argument forward that people, based on their everyday experiences, form well-articulated theories of motion, that can be best characterized as a 'naïve impetus theory'. However, later research questioned whether students' ideas are consistent enough to be viewed as naïve *theories*. Halloun and Hestenes (1985a; 1985b) could, for example, conclude that students seemed to possess a mixture of concepts and that they were inconsistent with their applications of such concepts. Finegold and Gorsky (1991) also reached a similar conclusion, with the exception that they found some consistency in students' conceptions regarding forces acting on objects in motion.

The work on students' conceptions also helped to give rise to an influential model for learning called 'conceptual change' (see, for example, Posner et al. 1982). The basic idea in conceptual change is that a person exchanges an existing conception for a more suitable alternative conception, by coming to understand how this alternative conception is more intelligible, plausible and/or fruitful than the existing conception (Hewson 1982). Duit and Treagust (2003) describe how this is usually done in practice:

> The classical conceptual chan ge approach involved the teacher making students' alternative frameworks explicit prior to designing a teaching approach consisting of ideas that do not fit the students' existing ideas and thereby promoting dissatisfaction. A new framework is then introduced based on formal science that will explain the anomaly. (p. 673)

The conceptual change model has been extensively debated, developed and criticized. For example, from a physics perspective, it was challenged by Linder (1993) who argued that it is inadequate to portray meaningful learning as a change of conceptions. Since, without consideration of the context even many physics conceptions cannot be viewed as ‘correct’ or ‘incorrect’, thus the notion of conceptual change as a model for learning needs to be understood in terms of changing one’s relationship with the context.

Initially most of the research on students’ conceptions were situated in mechanics, but later there has was an expansion into other areas, such as thermodynamics (for example, Yeo and Zadnik 2001), optics (for example, Goldberg and McDermott 1987; Singh and Butler 1990; Ambrose et al. 1999; Colin and Viennot 2001), mechanical waves (for example, Wittmann et al. 1999), electromagnetism (for example, Maloney et al. 2001), special relativity (for example, Hewson 1982) and quantum mechanics (for example, Mashhadi 1994; Petri and Niedderer 1998; Müller and Wiesner 2002; Domert et al. 2005).

In summary, ‘[a]mong those who follow or participate in science education research, it has become standard to accept that students come to courses with conceptions that differ from scientists’ and must be addressed in instruction’ (Hammer, 1996, p. 1319). How this ought to be done in practice is, however, a highly debated question. One approach that has been used to address misconceptions in learning is the *elicit, confront, resolve* approach, where a conceptual conflict between a widespread misconception and the corresponding expert conception is generated, that the students then, are required to resolve (Shaffer and McDermott 1992). The research on student conceptions has thus given rise to the development of teaching methods (see section 2.1.5) and also the development of theories of learning (see section 2.1.3).

2.1.3 Development of theories of learning

As pointed out by Smith et al. (1993-1994) much of the research into students’ conceptions has been largely a-theoretical; aiming to describe students’ conceptions rather than developing theoretical frameworks to relate students’ conceptions to their learning. Smith *et al.* furthermore criticizes much of the conceptions framework for its lack of developing mechanisms for change of conceptions. In short, they consider the depiction of a ‘misconception’ as something that needs to be confronted and replaced as being inconsistent with a constructivist perspective on learning. Within the constructivist perspective of learning the focus is on how more advanced knowledge states (for example, expert understanding of physics) are contiguous with prior knowledge states (for example, novice understanding of physics). Consequently Smith et al. (1993-1994) argue that there are more similarities between expert and novice understandings of physics than first was apparent. For example, novices do use highly abstract entities in their reasoning about physics problems and naïve physical conceptions do continue to play an important role in experts reasoning. Thus, differences between novice and expert reasoning differ more in *quantity* rather than in *quality*, and what will 'shift' as a novice moves to a more expert understanding of physics is not the concepts themselves, but the contexts wherein they are applied. In other words, misconceptions are characterized as 'faulty extensions of productive prior knowledge' (Smith et al., 1993-94, p. 152). diSessa (1993) makes a similar argument in his 'Towards an Epistemology of Physics'. At the heart of his argument is the view that novice physics learners' ideas about the physics world do not constitute an organized structure. Instead, he argues that novice physics learners posses a set of loosely connected ideas that are evoked in particular situations. He refers to these constructs as phenomenological primitives (p-prims). P-prims are, according to diSessa, based on experience (thus, the name) and linked to specific phenomena. In our learning of physics these p-prims become refined, not replaced. Here Hammer and Elby (2002) point out:

> The ontology of p-prims has several advantages over the ontology of conceptions. First, it provides theoretical structure to account for the sensitivity to context of students' reasoning, as different p-prims are more or less likely to be activated in different circumstances. Second, it provides an account of productive cognitive resources from which students may construct more adequate understanding.

Hammer et al. (2004) have, using a cognitivist approach, developed diSessa's (1993) ideas. They argue that conceptions are too large a cognitive unit for understanding students' learning and suggest an approach based on the idea of the more fine-grained *resources*[6]. A resource, for example, could be 'more effort implies more result' or an intuitive sense of 'balancing'. Thus, resources cannot be thought about as correct or incorrect (as in the case with 'misconception'), but a key to an expert understanding of, for example, physics is to apply the appropriate set of resources for a given context. Consequently, learning is described 'not as the acquisition or formation of a cognitive object, but rather as a cognitive *state* the learner enters or forms at the moment, involving the activation of multiple resources' (p. 5). Hence, a crucial aspect in Hammer et al.'s (2004) view of teaching is one of helping students to gain knowledge of the cognitive resources they already have and to be able to apply these appropriately across different contexts. This could be characterized as a metacognitive teaching approach.

[6] They use the term resources as a generic term for p-prims and epistemological primitives (see section 2.1.4.1)

In summary, there has been a move from viewing students' ideas as problematic misconceptions that need to be confronted and replaced to a view of them as resources for learning that can be developed through teaching. This is consistent with taking a constructivist perspective to view student learning. Smith (1993-1994) formulates this point of view as follows:

> Rather than opposing [students' misconceptions] to the relevant expert view, instruction should help students reflect on their present commitments, find new productive contexts for existing knowledge, and refine parts of their knowledge for specific scientific and mathematical purposes.

2.1.4 New directions in PER

Early research within PER was, as I have pointed out, largely focused on students' (mis)conceptions. Recently, the scope of PER has broadened within two important theoretical domains; epistemology and metacognition.

2.1.4.1 Student epistemology

One of the more important theoretical areas of growth in PER is in epistemology. I will primarily focus on two different types of research within this domain. Firstly, on research seeking to build a cognitive model for students' epistemologies. Then secondly, on research focusing on the relationship between students' epistemologies and their approaches to learning.

Elby and Hammer, applying the resource perspective described earlier in relation to students conceptions, have developed a cognitive model for students' epistemology (Elby and Hammer 2001; Hammer and Elby 2002). Their starting point is a critique of what they claim to be a general consensus among the majority of researchers examining student epistemology, namely that students, for example, ought to understand science as 'fundamentally tentative and evolving rather than certain and unchanging' (Elby and Hammer, 2001, p. 555). Their argument is that this sort of claim is far too general to be helpful for better understanding of student learning. Thus 'epistemological stances' need to be understood as context dependent and, further, that it is important to distinguish between the correctness and the productivity of epistemological beliefs. For example, viewing knowledge as tentative rather than certain is neither productive nor correct across all contexts. Viewing Newton's laws as certain might, for example, be productive for introductory physics students, but not for more advanced physics students (Elby and Hammer 2001).

The projected context-dependentness of epistemological beliefs is further elaborated by Hammer and Elby (2002). They argue that instead of viewing epistemologies in unitary terms, they should be viewed as consisting of epistemological resources that are neither correct nor incorrect, but which need to be applied in their appropriate contexts.

Building on previous research in PER as well as fields such as neuroscience and sociolinguistics, Redish (2004) formulated a suggestion for an overarching theoretical framework for understanding students' learning of physics, that included notions of conception and epistemology. The framework can be seen to be rooted in research on human cognition. Redish (2004) describes the core of his theoretical framework as follows:

> At its core, my theoretical framework describes student knowledge as comprised of cognitive resources in various forms and levels of hierarchy. Within each level is a collection of resources that are primed, activated, and deactivated depending on context and control. (p. 16)

Thus, both in dealing with students' conceptions and their epistemologies Redish models them in terms of resources. Within a certain context, a certain frame, a number of associated resources will be activated. Hence, learning physics is largely about 'reorganizing' the students' existing resources. Consequently, for a teacher it is of crucial importance to 'frame' not only the actual problems in a way that activates the appropriate resources, but also to 'frame' the learning situation in a way that activates the most useful epistemological resources. This idea is further developed by Redish (2004) as he discusses possible implications of his framework both for instruction and for research.

Another strand of research on student epistemologies has focused on the relationship between students' epistemological stances and their approaches to learning (see, for example, Linder and Marshall 1998 and Ryder et al. 1999). Linder and Marshall's (1998) starting point is an introductory physics course designed with the purpose of making students become independent, lifelong learners, through developing students' reflections on their own learning to create a metacognitive epistemological framing. In their study, in the beginning of the course all students were voicing relatively unsophisticated views of learning as well as

A. science as discovery or 'knowing about the world'
B. science as accumulation of fact and explanations of how things are and how they work
C. science as a process of enquiry undertaken by 'scientists'
D. science as an accessible way of looking at the world and, as such, part of everyday life
E. science has a social dimension
F. science as empowering

Table 1.

of science, characterized as belonging to categories A, B and C in table 1. At the end of the course students had essentially shifted their perceptions to in categories D, E and F. Furthermore, the students were also voicing what was categorised as more sophisticated views on learning. Their final conclusion was that ‘such an epistemological framing can profoundly influence students’ conceptions of science and conceptions of learning’ (Linder and Marshall, 1998, p. 116).

Ryder et al. (1999) carried out a related study where they investigated how undergraduate science students developed their views about the nature of science during project work. Their investigation was focused on three different areas; the relationship between data and knowledge claims, the nature of lines of scientific enquiry and science as a social activity. They were able to identify two key areas of development: ‘the role of theory in guiding the questions which scientists investigate and the significance of critical experiments and procedures in the proof of scientific knowledge claims’ (Ryder et al., 1999, p. 215). However, such development was not in relation to the perceived significance of social processes in science.

An interesting study in this context was done by Lising and Elby (2005), who were able to show how a student’s personal epistemology had a direct, causal influence on her learning. Further, just as numerous tests have been developed in order to probe students’ conceptions in various content areas, similar tests have been developed in order to probe students’ epistemological beliefs. Two examples of such tests are the well-known Maryland Physics Expectations Survey (Redish et al. 1998) and the Colorado Learning Attitudes about Science Survey (Adams et al. 2006).

So far, studies on students’ epistemologies, albeit of different kinds, have been discussed. However, the question of the impact of epistemology on the learning of physics can also be approached from a different perspective; by looking at how teachers’ epistemological stances affect their teaching. Two examples of such studies are Linder (1992) and Hammer (1995). Linder (1992) argues that ‘teacher-reflected epistemological commitments may be influencing physics teaching and its outcomes’ (p. 120). In particular, he brings to the fore how a view of physics as being ‘an on-going collection of mind-independent facts about objective reality’ (p. 111) can be a source of conceptual difficulty among students since this view can encourage students to rote-learn facts rather than reflecting on their own understanding. Hammer (1995) takes on a different dynamic by exploring how a view of students as having epistemological beliefs can motivate a shift in teaching, from traditionally solely content-oriented towards including epistemological objectives.

2.1.4.2 Metacognition

Outside of cognitive science metacognition is often taken to represent 'thinking about one's own thinking'; the ability to reflect upon and have control over one's own learning (see, for example, Gunstone 1991 and Georghiades 2004). Thus, metacognition is increasingly becoming considered as an important part in successful learning. This is particularly true for constructivists, where the metacognitive learner is typically characterized by an ability to recognize and evaluate existing ideas, and where needed, replace those ideas (Gunstone 1991). Research on metacognition within physics education is a relatively new and rather undeveloped area. Examples of such studies are Linder and Marshall (1997) and Koch (2001) where metacognitive techniques for improving students' comprehensions of physics texts are developed and then evaluated. Metacognition in the context of the physics student laboratory is explored by Lippmann Kung et al. (2005). They argue that it is important to consider the outcome of metacognition, not just the amount and that whether students are encouraged to change their behaviour as a result of metacognition is dependent on the laboratory design. An excellent overview of research on metacognition, particularly in relation to science education, is given by Georghiades (2004).

2.1.5 Approaches to teaching

Studies of students' conceptions has, together with studies of students' epistemological beliefs, influenced the development of teaching approaches within physics (van Aalst 2000). One example of such development is 'Workshop Physics' (Laws 1997), where introductory physics courses are taught without lectures. The students instead engage in, for example, discussions with teachers and peers and use computer-based laboratory tools, all aiming to create an 'active learning environment'. Another insightful example of how PER have been used to develop teaching is 'Modelling Workshop' (Hestenes 1996; Etkina et al. 2006). Starting from a claim that construction, validation and application of scientific models is basically what scientists do, it is posited that this is also what we ought to teach our students. In other words, the focus here is on teaching students to think in a 'scientific way', rather, for example, than learning isolated concepts. By allowing the students to be included in the explicit construction of the representations used, their 'misconceptions' are argued to be indirectly challenged. Yet another example of a teaching method developed by physics education researchers is 'Physics by Inquiry' (McDermott 1991), where the teaching is embedded in the idea that 'physics should be taught as a process, not an inert body of information' (p. 306).

PER is also concerned with the evaluation of teaching. In doing so concept inventories such as the 'Force Concept Inventory' (Hestenes et al. 1992) and the 'Mechanics Baseline Test' (Hestenes and Wells 1992) have been commonly used. For example, using these tests Hake (1996) showed that the use of interactive teaching strategies enhance both students' problem-solving abilities and their conceptual understanding. Similar arguments about how students learn more from teaching that actively engages them in contrast to the kind of traditional teaching, which has students typically become passive observers, are also made by, for example, McDermott (2001), Meltzer and Manivannan (2002), Crouch et al. (2004) and Crouch and Mazur (2001).

2.1.6 Physics education research outside PER

Most of the research cited above could be classified as belonging to PER, however, there is also notable research on students' learning of physics outside the immediate PER community, such as work situated in education or science education. In this broader educational realm one, for example, finds research that could be referred to as 'student learning research' (see, for example, Prosser and Trigwell 2001). This kind of research is typically interested in questions such as how students' understanding of the subject matter is related to how they view the nature of learning and of their discipline (see, for example, Prosser et al. 1996a and Prosser et al. 2000).

To illustrate this research I exemplify a study by Prosser et al. (1996b). Here most students were classified as having a low-level understanding of how physics is best learnt, and students claimed that success was about innate abilities and/or hard work rather than how their studies were approached. Prosser et al. (1996b) also found that even though most students characterized physics as a study of the physical world, few of them approached their studies in terms of understanding the physical world.

2.1.7 Where do we go next?

Recently the area of PER has stared to expand in a whole array of directions and focus can no longer be said to be on students' conceptions of physics content. Contemporary research includes, for example, how the language of instruction affects the students' learning (Airey and Linder 2006), how physicists talk about physics (Ingerman and Booth 2003) and how the context plays an integral part for understanding the learning of physics (Finkelstein 2005). Other recent strands of research explore the scholarship of teaching and learning in relation to PER (Dominicus and Linder 2005) and undergraduate physics students' expectations of teaching (Linder and Marshall 2005).

In summary, this kind of diversity in research can be said to focus, through different perspectives, on broader cultural aspects cutting across the physics discipline. This thesis falls within this dynamic where gender is treated as such a cultural aspect, which permeates the discipline of physics as well as students learning of physics (Danielsson and Linder 2006). This idea will be further developed in section 2.3.

2.2 Situating the study in previous research

This study deals with how students, in the doing of laboratory work, develop a physicist identity and learn to become physicists and, further, how gender plays a role in this learning. In the following section previous physics education research on gender and on laboratory work is reviewed in order to map out how my study is situated in relation to previous work.

2.2.1 Physics education research and gender

To date the extensive number of gender studies within the PER community have commonly dealt with gender in the sense of 'closing the gender gap'; how to recruit more women to physics and make the teaching more gender inclusive, by using, for example, peer instruction or cooperative work (McCullough 2002). In the context of the 'gender gap' we also find numerous article where physics teachers share their experiences of the 'best' ways of teaching more gender-inclusively (for example, Norby 2000; Parker 2002; Blanton 2005). Further, there is also some research on gender specific approaches to learning in physics (Murphy 1991).

The extensive research on how to narrow the 'gender gap' can be said to be centred around two major themes; more inclusive teaching methods (see for example Etkina et al. 1999; Schneider 2001; Gustafsson 2005; Lorenzo et al. 2006) and integration of everyday examples that are believed to be relevant to both male and female students (for example, Duit et al. 1992; Benckert 2001; McCullough 2004; Williams 2006). It has, for instance, been pointed out that physics, having been male-dominated for such a long time, is filled with examples that tend to come from a male sphere of interest. One example of this is the widely used 'Force Concept Inventory' (Hestenes et al. 1992), where the questions concern such things as rockets, hockey pucks and cannonballs; the kind of settings that men would typically be expected to be more at home with than many women may (McCullough 2004). Two studies that report on female students responses to particular forms of teaching are Laws et al. (1999) and Heller and Hollabaugh (1992).

2.2.2 Learning in the student laboratory

Laboratory work is central to university science education, since it presents a unique opportunity to learn the essentials of scientifically based empirical activity; 'learning science by doing science' (Hofstein and Lunetta 2003). Doing laboratory work is widely considered helpful in generating an understanding of the natural world in terms of a scientific approach to enquiry (Millar et al. 1999). Learning in the student laboratory has consequently also been the subject of extensive research, as summarized in a review article by Hofstein and Lunetta (2003).

The student laboratory is a highly complex learning environment where students are expected:

- to *understand* theory (concepts, models, and laws) as described in textbooks and labsheets, or as explained during lectures;
- to *learn* concepts, models, and laws;
- to *do* various experiments, using different pieces of theory and different procedures, in order to acquire a significant experience;
- to learn to '*do again*' the same experiments, and to follow the same procedures as utilized during preceding sessions;
- to *learn* processes and approaches and be able to apply and follow them in other contexts;
- to *learn* to use scientific knowledge, think with it, as experts do, and acquire the capacity to manage during a complete investigation. (Séré, 2002, p. 625)

According to Millar et al. (1999) one of the main purposes of laboratory work is the linking of the domain of ideas to the domain of objects and observable things. Furthermore, the completion of laboratory tasks is argued to be dependent on three 'conceptual domains', namely:

> *Declarative knowledge:* knowledge and skills in practice relating to science concepts, i.e. the phenomena, laws, relationships.
> *Procedural knowledge:* knowledge and skills in practice relating to 'how to do science', i.e. the understandings underpinning the methods of scientific enquiry that the learner brings to and takes from laboratory work.
> *Communicative competence:* ability to participate in the scientific discourse community. (Rollnick et al., 2004, p. 17)

Overall, the research on laboratory work to date covers a wide variety of issues, very much in line with PER in general, such as, student conceptions (of, for example, measurements) (for example, Buffler et al. 2001; Lippman Kung 2005), student epistemology (for example, Séré et al. 2001; Wickman 2004), metacognition (for example, Davidowitz and Rollnick 2003) and new approaches to teaching and the evaluation of these (for example Allie et al. 1997; Johnstone et al. 1998; Hart et al. 2000; Cox and Junkin 2002; Allie et al. 2003). Research on learning in the student laboratory has further been summarized in review articles by Klainin (1988), Lazarowitz and Tamir (1994) and Hofstein and Lunetta (2003).

2.3 My study

I have presented PER as a research field that has moved from a strong focus on students' conceptions of the content of physics to a broadened interest in diverse student learning issues regarding student and teacher epistemology as well as fields such as metacognition and scholarship. However, research on gender and PER is still in its infancy with most of the research described in section 2.2.1 focusing on making physics more 'women-friendly'. To date no attention to gender on a symbolical level has yet emerged; gender in the individual students is seen without explicitly recognising that physics as a discipline also possesses gendered characteristics. As pointed out by Henwood (1996):

> the problems faced by women entering engineering or other areas defined as 'men's work' need to be understood within a much broader context of gender and work which examines how gender is constructed through work and by what mechanisms gender inequality is maintained (p. 212).

Consequently, this thesis brings to the fore yet another cultural aspect of physics (apart from, for example, epistemology) that needs to be understood in the quest to improve the experience of learning physics and learning outcomes. The argument is that in order to understand students' learning of physics, it needs to be seen against the backdrop of the norms and values that are tied to the discipline. Thus, students' experiences of learning and learning outcomes need to also be explored by drawing on the ideas of gender embedded in the physics disciplines ways of knowing.

Previous research, on laboratory work as well as on PER in general, has often focused on learning outcomes – how well the students perform in everything from problem solving to co-operative learning. Here it is seemingly taken for granted that the student who performs well is striving to be a member of the physicist community. Seymour and Hewitt (1997), however, in their social anthropological study 'Talking about leaving' clearly demonstrate that it is not necessarily so straight forward, particularly for students from non-traditional groups (for example, female physics students), since many of these, despite excellent achievements, choose to leave their science studies as they do not feel comfortable with the educational environments they find themselves in at science departments. The laboratory work which strives to include students in a future physicist community can thus only function if the students see this as something that is compatible with who they are and who they want to be. But, the reasons behind whether students are able to fulfil the goals or not are seldom discussed – or rather, the discussion seldom appears to reach outside the narrow limits of the scientific culture.

Part of the focus of this thesis represents a shift from laboratory exercises as such – and how well the students succeed in doing these exercises, to how students experience learning in relation to the cultural norms of the physics student community. In other words, this is not a study that investigates learning in the student laboratory *per se*, but rather is a study of the very complex learning environment of the laboratory in terms of 'doing science'. The laboratory setting is chosen because of its complexity; in this environment declarative knowledge, procedural knowledge and communicative competence are all essential ingredients in the learning setting.

Studies of this kind are more common in educational research situated in mathematics (for example, Herzig 2004; Mendick 2005; Rodd and Bartholomew 2006), engineering (for example, Henwood 1998; Tonso 1998; Walker 2001; Phipps 2002; Stonyer 2002; Sagebiel and Dahmen 2006) and computer science (for example, Stepulevage and Plumeridge 1998) than in PER. My study thus draws inspiration and methodological links from a diversity of studies dealing with students learning experiences in relation to the cultural norms of different scientific and technological disciplines.

Furthermore, the gender perspective I use is quite different from those of earlier gender studies in PER. In these earlier studies gender has been treated very much in an a-theoretical way; discussing it in terms of individuals yet rarely beyond that. In contrast, gender in this thesis is taken to be something people do; a view that allows for treating gender as an analytical tool rather than a way of grouping individuals. Moreover, I agree with Sowell (2004) that:

> By promoting 'female-specific intervention programs' the complexities of gender are not fully explored; in fact, they are greatly reduced. The underlying assumption is that all females express the same form of femininity and that all would benefit from the same type of 'female appropriate teaching strategies'. I would argue that such pedagogical approaches work to sustain existing gender inequalities by promoting the naturalness of what we consider male and female. (p. 58)

In other words, in order to do gender research that does not potentially reinforce stereotypical ideas of male and female it is necessary to consider a continuum of multiple masculinities and femininities, that are not necessarily tied to an individual's sex-category. Furthermore, the discipline of physics needs to be seen as gendered, on the individual level as well as the structural and symbolical levels, with students' learning in and about the discipline being seen against the backdrop of the *no-longer-gender-neutral* discipline of physics.

I have argued for a further broadening of PER so as to include gender as one of the cultural aspects of physics influencing students' learning of the discipline. In order to do so in relation to my guiding research question (see Section 1.1.) I have developed a novel conceptual framework that draws on a view of learning as participation (in contrast to a view of learning as acquisition, see, for instance, Sfard 1998) as well as a view of gender as something that is done by people. This conceptual framework is extensively presented in the next chapter.

3 Conceptual framework

3.1 Outline of framework

The conceptual framework that I outline in this chapter is centred around an incorporation of gender theory into a theory of learning that will be able to appropriately underpin an analysis of the gendered experience of learning in the university physics-student laboratory. My starting point is that such a learning theory is anchored in situated cognition. From here a proposal is formulated around how situated cognition and gender theory can be merged together. Here two different components – gender *in* communities of practice and gender *as* communities of practice – form part of a unique proposition that draws on situated cognition and Paechter's notion of gender as communities of practice (Paechter 2003a, 2003b).

