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*Physics and feminism: a personal reflection on one physics teacher's doctoral journey.*

WAIN, Heather

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**Master of Professional Studies  
(Educational Research)**

**Heather Wain**

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# **Physics and Feminism: A personal reflection on one physics teacher's doctoral journey.**

## **Abstract**

*This is a personal account of a doctoral journey, embarked upon to legitimise an academic identity, founded in the transition from secondary physics teacher to physics educator in the Higher Education sector. An autobiographical background provides the context for the starting point and subsequent direction in which this journey progressed. The key area of focus: the low participation of girls in physics through research into physics teachers' beliefs and pedagogy. A narrative, broadly chronological account of significant learning charts moments of enlightenment in moving from a physical scientist's positivist view of the world to that of social constructivism via a deepening theoretical understanding of feminism, gender and feminist methodology. Despite the doctoral journey not reaching its intended final destination, significant achievements are explored, not least the impact on professional practice.*

*Unresolved issues remain, particularly around methodology and methods, but the writing of this very personal reflection has been integral to the development of my identity as an academic and professional researcher.*

## **Introduction**

The Doctorate in Education (EdD) as studied and discussed in this dissertation involved a 'taught cohort phase' consisting of 4 modules:

- Framing your research
- Research methodologies in professional education
- Researching pedagogical practice – literature review
- Research designs in the educational field – pilot study

Successful completion of these modules is a requirement for progression to the research phase. It is also possible at this stage to transfer to the Master in Professional Studies (Educational Research) award, for which this dissertation is written.

The overall aim of this dissertation is to provide a vehicle through which to reflect on my learning by synthesising material from the four modules and reviewing and evaluating my research thinking and development (Garland 2012). Here, I review the work of the cohort phase, including the papers written for the modules, and write a reflective account that summarises the contribution this work has made to my own development as a researcher and my professional knowledge and practice.

Key themes that emerge from this review and reflection are: recognising the role of theory in social science research; developing and applying my own theoretical thinking in this regard; and a philosophical exploration of positivism vs social constructivism and associated methodological implications. Specific areas of focus that are explored are physics as both a curriculum and pedagogic entity, theories of gender and feminist methodology. Engagement at this level of scholarship both in general and in each specific area of focus has resulted in significant impact on my professional practice. This is discussed along with an honest, critical appraisal of some significant issues that remain unresolved.

I have attempted to signpost the reader to specific aspects such as significant achievements, significant learning, development of theoretical thinking and impact on professional practice. However, in reality there is a complex inter-connectedness between each of these aspects and so this reflection has been written and should, I would urge, be read holistically.

### **Autobiographical background**

I offer this brief autobiographical summary as background context for the significant events leading up to embarking on the EdD. This will also enable me to situate and reference my significant learning, achievements and development throughout the cohort phase not least because of a recognition, through my own learning, of the importance of reflexivity and “the personal experience of the researcher as an integral part of the research process” in feminist research (Ezzy, 2002, p153, cited in Cohen et al, 2011, p40). Furthermore, it offers a potential platform for continued exploration into an auto-ethnographical study of my own, gendered relationship with physics and physics education.

I was a physics teacher in secondary schools for 17 years and am now a physics educator working in Initial Teacher Education. Studying physics for my degree was a result of a series of events at key points throughout my schooling: a love of history that was quashed by one particular teacher in option year; a grade slip that prevented me studying mathematics alongside physics; and even, perhaps, a lack of imagination to look beyond the ‘traditional’ subjects. For sure, I was, and am, interested *in* physics and knowing about the physical world, I read *about* physics and physicists, I am in possession of that defining physics degree and have also been accepted as a Member of the Institute of Physics. However, reflexivity as

an EdD researcher has helped me to think about my professional identity. This has led me to the conclusion that I am not sure that I identify as, can claim to be, nor would even be accepted as, a ‘physicist’.

Hyland (2012) suggests that:

*“How we choose to express ourselves must resonate with group members so that our claims to membership are visible ..... and acknowledged by insiders. Whilst all identities are a negotiation of a self which is coherent and meaningful both to oneself and others, disciplinary identity seems particularly dependent upon this kind of acceptance. It crucially involves the identification with some community of others, taking on and shaping its discourses, behaviours, values and practices to construct a self both distinctive from and similar to its members. Identity, then, is a two-way street in that our identities are successful only to the extent that they are recognised by others.”* (Hyland, 2012, p71)

And therefore, disciplinary identity could also be considered as being formed not only by inclusion, but equally, by exclusion. Whilst the Institute of Physics support the view that “teaching physics is doing physics” (IoP, Twitter 2017), what would those who *do* identify as physicists think? Tellingly, I’m not even sure that the recognition of those who do identify as physicists is particularly important to me.