I use Wenger's (1998) conceptions of practice and identity to illuminate gender in the learning in physics in two steps. In the first step I relate previous research on gender and the learning in physics to the different dimensions of Wenger's notion of practice and thereby present a comprehensive overview of how the practice of physics can be seen as gendered. In the second step I draw on Wenger's notion of identity for an elucidation of how an individual student's joining of such a learning community becomes affected by the gendering of the practice.[7]

3.2 Gender theory and situated cognition

Brickhouse (2001) compellingly argues that situated cognition is the theory of learning that has most to offer when examining science learning from a feminist point of view. She bases her argument on the many epistemological and historical similarities between situated cognition and feminism. For example, how they both are influenced by Marxist epistemology and poststructuralist writing. In particular, situated cognition recognizes identity-

[7] Please note that not all parts of the conceptual framework presented in this chapter are used in the analysis in Chapter 6. Some parts, as, for example, the discussion on power relations, will only be explored in the coming doctoral thesis.

formation as an essential component in the quest to better understand learning. Situated cognition thus makes social categories, such as gender, central for understanding student-learning. Consequently, Brickhouse (2001) sees situated cognition as a powerful framework when seeking to understand the gendered experience of learning science. Following Brickhouse's suggestion situated cognition started to be used in studies researching the gendered experience of learning. Good examples are Brickhouse and Potter (2001), Case and Jawitz (2004) and Du (2006). Brickhouse and Potter (2001) studied how young women in an urban context form scientific identities and how this identity formation is affected by their experience of marginalisation due to gender or ethnicity. Case and Jawitz (2004) studied how issues of race and gender affect South African engineering students' experiences of vacation work. Finally, Du (2006) studied engineering students gendered identity formation in a problem-based learning environment.

I will now expand and develop the conceptual framework in relation to earlier studies by including Wenger's later work, such as Wenger (1998), and the related work by Paechter, such as Paechter (2003a; 2003b).

Brickhouse's (2001) article is fundamentally a discussion of theory development. How the integration of situated cognition and gender theory can actually be done in practice has, however, been left largely undeveloped. I am now suggesting one way of doing this. This approach is based on bringing situated cognition (Lave and Wenger 1991; Wenger 1998) and post-structural gender theory (Butler 1999) together in a two step analysis resting on the notions of gender *in* communities of practice and gender *as* communities of practice. Before going on to describe this approach in more detail a brief introduction to some of the main ideas of situated cognition and also to Paechter's (2003a) suggestion to treat masculinities and femininities as communities of practice will be given.

3.3 Important ideas in situated cognition

In the situated cognition of Lave and Wenger (1991) knowledge is understood as being 'situated', meaning that it is a product of the activity, context and culture within which the knowledge is developed and used. The accompanying social structures of a given practice are seen as providing and thus defining the possibilities for learning. In other words, learning itself is viewed as contextually bound activity; the context does not only shape how things are learnt but also what can be learnt. Central to situated cognition is the concept of *communities of practice*. In its simplest form this concept can be seen as characterising the learning of groups of people engaged in a shared practice, which 'binds' the learning of the community together. In order to characterise how newcomers become integrated members of such a community of practice, in other words how learning takes place, Lave and Wenger introduced the concept of *legitimate peripheral participation*. Thus, in essence Lave and Wenger (1991) constituted a model of learning that brought participation to the fore. In this model, newcomers first participate in activities that are not central to the practice and then move on to increasingly complex and important activities. In this way the newcomers not only develop their expertise in the practice itself, but also develop an understanding of the surrounding culture. In this way, situated-learning theory focuses strongly on the individual, but as an individual-in-the-world; a member of a sociocultural community. Lave and Wenger (1991) describe this as follows:

> As an aspect of social practice, learning involves the whole person; it implies not only a relation to specific activities, but a relation to social communities – it implies becoming a full participant, a member, a kind of person. … To ignore this aspect of learning is to overlook the fact that learning involves the construction of identities. (p 53)[8]

3.4 Important ideas in post-structural gender theory

To do research with a gender perspective can mean a number of things. Still, ideas about gender can be broadly divided into two categories: either viewing our actions as a consequence of our gender, or viewing our gender as a consequence of our actions. The latter of these characterises a post-structural perspective, where the various parts of our identities do not exist beyond the daily actions we perform. In other words, our gender is a consequence of our actions, not a cause of them and there exists no such thing as an inherent, nature-given gender (Butler 1999). Furthermore, in this view our gender identity is not something fixed, and instead of focusing on the difference *between* two genders, the difference and dynamics *within* the genders are focused upon.

In order to better understand what the post-structural gender perspective could mean in practice consider this next example from the context of gender and science. Viewing gender as performative, as something we do, rather than something inherent, provides us with an alternative framework for understanding the male-dominance in physics. The reasons for the lack of females in science and technology have been continuously debated for at least thirty years. Yet much of this debate has, and is still, to a large extent focused on *differences* between girls and boys, let it be differences in achievements, motivation or socialisation (for a discussion on this, see, for example, Stonyer 2001; Berner 2003). One example of this relating to this particular study is Nair and Majetich's (1995) argument that female's fewer experi-

[8] The notion of meaning in situated cognition will be developed in section 3.5.1.1.

ences of tinkering could be a severe shortcoming when working in a science laboratory and something that needs to be 'fixed'. Now, when looking at gender as something people do the different practices engaged in become absolutely crucial for the gender identity since this is in fact what creates this identity. In post-structural gender theory our gender identity is not something fixed, and instead of difference *between* two genders the difference and dynamics *within* the genders are focused upon. A person's decision to study or not to study science then becomes an active choice (within certain limitations), not the consequence of socialisation. This, for example, leads to an appreciation that in the creation of a certain masculine subjectivity the choice to study science might be an important component, whereas in a certain feminine subjectivity the choice *not* to study science might be equally important.

3.4.1 Masculinities and femininities as communities of practice

Taking that gender is performative (see, for example, Butler 1999), Paechter (2003a) has suggested that communities of practice are a useful way to come to understand this performative dynamic. She writes:

> I am arguing that the learning of what it means to be male or female within a social configuration results in shared practices in pursuit of the common goal of sustaining particular localised masculine and feminine identities. It follows from this notion that the localised masculinities and femininities within which these identities are developed and sustained can be seen as communities of practice. (p 71)

One important advantage of treating masculinities and femininities as communities of practice is, according to Paechter, that it allows one to take into account individuals' many overlapping and context-dependent masculinities and femininities and gives the tools to analyse the interrelationships between these different gender manifestations.[9] Paechter mainly applies her ideas to how children and young people learn masculinities and femininities, through legitimate peripheral participation in localised communities of masculinity or femininity, and how transsexuals learn masculinities and femininities (Paechter 2003a and 2003b). However, in the following sections I will demonstrate how treating masculinities and femininities as communities of practice also can be a useful theoretical construct for analysing students entering a strongly gendered profession, such as physics. In the analysis of students' gendered physicist identities as communities of practice I will draw on Wenger's (1998) constructs of practice and identity, as developed in the following section.

[9] 'Masculinities and femininities' and 'gender manifestations' will hereafter be used interchangeably.

3.5 Practice and identity

In the earlier work by Lave and Wenger (1991) the concept of community of practice was largely left as an intuitive notion, but since then it has been further developed by Wenger (1998). It is this development I will draw on here. In the book 'Communities of Practice' Wenger approaches the notion of community of practice from two different perspectives; that of practice and that of identity. I will use the same analytical division between practice and identity here to show that the practice perspective is useful in particular when analysing gender in the physicist community of practice whereas the identity perspective is useful for analysing the gendered experience of learning in the physics student-laboratory. In this twofold analysis, viewing gender manifestations as communities of practice allows me to consider how the students constitute their physicist identities in relation to their sense of being male or female; their memberships in certain masculinities and femininities. A key assumption is further that masculinities and femininities can be understood as communities of practice. It is therefore possible to talk about participation in masculinities and femininities and also relate these participations to participations in other communities of practice (such as, for example, the university-based physicist community).

3.5.1 Practice

Wenger (1998) argues that it is shared practices which hold a community together. This shared practice can be understood as being composed of a number of dimensions (meaning, community, learning, boundary and locality). By exploring how these different dimensions can be understood in terms of being influenced by gender – some more and some less – one can form a comprehensive picture of the gendering of the practice of physics. Thus, this section serves as a useful lens for analysing *gender in the community of practice* of physicists: an understanding that then will be helpful for the exploration of how students form their identities in relation to that community.

Wenger (1998) treats communities of practices as highly localised entities, but I will here use the concept in a somewhat less strict sense. In Wenger's terms the physicist community would be a constellation of interconnected practices. My reasons for this decision are as follows: Firstly the students in this study cannot be seen as legitimate peripheral participants of one particular, localised physicist community, but rather of the physicist community as a whole, since their education opens up many possible trajectories into (and out of) the world of physics. Secondly, in agreement with Contu and Willmott (2003), I argue for the fruitfulness in focusing on practice rather than community and we see the practices of physicists across different local communities as similar enough to grant treating this as *one* community of *practice*.

3.5.1.1 Meaning

Central to Wenger's (1998) concept of practice is *meaning*. Meaning, as understood by Wenger, is located in the negotiation of meaning. He defines this as 'the process by which we experience the world and our engagement in it as meaningful.' (p. 53) He further elaborates:

> The negotiation of meaning is a productive process, but negotiating meaning is not constructing it from scratch. Meaning is not pre-existing, but neither is it simply made up. Negotiating meaning is at once both historical and dynamic, contextual and unique (Wenger, 1998, p. 54).

In other words, the concept of meaning negotiation captures the dynamic relation of living in the world; people do not make meaning totally independent of the world, but meaning at the same time is not just imposed on them by the world. The negotiation of meaning involves the two interacting processes *participation* and *reification*. Participation means the members actively taking part in the community. Reification, on the other hand, 'refers to the process of giving form to our experiences by producing objects that congeal this experience into "thingness"' (Wenger, 1998, p. 58), thus creating something 'real' to organize our negotiation of meaning around. Wenger goes on to describe the process of reification as central to every practice, producing abstractions, tools, symbols, stories, terms, and concepts. Moreover, participation is something that goes beyond our mere engagement in practice. You do not cease to be a physicist, for example, when you leave your laboratory to go home. Looking at how gender plays a role in the participation and reification of the physicist community opens the way for me to explore how the negotiation of meaning can be understood as gendered.

3.5.1.2 Community

The community formation in terms of practice is characterized by Wenger (1998) as practitioners' mutual engagement in a joint enterprise resulting in a shared repertoire. The negotiation of the joint enterprise gives rise to mutual agreement on, for example, what matters in the community and what does not, what is important and what is not, what to pay attention to and what to ignore. This in turn results in a shared repertoire of the community that includes things such as words, tools, ways of doing things, stories, and symbols. When considering students' joining a community I would argue that, in particular, an understanding of the shared repertoire of physics, or rather science in general, is crucial, bearing in mind that these students can (at best) be seen as legitimate peripheral participants in the physicist community and as such have very limited possibilities of actually influencing the shared repertoire. In a broader sense, the most important component of the shared repertoire of science is the delimitation of what is seen as belonging to science; what is considered scientific and how this has developed historically – most certainly a gendered process, which is as demonstrated by, for example, Schiebinger (1991).

3.5.1.3 Boundary

Whereas the dimension community describes what belongs to physics, it is equally important for its definition to include looking at what does not belong: how the *boundaries* of the physics community are defined and in particular how the community is related to other communities of practice. No community of practice ever exists in isolation and can consequently not be understood irrespective of other communities. This implies that when we join a community of practice we do not only engage in the practice as such, but also in this community's relations with the rest of the world. Furthermore, communities of practice can be seen as shared histories of learning, and over time these histories create discontinuities between those who have participated and those who have not. These discontinuities can involve both participation and reification. The reification sometimes takes the form of explicit markers of membership (such as titles or degrees), but barriers to participation are not necessarily explicit. An example of this is the often talked about 'glass ceiling' preventing women from reaching higher positions in academia, which can be just as impenetrable as any official policy. However, there are also possibilities for continuities between communities; one community of practice can be seen as connected to other communities through two types of connections, *boundary objects* and *brokers* (Wenger, 1998). Boundary objects are objects around which different communities can organize their interconnections. Brokers are people who by their simultaneous participation in different communities can create connections across these communities. The concepts of brokers and boundary objects will be used as analytical tools, firstly to look at how the physics community is related to other communities and secondly to explore how the individual student can negotiate a physicist identity in relation to other simultaneous memberships in (sometimes gendered) communities of practice.

3.5.2 Identity

Issues of identity are, according to Wenger (1998), 'an integral aspect of social theory of learning and are thus inseparable from issues of practice, community, and meaning' (p. 145). By changing focus from practice to identity we simultaneously zoom in on the individual and extend our view beyond the community, including the individual's engagement in a larger societal context. Thus, this perspective will allow me to consider the individual students' engagement with the gendered practice of physics, analyzing how they form their identities as physicists in relation to its gendered practice, while doing laboratory work.

3.5.2.1 Identity in practice

Whereas the different dimensions of practice are helpful in understanding how the practice of physics is gendered, the concept of *identity in practice* is what relates the individual student's identity formation to this practice. Consequently, identity is first of all seen as a negotiated experience, not a stable category. In other words, our identity is something we constantly – through participation and reification – constitute. This can be viewed as the analytical base for this understanding of identity. Thus, an identity is a constant becoming; a work that is always going on. Therefore, our identities can be viewed as forming trajectories, both within and across communities of practice, and this formation is in this purview what learning is all about:

> Understanding something new is not just a local act of learning. Rather, each is an event on a trajectory through which they give meaning to their engagement in practice in terms of the identity they are developing. (Wenger, 1998, p. 155)

This understanding of identity has a lot in common with a post-structural understanding of gender, as has been pointed out by Paechter (2003a), in that both situated cognition and this kind of gender theory put a strong focus on practice: it is our doings that create our identity/our gender. As Brickhouse (2001) also points out:

> The idea of learning as a transformation of identity-in-practice provides a way of thinking about learning that is gendered, but does not regard gender as a stable, uniform, single attribute. We are not born with gender. We do gender. (p. 290).

Together, situated cognition's notion of learning as an identity formation, how we through engagement in a practice constitute our identity, and the notion of gender as a community of practice provide an entirely new way of understanding and analysing students' participation in a gendered discipline, such as physics. Principally, because, as the students participate in practices in the student laboratory, not only do they constitute their identities as legitimate peripheral participants in the physicist community, they also constitute certain masculinities and femininities, in relation to the practice. Furthermore, this work of identity transformation must also be influenced by the students' simultaneous belongings to other (sometimes gendered) communities of practice. These multiple participations are discussed by Wenger (1998) in terms of *a nexus of multimembership*. According to Wenger an identity can be viewed as a nexus of multimembership, a concept that brings our multiple belonging to many communities of practice to the fore: 'Our various forms of participation delineate pieces of a puzzle we put together rather than sharp boundaries between disconnected parts of ourselves.' (Wenger, 1998, p. 159). In other words, the belonging to a community of practice is not something that we can turn on and off, and thus, this 'belonging' will influence our belongings to other communities of practice: 'different practices can make competing demands that are difficult to combine to an experience that correspond to a single identity.' (Wenger, 1998, p. 159) How students deal with such competing demands will be an important theme in my analysis, in particular regarding individual students' struggles to negotiate their participation in certain gender manifestations with their participation in the physics student community.

Of particular importance to the newcomers' learning is what Wenger (1998) has called *paradigmatic trajectories* – the possible trajectories within a given community of practice as represented by actual people and composite stories. And, it is by exposure to this set of possibilities that newcomers can negotiate their own trajectories. However, for many students, women as well as those of other minority groups, finding paradigmatic trajectories to identify with in the physicist community is both difficult and challenging.

I will use the concept of trajectories to illuminate students' varying ways of engaging in physics.

Furthermore, by belonging to a community of practice we learn certain ways of engaging with other people; how one should interact, how to work together etc. As described above, one of the things that defines a community of practice is a shared repertoire, and as we become more engaged in a community this repertoire 'translates into a personal set of events, references, memories, and experiences that create individual relations of negotiation with respect to the repertoire of a practice' (Wenger, 1998, p. 153). This is equally true for the physics student community and for the communities of practice constituted of localised masculinities and femininities. Consequently, the way physics students engage with others in the laboratory will be tightly interconnected with the ways these students have learnt to act in order to uphold their membership in certain localised masculinities and femininities. And, as these students interact with others in the student laboratory, not only do they 'do physics', they also 'do gender'.

3.5.2.2 Participation and non-participation

I have so far looked at how identity and practice are interrelated; but it is not only through our participation in certain practices that we form our identity. Equally important in fact, can be our non-participation in other communities. By constituting our identities not only by what we are but also by what we are not, non-participation becomes just as much a source of identity as participation. This becomes especially crucial when one looks at communities who define themselves by contrast to others: where being inside one community is the same as being outside another, for example, workers versus managers or different ethnic groups. In particular, this can make 'boundary crossing difficult because each side is defined in opposition to the other and membership in one community implies marginalization in another.' (Wenger, 1998, p. 168). By exploring how students talk about their (and others) participation in the physics student community versus how they describe their participation in various masculinities and femininities it is possible to create a new understanding of how these participations and non-participations are interconnected.

3.5.2.3 Modes of belonging

In order to understand identity formation and learning Wenger (1998) argues that engagement is not the only mode of belonging that needs consideration. He describes three distinct modes of belonging:

1) engagement – active involvement in mutual processes of negotiation of meaning.
2) imagination – creating images of the world and seeing connections through time and space by extrapolating from our own experiences.
3) alignment – coordinating our energy and activities in order to fit within broader structures and contribute to broader enterprises. (p. 173-174)

When considering students joining a community of practice I find the concept of imagination particularly useful: it can play a powerful role when creating a sense of belonging in the physicist community. By extrapolating from our own experiences we can imagine the working lives of other people. For example, how does a student experience the student laboratory in terms of resembling what professional physicists do? The work of imagination thus involves defining a trajectory that connects what we are doing, for example in the student laboratory, to an extended identity, for example, being a physicist. How a student does this can consequently make a big difference to the potential of learning through a particular activity: different students can learn very different things from the same activity. This is, then, in turn also interconnected with our other, sometime gendered belongings; to what extent can these hinder or facilitate our possibilities to imagine ourselves as participants in a particular community.

3.5.3 Relations of power

In order to understand students' 'joining the university-based physicist community' an understanding of relations of power are essential. The uneven distribution of women and men in physics, among other things, does say that not everyone has the same possibilities for legitimate peripheral participation in this community. Relations of power have, as argued by

Contu and Willmott (2003), a central place in Lave and Wenger's (1991) portrayal of situated cognition and even more so in Wenger's (1998) development. This is illustrated in, for example, the following quote from Wenger (1998):

> Identity is a locus of social selfhood and by the same token a locus of social power. On the one hand, it is the power to belong, to be a certain person, to claim the legitimacy of membership; and on the other it is the vulnerability of belonging to, identifying with, and being part of some communities that contribute to defining who we are and thus have a hold on us. Rooted in our identities, power derives from belonging as well as from exercising control over what we belong to. (p. 207)

A key construct here is 'control over what we belong to'; the ability to negotiate meaning within a certain community (in our case, for example, what it means to be a physicist). Here I posit Gee's (2005) notion of 'social goods' (anything a group of people believe to be a source of power, status, value, or worth) and the distribution of this across communities as a way of analysing relations of power in and across communities of practice in relation to students' possibilities for negotiation of meaning; their ownership of meaning. This would involve looking at what social goods students have access to through their memberships in various communities and relate what is seen as social goods in one community to what is seen as social goods in a different community. For example, what is considered social goods in a particular gender manifestation can either be recognised or not recognised as social goods in a particular professional community and, thus, empower or disempower you there.

In this a context I would argue that it is relevant to consider Hildebrand's (2001) feminist critique of situated cognition. She takes as her staring point the concept 'legitimate peripheral participant' and argues that learning through apprenticeship pacifies the learner because it is really just a copying of the 'master' without any possibility of critiquing the practice of the community. I do agree with her that situated cognition in this sense can be problematic for basing a feminist pedagogy upon and to a certain extent also when using it in gender-aware educational research. This possible passivity of the learner and their limited possibility to affect the community is also something that needs to be taken into account and, something Wenger (1998) also comments upon:

> Through engagement, competence can become so transparent, locally ingrained, and socially efficacious that it becomes insular: nothing else, no other viewpoint, can even register, let alone create a disturbance or a discontinuity that would spur the history of practice onward. In this way, a community of practice becomes an obstacle to learning by entrapping us in its very power to sustain our identity. (p. 175)

However, I would argue that Hildebrand's critique is partly due to an all too simplistic reading of Lave and Wenger; that learning is viewed as the inclusion of a newcomer into a community of practice is not necessarily the same as that '[a]ll of their practices and discourses are assumed as exemplary and beyond critique' (Hildebrand, 2001, p. 8). Or, at least, that this does not necessarily have to be the case.

In summary, I would argue, in agreement with Contu and Willmot (2003), that situated cognition's key notion of learning as involving the construction of identities (and not merely as acquisition of knowledge or skills) does in fact make power relations an important element in this theory of learning – and thus a suitable one for understanding the gendered nature of learning.

4 Research methodology

In the previous chapter the conceptual framework of my research was presented. My research, like any other research, is guided by a theoretical orientation that underpins my methodology (for a discussion on this see, for example, Bogdan and Biklen 1992). This theoretical orientation is partly built up of the conceptual framework; the lens through which I am looking at my data. But, equally important in the theoretical orientation is the informing of the method of collecting data and the method of analysing that data. These aspects of the theoretical orientation are of course tightly interwoven; with each other as well as with the development of the guiding research question. For example, had I chosen to situate my research within a different theoretical framework this would most certainly have shifted the research question; actor-network theory (used in a related study by Nespor 1994) and activity theory (used by Hasse 2002), for example, would both have shifted the focus from the individuals and their identity formation to the structures of the physicist community.

In the following chapter the data collection, the method of analysis and also how trustworthiness was established will be discussed. Finally, I will provide an account of how the research question has evolved over time.

4.1 Data collection

The research took place at Uppsala University, a well-established, traditional Swedish university. Thirteen volunteer students, who were enrolled in an undergraduate degree programme in physics[10], were interviewed by me. The interviewed students were in different stages of the programme, from the first to the fourth year. Within this undergraduate degree programme students can choose a number of specialisations such as meteorology, atomic and molecular physics, nuclear and particle physics, cosmology, astronomy etc. and the students interviewed had a wide variety of future goals.[11]

[10] Naturvetarprogrammet, inriktning fysik

[11] To ensure the anonymity of my interviewees I have chosen to not provide more detailed information about them, considering that relatively few students participate in the undergraduate degree programme in physics at Uppsala University.

4.1.1 The interviews

Kvale (1997) writes about the qualitative research interview as a conversation where two people talk about a subject both are interested in and thereby build knowledge. The aim of such an interview is to understand aspects of the life-world of the interviewee from the interviewee's own perspective. Hence, typically the qualitative research interview is semi-structured, and this is the type of interview I used (see Appendices B and C). A semi-structured interview, Kvale (1997) writes, is neither a totally open conversation or one directed by a detailed questionnaire. Instead an interview protocol, where certain themes and questions are given, is used to guide the conversation from the interviewer's perspective. Throughout the interview follow-up questions are used in order for the interviewer to ensure herself that she has correctly interpreted what has been said. I as the interviewer further strive to create an atmosphere that allows the interviewees to talk as freely and honestly as possible. The strength of such interviews (as compared to, for example, a questionnaire) lies in the depth to which different issues can be explored and the openness for the discussion to take other routes than the ones perhaps anticipated by the interviewer. In this context it is also important to remember that the interview situation is co-constructed by the interviewer and the interviewee; thus, the interviewer also plays an active and unavoidable part in what contextual identity is constituted by the interviewee (Gee 2005).

The interviews for this thesis lasted between 30 and 90 minutes. Students were asked to talk about their experiences of doing laboratory work in physics; what they saw as valuable skills to have and to develop for the student laboratory, what previous experiences they perceived as being useful, how they thought of themselves as laboratory students, the purpose of laboratory work etcetera. Then, during the final stages of the interview issues of gender in physics education were explicitly brought up. The interviews were audio-recorded and transcribed verbatim. It is these transcription that were used in my analysis. Examples of partial transcripts can be found in Chapter 6.

The main reason I decided to use interviews and their transcripts as my data – instead of, for example, using questionnaires – is that interviews, especially when they are done in a semi-structured fashion, facilitate a much deeper probing into the experiences of the interviewees (Kvale 1997). Secondly, it was important for me to let the students themselves give voice to their experience; what I wanted to capture was their experiences of doing physics in the student laboratory. This ruled out, for example, participant observations as a method for data collection since this would involve me observing the students and making interpretations from these observations, rather from rich descriptions of the students' personal experiences. The choice of method of data collection will also be further discussed in section 4.4.

4.2 Analysis

The method of analysis in this thesis gets its inspiration from two principal and related sources; narrative inquiry (see, for example, Connelly and Clandinin 1990) and Gee's (2005) Discourse analysis. To introduce the ideas behind this kind of socio-cultural qualitative research I will start with a quite lengthy quote from Polkinghorne (2004). My main aim here is to try to capture the mood and thrust of such research perspectives:

> Instead, the new post-modern philosophy advocated that the idea of self has no actual referent; that is, there was no real self and no real centre of personal identity. It proposed that the idea of a personal self was an artefact of a subject-verb language grammar. The narrative approach to personal identity occurs within the context of the post-modern rejection of the idea that personal identity is linked to a person's unchanging soul-like mind. However, the narrative approach takes seriously people's experience of having a self-identity. It retains the post-modern position that understanding (including self-understanding and personal identity) is affected by the language in which it is articulated. The narrative approach holds that people construct and recognize their identity through the narrative or storied form of understanding. (Polkinghorne, 2004, p. 28)

This theme is also further elaborated on by Clandinin and Connelly (1994) who discuss how our understanding of humans and their relations to each other and their environments are founded in the study of experiences. Experiences are therefore the starting-point for all such inquiry. Furthermore, they argue that stories are as close as we can come to people's experiences. Thus, 'experience, in this view, is the stories people live. People live stories, and in telling of them reaffirm them, modify them, and create new ones' (Clandinin and Connelly, 1994, p. 415).

Following Clandinin and Connelly (1994) I have treated my interview data as students' storied experiences. However, narrative inquiry also has a different side; the narrative I as the researcher present. Polkinghorne (1995) describes this dynamic as follows:

> In this type of analysis, the researcher's task is to configure the data elements into a story that unites and gives meaning to the data as contributors to a goal or a purpose. The analytic task requires the researcher to develop or discover a plot that displays the linkage among the data elements as part of an unfolding temporal development culminating in the denouement. (p. 15)

Thus, the story I – the researcher – tell is not simply a reproduction of the students' stories. By re-telling their stories through my research perspective, I aimed to create a final story that 'must fit the data while at the same time bring an order and meaningfulness that is not apparent in the data itself' (Polkinghorne ,1995, p. 16). The final aim of such analysis is to create a rich and explanatory description of the data.

My analysis also continued in the writing process: Richardson (1994) explains such a continuation as 'I write because I want to find something out, I write in order to learn something I didn't know before I wrote it' (p. 517). This is in sharp contrast to how many of us have been 'trained' to 'write up' our research; to put a finalized analysis into text, not to see the writing in it self as a method of discovery (Richardson 1994). My analysis thus starts in the narratives co-constructed by me and the interviewee during the interview (Gee 2005) and continues as I put this thesis together.

Note, however, that I make no claim to be doing a full-fledged narrative analysis (for illustrative examples of such analysis see Clark 2000 and Povey et al. 2006) nor am I following Gee's (2005) approach to the letter. Instead I am following the advice Gee (2005) gives:

> …this book is meant to 'lend' readers certain tools of inquiry, fully anticipating that these tools will transformed, or even abandoned, as readers *invent their own versions of them or meld them with other tools* embedded in different perspectives. (emphasis added, p. 5)

Narrative inquiry, both in terms of viewing the interviews as the interviewees' narratives and in terms of creating a narrative as the outcome of research could be understood as the methodological base of my analysis. In conducting the actual analysis in how to read the empirical data – through the lens of my conceptual framework – an important source of inspiration was Gee's 'big D' Discourse analysis. Discourse analysis is a common tool within educational research (see, for example Northedge 2002 and Wickman and Östman 2002), Gee's 'big D' Discourse differs from other forms of discourse analysis in that is takes a more holistic approach to the discourse. Gee writes, 'when "little d" discourse (language-in-use) is melded integrally with non-language "stuff" to enact specific identities and activities, then I say that "big D" Discourses are involved' (p. 7). Gee's Discourse can thus be characterised as including the broader societal context in which the language is used; where, for example, gender becomes an important component. In summary, Gee views us as building and rebuilding our world through language used together with 'actions, interactions, non-linguistic symbol systems, objects, tools, technologies, and distinctive ways of thinking, valuing, feeling, and believing' (p. 10) and in doing so we employ seven building tasks of language:

> ***Significance***
> We use language to make things significant (to give them meaning or value) in certain ways, to build significance. …
>
> ***Activities***
> We use language to get recognized as engaging in a certain sort of activity, that is, to build an activity here-and-now. …
>
> ***Identities***
> We use language to get recognized as taking on a certain identity or role, that is to build an identity here-and-now. …
>
> ***Relationships***
> We use language to signal what sort of relationship we have, want to have, or are trying to have with our listener(s), reader(s), or other people, groups, or institutions about whom we are communicating; that is, we use language to build social relationships. …
>
> ***Politics (the distribution of social goods)***
> We use language to convey a perspective on the nature of the distribution of social goods, that is, to build a perspective on social goods. …
>
> ***Connections***
> We use language to render certain things connected or relevant (or not) to other things, that is, to build connections or relevance. …
>
> ***Sign systems and knowledge***
> We can use language to make certain sign systems and certain forms of knowledge and belief relevant or privileged, or not, in given situations, that is to build privilege or prestige for one sign system or knowledge claim over another. (Gee, 2005, p. 11-13)

These seven building tasks are then in turn what we can use to analyse a certain piece of data, to ask certain questions to that data; sometimes all building tasks will be applicable to the same data, sometimes we will chose to focus on one or a few. I agree with Case and Marshall (2006) in that central to Gee's Discourse analysis are identities and the constitution of identities; learning seems to be, by Gee, largely understood to involve a process of identity formation. Further, as argued by Airey (2006) learning is today increasingly understood as the entering into a discourse and with Gee's wider definition of discourse entering of a discourse is very much in line with becoming part of a community of practice. The fundamental similarities between Gee's Discourse analysis and situated cognition (and post-structural gender theory, for that matter) have led me to use Gee's Discourse analysis as an additional analytical tool for my analysis. These similarities become apparent as Gee (2005) explains how Discourse allows one to be recognized as a particular kind of person:

> The key to Discourse is ‘recognition’, If you put language, action, interaction, values, beliefs, symbols, objects, tools, and places together in such a way that others *recognize* you as a particular type of who (identity) engaged in a particular type of what (activity), here-and-now, than you have pulled of a Discourse. Whatever you have done must be similar enough to other performances to be recognizable. However, if it is different enough from what has gone before, but still recognizable, it can simultaneously change and transform Discourses. (p. 27)

In other words, the ‘activity’ (the ‘doing’) is absolutely crucial to one’s identity, whether it has to do with becoming a physicist through practicing physics or ‘doing gender’.

The analysis of the empirical data, of the interview transcripts, took place through an iterative process where the data was ‘cycled through’. In order to identify patterns and themes the iterative process was guided by narrative inquiry and Gee’s Discourse analysis and my conceptual framework. In this process the empirical data is also allowed to ‘speak back’ to the framework and the analytical tools, which then are developed in conversation with the data. In summary, my research aims towards to:

> …both understand and try to give an account of the ways in which the individual is shaped by the situation and shapes the situation in the living out of the story and in the storying of the experience. (Clandinin, 1992, p. 128)

4.3 Trustworthiness

The first thing that needs to be pointed out regarding issues of quality in qualitative research is at the same time quite obvious and highly difficult to grasp; the knowledge claims sought in qualitative research are usually quite different from those sought in quantitative research. Qualitative research such as I have done seeks subjective understanding, not objective predictive ability. Thus the differences are not only about whether we count things or not, the differences stretch far beyond that; the differing knowledge also implies that most appropriate ways of assessing the quality of the research are different too. Commonly, in quantitative research, issues of quality are discussed in terms of validity, reliability and generalizability. However, within qualitative research – where the researcher seeks understanding, not facts – such constructs can be replaced by credibility, dependability and transferability (Lincoln and Guba 1985).

Qualitative research in general can be seen as concerned with knowledge as a human construction, and the objective is thus not to reach the ‘true reality’ but to understand the lived experiences as told by, for example, the interviewees.

4.3.1 Credibility

Credibility parallels the criteria of internal validity, but

> instead of focusing on a presumed 'real' reality, 'out there', the focus has moved to establishing the match between the constructed realities of respondents and those realities as represented by the [researcher] and attributed to various [respondents] (Guba and Lincoln, 1989, p. 237).

In other words, the key is to be 'true' to the storied experiences of, in my case, the interviewee. To ensure that my story is in fact their story the continuous discussions of my findings that I have had with my research colleagues were of crucial importance. 'Prolonged engagement' with the site of inquiry is commonly used as a way to ensure credibility; even though I have not participated in the laboratory work together with the interviewees I do see my experiences of completing an undergraduate degree in physics at the same Physics Department as the interviewees as valuable in this sense.

4.3.2 Dependability

In research aimed at predictive ability it is of vital importance to make sure that the data is stable over time, that it is reliable. In qualitative research such as mine, on the other hand, changes must expected; this is seen as a desirable part of the evolution of the research process. As the research is maturing it is likely that methodological decisions will shift the hypotheses, constructs etc. and perhaps even the research questions. These shifts, however, need to be tracked by the researcher (and trackable by others) – which is what ensures dependability (Guba and Lincoln 1989). In the case of my research, I kept a research journal in order to document the progression of my research, for example, how the guiding research question has evolved.

4.3.3 Transferability

My research is very much situated in the context where it took place, as is most qualitative research, and consequently the results are not expected to be generalizeable in the 'predictive research' sense of the word, but in the 'understanding research' sense of the word. Instead, I have strived for transferability to 'provide as complete a data base as humanly possible in order to facilitate transferability judgements on the part of others who may wish to apply the study to their own situation' (Guba and Lincoln, 1989, p. 242). Thus, I will provide an account of the research from which the reader can create a deepened understanding of some aspect of their life, that they themselves can 'generalize' from. This can, for example, take the form of readers raising questions of their own practice and their own ways of knowing (Clandinin 1992). An analogy would be how reading an autobiography can help to shed new light on issues from life for the reader; whether it has to do with recognizing ourselves in the text or from gaining a different perspective.

Transferability have also been characterized in terms of ‘naturalistic generalization’ (Stake 1994), where readers make their own ‘generalizations’ based on what *they* find in the study. Thus, for quality assurance, my responsibility as a researcher is to provide readers with a sufficiently ‘thick description’ (Lincoln and Guba, 1985, p. 316) to enable the readers themselves to relate to my interpretations. Here it is important to point out that whether readers agree with my interpretations or not is not the condition for a transferable study. It is the readers’ ability to understand and thereby judge my interpretations that is necessary.

I have tried to ensure transferability by providing such a sufficiently ‘thick description’ including, for example, lengthy interview transcripts, thereby making it possible for the readers to judge whether they agree with my interpretations or not, as well as by giving detailed accounts of the method of analysis and the conceptual framework.

4.3.4 Confirmability

Confirmability can be thought of as a parallel to objectivity, in that both are concerned with ‘assuring that data, interpretations, and outcomes of inquires are rooted in contexts apart from the [researcher] and are not simply fragments of the [researcher’s] imagination’ (Lincoln and Guba, 1985, p. 243). Confirmability is assured by seeing that the data can be tracked to its sources and that it is explicit in the final narrative how this has been logically assembled from the data.

Here, just as in the case of transferability, a suitably thick description will play a crucial part. By providing lengthy excerpts from the interviews together with full details of the process I hope I have made it possible for readers to trace my analysis back to the empirical data. Throughout the research process I have also continuously shared my findings, conclusions and tentative analysis with my research colleagues – in order to ensure myself that my interpretations are plausible, thereby giving the research process confirmability. Primarily this sharing has taken place within my research group, both informally and in formal seminars where we have read and discussed my interpretations. I have also discussed my interpretations with researchers outside the research group and presented earlier versions of my analysis at a number of international conferences (see, List of papers and conference presentations). This ongoing process of sharing and discussion has given me much valuable input and at times it has made me re-think critical aspects of my analysis.

4.3.5 Yet another set of criteria: Fidelity

The previously described criteria are not the only ones that have been suggested as appropriate for establishing the quality of my kind of qualitative research. While it is beyond the scope of this thesis to go into the discussion on other paradigmatic criteria (for a study where different criteria are used and discussed see, for example, Mullholland and Wallace 2000), I would, however, like to bring to the fore one set of such criteria: that of fidelity (Blumenfeld-Jones 1995). This is because I think that the notion of fidelity illustratively captures the complexity of assessing the quality of narrative inquiry and related forms of qualitative research. Fidelity is basically about being true to the data, representing it in a way that is true to the lived experience of, for example, the interviewee. However, there is more to the story:

> …the narrative inquirer must maintain fidelity both towards the story of a person (what the person makes of his or her story) and towards what that person is unable to articulate about the story and its meaning (and the context in which the story exists). Second, what the original teller makes of her or his own story is bounded by her or his purpose in telling that story. This reminds us that even the original teller is also reconstructing the narrative. To make the situation even more complex, the narrative inquirer must remember that she or he has intentions and is reconstructing as well. Narrative inquiry is an artificial endeavour existing within layers of intention and reconstruction. (Blumenfeld-Jones, 1995, p. 28)

Thus, we must always remember that the researcher's final narrative consists of layers of constructions and re-constructions – and the notion of fidelity brings out the ethical character in representing these constructions and re-constructions.

Finally, I would like to say a few words about why I have not done member-checks, an often recommended way of ensuring fidelity as well as credibility and confirmability in qualitative research (see, for example, Guba and Lincoln 1989; Blumenfeld-Jones 1995). The reason for this is that I have worked in parallel, analysing the data and developing the framework, letting the two processes inform each other. This means that it has been a lengthy process to get from the interviews (conducted during the spring of 2005) to the final research narrative presented in this thesis. Consequently, even to get hold of certain students would be difficult for me, and I do not think that member-checks with only some of the participating students would contribute to the quality of my work. Furthermore, the students are very likely to today find themselves in a very different stage of their development of a physicist identity than they did when I interviewed them a year and a half ago – for that reason, conducting member-checks becomes virtually impossible. However, I do plan to build in member-checks as a means to ensure trustworthiness in the next stages of my research project. When doing so it is my intention to, for the member checks, use narratives similar to that of Eva's story in the next section, what could be characterized as an 'interpretive story' (McCormack 2000a, 2000b). An interpretive story is for my purposes a story written using the combined lens of narrative inquiry and Gee's (2005) discourse analysis, that then is analysed further using the conceptual framework. Thus, it is this initial interpretive story that I would find useful to discuss with the interviewees, to see to that I got their story 'right'. I do not, however, think that sharing the full analysis with the interviewees necessarily is a way of ensuring credibility and confirmability, considering that the interviewees are not familiar with the conceptual framework. After all, the final research narrative is by all intents and purposes the researcher's narrative.

4.4 The evolution of the research question

Today the research question reads:

How do undergraduate students in the context of laboratory work constitute physicist identities in relation to the cultural norms of the university-based physics community?

And the focus of empirical investigation presented in Chapter 6 is on the questions:

- What are the gender manifestations underpinning students' identity formation in the physics student-laboratory?
- How do different students experience themselves as constituting their physicist identities in relation to these gender manifestations?

Developing these research questions has, however, been a lengthy process. As recommended for qualitative research (for example, Ely 1991) I started with a very broad guiding research question, or rather, with a very broad research interest. Coming from a background in experimental physics, the actual doing of physics, the laboratory work has always interested me, and that was what I decided to focus on. I also had a feeling that 'gender' could be important for understanding learning in this context, if for no other reason than because of the male dominance in physics, and my own choice to pursue physics studies partly because of the masculine power associated with the discipline. I was intrigued by writings such as Rosser (1995):

> Girls and young women who lack hands-on experience with laboratory equipment are apt to feel apprehensive about using equipment and instruments in data gathering… Making young women feel more comfortable and successful in the laboratory can be accomplished by providing more hands-on experience during an increased observational stage of data gathering. In a co-educational environment, it is essential that females be paired with females as laboratory partners. Male-female partnerships frequently result in the male working with the equipment while the female writes down the observations. (p. 8-9)

These claims that hands-on experiences are so crucial to success in the laboratory further triggered my interest and made me want to talk to the students themselves about what experiences they saw as being useful. For example, did they value having tinkered with their cars or did they see totally different things as useful? In order to investigate this I handed out a free-write questionnaire to a class of physics students, but then realised that the answers I got were far too shallow for my purposes. This made me turn to semi-structured interviews. At this point, my ideas about which theoretical framework to use were vague. Being familiar with phenomenography (Marton and Booth 1997) from my undergraduate degree project[12] this was the first framework I explored. Having a firm belief that gender research ought to go beyond comparing men and women I saw phenomenography as a way of achieving this, and in August 2004 I wrote:

> Gender is however much more complex than just the gender/sex of the individual and this is something I would like to take as the starting point of my research, to try and bring the gender aspect beyond the individuals. Here I believe phenomenography can be of great help. In their article 'Issues in gender and phenomenography' Hazel *et al.* (1997) argue that the major conflict between feminism and phenomenography has to do with the latter's separation of the data from the 'bodies' of those who are its source. This is certainly true if you want to study individual men and women, but it can also be seen as a possibility. If I want to study how students experience [some part of laboratory work] one way of doing this is of course to look at men's and women's experiences. One could however also look at the experiences across all individuals and then analyse the categories of description, rather than the individual students, in terms of gender. This way a male or female student can fit into both male, female and possibly gender neutral categories, avoiding the problem of categorising individuals, who are likely to posses both male and female gender characteristics. It will also help in avoiding the pitfall of putting an individual's sex equal to their gender. I believe that this is especially important when dealing with students in an academic discipline with such a strong gender bias as physics, where it is likely that all students, male and female, have been at least partly socialized into the male values of the discipline.

[12] My 'examensarbete'

With these ideas in mind I conducted pilot interviews with three engineering students (the interview protocol for these interviews can be found in Appendix B). Following one of the interviews I had a more informal conversation with one of the interviewees about, amongst other things, her background and how that had affected her choice of study and study habits. For me this conversation brought to the fore how very different identities could be constituted by students within the same studying environment. Encouraged by my supervisor and inspired by a course in Narrative Inquiry I decided to try out situated cognition as a way of capturing this identity formation and narrative inquiry as an innovative and fruitful way of analysing and presenting this identity formation. In an essay for a course at Umeå University called 'Gender, Science and Education' I, for the first time, tried such a research approach. Below I share a quite lengthy excerpt from that essay, to be compared and contrasted to the analysis as it looks in this thesis:

> What I am looking for in my research is probably best illustrated with an example, a student's story about her experiences of laboratory work – of course seen through my eyes. This is in other words not Eva's story, but rather my story about Eva's story.
>
> **Eva's story**
> The following narrative comes from an interview with Eva about her experiences of a laboratory course in mechanics and the following informal conversation. The interview was tape recorded and the impressions from the following conversation I wrote down directly afterwards, from memory. During the interview I tried on the one hand to reach Eva's impressions of the course, and on the other the ways in which she connected the work in the student laboratory to her previous experiences and future plans.
>
> Eva is in her thirties, she is married and has children. In gymnasiet (secondary school) she followed the four-year techinical stream, after which she was both accepted for university education and was offered a job. She chose the job, because her boyfriend had already worked for a couple of years, and both of them thought it was time for her to start working as well. Eva also brings up her working class background as a reason to why she chose not to continue her studies. She is currently studying the second year of energy systems, a relatively new engineering degree at Uppsala University. Eva explains her decision to go back to studying by referring to her employer the Swedish Armed Forces Supply Group, who liked all their employees to have an engineering degree. The reason she chose Energy systems was because her family is in Uppsala, and she is interested in energy distribution. During her studies she is on leave from her job as a project leader at Swedish Armed Forces Supply Group – something that gives her much valued security. In her job as a project leader there was quite a bit of examination of research reports, an experience that is very visible in her description of the mechanics labs. Her focus in the interview is very much on writing of reports. In this course the reports were to be written and handed in during the laboratory session, something she found stressful. She consequently mentions the ability to think quickly and to be able to put down one's thoughts on paper in a short

period of time as the most important quality for a student to be successful in this kind of laboratory work. The writing of reports is important for Eva and through her line of work she has seen quite a few research reports and states that this has given her knowledge of what good and bad reports look like. Several times she comes back to the importance of writing so that other people can understand.

The purpose of the laboratory course is, as she sees it, to learn how to do laboratory work, to learn error analysis – not to learn mechanics. She is very clear that what is focused on in the course is not learning physics – but it is harder for her to pinpoint what is meant by learning physics. She has a vague idea that it is about learning how things work, and on the whole concrete applications of knowledge are important to her. Eva describes herself as being theoretical – for her learning is learning the theory behind an experiment and she thinks that the purpose of a lab should be to illustrate a physical theory. It can however be mentioned that what she means by 'being theoretical' appears to be about an ability to examine theoretical descriptions of other people's experiments, not theoretical physics. Despite this she has no problems with 'seeing through' the purpose with this kind of laboratory work. Her answer to the question what she has learnt, since she emphasizes that she has not learnt physics, is: 'Not to take things for granted.' One of the most important future uses, as she sees it, is to be able to critically examine the results of others. This is something she has done earlier in her job and she says that she has developed it more in the course – primarily however she thinks this lesson is important for the students who have not got previous experiences like she has. On the whole she values her work experience as very important for her studies, claiming that it makes her more motivated, and she thinks that everyone really should try working before they start studying.

She claims not to be interested in an academic career, partly because of economic issues, partly because of her working class background – it is however not out of the question that this can change.

Looking back at Eva's story: The narrative seen through the eyes of situated cognition

Eva clearly sees herself, her studies and the choices she has made in her life in a broader social context. She brings a confident professional identity to her physics studies, from the job she is on leave from, and the interview returns again and again to her earlier work experiences. Through her earlier work she is already a member of one of the communities the education is designed to include the students in, and for her the education is almost about further training – deepening her membership in this community rather than entering a new community. Becoming a member of the scientific community is therefore not a problem for her, or rather not something that is a problem now – she has already done that.

In terms of situated cognition, what students do in the student laboratory can hardly be described as authentic practice. However, through her earlier work experience, Eva can quite easily relate what happens in the laboratory to an authentic practice. Furthermore, she is very conscious about what she wants to use the knowledge gained in the lab for, and in her description of the student laboratory it becomes clear that she chooses to let the laboratory work give her the kinds of knowledge she finds useful and valuable. This also clearly shows that our identity – who we are and who we strive to become – can affect the ways in which we approach an education in a very concrete and tangible way.

Eva does not identify herself much with her fellow students, when she mentions them it is almost without exception in the context of 'how she is different from them'; she is older, has children and has experience of full-time employment. Instead it is her earlier job, her family and her background that are important for her identity. In particular I find her class background to be important to her.

Eva's strong identification with her earlier job gives her the possibility to relate to *one* authentic practice, something that motivates her in her studies. However her strong identification with her previous work, rather than the present education and with her background and her family rather than her fellow students can also be limiting. Throughout our talk I get the feeling that Eva has no interest in entering, or perhaps does not dare, to enter any of the other possible communities the education offers. Rather she stays in her old professional role and picks out the parts of the education she finds valuable there. This makes inclusion in the physicist community less desirable; she even dissociates herself explicitly from the academic community. To summarize, my interpretation is that Eva has definitely been successful in creating a strong, alternative identity within a discipline dominated by males, but that this identity at the same time is limiting and does not give her access the entire potential of the education. I would therefore argue that Eva's example clearly shows that a (too) strong identification with an authentic practice is not entirely positive. It is possible that an identity like Eva's can help a student to get through an education, but at the same time it can hamper the possibility to change and develop as a person – the very thing which is seen as learning in situated cognition.