On the other hand, and even by this definition, becoming and being a teacher was never in doubt. The ‘teacher’ part of ‘physics teacher’ is the bit of me that is deep and connected; it was, and still is, part of what identifies me. I am, perhaps, at my most fulfilled and content, when I am teaching - whatever I am teaching. It is interesting to reflect on whether this is a personal identity, a professional identity or both and what this means. I think I would have been classed as a pretty decent secondary school physics teacher, certainly in the mid-part of my career, after I had acquired a comprehensive knowledge of curriculum and subject (by teaching it) and developed some pedagogical approaches that seemed to motivate pupils. I measured my success by the burgeoning number of pupils opting for A level physics in my department. It was also the case that the proportion of girls within my A level classes also exceeded the national average (then and now) of approximately 20% (IoP, 2017). I am not sure that at the time, I really gave critical thought to the issue of gender and was simply pleased with the number of students opting for the subject. I simply accepted, like so many,

that that was the way it was – and did it really matter anyway? To return to Hyland (2012); although I did take on physics teaching's discourses, behaviours, values and practices, particularly in relation to male gender-biased contexts, a distinctly positivist approach and valuing mathematical process over conceptual understanding, I believe I had also been able to construct a self which was in some ways distinctive from other physics teachers, particularly in relation to pedagogies that led to the engagement of girls.

In 2004, while I was still in secondary teaching as a director of science in a specialist science college, the government launched its Science and Innovation Investment Framework 2004-14 (BIS, 2004). This framework was clear in its message that the number of students choosing science, engineering and technology (SET) subjects post-16, and the quality of science teachers and lecturers, are a key element of the future wealth and economic development of the country. This framework resulted in significant funding for science education. My department was a beneficiary of some of this and I became involved in three significant projects: a research project with Leeds University on scientific conceptual understanding (Leach, Ameteller and Scott, 2009); the newly launched, government funded, Science Learning Centres; and the Institute of Physics' Girls in Physics and Stimulating Physics projects. Through these projects I became aware, perhaps for the first time, that there was a world of education beyond the classroom and that the issue of the participation of girls in physics had been identified as, and continues to be, an area of concern and focus. Despite this investment the overall proportion of girls opting for A level physics stubbornly refuses to shift significantly. The most recent data from the Institute of Physics states that:

*“The number of girls taking A-level physics has increased since 2010, but this has been in line with the overall rise in the number of entrants and the proportion of girls to boys has stayed roughly level at 21% (+/- 0.5%) during this time. Since the early 1990s, the proportion of girls to boys has not fallen below 20.7% but not risen above 23.1%.” (IoP 2017)*

Two publications from the Institute of Physics (2006) (popularly known as the 'red books' on account of their binding), were my first real engagement with educational research literature. The first, *Girls in the Physics Classroom* (Murphy and Whitelegg, 2006a), was a comprehensive review of the literature on the participation of girls in physics. The second, *Yes, She Can* (Ponchaud, 2006), was an investigation into schools that had proved to be successful in attracting girls to study A-level Physics. My tacit knowledge of physics

teaching, the pedagogies I had developed (not through any kind of professional development, but through trial and error and reflective practice) suddenly found a home or, perhaps, an endorsement in this literature.

This engagement with education research came at a mid-career, mid-life crossroads. On the career front, I had been in middle to senior management in school for 5 years, getting further from my subject and even further from the teaching of it. My ambition shifted to that of leadership and I completed my National Professional Qualification for Headship (NPQH) fully in the expectation that I would progress next to deputy headship. At this time, a period of serious illness stopped me in my tracks for several months. It was stepping off the treadmill during treatment, and reassessing both life and career, that I decided to move away from leadership and back to subject teaching. Having resigned my position in school with no job to go to, an opportunity presented itself to apply for a post as a Continual Professional Development (CPD) leader at one of the regional centres in the national network of Science Learning Centres. This network was established and funded to provide subject specific CPD for science teachers and was an organisation with which I had had some involvement as a teacher. Application led to appointment and so came the necessity to begin to forge a new a new disciplinary and professional (academic) identity.