My role as a researcher in the narration and the interpretation of the story

That it is my interpretation that comes forward in the above section is quite obvious. But also in Eva's narrative I, the researcher, play almost as important a role as she does. It is far from obvious that Eva is the main character in her own story. I am the one who chooses the questions and guides the interview, even though I try to be as open as possible for all different directions we might take, to what is important to her.

I deliberately chose not to bring up gender explicitly during this first interview, since I was afraid this might dominate our conversation and I would be too governing in the discussion. This I saved for a later interview. Despite this fact, or possibly because of it, I do not see analysing the interview in terms of gender as problematic even though Eva herself has not had anything to say about the issue. It is however not only my academic interests that will affect the interview, my background in terms of, for example, gender, class and ethnicity will also contribute. The extent to which this will affect the interview is of course impossible to say, but as an example I can mention that I,

> just like Eva have a working class background – and I, just like her, have thought a lot about how it has affected my choices in life. Therefore it is natural for the conversation to focus on this commonality, whereas for example ethnicity was not touched upon at all.

Having my peers in Umeå read Eva's story and my interpretation thereof made me realise the power in using such a narrative style and also the possibilities of using ideas from situated cognition. My research focus started to narrow down to looking at identity: how students become physicists, in the setting of the student laboratory. The reason for focusing on the student laboratory had also shifted. It grew from an interest in it for its own sake, to looking at it as an example of a complex learning environment where students can stage a wide variety of possible physicist identities. Next, I developed a new interview protocol (see Appendix C) and conducted semi-structured interviews with thirteen students studying physics within the Master of Science programme at Uppsala University.

At this stage, one important issue in terms of the theoretical framework needed to be resolved: what gender theory to use and how to combine this with situated cognition? In reading my interview transcripts I could see a variety of different gender manifestations, in particular, different masculinities being constituted by the students and I set out to look for a possible way of analysing these. In this search I came across Paechter's papers on understanding masculinities and femininities as communities of practice (for example, Paechter 2003a, 2003b). This was the starting point of the development of the conceptual framework I presented in Chapter 3 and also what helped me formulate the two questions that focused the empirical investigation described in Chapter 6. Finally, this leaves the thesis as it looks today in terms of research question, conceptual framework and methodology.

5 Literature Review: Gender in the physicist community of practice

As I outlined earlier, the research about gender within the PER community is somewhat sparse, but researchers from many other fields have been interested in the interplay between physics and gender; anthropologist Sharon Traweek (1988) being one of the better known examples. The interplay between gender and physics has also been studied by, amongst others, Cohn (1996), Thomas (1990) and Fox Keller (1992). It is this kind research that I now will draw on as I examine *gender in the community of practice* of physicists. Thus, drawing on feminist critiques of science as well as empirical studies of gender in science, this chapter will provide an overview of the various ways that gender has been found to influence the physics community.

As discussed in Chapter 4 qualitative research of the type I am using in this thesis is not expected to be generelizable in the traditional sense. This also holds for the research described in this chapter. So instead of generalizing what is said in this chapter to the Uppsala physicist community, it ought to be read as understanding possibilities; the following description of how physics can be seen as gendered is a way to create an understanding of how gender can possibly influence the studying environment of the interviewees.

5.1.1 Practice

As discussed earlier, Wenger (1998) argues that it is the shared practice that holds a community together. Here I will explore how the various dimensions of this practice can be seen as influenced by gender, thereby forming a comprehensive picture of the gendering of the practice of physics. This will then in turn serve as a reference for understanding how students' constitute their physicist identities in relation to this gendered practice.

5.1.1.1 Meaning

The concept of meaning negotiation is a key concept in Wenger's (1998) description of a community of practice. Meaning, as portrayed by Wenger, is not something we make independent of the world, but, at the same time, neither is it just imposed on us by the world. Meaning is negotiated through two interacting processes that Wenger characterizes as *participation* and *reification*. Participation refers to the members actively taking part in a community. The explanation of reification needs to wait until the end of this section.

An illustrative example how of participation in science can be shaped by gender is Conefrey's (1997) ethnographical study of a laboratory group in life science. Conefrey focuses on one member of the research group, Lilly, a young female who has recently joined the group. Lilly's participation in the group is in many ways shaped by gender. This includes, for example, a conversational style that Conefrey suggests to be more compatible with men's way of talk than with women's, the groups many references to physical competition, and also Lilly experiences what the male group members considered as 'normal joking around' as uncomfortable.

Thomas (1990) interviewed students and teachers in English and physics courses to explore connections between gender and study choice. She demonstrates how it is not only the relative proportions of women and men in a discipline that can give rise to marginalisation, but also how cultural conceptions about femininity and masculinity can be critically important. The male English student saw the fact that they were a minority as an asset; in English individuality was valued as a virtue and both the male students and their teachers viewed male students as more special. One consequence was that male students were considered to have more interesting viewpoints to offer than the females. On the other hand, the female students studying physics felt that they had to prove that they were as good as the men; individuality was not highly valued by either physics students or teachers. Consequently, the students' participation in these disciplines are affected by the cultural conceptions about gender.

It is through the process of reification (which Wenger 1998 described as giving form to our experiences) that we produce, for example, abstractions and concepts, which is certainly a most important process in physics. But how do physicists reify their practice? What abstractions, terms and symbols are chosen? Crucial to this process is how physics is described in words; a part of the physics discourse. Cohn (1996) has shown how much of the language used in nuclear strategic thinking can be seen as filled with sexual imagery. Calabrese Barton (1997) has criticised the language of science for being unemotional, competitive and aggressive – characteristics all associated with hegemonic masculinity. Merchant (1984) points out how the symbolic structure in science is permeated with ideas about gender and how these symbols, these metaphors, do in fact have a normative function for the formulation of what science is. In particular, she emphasizes the identification of nature with a woman, often a woman carrying secrets, as one of the strongest of those symbolisms. A symbolism that throughout history has been used by scientists when they discuss their research.

5.1.1.2 Community and boundary

Two important, and interrelated, dimensions of a practice are *community* and *boundary*. Together these define what is seen as belonging to, for example, the physicist community. It can, for example, have to do with the shared repertoire of physics; what is seen as important, what matters within physics. In Gee's (2005) terms, what are the 'social goods' in physics. However, when defining a community it is equally important to consider what is defined as 'not belonging' in contrast to what is defined as 'belonging'; how the boundaries are set. Here we also need to consider how a community relates to other communities; the continuities and discontinuities between them. In the following I will give consideration to how gender matters when the community of physics is defined and its boundaries set.

In a broader sense the most important component of the shared repertoire of science is the delineation of what is seen as belonging to science, what is considered scientific and how this has developed historically. How gender plays a role here is a complex philosophical issue that has received a lot of attention over the last 25 years or so from feminist philosophers of science, so I will only provide a brief overview of some of the main ideas.

Underlying most feminist philosophy of science is an epistemology that sees all knowledge as situated and as such influenced by the context in which it has been constructed. In other words, it does matter that physics has been developed predominantly by white, middle- and upper-class men. An example could be how the qualities valued in science such as objectivity, reason and mind are at the same time qualities that the broader societal culture associates with masculinity (Schiebinger 1991; Brickhouse 2001). Often dichotomies such as active/passive or objective/subjective are used to describe and organize the world around us (here adapted from Benckert 1997):

objective	subjective
active	passive
rational	irrational
mind	feeling
hard	soft
strong	weak
culture	nature

When looking at the list of words one can see that the words in the left hand column are commonly associated with masculinity, whereas the words in the right hand column are commonly associated with femininity. I probably did not have to specify which column was which, as from an early age we learn which words are associated with masculinity and femininity. Benckert (1997) further discusses how both columns are not seen as equivalent; those things that are associated with femininity are commonly seen as having less value than those things that are associated with masculinity. She also writes:

> Science and in particular physics is connected to the masculine. Words that can be used to describe physics are rational and objective and perhaps also hard. We talk about hard and soft sciences. Science is hard while the humanities are soft and within science physics is harder and biology softer and it is therefore seen as more suitable for women. (p. 59, my translation from the original Swedish)

The common assumption that science is value-free, neutral and objective in its pursuit to 'explain reality' is replaced by a view that our possible experiences of this reality are always determined by culture: that ultimately all knowledge is socially constructed. For example, Fox Keller (1992) has argued that what is seen as science, how the boundaries of the scientific community is set, is a social construction. Furthermore, from this epistemology it is argued that there is no such thing as 'pure science', that science never can be disconnected from its technological applications since science and technology are mutually dependent for progress (see, for example, Harding 1986; Fox Keller 1992).

Furthermore, the *shared repertoire* also includes, for example, anecdotes from the history of science and pictures of scientists found in students' textbooks and on the walls of many physics departments; contexts that are all largely male dominated (see, for example Traweek 1988).

The historical process of defining what today is seen as scientific is the central theme in Schiebinger's 'The mind has no sex?' (1991). Her book can be viewed as an authorative, albeit unconventional history of science, where she demonstrates how masculine/feminine and scientific are not static conceptions, but 'living' conceptions that have been defined and redefined throughout history. Science has, according to Schiebinger, been defined and made academic through both the exclusion of individual women, and the exclusion of areas that have been traditionally dominated by women (e.g. health-food) and of ways of doing science that have been accessible to women (e.g. family-based laboratories). By these processes, what is seen as feminine, and what is seen as scientific have been defined in opposition to one another; what is scientifically correct is automatically unfeminine and characteristics seen as feminine are by the same token undesirable in science. In other words, it can be argued that the two communities 'feminine' and 'science' have become almost mutually exclusive.

One important *discontinuity*, in the science context, is between femininity and science. As discussed by Brickhouse (1991), cultural values associated with science (objectivity, reason, mind) are largely aligned with those associated with masculinity through a historical process beginning with the Enlightenment where not only masculinity but also what is scientific has been defined in opposition to femininity. Sharon Sue Kleinman (1998) has likewise argued that the underlying ideology of science can be interpreted as masculine and Byrne (1993) claims that such disciplinary culture is most likely to be the greatest barrier for adolescent girls, who want to be seen as ‘feminine’, to pursue a career in science.

How this discontinuity can be experienced by an individual student has been described by Calabrese Barton (1997). As an undergraduate she did not feel confident nor comfortable with quantum mechanics, seeing it as a subject reserved for ‘geniuses’ and attributing her good grades to ‘pure luck’. However, she claims that her study of feminist theories of science made her understand that her discomfort with the world-view of physics was not rooted in a lack of intelligence but a consequence of her attempts to ‘engage in a world that historically [had] not appreciated or even respected the beliefs and values I had learned to value as a woman’ (p. 148).

On the other hand, the *continuity* that is possible between different communities of practice is illustrated by thinking about how certain child gender-manifestations get their continuations in certain adult gender-manifestations. Mellström (1999) has, for example, described the world of technology as a world of eternal youth, where boys childhood play with technological toys (i.e. a certain child masculinity) gets a theme of continuity in a professional technological world that rewards ‘boyish’ curiosity and inventiveness. Thus, technology as a male way of life is often founded in the early childhood; the boy interested in technology is expected to grow up to become an engineer. Hasse (2002) has also described how ‘playing around’ (with equipment, for example) is an important aspect of many male physics students participation in physics.

6 Results and analysis

6.1 Introduction

In the following chapter the conceptual framework I presented in Chapter 3 is employed to analyse how students' form physicist identities in relation to their practice in the student laboratory. As I earlier argued for, identity is here viewed as a negotiated experience, a work that is constantly going on; not a stable category. Any individual student will, however, only be able to provide insight into their current view of their identity constitution, in other words, as it looked at the time of the interview.

As stated in the introduction the guiding question of the research presented in this thesis is:

How do undergraduate students in the context of laboratory work constitute physicist identities in relation to the cultural norms of the university-based physics community?

The focus of the empirical investigation in this chapter is on the sub-questions:

- What are the gender manifestations underpinning students' identity formation in the physics student-laboratory?
- How do different students experience themselves as constituting their physicist identities in relation to these gender manifestations?

For the purpose of my study, a student's identity is understood in terms of *nexus of multimembership*; a single person will belong to a number of different communities of practice and these various belongings are seen as affecting one and another. However, a person's identity formation is not only depended on what communities they participate in.[13] Equally important, for a person's identity formation, is their non-participation in other communities. Thus, the concepts of participation and non-participation contribute to the

[13] See, for example, Paul in section 6.3.

understanding of how students position themselves in and against certain communities (this is of particular importance for the female students). Further, engagement is not the only mode of belonging that is important to the students; in particular, imagination can play a powerful role when creating a sense of belonging in the physicist community. Finally, a person's various 'belongings' will also affect their interactions with other people.[14]

A key aspect in my analysis is that masculinities and femininities are understood as communities of practice. This allows me to talk about *participation in masculinities and femininities and also relate these participations to participations in other communities of practice* (such as, for example, the university-based physicist community).

The focus in the analysis is on how the individual students constitute physicist identities. However, in order to do this it is necessary to take a step back and look at the collective (all thirteen interviewed students) in order to map out the different gender manifestations that are present in their talk about the university based physicist community. My analysis therefore starts on a collective level and then moves on to focus on individual students (section 6.2). In this second step of my analysis the focus is on six of the interviewed students, but excerpts from other students will also feature in order to further help to illustrate certain important issues (sections 6.3-6.8). Furthermore, in relation to the stories of different students, different aspects of the conceptual framework will be brought to the fore depending on what experiences the student voiced in the interview.

6.1.1 Name conventions

All students' names used in the thesis are pseudonyms. The interviewed students are all Swedish and consequently Swedish pseudonyms have been chosen for them. When exploring the gendered experience of learning physics, students genders are of crucial importance, how they experience, for example, being in such a male dominated environment is expected to be different for many male and female students. Therefore, female students are identified by female pseudonyms and male students by male pseudonyms.

6.2 Masculinities and femininities in and against physics

Physics is, as described in the previous chapter, generally seen as having strongly masculine connotations. This kind of connection between masculin-

[14] This is particularly pertinent in the case of Mia, in section 6.8.

ity and physics also emerged during my interviews when the students spoke about gender and physics. As interesting as the association between masculinity and physics is, I would argue that we need to go beyond the rigid dualism of masculinity versus femininity in order to nuance students' gendered identity-constitution. However, research on different gender manifestations among physicists is sparse. The following mapping of gender manifestations present in the interviewed students descriptions of 'doing physics' will therefore get its inspiration from research on different gender manifestations in relation to related fields such as technology in general (Wajcman 1991) and engineering (Mellström 1999; Walker 2001; Faulkner 2005).

In Wajcman's (1991) pioneer work on technology and masculinity she gives a theoretical description of technology as a masculine culture. In this description she argues that control of technology is at the core of hegemonic masculinity and she distinguishes between two different forms of technological masculinity: one based on physical strength and mechanical skills and one based on 'the professionalized, calculative rationality of the technical specialist' (p. 144). Furthermore, it is interesting to notice that she found that, 'masculinity is expressed both in terms of physical strength and aggression and in terms of analytical power' (p. 145), making the masculine ideology of technology a very flexible one. Faulkner (2005) also distinguishes between two different forms of masculinity within engineering:

> One takes its marker from the hands-on work with technology, and is modelled on the technician engineer – hence 'nuts and bolts'. The other takes its marker from corporate authority and commerce, and is modelled on the senior manager or businessman. (p. 21)

Mellström (1999) relates the two technological masculinities described by Wajcman to a Swedish context. In Sweden being practical has traditionally been valued highly and also tightly interconnected with 'being a man' (Mellström 1999). This ideal, according to Mellström, is found in a variety of social contexts but perhaps primarily in rural areas and smaller towns and among the 'working class'. Mellström (2002; 2004) further showed how, across many different contexts, identification with technology is an important part of what it means to be a man. Consequently, the relation between femininity – and therefore women – and technology is often depicted as virtually non-existent. The contexts Mellström studied were exclusively male, his focus being on men and their homosocial bonds in relation to different technological practices. In this thesis I expand this focus by including an investigation into how females in a male-dominated environment relate to masculinities.

So far, I have described a focus that has been primarily on masculinities in relation to technology and engineering, yet, the two technological masculinities described by Wajcman (1991) do, in important aspects, parallel how the thirteen interviewed students talk about doing laboratory work in physics. In the interviews the students were asked about what they see as important/unimportant to be skilled in when working in a student laboratory, what they see themselves as skilled in and how they approach the laboratory work. The students' answers to these questions could be described in terms of two broad categories: the practicalities of laboratory work (e.g. putting the equipment together) and the analyses of the results. Therefore, I would argue that Wajcman's (1991) two technological masculinities also are applicable to the university-based physicist community. This should come as no surprise considering how the discipline of physics historically has its roots both in a tradition of craftsmanship (for example, building of precision instruments for measurement) and an academic, university-based tradition (Schiebinger 1991).

In the following, the two physicist masculinities are described in more detail and illustrated with interview excerpts. Note that the selected excerpts can by no means capture the full complexity of the gender manifestations, but are simply illustrations of certain aspects in the discussion of my results. Furthermore, note that individual students do not necessarily 'belong' to one masculinity or the other – these are after all distilled from the student collective – but the individual students are in various ways relating to these archetypical masculinities in their identity constitution.

6.2.1 The practical physicist masculinity

The practical physicist-masculinity is characterized by a focus on the practical rather than the analytical; 'having a feeling' for the work, being intuitive, is highly valued. Consequently it is not seen as always necessary to read instructions, one should be able to just figure out or 'tell' what one is supposed to do. One student who voices this view of laboratory work is Paul; he takes a great pride in being able to do practical work:

I: But in the student laboratory, what do you view yourself as good at there?

Paul: Connecting stuff! … I'm fairly good at connecting, connecting things together, setting things up, get the stuff working, start the measurements and stuff like that.

Another student with a similar view of laboratory work is Kalle. Before coming to study physics Kalle was working in industry and he sees many connections between his previous experiences and working in a physics laboratory. In fact, what attracts Kalle to physics is its similarities with working in a workshop (lines 15-16). Note that when Kalle talks about coming up with solutions (lines 9-10), I, from the wider context, interpret this to mean practical solutions, i.e. how to construct certain things.

I: But why did you choose to study physics then?

Kalle: Always thought that physics is fun. But for me it has always been the experimental part, it's never been to become a theoretician or something like that…

I: What do you see as so appealing with the experimental then?

Kalle: Ehm… It's this that… you can come up with solutions yourself then, and then you get… to manufacture these ideas then, even though it's not me who gets to do it, but it's the people in the workshop… But it is precisely that that's so appealing, that it's so close to working in a workshop really…

How it is not seen as necessary to read instructions, but rather how having a 'feeling for what to do' is what is valued, is neatly captured in the following excerpt from the interview with Lars:

I: Why don't you do that [read the instructions first]?

Lars: No, I don't think it's necessary that you read 'put it there', that you can understand.

6.2.2 The analytical physicist masculinity

One of the technological masculinities described by Wajcman (1991) is characterized by 'the professionalized, calculative rationality of the technical specialist' (p 144). In the physics student-laboratory this is manifested in a focus on theory (David), analysis (Lisa), mathematics (Dan) and logical thinking (Susan) rather than the practical doings.

David: It [practical physics] surely fits some, but for me it rather counteracted the interest sort of, I didn't find it fun to play with circuit cards and sit and tinker and so on, I, like, wanted to see the theory behind…

…

I: What to you think the purpose of labs is?

Lisa: I think it's the understanding, when you write the report you really have to go deep and read in the books, understand what it says…

…

Lisa:	I think it's the most fun when we go through it, when we've done the lab and are to write the report and will figure out the theory part and draw conclusions from the results we've got, such things…

…

I:	What do you try to learn when you step into the lab?
Dan:	Well, first you have to try to figure out what you're doing, but.. What you do first is to make a mathematical model, cause that you're supposed to do and then the thing is to get all, on one hand to get all the formulas right, yeah, and then all definitions in order to derive an expression and then check so that the expression you've derived agrees with what you measure in reality. So I think that the biggest challenge is the mathematical preparation really, if it's not a very complicated lab, cause I mean… Carrying out the lab, that's only mechanical stuff you're doing.

…

I:	So what is important to be good at in order to be a good physicist?
Susan:	It's to be able to see connections I think, to be able to think logically and see connections, to be able to connect different things.
I:	Is there any difference between what is important to be good at in the laboratory compared to other stuff?
Susan:	No I don't think so.

Many of the students with the above kind of approach also find reading of instructions necessary (David), focus on the report writing (Lisa, above) and value being structured (Dan). How these associated characteristics perhaps make the analytical masculinity the more inclusive one will be further explored in the forthcoming analysis and in the discussion.

David:	I think you benefit more from reading the instructions than just ignore them and try to figure out how the apparatus works right away.
Dan:	What I'm good at… Well, trying to think calmly and structured, not to stress, cause if you just haste past some part of the lab, then it's easy that you miss something…

6.2.3 What about femininities?

It is worth noting that neither of the versions of being a physicist has strong feminine associations. And, as by pointed out by Faulkner (2005), neither do the engineering masculinities that are described by her. Consequently, when femininities are talked about by the students in the majority of cases it is terms of how ‘normal femininity’ is not resonant with doing physics. In their interviews both Ann and Lisa position themselves as being different from other women.

Lisa: I’m not like everyone else, I walk my own way I think. I did start studying really late.

Ann: I can never be like normal… So I feel very comfortable among guys…

This counter-identification with traditional femininity amongst female students in science and technology has also been well-documented in previous research (see, for example, Walker 2001, Hughes 2001 and Henwood 1998). This will be explored further in relation to the individual students’ identity constitution.

6.2.4 Format of data analysis

The analysis presented so far has focused on the collective of interviewed students, in what follows the focus moves to individual students and how they constitute physicist identities in relation to the above described gender manifestations. Each section explores the identity formation of an individual student starting with the actual analysis, in which references are made to subsequent interview transcripts. The interview transcripts that follow the analysis consist of excerpts from the full transcriptions which are judged to be relevant for the reader to be able to follow how I engaged with the data. The analysis, however, is based on the full transcripts, not only the excerpts included in the thesis. The excerpts are presented in chronological order and the ‘cuts’ between different excerpts are indicated by […].

6.3 Paul

In her classic study ‘Gender and subject in higher education’ Thomas (1990) writes:

> For these men, the physicists and the physical scientists, self-image was concerned with the particular nature of one’s abilities and the sort of job one could do with them; it was rarely concerned with one’s identity as a *man*, as opposed to scientist: the two were one and the same thing. There was, as we might expect, no conflict between the two. (p. 116)

The relationship between men/masculinity and physics is often depicted like this; as unproblematic and straightforward. In order to go beyond this I needed to think about a student's identity in terms of a 'negotiated experience'. That is, different gender manifestations and memberships in, for example, professional communities (such as the university-based physicist community) are seen as being constituted into an *identity in practice*. This brings to the fore how an identity is not a stable category that is set once and for all but a continuous work. In the case of Paul, he is at the time of the interview struggling to combine different (gendered) ways of being a physicist into the nexus of multimembership that is his identity. As in the description given above from Thomas (1990) there is for Paul perhaps no conflict between being a man and being a scientist, but between how to be a man *and* how to be a scientist.

In the sections 6.2.1 and 6.2.2 the interviewed students were discussing how to be a physicist in terms of two different physicist masculinities. Both these issues are also discussed by Paul. He identifies strongly with the practical physicist masculinity[15] (see lines 39-43 in the transcript). But he also sees a fulfilment of a membership in the analytical physicist masculinity as necessary for gaining acceptance in the university-based physicist community, since this is what he recognizes as being the generally accepted physicist norm among many of his classmates (lines 22-35). Being an analytical physicist is what Paul views as the norm. This is further reinforced in lines 76-81. He certainly gives value to both practical and theoretical work. However, in lines 80-81 it becomes apparent that being analytical is sort of the default situation, something that is seemingly taken for granted in the physicist community.

In other words, Paul's identity is something he is constantly constituting; he does not posses a stable physics-student identity, but is constituting one in relation to the practice; in relation to what he views as the norms of the university based physics community (see, for example, lines 1-20 and 69-71). Paul's multiple belongings in different gender manifestations within the university-based physicist-community can be thought of in terms of viewing the identity as a nexus of multimembership where the various belongings affect one another, and where the competing demands of the different communities of practice is what makes Paul's constitution of a physicist identity perhaps not as straightforward as expected. Further, this also shows the importance of considering multiple, and sometimes conflicting, gender manifestations. For example, struggles like Paul's would get lost in a framework that only considered masculinity versus femininity. Paul does not posses one stable

[15] Masculinities and femininities are, as described in section 3.4.1., treated as 'communities of practice' in the analysis.

and uniform gender identity; his gender identity is something he is doing in relation to the practice.