One of the first major projects I became involved with was to develop and deliver programmes of professional development for non-specialist teachers of physics. At the time, it was estimated that almost 1 in 5 11-16 schools had no 'physics specialist' teacher at all (IOP 2010) and that 31% of teachers of physics did not have a relevant A level qualification (School Workforce Census, DfE 2011). Current data suggests that just 51% of physics teachers have a relevant degree and that physics teacher recruitment has consistently failed to meet its target over several years (Kirby and Cullinane, 2017). It is therefore evident that many, many physics lessons particularly in state schools and particularly in those in challenging circumstances, are being taught by 'non-specialists'. Given that A level physics is a gateway qualification to many careers with higher earning potential, this presents a serious concern over both equality of opportunity and social mobility. This leads me to the conclusion - and to a conviction - that physics, as it is currently taught, is 'broken'.

If the way we teach physics is broken then it follows that we must do something differently in order to fix it. Government initiatives to address the physics teacher shortage in recent years have included programmes designed to enhance the subject knowledge of non-specialist



physics teachers who are teaching physics to GCSE. Being involved with the development and leading of these programmes in both pre- and post-Initial Teacher Training (ITT) sharpened my awareness of the fact that there is a world in which researchers, academics and physics educators study *how* physics should be taught to best effect (e.g. Scott and Leach 2006 and Loghran, Mulhall and Berry, 2003). I became increasingly interested in approaches which promoted the importance of conceptual understanding as a foundation and pre-cursor to the procedural and mathematical calculations that are, all too often, deemed to be what physics 'is' (e.g. Knight 2004).

The transition from physics teacher to physics educator was underway. Working with other experienced physics educators on the government funded Science as an Additional Specialism programme from 2008-10 was a particular catalyst for this transition. This programme funded non-specialist teachers of physics to be seconded for one day a week over a school year to embark on an intensive programme of accredited professional development at the end of which they 'added the specialism' of physics to their existing specialism. Actively, knowingly and implicitly putting theory about physics pedagogy into practice and seeing the effects first hand was a defining moment in my career. Subsequently, in 2011, I conducted a small-scale research project that followed the development of these two cohorts of 'SASPers' up to three years after engaging with the programme. This was my first significant engagement with educational research as a researcher and was an important learning experience, largely self-taught, but with some very welcome informal mentoring from more experienced colleagues. This piece of work was really little more than the construction, analysis and evaluation of a survey questionnaire but, nonetheless, designing the questions and then the means of analysis enabled me to develop important skills upon which I have subsequently been able to build. The small-scale survey found that all 24 respondents agreed that their confidence, subject knowledge and the way that they now teach their additional specialism had improved. Most had been able to influence the teaching of their colleagues and a third identified either increased attainment of their pupils or a greater uptake at A level, or both. (Wain and Carpenter, 2011). This study was never published in any form although, looking back now, it possibly did have the potential to be. This raises an important issue of confidence or perception of 'worthiness' in my own academic credibility, a theme to which I will return.

In my view, but also from the findings of my research, the SASP programme could have been the beginning of a renaissance in the teaching of physics and the solving of the physics

teacher shortage. Instead, reduction of funding meant that all Subject Knowledge Enhancement programmes since, whilst certainly of some value, have been but a pale reflection of this programme with respect to intensity and duration. There is, perhaps, some scope for a follow-up research project comparing the effectiveness (which would need defining) of the various iterations of such courses.

In the past few years, then, my knowledge and understanding of physics pedagogy and therefore my physics teaching *and* teaching of physics teaching has developed rapidly and has had an impact evidenced through: evaluations of CPD delivered; the SASP three years on study; an Inspirational Teacher Award and less formal anecdotal feedback from school based colleagues who had engaged in varying types and lengths of this non-specialist CPD. Meanwhile, I also continued to engage in reading about girls and physics and apply this to my practice. In particular, linking my deepening understanding of subject specific pedagogy to the fact that these pedagogies were complementary to the findings from the ‘red books’ (Ponchaud, 2016 and Murphy and Whitelegg, 2006a) that had first opened my eyes to physics education research and, in particular, girls’ views about, and relationship with, physics.

My academic self-concept and credibility was beginning to gain some traction but I needed some legitimacy. I also felt that I was now sufficiently understanding of the issues to add something new and of my own to the field and it was at this point that I embarked upon the Doctorate in Education (EdD).

### **Summary of significant learning and development of theoretical thinking**

At the outset, I had a clear idea of an area of focus and had embarked upon my doctoral study with a view to focussing specifically on physics pedagogy. After all, this was where I had made the most significant, research informed changes in my own practice since leaving the secondary classroom. It was also where I saw the biggest impact on my current students’ attitudes to physics. Therefore, I had an interest in exploring the potential of pedagogical change to be part of the solution to the physics teacher shortage. My premise was that if more pupils had a positive learning experience in physics, more would opt to study it post-16 and move to related fields post-18. There would then be a larger potential pool of appropriately qualified people from which more specialist teachers would emerge. Furthermore, working on the principle that teachers often teach as they were taught, this might be a catalyst for more fundamental and wide-spread change. If I could demonstrate, through my own research,

that attitudes to physics can change when physics is *explicitly* taught differently, then that would be a major contribution to the field.

For the purposes of this narrative summary, I will give an account of the taught, cohort phase of the EdD within which I will highlight: my significant learning over the period of the cohort phase; significant achievements in my development as a professional researcher; and outline the development of my theoretical thinking

In doing so I cover the following main themes:

- the process and design of education research – the importance of designing ‘the whole’
- educational research as social research – developing an understanding of a social theoretical framing
- the social construction of gender, physics pedagogy and a lot more besides
- identifying a gap

To the experienced researcher (and in some respects, now, to me) much of this may seem obvious but, when considered in the context of my starting point, these themes represent highly significant learning and development. It should be said that the writing of this reflection and summary has further developed my theoretical thinking- and I also explore this throughout.

### **Research design**

Before summarising my learning from each module, I would like to highlight an area of significant learning that is rather more overarching and certainly more fundamental. This is the developing appreciation that, when embarking on a substantive piece of educational research, it is important to have an understanding of, and vision for, ‘the whole’. Whilst the chronological, linear and modularised nature of the taught phase of my studies provided important structure for me as a fledgling researcher and, indeed, a structure for this reflective account, the disadvantage was that it resulted in a linear building of the process of research. By this I mean that the structure of the taught phase resulted in a piecemeal approach to the way in which my research proceeded such that theoretical framing, philosophical underpinnings, methodological considerations, literature reviews and methods initially lodged in my mind as separate entities. Cohen, Manion and Morrison (2011) suggest this type of

linear sequence is “beguilingly deceptive, for rarely is such linearity so clear” (p117). That said, they also warn that:

“it is essential as far as possible to plan every stage of the research. To change the rules of the game in midstream once the research has commenced is a sure recipe for problems.....The setting up of the research is a balancing act, for it requires the harmonising of *planned possibilities* with *workable, coherent practice*.” (p115 original italics)

No doubt I read the chapter from which these quotations are taken at an early stage and I'm sure it had little impact at the time. Feedback for the second module on methodology makes exactly this point and suggests that, at that stage, there was still more ‘hybridisation’ to do between theories, philosophies and methodology. It is only retrospectively that I have been able to recognise the importance of the interdependence and symbiotic relationship of each of these aspects and acknowledged that, even as ideas develop, evolve or emerge, a wholistic understanding of the ‘research design’ is key. To an experienced researcher, this is no doubt obvious, but for me, this has been essential significant learning. It is clear that, in the future, I will need to trust in my ability to apply my learning, research skills, deeper critical insight and wider perspectives and have the confidence to produce a research design which is a coherent, harmonised whole. Meanwhile, I must maintain an openness and flexibility to adapt to what may emerge and develop as the research proceeds.

### **Framing my research**

My second area of significant learning, has been to acknowledge, and understand better, educational research as a facet of social science and, within that, how social theory provides a theoretical framework for educational research. As I explored the idea of physics as a curriculum subject with specific pedagogical approaches, I was introduced to the theories of Basil Bernstein (1977, 2001) by a peer on the course. I found Bernstein’s theories to be relevant in a number of key areas but also an accessible introduction to educational and social theory.