That Paul's goals are continuously changing during his education (lines 1-3) is not too surprising, after all this is what is 'expected' of students. However, I would argue that what is going on here is more complex than just a passive transformation into a fixed physicist identity, what Hildebrand (2001) criticised situated cognition for. One can see in lines 7-20 that there is a negotiation of what it means to be a physicist. This could certainly be read as Paul coming closer to realising what physicists are 'actually' like: that they are not necessarily extremely smart, but that important characteristics for a researcher include interest and discipline. Nonetheless, in making this explicit, Paul is for himself negotiating what it means to be a physicist. In doing so, he, as a 'legitimate peripheral participant' in the university-based physicist community, is also shaping the meanings that matter within that community.

Paul:	And, then I come closer to my goals, which are continuously changing when you do this education.	
I:	How have they changed, the goals? Did you want to become a researcher already from the start?	
Paul:	No, I… it would be fun, but that I should become a researcher, that's not something I thought. I've grown up with pals who are everything from construction workers to… yeah, everything, but there are very few people who've continued to higher education among my friends. And, researcher, yeah, it would be fun, but I've never thought of myself as smart enough for that, but since I started here I've realised that maybe it's not about being so very smart, but it's about thinking that it's fun, to be interested, and have discipline…	*Negotiation of meaning*
…		
Paul:	I've studied together with Jörgen too, and he's kind of such that the theoretical is better than the practical, he thinks. … and I can say that I don't think it is.	*Analytical masculinity higher valued*
I:	Like that, that kind of knowledge is higher valued?	
Paul:	Yes, he somehow seems to think that it's better to be a theoretician, or that it's better to... you should get away from all the manual work and I can think that, it	

has exactly the same value this, 'cause they are two side of the same thing kind of, it's good with theory, but if you can't tie it to the practical...

...

I: But in the student laboratory, what do you view yourself as good at there?

Paul: Connecting stuff! … I’m fairly good at connecting, connecting things together, setting things up, get the stuff working, start the measurements and stuff like that. What I on the other hand can think... sometimes I can think that my weakness is this thing that I sometimes have difficulties to connect measurement results and get something out of it. [*Identifying with practical masculinity*]

I: The analysis..?

Paul: There I can think that I'm a bit weak sometimes. But maybe that's because I do the labs together with people like Lisa and Erik, who are... who are really skilled at that it, or Erik anyway is extremely skilled, he is so bright when it comes to analysis. But when I do lab work with others I don't see it as my weakness, so it's...

I: So it depends on...

Paul: Yes, it depends somewhat on who I'm working with, if I'm working on my own or if I kind of... I don't think that I have any particular... Well, I'm probably better at connecting stuff and such, at the same time as I probably was better at it in the beginning, I think that I'm better at analysis today, after spending almost three years here... It's a smaller difference between connecting stuff, but I'm still somewhat better at connecting, I'm working on that I next years will be just as skilled at connecting as analysing...

…

I: But if you think about the ideal students, when it comes to working in the student lab – what are they good at? [*Ideal student*]

Paul: … I can’t say that I think that you ought to be more practical or theoretical, but I think that you ought to be both. You ought to be interested both in the manual and the theoretical. If you’re only a

81 theoretician…

6.4 Ann

In Ann's identity formation the relation between femininity and physics is central. To illuminate how she positions herself within this relation the notions of *participation* and *non-participation* are useful. In her description of how she works in the student laboratory Ann talks about herself as being 'a bit slow' and therefore 'taking the female role' (lines 173-176). From this quote we can see that Ann, firstly, recognises being a female as a role, as something that is 'done'. Secondly, this feminine role is for her associated with being 'a bit slow', consequently, participating in this 'female role' implies non-participation in the scientific community. This is well in agreement with how many women in science and technology explain their presence in such a masculine subject by constructing themselves as different from other women, i.e. 'as being one of the boys' – as participating in a masculinity (see, for example, Hughes 2001, Henwood 1998 and Walker 2001). This counter-identification with traditional femininity is also described by Ann, who on several occasions during the interview talks about herself as being more comfortable in all-male than in all-female environments and thinks of herself as not fulfilling a 'normal' femininity (see lines 163-167, lines 195-196 and lines 201-204). The same counter-identification is also described by Lisa:

Lisa: I'm not like everyone else, I walk my own way I think. I did start studying really late.

Here it is also interesting to notice that not only women, but also some men constitute their physicist identities in relation to what they see as feminine or associated with the female students. John, for example, when asked why he thinks men are in the majority in physics, compares his way of thinking with that of his girlfriend:

John: My girlfriend studies the same program as I do, well, I've compared a bit how she thinks and how I think and it's… the biggest difference is that I often think a bit differently in like kind of formulas back and forth, whereas she remembers one thing and then learns that thing and has difficulties building it on, comparing it to other things she's learnt. But she is better at learning a lot of things at the same time. I learn a few things and then I develop a theory and that is… I don't know… and that to just learn a few things, it's… better if you learn languages and such, but for physics and mathematics then you should rather be able to continue building on formulas also.

As in the case with Ann and Lisa we can see here how John views science and femininity as something impossible to combine, and how participation in one implies non-participation in the other.

The counter-identification can be understood in terms of the historical discontinuity between femininity and science, as described by Schiebinger (1991). She argues that what has been seen as feminine and what has been seen as proper science historically have been constituted in opposition to each other: what was scientific was automatically unfeminine and characteristics seen as feminine were automatically not wanted within science. Consequently the categories 'feminine' and 'proper science' became almost mutually exclusive. In other words, participating in both femininity and science was just not possible, an idea that is still prevalent among today's female physics students (see, for example, Walker 2001). The 'normal' femininity discussed here can be understood as a community of practice, where you through participation in certain practices, within certain boundaries, become a member. The same can be said for the physicist community. The argument here is that these two communities need to be understood collectively in order to fully appreciate how, in particular, female physics students constitute their physicist identities. Ann is thus, drawing on the discontinuity between 'normal' femininity and physics in order to position herself within one and outside the other.

However, Ann's perceived participation in a masculinity is not a participation in a generic masculinity (for example, she sees herself as different from Paul, line 142), but in a particular branch of physicist masculinity. For her it is the analysis that is the primary focus in the laboratory (line 45-110). She further sees herself as skilled at preparation and planning as well as writing reports, but not at practical work in the laboratory (lines 112-121 and lines 125-135). Furthermore, she makes a clear distinction between the masculine environment in her previous workplace and what she now finds at the physics department. Ann is a mature student and prior to her physics studies she was working as a kind of electrician, a profession that is far more male dominated than even physics and where she commonly was the only woman. She describes her earlier work place as having been very masculine, with a very masculine jargon, something she eventually felt did not suit her. Due to this earlier experience of an extremely male-dominated working environment she strongly opposes the idea that physics should be masculine (lines 1-37). When friends of hers visited her at the university and pointed out to her how many men there in fact were, she was surprised, since she had not experienced her studying environment as being particularly male-dominated. This is not, I would argue, a sign of physics at Uppsala University being somehow feminine, but rather it brings to the fore how gender is a relational concept; how what we see as masculine and feminine obtains its meaning in relation to each other (see, for example, Svennbeck 2004).

Despite Ann's feeling of not fitting in at her earlier work place she, however, claims to feel very comfortable among men, often appreciating their jargon and attitude. As discussed earlier, she also views herself as a non-participant in a traditional femininity, which is partly due to her untraditional previous experience of working in a workshop. Nevertheless, she does see a sharp discontinuity between the workshop community and the university-based physics community. Not too surprising perhaps, but in contrast Kalle, in section 6.5, constitutes his physicist identity through a perceived continuity between a workshop community and the university-based physics community.

The lines 144-161, where Ann is talking about the possibility of working in a research laboratory in the future, represent a negotiation of what kind of physicist she wants to be; what being a physicist can mean. Here it is again clear that it is doing analysis that is the focus for Ann; 'connect stuff together and such, that doesn't fit me' (lines 151-152). It is important to notice that she talks about the practical physicist masculinity as not fitting her and not as being at odds with physics. Overall, Ann views the physicist community as made up of numerous different communities, where a wide variety of people can find a home (line 215-217). And, it is within this variety of possible physicist communities that she has constituted her specific way of being a physicist.

Ann does, however, despite her strong focus on doing analysis when doing laboratory work in physics, value practical skills in her everyday life; she thinks one should be able to do practical work (lines 207-210). Further, she is very pleased that her oldest daughter is 'tomboyish' (lines 178-186). Together this can be interpreted as a valuing of what could be characterized as a 'female masculinity' (Halberstam 1998). 'Normal femininity', on the other hand, is for Ann seen as limiting (lines 188-193). This further demonstrates the need to consider multiple and sometimes conflicting gender manifestations; Ann values different gender manifestations in different contexts.

Ann:	At first I was working as kind of electrician in one place and then I moved to the next place, the next step so to speak, if you're going to go on, then I became a consultant and then I started to feel that, no what, this doesn't fit me. Here you're supposed to be so masculine, and I can't explain, it was a totally different… jargon. And then I felt that I can't walk around and talk about ice hockey just to fit in. I was the only women all the time. In all of Sweden I think. There were one more women in Sweden who did	*Analysis her focus in the lab – non-participation in practical physicist masculinity*

what I did and … yeah. Here it feel more that it’s competence, not jargon, if you’re good it doesn’t matter if you’re… how should I explain, there it was more collective behaviour that gave go-ahead spirit and here it’s more competence, you learn something and think that it’s fun and get good at it and continue working on it.

I: So for you, physics isn’t particularly masculine?

Ann: No, absolutely not!

I: I could imagine many women who…

Ann: No, not at all! This isn’t masculine at all.

I: I could imagine many women who would say the opposite…

Ann: No, no, no.

I: …that physics is very masculine.

Ann: No! Not! Here it’s much more… no…

I: But there’s after all a lot of men who study physics. It is.

Ann: But the attitude is totally different, it’s much, much… when you study it feels more… how should I explain…. it’s not such workshop mentality. Nothing bad about that, I loved those guys and we had a blast and it was really funny, but… no.

….

I: What do you see as the purpose of doing labwork?

Ann: That you should understand what you’re doing in a larger context. …

I: What do you mean by understand what you’re doing?

Ann: How should I put it… The labwork as such sort of… But as an example, now that we were doing nuclear and particle physics, then you’ve been reading about different decays and beta-decay and everything, but then it becomes so clear that, yeah, annihilation that’s them and from the positron you get that… so really I see the labs as a way to study, cause you understand what you’ve earlier have been struggling with, it falls into place.

I: Because you do it in yet another way?

Ann: No, maybe because you talk, you think so much about the same thing an entire day.

I: So it’s not the labwork as such, it’s more that you work in a group and discuss…

Ann: Yeah, more that. Not [the lab] as such, cause it’s often very abstract, you see some curve or some line or some spectrum, most of the time I think it’s… all the going through, that it’s like studying for an exam kind of, ‘aha, that’s how it was!’, that I think is almost the most important thing with the labs, that you understand the theory.

I: More the analysing?

Ann: Yes, precisely.

I: Than the actual doing?

Ann: Yes, absolutely.

I: Has there been any difference between, if you think about the introductory mechanics course compared to the nuclear and particle physics now?

Ann: Yes, they’ve been great. Now has [inaudible] wished that they’ve had a lesson before and had a proper introduction. Often when you get to a lab and then you’re not really in phase with the course and you haven’t had time to read what you’re supposed to and then you stand there like a fool when you’re supposed to do things, but here they really had half an hours introduction and went through all the theory we had in the lab and that was great. And then… on one hand you understand more what you’re doing, on the other hand all the concepts come together.

I: That you understand the theory cause now you see… Cause now you talk about it, not because you see it, or..?

Ann: No, because you talk about it all the time, at least that’s what I think.

I: Yeah, that’s really interesting. So it’s not so much that it’s good to do physics but it’s the discussions that are the interesting part..?

Ann: Yes, I think that most of the time when it comes down to the harsh experiment, then you never know if there’s something wrong with the oscillator or… Honestly, you don’t know…Oh no, we were wrong like this, what’s it called, when you tune in the amplifier or something, then I think that often you have… You never know when you analyse if you’ve done it right or not, that then it was correct, then the peaks were in the right places or what ever it was, So, the experiment as such I often think that you, no, it’s a bit abstract kind of. That's how I think.

…

Ann: I think I benefit from being quite structured, I can take… It's almost the same thing, that first I do this and then I do that. And that you've learnt along the way that you bring that to the labroom too, that you… that you do one thing at the time and that you kind of… you reconnoitre first, ok, what am I supposed to do, what apparatus should I use and how do I do that… you're really careful throughout all the steps. That you've learnt.

…

I: What do you see yourself as good at when it comes to labwork?

Ann: I'm pretty lousy I have to admit. Well, I'm positive. I inspire my friends when they kind of feel low. No, but really I'm not that good, most of the time when I do labs I'm not that good and the person I'm doing the lab with is better, but… I can be structured beforehand, that I can… I've tried to go through stuff before and then I think I'm pretty good at writing reports, that I'm good at the work afterwards. When it comes to pure labwork it's those things I'm good at.

Non-participation in practical physics masculinity

…

Ann: Paul, 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 haven't slept and he sure starts to tinker kind of! He's so very different, he really fits in a lab!

Non-participation in practical physics masculinity

…

I: Could you see yourself working in a lab in the future?

Ann: Yes, if it weren't too – I thought about this – if a lab is enough… … If you are to do labs, put some stuff in and then measure the result, that fits me really well and then analyse it, but not if you have to tinker to much yourself, try new things, and connect stuff together and such, that doesn't fit me.

Negotiation of meaning

I: Cause your not interested?

Ann: I don't think I'm as careful as it takes, then you have to be very precise and not so slovenly, you have to be so very controlled and precise and I'm not. But as I said, in for example Eva's lab, then you put some things in, close it and let it sit for a while and then you check what happens. That feels like great fun. That's the difference then.

…

Ann: I feel very comfortable among guys, I like that jargon and that attitude a lot of the time, I would be more nervous if it only was women. I've had a horse you know. Only women in a stable. Not so easy, I can tell you.
Non-participation in 'normal femininity'

…

I: Do you think there's any difference between how male and female students work in the lab?

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.

…

Ann: I've got two daughters, both are kind of – the oldest is six years old and it's most apparent on her, she's sort of tomboyish, plays with both girls and boys and so on. And that really pleases me, you notice already now how easy it is that girls become girly and sit and draw, kind of, and have nice hair. And that's really sad. And you bring that role along all the way.

I: And that's limiting here then..?

Ann: Yes, cause then you've kind of, how should I explain, if you've been out in the garage and tinkered with the cars instead of sitting inside and looked pretty and drew, than you've understood something, so when you eventually get here you dare to do more things.

…

Ann: I can never be like normal… So I feel very comfortable among guys…
Non-participation in 'normal femininity'

…

I: Some also talk about how boys have more experience of tinkering and stuff and how that might be important in this context…

Ann: Yes, but there I think I'm untraditional. Because on one hand I've worked in that workshop, well, I wasn't so very, I wasn't the one who got the more difficult jobs, but I worked there quite a lot, you know you stand there and connect stuff. … So I'm pretty handy when it comes to such stuff. Have
Non-participation in 'normal femininity'

208		changed the break shoes on the car once, just	
209		so that I should have done it sort of. Now	
210		I've done it, will never do it again.	
211	…		
212	Ann:	Yeah, that person [the very girlie female]	*Negotiation of*
213		will perhaps not be the experimental expert,	*meaning*
214		but becomes perhaps this brilliant theoreti-	
215		cian. That there is a place for all kinds of	
216		people. That I really like, that it's sort of	
217		very open.	

6.5 Kalle

Kalle constitutes his physicist identity by participation in the practical physicist masculinity (lines 1-25), as well as non-participation in the analytical physicist masculinity (lines 29-30, and lines 35-37). This illustrates how it is not self-evident which masculinity is perceived as having a higher value in the laboratory context. That physics is associated with forms of masculinity is, however, clear; when Kalle is asked whether there are any differences between how male and female students work in the student laboratory his answer explicitly shows that it is the male student who (using the language of Hirdman 2003) is the 'norm' in this context, the 'norm' with which the female students are compared (lines 42-63). Note that what is interesting here is not whether the teaching assistants' in fact spend more time with the female students or if the female students do 'use' their femininity – but that this is how the situation is perceived by Kalle. The female students and the teaching assistants might perceive the situation totally differently, as concluded by Yancey Martin (2003), 'people [are] routinely perceive others as practicing gender despite denials by those who are perceived this way' (p. 356).

Kalle is a non-traditional student with a background in industrial work. This can be seen to very much shape his participation in the physicist community. For example, he states that what he finds appealing with physics is 'that it's so close to working in a workshop really…' (lines 15-16). Following this statement he explains that he would very much like to be involved in the entire process of equipment production, since he could do it just as well as the people in the university workshop (lines 21-25). Here we can see how the workshop serves as a *boundary object* for Kalle, that creates a continuity between his earlier experiences of industrial work and his current physics studies. This is interestingly enough in opposition to Ann's experience of two similar communities.

1	I:	But why did you choose to study phys-
2		ics then?

Kalle:	Always thought that physics is fun. But for me it has always been the experimental part, it's never been to become a theoretician or something like that…	*Participation in practical physicist masculinity*
I:	What do you see as so appealing with the experimental then?	
Kalle:	Ehm… It's this that… you can come up with solutions yourself then, and then you get…to manufacture these ideas then, even though it's not me who gets to do it, but it's the people in the workshop… But it is precisely that that's so appealing, that it's so close to working in a workshop really…	
I:	But you're not interested in doing the practical work yourself? You want to come up with the solutions and then give it away to someone else?	
Kalle:	Well, I'd like to do it all myself, but I'm not allowed to so to speak. It's the workshop that does the manufacturing, then, and that's a pity. Cause I can do it just as well as they can.	
…		
I:	What would you like to work with eventually?	
Kalle:	I don't want to continue in the university world, for sure.	*Non-participation in analytical physicist masculinity*
…		
Kalle:	I worked with someone like that in the nuclear and particle physics…	
I:	Someone that wasn't prepared?	
Kalle:	No, but someone who was looking for too much understanding the entire time. Then it just gets frustrating.	*Non-participation in analytical physicist masculinity*
…		
I:	Have you seen a difference between how male and female students work in the lab? Is there such a difference?	
Kalle:	Yes, in general you can see a difference, but there are also girls who are just as skilled as the guys...	*The male students the norm*
I:	What is this general difference then?	
Kalle:	But the big difference you can see when you do a course or have a lab in some course, it's that surely the lab... it you are really mean then... then you see that the TA:s are with the girls the entire lab [OK] 'cause they can't man-	

age anything, if you’re really mean now...

I: Why don't you think they can manage anything?

Kalle: ... Eh, yeah, if I'll continue to be mean, then I think – or both mean and kind now – I really think they can manage just as well as we do, but it's guys who are TA:s and then it's easy for the girls to get it served on a silver plate, why do anything when you can get it for free...

…

I: Do you think it can have to do with differences in previous experiences? Maybe it’s more common that guys tinker and stuff like that? Does that mean anything here?

Kalle: A bit maybe, that guys dare more, that they’re not so afraid to get it wrong compared to the women, it can be because of that women need more help then… Guys have often had a moped and been in the garage with their dad… and are interested in cars for example and everything like that, but then, if you take, I come from a small town and there the girls drove mopeds just as much as the guys… There I’m not sure if it’s such a big difference, on a small town girl then, where I come from, but it’s surely different if you come from the big city. There girls are more girls. So to speak.

6.6 David

David’s identity constitution is, in sharp contrast to that of Kalle, centred around a participation in the analytical physicist masculinity (lines 1-5, 55-64). He also, like Paul, views the analytical physicist masculinity as the highest valued one among his classmates (line 56-62). Further, not only does David, like Ann, position himself as a non-participant in the practical physicist masculinity; David even sees this masculinity as being at odds with physics, a participation in that masculinity would for him imply a non-participation in the physicist community (lines 35-39, 66-87). Thus, he sees a sharp discontinuity between the communities, while Kalle on the other hand perceives a continuity between them. In doing so David is negotiating his own way of being a physicist in terms of what he perceives to be valued within the physicist community. For David then, tinkering experiences are more a disadvantage than an advantage when it comes to doing laboratory work in physics since such experiences can foster an unproductive way of doing laboratory work (lines 29-39). Consequently, he also sees many women's non-participation in such a practical masculinity as an advantage for them when doing laboratory work (lines 66-67). This association of a more structured and 'following of instructions' approach to laboratory work with female students is one that was also made by several other interviewed students. For example, one of the interviewed male students, Lars, explained:

Lars: Guys tinker more with stuff and girls do it properly and do what they're supposed to.

This is well in agreement with previous research were female students are described as 'doing what they are told', whereas the male students have a more playful approach to science and technology (Mellström 1999; Jones et al. 2000; Hasse 2002). In physics in particular, women's rule-following has been understood as a way of compensating for lack of earlier scientific and technological experiences (Nair and Majetich 1995). This discourse is moreover also present at Uppsala University. Two of the interviewed students, for example, told of how a lecturer in relation to doing laboratory work in electricity and magnetism had said that the laboratory exercises were often easier for the male students, but that the females usually compensated for their possible shortcomings by being more thorough.

David:	It [practical physics] surely fits some, but for me it rather counteracted the interest sort of, I didn't find it fun to play with circuit cards and sit and tinker and so on, I, like, wanted to see the theory behind…	*Participation in analytical masculinity*
…		
David:	I think that it is the previous knowledge when you step into the lab that is the important thing. … But the lab as such, the experimental doings that can everyone manage, that's no problem and is there something you can't manage, then the TA:s can always help you. So that's nothing that hinders you, it's the previous knowledge that totally affects, I think, how well you know what you're doing in the lab.	
…		
I:	Could you see yourself working in a lab in the future?	

David:	No, I don’t think so, it’s a bit too much, technical stuff and machines and such and so on for me to really… It’s too many such things, it’s a bit like, I don’t mind them, cause they’re needed and so on. I’ve got nothing against computers cause they’re needed, but I’m not so very interested in it generally, it’s more that I might need it…	*Participation in analytical masculinity*
…		
David:	No, well, if you’re going to work in a lab maybe it can be an advantage, if you know how to tinker with mopeds, cause it’s so much apparatuses and then you’re obviously interested in it, but to do a lab I don’t think so. Cause it’s like I said, it’s more about reading the instructions than, I think you benefit more from reading the instructions than just ignore them and try to figure out how the apparatus works right away.	*Participation in practical physicist masculinity implies non-participation in physicist community*
I:	The stereotypical guy who just tinker away, that doesn’t work here?	
David:	No, it might exist, but it doesn’t work here. I don’t think so, cause it’s not that kind of machines we work with, then it more becomes that you turn some knobs on random and then you might not at all get the correct values, you might not get the correct measurements, you might not turn the correct knobs at all so to speak, it’s very, it’s… At least I don’t think you can have a feeling for something before you’ve seen it.	
I:	So what’s interesting for you is the analysing, not the doing as such?	
David:	No, not the doing, it’s the analysing that I find interesting and that I think… somehow I’ve got the impression that it’s like that for a lot of people at our education since that’s what the focus is on and that you know when you apply, that the focus is on the scientist who does a lot of analysis. Sure, you can end up in a lab, but still it’s somehow the analysing that the focus is on, it’s not the doing, it’s the analysis.	*Analytical physicist masculinity the norm*
…		
David:	No, I don't think so, in that case I think that girls have a small advantage, I think that in general here there is no difference.	

I No...

David: But there can always be guys who think... that... it's in a higher degree, even if it's in a smaller degree, there are guys who might think that ‘hm, I don't need to read these instructions, I just tinker anyhow’ like we talked about before, but that I think you discover quite quickly here, that you can't... have that attitude, but sure it might be tried a few times so to speak, that ‘this I can tinker together, no problems’.

I: And, that's because the guys have such experiences..?

David: Have such experiences that it works, 'cause maybe it was working when I was putting together my moped when I was sixteen...

I: Precisely, but here...

David: Here it doesn't work and that I think you discover quite quickly...

6.7 Susan

Susan constitutes her identity in a similar way to that of David. For her, laboratory work is all about theory and analysis, not practical skills; tinkering skills are viewed as relatively unimportant (lines 59-60). Instead she values mathematical knowledge (lines 5-7). She stresses how she is not at all interested in the equipment in the laboratory for its own sake: it is what this equipment can accomplish that interests her (lines 9-23). Thus, Susan positions herself firmly within the analytical physicist masculinity. In fact, for Susan participation in a practical masculinity implies non-participation in the university-based physics community. For example, she talks about how the male pupils in her high school class used to throw themselves at the equipment when they had laboratory classes, whereas the females were more reserved (lines 76-80). She is however, certain that doing laboratory work without paying close attention to the instructions could never work at the university level (lines 91-94).

This view of tinkering as counter-productive and incompatible with a productive physicist identity is also shared by Lisa. Paul, Lisa and Ann are all in the same class, and in my interview with Ann, she told me the following about Lisa and Paul:

Ann: Paul is so much fun 'cause he, when he does labs, 'cause he always tries something of his own, kind of like... I remember one time when Adam [the TA] had said, he had made some adjustments with the laser and then ‘don't touch his!’ he said and then he left and Paul started to tinker, and then everyone else had to wait half-hour cause he had to redo it. And Lisa was so annoyed, and it's so typically him!

Despite Susan's view of practical skills being unimportant in the student laboratory she does, like Ann, value such skills in a broader sense; you 'should', for example, be able to fix certain things on your car (lines 47-55). As with Ann, this could be interpreted as a valuing of a form of 'female masculinity'. Once again it is seen how multiple and sometimes conflicting gender manifestations need to be considered; Susan also values different gender manifestations in different contexts.

I:	So there's really no particular previous experiences or knowledge that are important when one starts studying physics?	
Susan:	You need to know maths. If you don't know maths you're going to have a really hard time.	*Participation in analytical physicist masculinity*
…		
Susan:	No, it's not like you're afraid to touch the lab equipment. It's like at home, you have a computer.. it's like the car, a computer and a car, they should work, I don't like to tinker with the stuff, I don't like fixing the car and I don't like tinkering to much with the computer, for the computers own sake, for me it's a working tool and it should work. Period. …	
I:	So the testing isn't so interesting for it's own sake?	
Susan:	No, not for it's own sake.	
I:	It's best when stuff works…	
Susan:	Yes, it should work, cause it's a working tool that should work, period. Well, I did have a period when I thought it was fun to put some more memory into the computer, but that's nothing advanced, just open the lid and stuff it in, more or less, so that… That's not much of a challenge. But I once took a course in… it's such a long time ago, I can hardly remember the name of it, digital technology I think it was. But after that, then you	

	learnt how to do calculations on…	
	different codes and stuff like that	
	and then there were, we had labs	
	where we connected AND and	
	NAND gates to get different things	
	to happen, that I enjoyed, then	
	anyway, so what was on the top of	
	my list of presents was a small, I	
	wanted a soldering-iron, so I could	
	sit and potter about.	
I:	But that’s tinkering if anything?	
Susan:	Yeah, that’s tinkering if anything,	*Multiple gender mani-*
	but it’s not the car cause it’s big and	*festations valued*
	nasty and it should work, I could	
	possibly… I know how to change	
	fuses and I can fill up the liquids	
	and so on, I don’t want to do any-	
	thing more on a car. OK, I think	
	you should be able to change the	
	spark plugs…	
…		
I:	But you don’t think it’s important	
	to be good at this tinkering?	
Susan:	No, I don’t think so at all, but it is	
	good with logical thinking.	
I:	So what is important to be good at	
	in order to be a good physicist?	
Susan:	It’s to be able to see connections I	*Participation in ana-*
	think, to be able to think logically	*lytical physicist mascu-*
	and see connections, to be able to	*linity*
	connect different things.	
I:	Is there any difference between	
	what is important to be good at in	
	the laboratory compared to other	
	stuff?	
Susan:	No I don’t think so.	
…		
I:	In the lab, do you think there’s a	
	difference between how men and	
	women work?	
Susan:	No, not that I thought of. I, when	
	you went to high school, the guys	
	just throw themselves at the equip-	
	ment and started pulling it without	
	checking it first…	
I:	That’s the stereotype I guess…	
Susan:	Yeah, that happened a lot when I	
	went to high school, but since I	
	started here it hasn’t been like that I	

	think. Nor have I been affected by that stereotype the guys just elbow their way along and lay their hand on everything, that hasn't happened to me. Maybe I've been lucky, I don't know.	
I:	The high school thing, that you throw yourself at the equipment, does that work here?	
Susan:	No.	
I:	To approach the labs in that way?	
Susan:	No, it's more advanced stuff, I mean, maybe it could work on the introductory mechanics course, the first lab in that course, then it works. Then you can throw yourself at the stuff and start pulling, it doesn't matter, but then…	*Practical physicist masculinity unproductive*

6.8 Mia

Mia is a female student whose participation in the physicist community is strongly influenced by her participation in a particular femininity. She has strong views on men and women's participation in the physics discipline; she does value both practical and analytical skills in the laboratory, but sees the former as unattainable for her as a woman (lines 36-59). Thus, participation in practical physicist masculinity implies non-participation in femininity and vice versa. Her focus is mainly on mathematics, a field she feels confident in, and claims to be associated with femininity (lines 71-75). This association of mathematics with women can be understood as a localised femininity that Mia is participating in. Mathematics is otherwise generally associated with masculinity (see, for example, Connell 2003a).

Mia is not particularly confident in the student laboratory and prefers detailed instructions, so that she knows exactly what to do. When working together with a male peer, Mia left him to do most of the tinkering (lines 28-32). This 'division of labour' could, in line with previous research, be explained as a consequence of women's often fewer experiences of tinkering (Jones et al. 2000).

I do not oppose that view but would like to broaden the argument. I would argue that Mia, by not actively participating in the practical work in the student laboratory, is doing a particular femininity, a femininity that for her is associated with mathematics and logical skills, and with *not* being handy. In other words, the way she interacts with her laboratory partner, her 'engagement in practice', is tightly interconnected with the way she has learnt to act in order to uphold her membership in a localised femininity.

I:	What's important to be skilled at then, to gain as much as possible from doing labs?	
Mia:	Mm, yeah, it's important that you can grasp the information in the instructions, the you can convert it into practice so to speak, that you can handle the equipment. Afterwards it's the mathematical part, to get everything together. So it's that, I don't know, it feels like it's a lot…	
I:	Is there a difference between what's important to be skilled at in the lab compared to other elements in the physics education?	
Mia:	Yes, well, it's more the practical in the lab. That you don't have, those elements you don't have otherwise, it's that you have to be able to convert the theoretical into practice and tinker together all the stuff and see to that it works.	
I:	Is that something you like? That you feel comfortable doing?	
Mia:	No!	*Non-participation in practical physicist masculinity*
I:	Why not?	
Mia:	I'm generally bad at tinkering…	
…		
Mia:	Aha, I had a lab partner who, I don't really know if he thought it was any fun to tinker with the equipment, but he was doing it while I was handling the computer or...	
I:	Why do you think you divided the work like that, that he was doing the tinkering..?	
Mia:	Well, that's in the genes! That's left since, I'm quite convinced that that's left since the Stone Age, that the men were out with their tools, fishing equipment and hunted and so that they developed a feeling for it that the women didn't develop, so I think it's very natural that it's still left today, that men find it easier, that their brains are more developed for such things...	*Participation in practical physicist masculinity unattainable*

…

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 program in high school too, and the females 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.

I: So, how come that you study physics then?

Mia: Yes, it's my interest in space that has, that's the reason to that. Well I haven't either, I haven't an easy time when it comes to physics really, it's something I have to sit down and set to work with assignments and so on and that came along with, I want to work with space and then that's the route I got to take.

…

Mia: Women are more logical, women have an easier time doing logic, but that I've seen evidence of too that girls I've had in my class or so, have had an easier time doing maths than physics.

Participation in localized femininity

I: So what is the big difference between maths and physics then?

Mia: Well, maths is really logic, you have some kind of pattern that you work from and then it can be a number of different things that are related and then you have to pick out one thing at a time and reach a conclusion, so it's really no understanding, just routine, you have to work back and forth and have patience if it's difficult problems, whereas in physics it's much more that you have to understand relationships, yeah, if it rolls to the right and pull down that way it will move in that direction and then you have to sort of picture things in a different way, forces and...

6.9 Summarising discussion

The focus in the analysis just detailed has been on how students position themselves within and against the communities of practice I have characterized as masculinities and femininities in relation to their legitimate peripheral participation in the university-based physicist community. Briefly summarized, some of the students' positionings can be characterized as follows: Paul and David both view the analytical physicist masculinity as the higher valued one within physics; a view David agrees with but Paul opposes. Kalle positions himself within the practical physicist masculinity, and sees this as the productive way of doing laboratory work. In opposition, Susan and David view the practical physicist masculinity as unproductive and at odds with physics. Mia does value the practical physicist masculinity but sees it as unattainable for her as a woman. Finally, Ann sees a wide variety of gender manifestations as possible within the physicist community.

From this we can conclude that physics can be understood as gendered in contradictory ways, similarly to how Faulkner (2000) writes about engineering:

> …many dualistic epistemologies found in engineering practice are gendered in contradictory ways and that many fractured masculinities within engineering are sustained simultaneously – among engineers as a group and, to varying degrees, by individuals: they coexist in tension. (p. 98)

Consequently, to bring out the full variation in how students' physicist identities are shaped by gender we need to consider multiple and sometimes conflicting gender manifestations. There is no one way of being a male physics student or a female physics student. Here I agree with Hasse (2002) when she writes:

> When we look for gender differences we might overlook differences that are not sharply defined and cannot be distributed in two groups defined by the categories *male* and *female*. (p. 253)

I therefore chose to focus on the individuals; to try to capture how individual students navigate within the gendered discipline of physics.

Despite the fact that this thesis is not a comparative gender study there are some gender-trends in the material worth mentioning.

Firstly, all the female students (apart from Mia) are aspiring to the analytical physicist masculinity. In part this can be understood as them aspiring for the most high-valued way of doing physics. It could, however, also have to do with the analytical physicist masculinity being closely related to characteristics generally associated with female students and with femininity, such as being structured and well-organized; using the equipment following the rules rather than playing around with it (Jones et al. 2000; Hasse 2002). Further, it is also closely related to the secretarial role (taking notes and writing up the laboratory report), which also is associated with the female students (Rosser 1995).

Secondly, the male students seem to have access to a wider variety of physicist identities; none of the female students, for example, take on the kind of pronounced practical physicist identity that Kalle does.

Hildebrand (2001) has criticized situated cognition for its passivity, how students as legitimate peripheral participants have little possibility of affecting the community they are joining. This standpoint will be further discussed in the next chapter, but for the time being I would just like to point out that the students discussed in sections 6.2-6.8 cannot be described as just passively taking on physicist identities: there is in fact a negotiation of what it can mean to be a physicist taking place.

7 Discussion

I would like to begin this discussion by quoting what Heron and Meltzer (2005) wrote in their guest editorial on the future of physics education research in the American Journal of Physics:

> We highlight those directions that address intellectual issues that are specific, but not necessarily unique, to the subject matter and reasoning of physics. Therefore we omit important work on investigating gender-equity issues, for example. (p. 390)

The purpose of their editorial was to discuss the future of physics education research, a comprehensive discussion in which they give gender absolutely no consideration at all, as the above quote shows, since they view gender issues as not being specific to physics. Yet the basic argument in my thesis has been that there are gender issues that are specific to physics and in order to fully understand students learning of physics we do need to take gender into account. I tried to achieve this by developing a conceptual framework that incorporates gender theory into a theory of learning. The strength of the framework is that it provides a way to analyse gender as an active process and to relate the dynamics of this process to the emerging physicist identities of students. Furthermore, the framework gives the possibility to consider multiple and sometimes conflicting gender manifestations, an important aspect in highly complex learning environment such as the student laboratory.

The guiding question of my research project as presented in Chapter 1, was:

How do undergraduate students in the context of laboratory work constitute physicist identities in relation to the cultural norms of the university-based physics community?

In the discussion that will follow I will focus on two issues raised by the empirical data that emerged from my study; the influence of social categories other than gender and the possible fluidity of the gender manifestations within the physicist community. Finally, limitations of the study are discussed.

7.1 Beyond gender

While the principal focus of my research is gender, during my interviews with students the importance of other social categories for their identity formation also emerged. This should come as no surprise considering how identity-formation in terms of gender never really can be detached from that in terms of, for example, class, ethnicity, sexuality and ability.

In the following I have chosen to exemplify the existence and importance of other social categories in relation to the gendered experience of doing physics in the laboratory by taking a look at class.

Firstly, notice how the student Bo makes a very common association between generic masculinity and physics. Initially he rejects the notion that physics somehow is associated to men or masculinity, but then he says:

Bo: I just think that it very much, like, physics is seen as difficult... science in general is seen as difficult, earlier on those teachers were even seen as having a more qualified education or something, they were seen as having higher status, far back in time, and that lingers. Then it was of course more men who was attracted by... by that education then. You women haven't had the same need for 'exterior attributes'.

What is especially interesting in this quote is how Bo includes me, the interviewer, a female physicist, in the 'you women' who have not had the need for exterior attributes. Thus, physics for Bo is something that can provide exterior attributes, but apparently only attributes that men are interested in.

For Kalle, whom I introduced in section 6.5, physics is not only tied to masculinity: doing physics reinforces a particular way of being a man for him, in that in the laboratory he can be 'handy and practical'. He also talks about wanting to study physics because working in a research laboratory is 'so close to working in a workshop'. This is a form of masculinity that can be seen as tied to working class values, Mellström (1999) writes:

> To be practical is in many aspects tightly interconnected with being manly. This, 'mechanical ideal', or in other words a practical know-how within the technological world, is an ideal for men that we find in several places in society but maybe above all in rural areas and smaller towns in Sweden. But even if we can see a geographical distribution, it is the class aspect that is more important here. (p 29-30, my translation from the original Swedish)

Wajcman (1991) also analysed the two different forms of technological masculinity described by her in terms of class:

> In our culture, to be in command of the very latest technology signifies being involved in directing the future and so it as a highly valued and mythologized activity. The mastery of other kinds of technology, such as that often found amongst working-class lads who are adept with cars, does not convey the same status or agency. Neither in fact does hegemonic masculinity, which is more strongly possessed by working-class then ruling-class men. The exaggerated masculinity found amongst working-class cultures must be viewed against the backdrop of their relative derivation, their low status and their comparative powerlessness in the broader society. The point here is that although technical expertise is a key source of power amongst men, it does not override other sources of power, such as position in the class structure. (p. 144-145)

The conflict between two different masculinities becomes particularly apparent in the case of Paul who is so explicitly drawn between two different ways of being a man; the more practical masculinity valued in his working class background versus the more analytical masculinity valued in the academic, middle class based physicist community. Thus, we can conclude that what counts as masculine is strongly dependent on social class. The same also applies of course to femininity as may be seen from Kalle's statement that 'girls are more girls' in the big city than in the small town he grew up in.

Finally, I would also like to say something about how new ways of doing femininity within science can be opened up in the intersection between gender and ethnicity. This example comes from a study by Hughes (2001) who shows how the 'otherness of ethnicity' can make it possible for students to constitute femininities that are compatible with membership in a scientific community. She exemplifies this from discussions with a female science student from an ethnic minority who is able to reconcile her various belongings into a scientist identity by drawing on a popular discourse of 'minorities as highly motivated to study'. In doing so the student can dissociate herself from the dominant, white femininities and constitute a comfortable scientist identity. This is done by construing a continuity between her ethnic heritage and being a motivated science student, and at the same time acknowledging the discontinuity between white femininities and science.

7.2 Masculinity gone femininity (for some)?

I argued in section 6.9 that all the female students in my study (except for Mia) are aspiring for the analytical physicist masculinity. This, I think, could be partly explained by it being the higher valued form of masculinity within large parts of the university-based physicist community. Equally, or perhaps more importantly, I would say that the larger possibilities for negotiation of meaning are within the analytical masculinity.

At the core of the analytical physicist masculinity we do find a valuing of characteristics such as rationality and mathematical ability, characteristics often closely associated with masculinity. But, at the same time closely tied to these core values we also find a valuing of being structured and organized, values often associated with female students (Jones et al. 2000; Hasse 2002). Consequently, these secondary characteristics allow for a negotiation of the gendering of this way of doing physics. This can be seen from the excerpts from David's interview below. As presented in section 6.6, David is the only male student who did not to any extent recognise the value of practical skills for a physics student and placed himself fully within what has been described as an analytical physicist masculinity. When asked whether there is a difference between how male and female students work in the laboratory David answered:

David: No, I don't think so, in that case I think that girls have a small advantage, I think that in general here there is no difference.

Interviewer: No...

David: But there can always be guys who think... that... it's in a higher degree, even if it's in a smaller degree, there are guys who might think that 'hm, I don't need to read these instructions, I just tinker anyhow' like we talked about before, but that I think you discover quite quickly here, that you can't... have that attitude, but sure it might be tried a few times so to speak, that 'this I can tinker together, no problems'.

Interviewer: And, that's because the guys have such experiences..?

David: Have such experiences that it works, 'cause maybe it was working when I was putting together my moped when I was sixteen...

Interviewer: Precisely, but here...

David: Here it doesn't work and that I think you discover quite quickly...

Thus, here we can see how David explicitly devalues the 'tinkering approach' to laboratory work and further, how he to a certain extent associates a more structured and analytical approach to laboratory work with the female students. Thus, the analytical physicist masculinity has in part been transformed into a localised femininity. The possible existence of localised femininities is also visible in the following example: Mia (and to some extent also Paul) link mathematical skills and femininity. Mia expounded on this link as follows:

Mia: Women are more logical, women have an easier time doing logic, but that I've seen evidence of too that girls I've had in my class or so, have had an easier time doing maths than physics.

Interviewer: So what is the big difference between maths and physics then?

Mia: Well, maths is really logic, you have some kind of pattern that you work from and then it can be a number of different things that are related and then you have to pick out one thing at a time and reach a conclusion, so it's really no understanding, just routine, you have to work back and forth and have patience if it's difficult problems, whereas in physics it's much more that you have to understand relationships, yeah, if it rolls to the right and pull down that way it will move in that direction and then you have to sort of picture things in a different way, forces and...

This link between mathematics and femininity shows how what is seen as feminine or masculine varies with social context. Mathematics and logical skills are most certainly often associated with masculinity, Connell (2003), for example, writes about abstract mathematics being one of the positive aspects of hegemonic masculinity.

In summary, there is negotiation of what it can mean to be a physicist: the students in my study are – starting from what I have characterised as an analytical physicist masculinity – constituting their own ways of doing physics. In particular it is interesting to notice how the gender manifestations are possibly somewhat fluid and how there are then re-negotiations of them.

7.3 Limitations of the study

I would like to begin the discussion in this section by pointing out that no analysis can claim to capture the full complexity of a person’s identity formation. I would, however, claim that my analysis is able to provide in-depth insights into the process of identity formation.

The core of my thesis is the conceptual framework developed in Chapter 3, a framework I will develop further, alongside my evolving analysis. In particular, the development of my study will be focused on making the empirical part more complex and extensive. A limitation of the study at this stage is that the development of the conceptual framing and the analysis of the empirical data are somewhat out of phase. The empirical data has therefore not been allowed to ‘speak back’ as fully as it could have to the conceptual framework, which is something I will focus on changing for the next stages of the study.

Otherwise I see two distinct limitations in the work that I have reported so far. The first is, as discussed in section 4.3, that I have not been able to include member checks. The second is that, due to the small number of students enrolled in physics at Uppsala University, I have in order to guarantee the anonymity of the participating students not been able to provide a more detailed account of their background, in terms of, for example, age or study direction. In the next phases of my study I intend to plan to systematically minimize these two limitations.

8 Future research

The planned future work can be divided into two interconnected parts; the further development of the conceptual framework and the collection and analysis of more empirical data.

The further development of the conceptual framework I have presented will be one important part of my continuing research project. In particular, with regard to issues of power, ideas from situated cognition are still relatively undeveloped, and this is an area were further work is needed. Furthermore, the concept of agency (here taken to mean that we all have the ability to influence our lives and environment while we are also shaped by social and individual factors) is expected to add further understanding to students gendered identity formation. For this theoretical development the work by Holland et al. (2001) will be an important inspirational source, especially with regard to their theory of self-formation; how we have agency to improvise even within quite rigid structures, without for that sake diminishing the impact of the structures.

In this development of the conceptual framework the inclusion of more empirical data will play a crucial part. More importantly, however, is the combination of the empirical investigation and the conceptual framing as a means to answering future research questions. So, what will this empirical investigation look like then? The answer to this question is very much in its infancy, but I will try to provide an answer, as my ideas look today.

So far, I have focused on how physics is done in the undergraduate student laboratory. Next, I am planning to continue the exploration of my main research question in a different laboratory environment, that of the research laboratory as experienced by students doing their Master's projects in experimental physics. These students have, of course, also been doing various forms of laboratory work for a variety of courses at different levels throughout their education. By having the students contrast this experience with their present project work I hope to be able to capture different identities available within different sites where physics is done.

The students' experiences of their final project work are interesting for a number of reasons. Firstly, this is in a sense their first step into the community of professional physicists. Secondly, they will encounter in the research laboratory an environment where physics knowledge is actually made (or discovered, depending on your view of knowledge) – no longer do they repeat what others have been doing, they are themselves doing new physics. My main interest is how this change of perspective affects the students' identity formation and in particular how this is tied to gender.

To this I will also tie my own experiences of, as a PhD student, work in a physics research laboratory, thereby covering a range of possible ways of doing physics; from undergraduates first meeting with the student laboratory, through to doing an undergraduate degree project in experimental physics, to working in a research laboratory as a PhD student.

9 Some concluding thoughts

You have now reached the end of this licentiate thesis in physics education research. Hopefully my thesis has been an enjoyable read that has given you opportunities to reflect on issues of physics, education and gender. There are, however, a couple of questions I anticipate at least some of my readers may have. Firstly, this being a thesis in *physics* education research; what makes it physics? Secondly, this being a thesis in physics *education* research; where are the pedagogical implications? Well, in the two following sections I will try to provide answers to those questions.

9.1 Is physics education research physics?

Today physics education research is a widely acknowledged and well-established sub-discipline of physics being conducted, for example, in approximately 35 physics departments across the United States (UMD PERG Resources Homepage, 2007). This has, however, not always been the case; up until some ten years ago there was an intense debate about this. Essentially the debate was about whether PER should be seen and understood as an integral part of physics research and thus belonging to physics or whether it should be studied outside physics departments in say, education departments, as an integral part of science education in general. Given that this debate is an important part of the history of PER – and that the question if PER really is physics sometimes still is heard – I would like to say a few words on that matter.

PER today is thus typically conducted by physicists, who have turned to education research, in physics departments. There are several reasons for this trend. For example, McDermott (2001), one of the pioneers of PER in the USA, has argued that:

> Physicists are much more likely than science educators or cognitive psychologists to be able to explore student understanding of physics in depth. They have the background necessary to recognize and interpret subtle, yet important, differences between what we teach and what is learned. (p. 304)

Another pioneer, Redish (1999) further lists some more pragmatic reasons for physics education research being done in physics departments. Firstly, how it is crucial for education researchers to have good access to physics student and physics courses. Secondly, how physics education research primarily benefits physics departments, in terms of, for example, improved learning, it therefore would be arguably difficult to get another department to spend their resources on this type of research.

Personally, I believe that the most important reason for having physics education research conducted by people with a good physics background within physics departments is that they bring and have direct access to a level of physics knowledge and understanding of the physics culture that is needed. In order to be able to research students' learning the researcher needs to have in-depth knowledge of the discipline, both in terms of subject matter and the associated culture and discourse. For example, when I interview students my physics background lets me probe deeply into their experiences of learning physics in a way an 'outsider' would be unlikely to have been able to. Thus, as a PER researcher, based on my own experiences of studying physics, I am not only able to pose the 'relevant questions', but the interviewed students are likely to experience it as possible to discuss physics with me as a 'fellow physicist'; they know that I appreciate what they are talking about. Further, as pointed out by Ely (1991), in analysing the students' 'stories' my own experiences of studying physics becomes invaluable; by looking at the differences and similarities between my experience and those of the students I am able to create a much enhanced in-depth understanding of the students' stories.