In his early work, Bernstein makes the distinction between ‘curriculum’ and ‘pedagogy’ defining ‘curriculum’ as what counts as valid knowledge and ‘pedagogy’ as what counts as valid transmission of knowledge. He further defines ‘evaluation’ as “what counts as a valid

realization of the knowledge on the part of the taught." (Bernstein 1973, p85 in Sadovnik, 1991). Bernstein's later theory of *classification and framing* relates to power relations and control. Classification is a term that relates to the strength of the borders and degree of insulation between categories. These categories could be at an institutional level but can also be applied to curriculum subjects. Bernstein defines 'narcissistic' individual bodies of knowledge which have strongly insulated boundaries between them, and are oriented to their own development as 'singulars'. He also suggests that "the sacred face" of these singulars "sets them apart, legitimises their otherness and creates dedicated identities with no reference other than their calling" (Bernstein 2001, p54). Framing relates to the locus of control and is a way of describing who has control over the selection, sequencing, pacing and evaluation of the teaching and learning interaction (Robertson 2008) within the category. Both classification and framing can be described in terms of 'strength' or 'weakness'. Strong or weak framing relates to the relationship between the teacher and the learner with strong framing characterised by a limited degree of options for students, and weak framing implying more control by learners (Hoadley, 2006).

Physics can be considered to be strongly classified and therefore a singular, indeed Bernstein himself stated such (Bernstein 2001, p9). Bernstein also uses physics as a specific example in his discussion of the pedagogic discourse.

*"With physics as an example, we will distinguish between physics as activities in the field of production of a discourse, and physics as a pedagogic discourse. It is quite possible to look at the activities of physicists in the field in which physics is produced and sometimes it is difficult to believe what everyone is doing is physics.*

*This is not the case with physics as a pedagogic discourse. A text book says what physics is, and it is obvious that it has an author. The interesting point, however, is that the authors of textbooks in physics are rarely physicists who are practising in the field of the production of physics; they are working in the field of recontextualization."*  
(p34)

Bernstein goes on to state that "irrespective of whether there is an intrinsic logic to physics, the rules for its transmission are *social facts*." And therefore, decisions have been made in relation to its selection of content, sequence, pace and relation with other subjects. Thus, if physics is legitimised only by the identity created and perpetuated by its practitioners, then it

follows that what counts as valid knowledge in physics is socially constructed or even socially engineered. Furthermore, what counts as valid transmission of knowledge (pedagogy) is also constructed and perpetuated.

At the same time as I was considering Bernstein as a potential theoretical framing I was also reading Wertheim's (1995) 'popular' science book *Pythagoras' Trousers*, subtitled *God, Physics and the Gender Wars*. This book proved instrumental and pivotal in developing my thinking around social construction and also steered me back towards a more explicit focus on gender. Wertheim explains how she had originally intended simply to write a "cultural history of physics" for a popular audience. However, she found that "God and religion kept raising its head" and then, when she began to address the question of the under-representation of women, she developed the argument of physics as a "priestly culture" and therefore one from which women have, over history, been overtly excluded (Wertheim 1995, p xiii). Her final step is to suggest that if women had not been excluded from the development and practices of physics, physics itself would not be as it is today. In many ways, I felt I was following a similar journey to that of Wertheim; from intending to engage with a non-gender focussed study of the nature of physics and physics education to a conviction of the importance of a feminist perspective. Importantly, this book steered me towards a feminist framing that I had not initially intended to be the focus of my research.

In attempting to build my theoretical framing during these early days, it occurred to me that Bernstein's powerful definition of a 'singular' – the "sacred face" (Bernstein 2001, p54) concords with Wertheim's (1995) view of the "priestly culture" of physics. Theories of the historical and social construction of 'physics' in both writers' arguments is clear. I was also particularly interested in Bernstein's theory that curriculum and pedagogic practice perpetuate power division and inequalities in society. It was obvious that I should now extend my reading and develop my theoretical understanding of gender theory and feminist research.

### **Feminism and gender theory**

Even from an early age, I already had an instinctive and tacit understanding of feminist ideas, and even an emancipatory zeal for how things should be. Looking back to some of our round the dinner table discussions during my childhood in the 70's, the period of second wave feminism, I was clearly identifying as a feminist, although, of course, I would not at the time have couched it in such terms. For example, I had no intention of changing my name when I

married, why should the men or boys always ride in the front of the car, why do the men get the first call on seconds at mealtimes etc. I developed views and expressed opinions accordingly! Other than my forthright views, which were probably not entirely welcomed by my father, my parents were, actually, very good at not forcing upon me society's stereotypes and they pretty much let me be me, affording me a range of opportunities and experiences which have shaped me and my identity. However, I also recall times of extreme frustration that being a girl was limiting in so many ways. I was deemed to be good enough to play football for the school team but was not allowed to, I coveted my brother's Christmas gifts but got the same as my sister. To me, the equality of girls was obvious yet I was acutely aware of the inequalities all around me. However, it has only been as a result of the reading I have done for the EdD that I have realised the extent to which such issues of sex and gender are much theorised about.