9.2 How about pedagogical implications?

In a thesis in physics education research one might expect at least one section on pedagogical implications, something that is clearly missing from this thesis. The reason for me not including such a section is twofold. First of all, my research is for all intents and purposes in the category of 'basic research', and as so often with such research the applications are not immediately apparent. In the broadest sense, my research contributes to 'getting to know our students as learners' – as my supervisor so often phrases the essential purpose of much educational research. Secondly, the pedagogical implications of this kind of narratively inspired educational research, for a good study, should 'emerge' in the 'meeting' between the reader and the text. As discussed in section 4.3 qualitative research should not be expected to be generalizable in the traditional sense of the word, rather it is left to the readers to make their own 'generalizations' based on the meaning they find in the research narrative. This is what Stake (1994) characterized as 'naturalistic generalization'. In the same sense, I thus leave it up to you, the reader, to find the pedagogical implications for your practice from my research narrative; to find inspiration for informing your future teaching.

Finally, I must add that when writing my final PhD thesis my intention is also to include my thoughts – my naturalistic generalizations – to explore the pedagogical implications of my research.

Acknowledgments

As a PhD student in physics education research I do not, like many other physicists, belong to any large research collaborations. My research project is truly *my* research project. I am the one who does everything from the data collection, through the formulation of the research questions to the writing of the research narrative. Or perhaps it's not that simple... Jokes aside, there may be some truth in the above lines - given the invaluable independence my supervisor, Cedric Linder, has given me - but no researcher is of course an island. Therefore I would here like to take the opportunity to thank a number of people without whom this licentiate thesis never could have been written.

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Min familj och mina vänner – tack för allt!

Nu fortsätter jag mot doktorsexamen, viss om att:
Nog finns det mål och mening i vår färd -
men det är vägen, som är mödan värd.
Karin Boye

Anna Danielsson
Uppsala, januari 2007

References

Adams, W. K., Perkins, K. K., Podelfsky, N. S., Dubson, M., Finkelstein, N. D., & Wieman, C. E. (2006). New instrument for measuring student beliefs about physics and learning physics: The Colorado Learning Attitudes about Science Survey. *Physical Review Special Topics - Physics Education Research, 2*, 1-14.

Airey, J. (2006). *Physics Students' Experiences of the Disciplinary Discourse Encountered in Lectures in English and Swedish.* Unpublished Licentiate Thesis, Uppsala University, Uppsala.

Airey, J., & Linder, C. (2006). Language and the experience of learning university physics in Sweden. *European Journal of Physics, 27*, 553-560.

Allie, S., Buffler, A., Campbell, B., Lubben, F., Evangelinos, D., Psillos, D., & Valassiades, O. (2003). Teaching Measurement in the Introductory Physics Laboratory. *The Physics Teacher, 41*, 394-401.

Allie, S., Buffler, A., Kaunda, L., & Inglis, M. (1997). Writing-Intensive Physics Laboratory Reports: Tasks and Assessment. *The Physics Teacher, 35*, 399-340.

Ambjörnsson, F. (2004). *I en klass för sig. Genus, klass och sexualitet bland gymnasietjejer.* Finland: Ordfront Förlag.

Ambrose, B. S., Shaffer, P. S., Steinberg, R. N., & McDermott, L. C. (1999). An investigation of student understanding of single-slit diffraction and double-slit interference. *American Journal of Physics, 67*(2), 146-155.

Benckert, S. (1997). Är fysiken könlös? Reflektioner kring ett universitetsämne. In G. Nordborg (Ed.), *Makt & kön*: B. Östlings Symposion.

Benckert, S. (2001). *Context and conversation - a way to create a more gender-inclusive physics education?* Paper presented at the GASAT, Copenhagen.

Berner, B. (2003). Kön, teknik och naturvetenskap i skolan. In B. Berner (Ed.), *Vem tillhör tekniken? Kunskap och kön i teknikens värld* (pp. 119-144). Kungälv: Arkiv förlag.

Blanton, P. (2005). Educational equity or equality - which do we really want? *The Physics Teacher, 43*, 314-315.

Blumenfeld-Jones, D. (1995). Fidelity as a criterion for practicing and evaluating narrative inquiry. In J. A. Hatch & R. Wisniewski (Eds.), *Life history and narrative* (pp. 23-35). London: Falmer Press.

Bogdan, R. C., & Biklen, S. K. (1992). *Qualitative research for education: an introduction to theory and methods*. Needham Heights, MA: Allyn and Bacon.
Brickhouse, N. W. (2001). Embodying Science: A feminist perspective on learning. *Journal of research in science teaching, 38*(3), 282-295.
Brickhouse, N. W., & Potter, J. T. (2001). Young Women's Scientific Identity Formation in an Urban Context. *Journal of research in science teaching, 38*, 965-980.
Buffler, A., Allie, S., Lubben, F., & Campbell, B. (2001). The development of first year physics students' ideas about measurement in terms of point and set paradigms. *International Journal of Science Education, 23*(11), 1137-1156.
Butler, J. (1999). *Gender Trouble. Feminism and the subversion of identity.* New York.
Byrne, E. (1993). *Women and science: The snark syndrome*. Washington: Falmer Press.
Calabrese Barton, A. (1997). Liberatory science education: Weaving connections between feminist theory and science education. *Curriculum Inquiry, 27*(2), 141-163.
Case, J., & Jawitz, J. (2004). Using Situated Cognition Theory in Researching Student Experience of the Workplace. *Journal of research in science teaching, 41*, 415-431.
Case, J., & Marshall, D. (2006). The 'no problem' Discourse model: Exploring an alternative way of researching student learning (pp. 1-12).
Clandinin, D. J. (1992). Narrative and story in teacher education. In T. Russell & H. Munby (Eds.), *Teachers and teaching: from classroom to reflection* (pp. 124-137). London: Falmer Press.
Clandinin, D. J., & Connelly, F. M. (1994). Personal experience method. In N. K. Denzin & Y. S. Lincoln (Eds.), *Handbook of qualitative research*. Thousand Oaks.
Clark, J. (2000). Challenges to practice, constraints to change. Managing innovation in a South African township science classroom. In J. Wallace & J. Luoghran (Eds.), *Leadership and Professional Development in Science Education. New possibilities for enhancing teacher education*. London: RoutledgeFalmer.
Clement, J. (1982). Students' preconceptions in introductory mechanics. *American Journal of Physics, 50*(1), 66-71.
Cohn, C. (1996). Nuclear language and how we learned to pat the bomb, *Feminism and Science*. Oxford: Oxford university press.
Colin, P., & Viennot, L. (2001). Using two models in optics: Students' difficulties and suggestions for teaching. *Physics Education Resources, American Journal of Physics, Suppl., 69*(7), S36-S44.
Conefrey, T. (1997). Gender, culture and authority in a university life science laboratory. *Discourse & Society, 8*, 313-340.
Connell, R. W. (2003a). *Maskuliniteter*. Göteborg: Daidalos.

Connell, R. W. (2003b). *Om genus*. Göteborg: Daidalos.
Connelly, F. M., & Clandinin, D. J. (1990). Stories of experience and narrative inquiry. *Educational Researcher, 19*(5), 2-14.
Contu, A., & Willmott, H. (2003). Re-Embedding Situatedness: The Importance of Power Relations in Learning Theory. *Organization Science, 14*, 283-296.
Cox, A. J., & Junkin, W. F. (2002). Enhanced student learning in the introductory physics laboratory. *Physics Education, 37*(1), 37-44.
Crouch, C. H., Fagen, A. P., Callan, J. P., & Mazur, E. (2004). Classroom demonstrations: Learning tools or entertainment? *American Journal of Physics, 72*(6), 835-838.
Crouch, C. H., & Mazur, E. (2001). Peer Instruction: Ten years of experience and results. *American Journal of Physics, 69*(9), 970-977.
Danielsson, A., & Linder, C. (2006, September 2006). *Gendered identities in the physics student laboratory.* Paper presented at the GASAT 12, Brighton, U.K.
Davidowitz, B., & Rollnick, M. (2003). Enabling Metacognition in the Laboratory: A Case Study of Four Second Year University Chemistry Students. *Research in Science Education, 33*, 43-69.
diSessa, A. (1993). Toward an Epistemology of Physics. *Cognition and Instruction, 10*(2 & 3), 105-226.
Domert, D., Linder, C., & Ingerman, Å. (2005). Probability as a conceptual hurdle to understanding one-dimensional quantum scattering and tunnelling. *European Journal of Physics, 26*, 47-59.
Dominicus, L., & Linder, C. (2005). *Situating the scholarship of teaching and learning in university physics.* Paper presented at The International Society for the Scholarship of Teaching and Learning. Vancouver, Canada.
Du, X.-Y. (2006). Gendered practices of constructing an engineering identity in a problem-based learning environment. *European Journal of Engineering Education, 31*(1), 35-42.
Duit, R., Häussler, P., Lauterbach, R., Mikelskis, H., & Westphal, W. (1992). Combining issues of "girl-suited" science teaching, STS and constructivism in a physics textbook. *Research in Science Education, 22*, 106-113.
Duit, R., & Treagust, D. F. (2003). Conceptual change: a powerful framework for improving science teaching and learning. *International Journal of Science Education, 25*(6), 671-688.
Easlea, B. (1986). The masculine image of science with special reference to physics: How much does gender really matter? In J. Harding (Ed.), *Perspectives on gender and science*. Lewes: Falmer Press.
Elby, A., & Hammer, D. (2001). On the substance of a sophisticated epistemology. *Science Education, 85*, 554-567.

Elvin-Nowak, Y., & Thomsson, H. (2003). *Att göra kön. Om vårt våldsamma behov av att vara kvinnor och män*. Stockholm: Albert Bonniers Förlag AB.

Ely, M. (1991). *Doing qualitative research: circles within circles*. London: Falmer Press.

Etkina, E., Gibbons, K., Holton, B. L., & Horton, G. K. (1999). Lessons learned: A case study of an integrated way of teaching introductory physics to at-risk students at Rutgers University. *American Journal of Physics, 67*(9).

Etkina, E., Warren, A., & Gentile, M. (2006). The Role of Models in Physics Instruction. *The Physics Teacher, 44*, 34-39.

Falk, J., Linder, C. & Kung, R. (in review) Review of empirical studies into students' depictions of quantum mechanics. Manuscript submitted to Educational Research Review

Faulkner, W. (2000). The Power and the Pleasure? A Research Agenda for "Making Gender Stick" to Engineers. *Science, Technology, & Human Values, 25*(1), 87-119.

Faulkner, W. (2005). *Becoming and Belonging: Gendered processes in engineering.* Paper presented at the The Gender Politics of ICT, University of Greenwich, London, UK.

Finegold, M., & Gorsky, P. (1991). Students' concepts of force as applied ro related physical systems: A search for consistency. *International Journal of Science Education, 13*(1), 97-113.

Finkelstein, N. (2005). Learning physics in a context: a study of student learning about electricity and magnetism. *International Journal of Science Education, 27*(10), 1187-1209.

Fox Keller, E. (1992). *Secrets of Life. Secrets of Death.* London: Routledge.

Gee, J. P. (2005). *An introduction to discourse analysis. Theory and method.* (2 ed.). Great Britain: Routledge.

Gemzöe, L. (2003). *Feminism*. Stockholm: Bilda Förlag.

Georghiades, P. (2004). From the general to the situated: three decades of metacognition. *International Journal of Science Education, 26*(3), 365-383.

Goldberg, F., & McDermott, L. C. (1987). An investigation of student understanding of the real image formed by a converging lens or concave mirror. *American Journal of Physics, 55*(2), 108-119.

Guba, E. G., & Lincoln, Y. S. (1989). *Fourth Generation Research*. Newbury Park: Sage.

Gunstone, R. (1991). *Constructivism and metacognition: Theoretical issues and classroom studies.* Paper presented at the Research in Physics Learning: Theoretical Issues and Empirical Studies, University of Bremen.

Gustafsson, P. (2005). Gender inclusive physics education - a distance case. *European Journal of Physics, 26*, 843-849.

Hake, R. H. (1996). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. *American Journal of Physics, 66*, 64-74.
Halberstam, J. (1998). *Female masculinity*. United States of America: Duke University Press.
Halloun, I. A., & Hestenes, D. (1985a). Common sense conceptions about motion. *American Journal of Physics, 5,3*1056-1065
Halloun, I. A., & Hestenes, D. (1985b). The initial knowledge state of college physics students. *American Journal of Physics, 53*, 1043-1048.
Hammer, D. (1995). Epistemological considerations in teaching introductory physics. *Science Education, 79*(4), 393-413.
Hammer, D. (1996). More than misconceptions: Multiple perspectives on student knowledge and reasoning, and an appropriate role for education research. *American Journal of Physics, 64*(10), 1316-1325.
Hammer, D., & Elby, A. (2002). On the Form of a Personal Epistemology. In B. K. Hofer & P. R. Pintrich (Eds.), *Personal Epistemology: The Psychology of Beliefs about Knowledge and Knowing*. Mahwah, NJ: Erlbaum.
Hammer, D., Elby, A., Scherr, R., & Redish, E. F. (2004). Resources, framing, and transfer. In J. Mestre (Ed.), *Transfer of Learning: Research and Perspectives*. Greenwich, CT: Information Age Publishing.
Haraway, D. (2003). Situated Knowledges: The Science Question in Feminism and the Privilege of Partial Perspective. In E. Fox Keller & H. E. Longino (Eds.), *Feminism & Science*. Oxford: Oxford University Press.
Harding, S. (1986). *The science question in feminism*. Milton Keynes: Open university press.
Harding, S. (1991). *Whose Science? Whose Knowledge? Thinking from women's lives*.
Harding, S. (2005). Science and Technology. In P. Essed & D. T. Goldberg & A. Kobayashi (Eds.), *A Companion to Gender Studies*. Malden, MA: Blackwell.
Hart, C., Mulhall, P., Berry, A., Loughran, J., & Gunstone, R. (2000). What is the Purpose of this Experiment? Or Can Students Learn Something from Doing Experiments? *Journal of research in science teaching, 37*(7), 655-675.
Hasse, C. (2002). Gender Diversity in Play With Physics: The Problem of Premises for Participation in Activities. *Mind, culture, and activity, 9*(4), 250-269.
Hazel, E., Conrad, L., & Martin, E. (1997). Issues in gender and phenomenography. *Higher Education Research and Development, 16*(2), 213-226.
Heller, P., & Hollabaugh, M. (1992). Teaching problem solving through cooperative grouping. Part 2: Designing problems and structuring groups. *American Journal of Physics, 60*(7), 637-644.

Helm, H. (1980). Misconceptions in physics amongst South African students. *Physics Education*, *15*, 92-97,105.

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*(2), 199-214.

Henwood, F. (1998). Engineering difference: discourses on gender, sexuality and work in a college of technology. *Gender and Education, 10*(1), 35-49.

Heron, P. R. L., & Meltzer, D. E. (2005). The future of physics education research: Intellectual challenges and practical concerns. *American Journal of Physics*, *73*(5), 390-394.

Herzig, A. H. (2004). 'Slaughtering this beautiful math': graduate women choosing and leaving mathematics. *Gender and Education, 16*(3), 379-395.

Hestenes, D. (1996). *Modeling Methodology for Physics Teachers.* Paper presented at the International Conference on Undergraduate Physics Education, College Park.

Hestenes, D., & Wells, G. (1992). A mechanics baseline test. *The Physics Teacher*, *30*, 159-162.

Hestenes, D., Wells, G., & Swackhamer, G. (1992). Force Concept Inventory. *The Physics Teacher*, *30*, 141-153.

Hewson, P. W. (1982). A Case Study of Conceptual Change in Special Relativity: The Influence of Prior Knowledge in Learning. *European Journal of Science Education, 4*(1), 61-78.

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*(4), 439-457.

Hildebrand, G. M. (2001). Con/Testing Learning Models, *National Association of Research in Science Teaching (NARST)*. St. Luis, MO.

Hirdman, Y. (2003). *Genus - om det stabilas föränderliga former.* Sweden: Liber.

Hofstein, A., & Lunetta, V. N. (2003). The Laboratory in Science Education: Foundations for the Twenty-First Century. *Science Education*, *88*(1), 28-54.

Holland, D., Lachicotte Jr, W., Skinner, D., & Cain, C. (2001). *Identity and Agency in Cultural Worlds*. Cambridge, MA: Harvard University Press.

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*(3), 275-290.

Ingerman, Å., & Booth, S. (2003). Expounding on physics: a phenomenographic study of physicists talking of their physics. *International Journal of Science Education, 25*(12), 1489-1508.

Johnstone, A. H., Watt, A., & Zaman, T. U. (1998). The students' attitude and cognition change to a physics laboratory. *Physics Education, 33*(1), 22-29.

Johnstone, J., & Dunne, M. (1996). Revealing Assumptions: Problematising Research on Gender and Mathematics and Science Education. In L. H. Parker & L. J. Rennie & B. J. Fraser (Eds.), *Gender, Science and Mathematics. Shortening the Shadow*. Dordrecht: Kluwer Academic Publishers.

Jones, M. G., Brader-Araje, L., Wilson Carboni, L., Carter, G., Rua, M. J., Banilower, E., & Hatch, H. (2000). Tool Time: Gender and Students' Use of Tools, Control, and Authority. *Journal of research in science teaching, 37*(8), 760-783.

Jones, M. G., Howe, A., & Rua, M. J. (2000). Gender differences in students' experiences, interests, and attitudes toward science and scientists. *Science Education, 84*, 180-192.

Klainin, S. (1988). Practical work and science education. In P. Fensham (Ed.), *Development and Dilemmas in Science Education*. Lewes: Falmer Press.

Kleinman, S. S. (1998). Overview of feminist pedagogy on the ideology of science. *Journal of research in science teaching, 35*(8), 837-844.

Koch, A. (2001). Training in metacognition and comprehension of physics texts. *Science Education, 85*, 758-768.

Kvale, S. (1997). *Den kvalitativa forskningsintervjun*. Lund: Studentlitteratur.

Lave, J., & Wenger, E. (1991). *Situated learning. Legitimate peripheral participation*. Cambridge.

Laws, P. W. (1997). Milikan Lecture 1996: Promoting active learning based on physics education research in introductory physics courses. *American Journal of Physics, 65*(1), 14-21.

Laws, P. W., Rosborough, P. J., & Poodry, F. (1999). Women's responses to an activity-based introductory physics program. *Physics Education Resources, American Journal of Physics, Suppl., 67*(7), S32-S37.

Lazarowitz, R., & Tamir, P. (1994). Research in using laboratory instruction in science, *Handbook of research on science teaching and learning*.

Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic inquiry*. Beverly Hills: Sage.

Linder, C., & Marshall, D. (1998). Linking physics students' development as independent and reflective learners with changes in their conceptions of science. In C. Rust (Ed.), *Improving student learning. Improving students as learners* (pp. 107-117). Oxford.

Linder, C., & Marshall, D. (2005). Students' expectations of teaching in undergraduate physics. *International Journal of Science Education, 27*(10), 1255-1268.

Linder, C. J. (1992). Is teacher-reflected epistemology a source of conceptual difficulty in physics? *International Journal of Science Education, 14*, 111-121.

Linder, C. J. (1993). A Challenge to Conceptual Change. *Science Education, 77*(3), 293-300.

Linder, C. J., & Marshall, D. (1997). Introducing and evaluating metacognitive strategies in large class introductory physics teaching. In G. Gibbs & C. Rust (Eds.), *Improving Student Learning through Course Design* (pp. 411 - 420). Oxford: Oxonian Rewley Press.

Lippman Kung, R. (2005). Teaching the concept of measurement: An example of a concept-based laboratory course. *American Journal of Physics, 73*(8), 771-777.

Lippman Kung, R., Danielsson, A., & Linder, C. (2005). *Metacognition in the student laboratory: Is increased metacognition necessarily better?* Paper presented at the EARLI, Nicosia, Cyprus.

Lising, L., & Elby, A. (2005). The impact of epistemology on learning: A case study from introductory physics. *American Journal of Physics, 73*(4), 372-382.

Lorenzo, M., Crouch, C. H., & Mazur, E. (2006). Reducing the gender gap in physics education. *American Journal of Physics, 74*(2), 118-122.

Maloney, D. P., O´Kuma, T. L., Hieggelke, C. J., & Van Heuvelen, A. (2001). Surveying students' conceptual knowledge of electricity and magnetism. *Physics Education Research, American Journal of Physics Suppl., 69*(7), S12-S23.

Marton, F., & Booth, S. (1997). *Leaning and Awareness*. New Jersey: Lawrence Erlbaum.

Mashhadi, A. (1994). Students' Conceptions of Quantum Physics. In C. Bernardini & C. Tarsitani & M. Vincentini (Eds.), *Thinking Physics for Teaching* (pp. 313-328). Rome: Plenum Press.

Mayberry, M. (1998). Reproductive and Resistant Pedagogies: The Comparative Roles of Collaborative Learning and Feminist Pedagogy in Science Education. *Journal of research in science teaching, 35*(4), 443-459.

McCloskey, M. (1983). Naive Theories of Motion. In D. Gentner & A. L. Stevens (Eds.), *Mental Models* (pp. 299-323). Hillsdale, NJ: Lawrence Erlbaum Associates.

McCormack, C. (2000a). From Interpretive Transcript to Interpretive Story: Part I - Viewing the Transcript through Multiple Lenses. *Field Methods, 12*(4), 282-297.

McCormack, C. (2000b). From Interview Transcript to Interpretive Story: Part II - Developing an Interpretive Story. *Field Methods, 12*(4), 298-315.

McCullough, L. (2002). Women in physics: A review. *The Physics Teacher, 40*, 86-91.

McCullough, L. (2004). Gender, context, and physics assessment. *Journal of International Women's Studies*, *5*(4), 20-30.
McDermott, L. C. (1991). Millikan Lecture 1990: What we teach and what is learnt - Closing the gap. *American Journal of Physics, 59*(4), 301-315.
McDermott, L. C. (2001). Oerstedt Medal Lecture 2001: Physics Education Research - the key to student understanding. *American Journal of Physics, 69,* 1127-1137.
McDermott, L. C., & Redish, E. F. (1999). Resource Letter: PER-1: Physics Education Research. *American Journal of Physics, 67*(9), 755-767.
Mellström, U. (1999). *Män och deras maskiner*. Nora: Bokförlaget Nya Doxa.
Mellström, U. (2002). Patriarchal machines and masculine embodiment. *Science*, *Technology, & Human Values*, *27*(4), 460-478.
Mellström, U. (2004). Machines and masculine subjectivity. Technology as an integral part of men's life experience. *Men and Masculinities, 6*(4), 368-382.
Meltzer, D. E., & Manivannan, K. (2002). Transforming the lecture-hall environment: The fully interactive physics lecture. *American Journal of Physics, 70*(6), 639-654.
Mendick, H. (2005). A beautiful myth? The gendering of being/doing 'good at math'. *Gender and Education, 17,* 203-219.
Merchant, C. (1984). Isis nya medvetenhet. *Kvinnovetenskaplig tidskrift, 4*.
Millar, R., La Maréchal, J.-F., & Tiberghien, A. (1999). 'Mapping' the domain. Varieties of practical work. In J. Leach & A. Paulsen (Eds.), *Practical work in science education: Recent research studies* (pp. 33-59). Roskilde: Roskilde University Press.
Mullholland, J., & Wallace, J. (2000). *Restorying and the legitimation of research texts.* Paper presented at the National Association for Research in Science Teaching, New Orleans.
Murphy, P. (1991). Gender differences in pupils' reactions to practical work. In B. Woolnough (Ed.), *Practical Science*. Buckingham: Open University Press.
Müller, R., & Wiesner, H. (2002). Teaching quantum mechanics on an introductory level. *American Journal of Physics, 70*(3), 200-209.
Nair, I., & Majetich, S. (1995). Physics and Engineering in the classroom. In S. V. Rosser (Ed.), *Teaching the majority. Breaking the gender barrier in science, mathematics, and engineering*.
Nespor, J. (1994). *Knowledge in motion. Space, Time, and Curriculum in Undergraduate Physics and Management*. London: The Falmer Press.
Norby, R. F. (2000). Equitable teaching of physics to women students: thoughts for the new decade. *The Physics Teacher, 38,* 494-495.
Northedge, A. (2002). Organizing excursions into specialist discourse communities: a sociocultural account of university teaching. In G. Wells

& G. Claxton (Eds.), *Learning for life in the 21st century. Sociocultural perspectives on the future of education*. Oxford: Blackwell Publishers.

Paechter, C. (2003a). Masculinities and femininities as communities of practice. *Women's studies international forum, 26*(1), 69-77.

Paechter, C. (2003b). Learning masculinities and femininities: power/knowledge and legitimate peripheral participation. *Women's studies international forum, 26*, 541-552.

Parker, K. (2002). Men are not from Mars. *Physics Education, 37*(1), 12-17.

Petri, J., & Niedderer, H. (1998). A learning pathway in high-school level quantum atomic physics. *International Journal of Science Education, 20*(9), 1075-1088.

Phipps, A. (2002). Engineering women: the 'gendering' of professional identities. *International Journal of Engineering Education, 18*(4), 409-414.

Polkinghorne, D. E. (1995). Narrative analysis in qualitative research. In J. A. Hatch & R. Wisniewski (Eds.), *Life history and narrative* (pp. 5-23). London: Falmer Press.

Polkinghorne, D. E. (2004). Ricoeu, Narrative and Personal Identity. In L. E. Angus & J. McLeod (Eds.), *The handbook of narrative and psychotherapy: Practice, theory, and research* (pp. 53-67). Thousand Oaks, CA: Sage.

Posner, G., Strike, K., Hewson, P., & Gertzog, W. (1982). Accommodation of a scientific conception: Towards a theory of conceptual change. *Science Education, 66*(2), 211-227.

Povey, H., Angier, C., & Clarke, M. (2006). Storying Joanne, an undergraduate mathematician. *Gender and Education, 18*(5), 459-471.

Prosser, M., Hazel, E., Trigwell, K., & Lyons, F. (1996a). *Qualitative and quantitative indicators of students' understanding of physics concepts.* Paper presented at the HERDSA, Perth, Western Australia.

Prosser, M., & Trigwell, K. (2001). *Understand Learning and Teaching. The Experience of Higher Education.* Buckingham: Open University Press.

Prosser, M., Trigwell, K., & Waterhouse, F. (2000). Students' experiences of studying physics concepts: The effects of disintegrated perceptions and approaches. *European Journal of Psychology of Education, XV*, 61-74.

Prosser, M., Walker, P., & Millar, R. (1996b). Differences in students' perceptions of learning physics. *Physics Education, 31*(1), 43-48.

Redish, E. F. (1999). Milikan Lecture 1998: Building a Science of Teaching Physics. *American Journal of Physics, 67*(7), 562-573.

Redish, E. F. (2003). *Teaching physics with the physics suite*. Hoboken, NJ: John Wiley & Sons, Inc.

Redish, E. F. (2004, July 15-25). *A Theoretical Framework for Physics Education Research: Modeling Student Thinking.* Paper presented at the Enrico Fermi Summer School in Physics, Varenna, Italy.

Redish, E. F., Saul, J. M., & Steinberg, R. N. (1998). Student expectations in introductory physics. *American Journal of Physics, 66*(3), 212-224.

Richardson, L. (1994). Writing: a method of inquiry. In N. K. Denzin & Y. Lincoln (Eds.), *Handbook of qualitative research* (pp. 516-529). Thousand Oaks, CA: Sage.

Rodd, M., & Bartholomew, H. (2006). Invisible and special: young women's experiences as undergraduate mathematics students. *Gender and Education, 18*(1), 35-49.

Rollnick, M., Allie, S., Buffler, A., Campbell, B., & Lubben, F. (2004). Development and application of a model for students' decision-making in laboratory work. *African Journal of Research in SMT Education, 8*(1), 13-27.

Rosser, S. V. (1995). Introduction: Reaching the Majority. Retaining Women in the Pipeline. In S. V. Rosser (Ed.), *Teaching the Majority. Breaking the gender barrier in science, mathematics, and engineering.* New York: Teachers College Press.

Ryder, J., Leach, J., & Driver, R. (1999). Undergraduate science students' images of science. *Journal of research in science teaching, 36*, 201-219.

Sagebiel, F., & Dahmen, J. (2006). Masculinities in organizational cultures in engineering education in Europe: results from the European Union project WomEng. *European Journal of Engineering Education, 31*(1), 5-14.

Schiebinger, L. (1991). *The mind has no sex? Women in the origins of modern science*. United States of America: Harvard University Press.

Schneider, M. B. (2001). Encouragement of women physics majors at Grinnell college: A case study. *The Physics Teacher, 39*, 280-282.

Séré, M.-G. (2002). Towards Renewed Research Questions from the Outcomes of the European Project *Labwork in Science Education*. *Science Education, 86*, 624-644.

Séré, M.-G., Fernandez-Gonzalez, M., Gallego, J. A., Gonzalez-Garcia, F., De Manuel, E., Perales, F. J., & Leach, J. (2001). Images of Science Linked to Labwork: A Survey of Secondary School and University Students. *Research in Science Education, 31*, 499-523.

Seymour, E., & Hewitt, N. M. (1997). *Talking about leaving. Why Undergraduates Leave the Sciences.* Boulder: Westview press.

Sfard, A. (1998). On Two Metaphors for Learning and the Danger of Choosing Just One. *Educational Reseracher, 27*(2), 4-13.

Shaffer, P. S., & McDermott, L. C. (1992). Research as a guide for curriculum development: An example from introductory electricity. Part II: Design of instructional strategies. *American Journal of Physics, 60*(11), 1003-1013.

Singh, A., & Butler, P. H. (1990). Refraction: conceptions and knowledge structure. *International Journal of Science Education, 12*, 429-442.

Sjöberg, S. (2000). *Naturvetenskap som allmänbildning. En kritisk ämnesdidaktik.* Lund: Studentlitteratur.

Smith III, J. P., diSessa, A., & Roschelle, J. (1993-1994). Misconceptions Reconceived: A Constructivist Analysis of Knowledge in Transition. *The Journal of Learning Sciences, 3*(2), 115-163.

Sowell, S. P. (2004). *Doing gender/teaching science: a feminist poststructural analysis of middle school science teachers' identity negotiations.* Florida State University.

Statistiska centralbyrån. www.scb.se

Stake, R. E. (1994). Case Studies. In N. K. Denzin & Y. S. Lincoln (Eds.), *Handbook of qualitative research* (pp. 236-247). London: Sage.

Stepulevage, L., & Plumeridge, S. (1998). Women Taking Positions Within Computer Science. *Gender and Education, 10*(3), 313.

Stonyer, H. (2001). The problem of women in engineering - is it women, engineering academics, curriculum or engineering - where to act? *Australasian journal of engineering, 9*, 145-161.

Stonyer, H. (2002). Making engineering students - making women: the discursive context of engineering education. *International Journal of Engineering Education, 18*(4), 392-399.

Svennbeck, M. (2004). *Omsorg om naturen. Om NO-utbildningens selektiva traditioner med fokus på miljöfostran och genus.* Unpublished Acta Universitatis Upsaliensis. Uppsala Studies in Education 104, Uppsala University, Uppsala.

Thacker, B. A. (2003). Recent advances in classroom physics. *Reports on progress in physics, 66*, 1833-1864.

Thomas, K. (1990). *Gender and subject in higher education*. Buckingham: Open university press.

Tonso, K. (1998). *Constructing engineers through practice: gendered features of learning and identity development.* University of Colorado, Boulder.

Traweek, S. (1988). *Beamtimes and Lifetimes. The world of high energy physicists*. London: Harvard University Press.

UMD PERG Resources Homepage (2007) http://www.physics.umd.edu/perg/homepages.htm

Wajcman, J. (1991). *Feminism confronts technology*. Great Britain: Polity Press.

Walker, M. (2001). Engineering identities. *British Journal of Sociology of Education, 22*(1), 75-89.

van Aalst, J. (2000). An Introduction to Physics Education Research. *Canadian Journal of Physics, 78*, 57-71.

Warren, J. W. (1979). *Understanding Force*. London: John Murray.

Wenger, E. (1998). *Communities of Practice. Learning, Meaning and Identity.* United States of America: Cambridge University Press.

West, C., & Zimmerman, D. H. (1987). Doing Gender. *Gender and Society*, *1*(2), 125-151.
Wickman, P.-O. (2004). The Practical Epistemologies of the Classroom: A Study of Laboratory Work. *Science Education*, *88*, 325-344.
Wickman, P.-O., & Östman, L. (2002). Learning as Discourse Change: A Sociocultural Mechanism. *Science Education*, *86*, 601-623.
Williams, G. (2006). Sir, are you wearing nail varnish? *Physics Education*, *41*(4), 317-322.
Wittmann, M., Steinberg, R. N., Redish, E. F. (1999). Making sense of how students make sense of mechanical waves. *The Physics Teacher*, *37*(1), 15-21.
Yancey Martin, P. (2003). 'Said and done' versus 'saying and doing'. Gendering practices, practicing gender at work. *Gender & Society*, *17*, 342-366.
Yeo, S., & Zadnik, M. (2001). Introductory Thermal Concept Evaluation: Assessing Students' Understanding. *The Physics Teacher*, *39*, 496-504.

Appendices

Appendix A: Gender and physics – a popular introduction[1]

Why are there so few women in physics?
This is a question that has engaged physicists and physics teachers alike for at least the past thirty years or so, but despite a great many focused efforts to get more women into physics men still constitute an overwhelming majority in the discipline. In her article in Physics Education 37(1) Kerry Parker (2002), for example, points to how difficult it has been for her to get her female students to stay in physics, even though she is a female physics teacher, who actively encourages her female students. I found this observation highly intriguing and it triggered the question: So what can we as physics teachers do then? Well, what I'm going to argue in this appendix is that the question of women and physics is a highly complex one and that encouraging female students and bringing forward positive role-models are (merely) two measures among many.

In her 2002 article Kerry Parker further discusses how efforts to interest girls in physics all too often have turned into investigations of sex differences, which neglect the variation within the sexes. She, therefore, argues that in order to teach physics as inclusively as possible we should not be focusing on generalised sex-differences, but instead should be meeting the needs of each individual student. However, I don't think one should stop the discussion there. Because, in order to understand why there are so few female physicists I believe we need to turn our eyes from the women to the physics and look at how physics itself may be gendered. When doing so it is important to remember that gender is not a fancier word for women, or even for biological sex, because gender represents more, it includes our socially constructed ideas of what is masculine and what is feminine.

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[1] Note that this is a *popular* introduction to the issues of gender and physics, written for an audience of physics teachers. Consequently, it reads somewhat differently than the rest of the thesis. Moreover, this appendix is not written with a particular gender theory in mind.

This appendix will therefore not focus on reasons for the female under-representation in physics, nor present statistics on how well female students perform in comparison to male students. Furthermore, the idea is not to give a ‘list’ of things teachers could/should do to make their physics teaching more inclusive, but rather to provide a flavour of how gender in various ways interacts with physics and discuss how this relates to teaching. To structure and shorten this very complex subject I have chosen to focus on three different levels on which physics can be seen as influenced by gender: how physics is presented, the culture of physics, and finally physics as a science.

How physics is presented

To present physics to our students we, as teachers, use examples set in everyday contexts, stories of famous physicists and, not to forget, language – things that all can carry gender.

Physics is never taught in a vacuum; teachers draw on everyday examples to illustrate physics principles and try to include contexts familiar to the students in their physics problems. As with almost everything in our society, these contexts often are gendered, and with physics having been male-dominated for such a long time the examples are likely to come from the male sphere of interests. One example of this is the widely used ‘Force Concept Inventory’ (Hestenes et al. 1992), where the questions concern such things as rockets, hockey pucks and cannonballs, with which men typically are more comfortable than women (McCullough 2004). Furthermore, physics is intimately connected with its long history of violent military applications. Moreover, violent imagery can also be found in not so obvious areas, such as how atomic reactions have be represented as atoms ‘attacking’ each other (Calabrese Barton 1997). Then, others have noted a frequent use of sexual imagery among physicists (Cohn 1996).

Considering the male dominance in physics, both past and present, it is no wonder that almost all the famous physicists in our students’ textbooks are men. It has been argued that the image of the ‘white male scientist’ can act as a kind of filter for women and other marginalised groups; they do not see what has been accomplished in science by people like themselves and the lack of role models can make them reluctant to pursue a career in physics (Kleinman 1998). To bring forward women and people from marginalised groups who have actually been successfully working in physics might be the most apparent solution to this problem – but also to discuss why there are in fact so few female scientists.

In addition, physics tends to be described by words such as: objective, logic, abstract, impersonal, rational, unemotional, and competitive. Not only do these words describe a stereotypical male rather than a female, they also describe physics in a very limiting way, with a limited epistemology. I'll return to this point in the discussion.

To summarize, how physics is typically presented both in class and in text-books (and even in the media) is by no means gender-neutral and I would argue that an awareness of gender in how we as teachers presents physics goes beyond the notion of making the subject more ‘girl-friendly’, it’s a way of giving our students a broader and more honest view of physics and its applications. After all, physics doesn’t only help us to understand the flight of cannonballs, it also helps us to understand everything from why the rain-bow looks the way it does to how a microwave oven works.

The culture of physics

The following is in one way obvious, but simultaneously highly difficult to fully grasp: That physics is much more than its subject matter and our pres-entation of this subject matter. One way of picturing this is to view physics as a culture, where the physicists (and physics students) value certain skills and abilities.

The gendering of the particular culture of physics students has been exam-ined by Thomas (1990). She explored how students studying physics and English respectively view themselves and their relations to their subject of choice. One of her more interesting outcomes is how different the male mi-nority in English and the female minority in physics view themselves. The students in English saw individualism, the ability to argue for your own opinion, as an important characteristic of their subject. As a consequence, the male students in English saw their minority sex as an asset; they had chosen an unconventional subject and their ‘male viewpoint’ made them feel special and interesting. The teachers in English also view the male students as having more interesting ideas. Physics, on the other hand, was described by the students as fundamental and certain and, thus, something you can’t really discuss. The physics students approached their subject as a body of information they had to ‘absorb’ and with respect to this ‘certain’ body of information the male students were the norm. The female minority in phys-ics, therefore, struggled to ‘fit in’ the male norm. Thus, how students experi-ence being a minority can be dramatically disciple specific. Furthermore, female physics students striving to be as ‘good as the men’ gives the male students an advantage, just by being men, and can become an additional obstacle to the female students learning of physics.

The culture of physics has also interested anthropologist Sharon Traweek (1988). She has studied high energy physicists in the U.S. and in Japan and argues that a society of scientists can be viewed as a culture, with its own manners and customs. The following example from her book ‘Beamtimes and Lifetimes' illustrates how dependent on culture our view of women and physics is: In the U.S. it's often claimed that one of the reasons women don't 'make it' in physics is that they aren't competitive enough, but prefer collaboration instead. In Japan a similar argument is used to explain the lack of female physicists, but here the argument is the opposite; professional women are in Japan considered to be highly competitive and therefore not suitable for the collaborative science of physics; same exclusion, opposite arguments. So, not only does physics have certain cultural characteristics, these also vary somewhat between different contexts.

One person who has applied the view of physics as a culture in a discussion of the actual teaching situation is Sjöberg (2000). He sees science as a culture with its own cultural characteristics, its own advantages and disadvantages, and argues for a teaching that helps the students to see science as a subculture. This subculture is, according to Sjöberg, characterized by qualities such as objectivity, rationality, and reductionism but at the same time these qualities do not have to characterize the scientist as a person, since being a scientist is only a small part of who we are and the subculture of science is a culture that the individual scientist can move in and out of.

In summary, we can see that physics is a culture were ideas about gender play an important role, and in various ways shape the learning experiences of our male and female students.

Physics as a science

So far we have looked at the gendering of how physics is presented and how gender matters in the physics culture but what happens if we dig even deeper, into the core of physics as a science – what can then be said about gender? This a complex philosophical issue that has got a lot of attention over the last 25 years or so in the field of feminist philosophy of science. I will here give you a brief introduction to some main ideas emerging in this debate. Underlying most feminist philosophy of science is an epistemology that sees all knowledge as situated and as such influenced by the context in which it has been constructed. In other words, it does matter that physics has been developed predominantly by white, middle- and upper-class men. An example if this could be that the qualities valued in science such as objectivity, reason and mind at the same time are qualities that we in our culture associate with masculinity. The common assumption that science is value-free, neutral and objective in its pursuit to explain reality is replaced by a view that our experience of this reality is determined by culture and its context. Furthermore, it is argued that there is no such thing as 'pure science', that science can never be disconnected from society and associated technological applications since they are mutually dependent for progress (see, for example, Harding 1986 and Fox Keller 1992). An example of this could be how, without the military-political cold war context, much of the laser research would not yet be done.

So far, so good. But what difference can these ideas make for our teaching? Well, it has been argued that teaching physics from a perspective aimed at understanding and critiquing the socially constructed nature of science can be empowering for women and people from marginalised groups. Calabrese Barton (1997), for example, describes how she as an undergraduate did not feel confident nor comfortable with quantum mechanics, seeing it as a subject reserved for geniuses and attributing her good grades to ‘pure luck’. However, she describes how the study of feminist theories of science helped her understand that her discomfort with the world-view of physics was not rooted in a lack of intelligence, but was a consequence of her attempts to engage in a world that historically had not appreciated the beliefs and values she had learned to value as a woman (Calabrese Barton 1997). Others go even further, arguing that a feminist pedagogy will not only affect the students positively, but may have a positive effect on the development of science itself because it would encourage students to critically analyse the epistemology of Western science and to be involved in asking new questions from ‘fresh standpoints’ (Mayberry 1998).

Discussion

When gender issues in physics education are discussed the focus is often on the female students, on ways of making the teaching more inclusive. I do acknowledge this to be an important part of the effort here, but at the same time hope to have convincingly argued that the gendering of physics concerns more than just the genders of the physics students. Furthermore, to bring an awareness of gender into our physics teaching can be a way to provide the students with a more thoughtful epistemology, something that in fact is crucial for their learning of physics (as demonstrated by, for example, Linder and Marshall 1998). It has been shown that it's common for undergraduate science students to have a positivistic view of science; they view scientific knowledge as absolute and scientific theories as a reflection of the truths of nature (see, for example, Ryder et al. 1999). Furthermore, Linder and Marshall (1998) describe how scientific activity most often is portrayed as a 'discovery of truth', in physics textbooks and elsewhere. This description not only distorts the contribution of actual people in the scientific process, but also supports the notion of learning of facts as being sufficient for conceptual understanding. Consequently, they argue, the epistemology reflected by traditional science teaching can prevent the development of independent and reflective learning. Their empirical results also show that students' conceptions of science and their conceptions of learning are in fact linked. Thus, a course that actively promotes metacognitive strategies, ‘aimed at getting students to reflect on their own learning, on the relevance of what they were learning and on the nature of their subject’ (p. 108) is an approach that is extremely useful for helping students develop both a more sophisticated view of learning and a more sophisticated view of science that acknowledges its social dimensions and empowering possibilities. To summarize, they say:

> It appears that such an epistemological framing can profoundly influence science students' conceptions of science and conceptions of learning and thus their orientation towards independent, reflective and lifelong learning. (p. 116)

My argument here is that such an epistemological framing will gain from including a discussion of gender and physics; thereby not only providing all students with a more appropriate epistemology, but also creating the possibility for a more inclusive learning experience. In other words, it's important to reflect upon what image of physics we are creating by our approach to teaching. For example, the common statement that physics is independent of gender and other societal factors, conveys, as stated by Ryder et al (1999):

> As mediators of the culture of science, science teachers at all levels in the educational system need to make explicit to themselves the images of science communicated through existing curriculum activities and those additional images they wish to incorporate in new curriculum developments. (p. 217)

In other words, making physics accessible to a wider audience means looking at how the interplay between culture, epistemology and gender both within physics and beyond physics affects the experience of learning.

Appendix B: Student interview protocol, pilot study

Halv-strukturellt protokoll
Målet med intervjun att förstå deras erfarenheter från lab-kursen. Förklara att du vill att de ska vara så öppna och ärliga som möjligt eftersom vad de säger kan hjälpa oss att utveckla kursen i framtiden. Be om deras tillåtelse att spela in intervjun i syfte att senare kunna gå igenom materialet i detalj. Påpeka speciellt att inspelningarna kommer att vara helt konfidentiella och kommer inte i något skede att sammankopplas med någon enskild individs kommentarer. Inget de säger kommer att ha någon som helst inverkar på individuella studier nu eller i framtiden.

Syfte; learning outcome; vad innebär det att lära sig fysik

- Vad ser du som syftet med denna typ av lab kurs?
- Hjälpte labbarna dig med att lära dig fysik?
    - Om inte, vad lärde du dig?
    - Vad innebär det för dig att lära dig fysik?
    - (Hur skulle du avgöra om någon förstått N III?)

Tidigare erfarenheter; framtida användning

- Vad skulle du rekommendera en student som kunde välja mellan denna typ av lab.kurs och en traditionell labkurs? Vad skulle denna student göra för att prestera bra i en kurs med detta upplägg?
- Kan du nämna några tidigare erfarenheter/kunskaper som du tror hjälpt dig i labkursen? Vad tror du hade varit till hjälp? *Vad är du bra på? Den ideala studenten?*
- När du är klar med dina studier, kommer du att komma ihåg något av den här kursen? Kommer du att använda dig av ngt du lärt dig i ditt framtida yrkesliv?
- Om du kör fast i labbet/analysen, vad gör du då?
- Om du hade obegränsat med tid, vad skulle du ha gjort annorlunda?

Jämfört med kemi.

Appendix C: Student interview protocol

I. För att komma i gång med diskussionen/leda in studenten i ett tänkande kring utbildningen i ett större sammanhang:

- Varför valde du den här utbildningen?
- Vad vill du jobba med i framtiden? När bestämde du dig för att det var det här du ville göra? Varför?

II. Laborationer

Syftet med att labba:	Lärarnas
	Ditt personliga: Vad försöker/vill du lära dig i labbet?

Lärande av fysik: Hur labbandet bidrar/inte bidrar till detta.

Labbandet i ett större sammanhang:

Tidigare erfarenheter/förkunskaper:

- ”En person jag intervjuade tidigare berättade att… tidigare yrke… rapportskrivande” – har du några liknande erfarenheter.
- Finns det några tidigare erfarenheter/förkunskaper du önskat att du haft?
- Vad är du bra på? Kan du koppla detta till något du gjort tidigare?
- Vad är viktigt att vara bra på, för att få ut mesta möjliga av fysiklabbar?
- Vad skulle du rekommendera en kompis som började plugga fysik att fokusera på i labbandet?
- Är det någon skillnad mellan vad som krävs/är bra att ha med sig i labbet jämfört med i övrig fysikundervisning?

Om du hade obegränsat med tid… Skillnader mellan olika nivåer..?

Framtiden:

- Vad kommer du att komma ihåg av arbetet i kurslab?
- Tror du att du kommer att använda något i ditt framtida yrkesliv?
- Kan du tänka dig att jobba i ett forskningslab, varför/varför inte? (Fysikens Världsbild)

- Kan du komma på någon lab som varit särskilt givande? Varför var den det?
- Kan du komma på någon lab där du bidragit med något särskilt? På vilket sätt?

Flera jag har intervjuat har haft svårt att sätta in labbandet i ett större sammanhang. Varför tror du att det är så?

”Vissa hävdar att arbete i kurslab är ett sätt för studenter att lära sig hur fysiker jobbar, hur forskarsamhället fungerar” – Hur ser du på detta påstående?

Normer och ideal:

- Om du skulle beskriva den ideala studenten, i synnerhet med fokus på att jobba i labbet, hur skulle denna se ut? Vilka erfarenheter har denna med sig?
- Vad anser du om detta ideal? Är det något du strävar efter, varför/varför inte?
- Om du skulle övertyga den övriga gruppen om att något du kommit på är bra, t.ex. en metod, hur skulle du göra detta? Vilka argument är OK att använda? Skiljer detta mellan olika nivåer tror du? Skulle du göra det annorlunda i labbet än t.ex. när ni löser problem i grupp?

Genus:

(Frågor med mycket tolkningsutrymme – låta den intervjuade styra diskussionen.)

- Det är ju mest killar som pluggar fysik, vilken roll tror du detta spelar?
- Har du reflekterat över att du valt en utbildning som många ser som traditionellt manlig?
- Om du tänker specifik på labbet, finns det någon skillnad på hur killar och tjejer arbetar? Vad tror du detta beror på? Kan skillnader i tidigare erfarenheter spela in?
- Vilken betydelse har ”genus” i fysiken för dig? I fysikundervisningen? I arbetet i labbet?