During the taught phase, I was conscious that my contributions to discussions often drew upon feminist thinking (even if only my own opinion) and I certainly found a legitimacy for my self-identification as a feminist. I can pick out several key moments when I had a breakthrough in my understanding of feminist theory and how it could be applied to the issues of girls and women in science and physics. After reading the more populist Pythagoras' Trousers I was recommended Heather Mendick's (2006) book *Masculinities in Mathematics* by one of the course tutors. In the introduction Mendick suggests that the word 'gender' has its most important meaning when it is used as a verb rather than its more traditional usage as noun or adjective (to assign or describe a particular identity).

*“Gender features traditionally as a noun, an aspect of the social world, and as an adjective, pinpointing a particular strand of identity. However, its most important use is as a verb. In other words, gender, as with all differences between people, is something that we do and are done by not something that we are.” (Mendick 2006, p10)*

In this sense, although we are ascribed 'a gender' by nature of our genitalia from the moment we are born, thereafter we are 'gendered' by society. I have cited this many, many times since in my own teaching. Butler in *Gender Trouble* (1990) took this a step further by suggesting that gender is further constituted through “repeated performance” – the “doing” of gender roles (cited in Elliot 2009, p216).

Mendick applies both feminist and queer theory to mathematics and the teaching and learning of it, but there are many parallels in science. Throughout the cohort phase I often quoted Evelyn Fox Keller's Templeton lecture (1996) which specifically addressed the issues of gender and science, suggesting compellingly that it was insufficient to "simply add women (to traditionally male spheres) 'and stir' and that "to do so risked a re-enforcement of gender divisions." (in Sarzin, 1996). In my first module's assignment, I suggested that at the extreme end of this argument it might even be unethical to do so if women in the field are culturally discriminated against, or even possibly, overtly discriminated against. (Wain 2012). So, rather than 'getting more girls into physics' perhaps we should, in fact, be reinterpreting the problem as changing the culture of science, technology and engineering in such a way that those with stronger female gender identities are able to identify with the subject.

*"This is not about women doing science differently to men. It is about everybody doing science differently when the gender ideology shifts"* (Fox Keller, 1996)

Furthermore, not only scientists but scientific methods, the physics curriculum and physics education practices can also become gendered:

*"I have argued that physics education reform movements should pay attention to feminist analyses of gender ideology in the culture of physics also because these analyses reveal that the culture of physics is dominated by certain styles of doing science"* (Rolin, 2008 p1112)

This led to greater clarity and added more weight to the idea that I was already formulating of physics teachers and physics educators (and the pedagogies they adopt) as, unwittingly being inculcated in these practices. I found an endorsement of this, and, crucially, a potential gap in the research during my literature review. Murphy and Whitelegg (2006b), suggest strongly that the attitude of girls to physics and their identity with it compared to boys *can* be disrupted. However, they decry the scarcity of UK-based research in this area generally, suggesting that the most fundamental reason for this is that "interventions that challenge the gender dualisms mapped onto science knowledge representations are non-existent." (p296). They also suggest that physics as currently and traditionally represented in the school curriculum does not portray a subject which is 'complex, diverse and tenuous' and that interventions that involve a wider range of practices, and a different selection of problems and potential solutions, may do something to challenge the gender divide.



And so how does all this inform my own future scholarly activity or empirical research? Since engaging with the taught phase of the EdD and especially in the writing of this dissertation, I have begun to wonder whether it is possible that where Bernstein talked about curriculum and pedagogical practices maintaining *class* divisions, could the same principles be applied to *gender* divisions? Could Bernstein's theories of classification and framing be applied to my developing critical analysis of physics, pedagogy and gender and be enriched by a feminist perspective as a theoretical framing for my study?

To summarise my key learning around the nature of educational research discussed thus far. There would be much to be gained (and it is reassuring) to look at how other theorists and researchers (albeit very few) such as Madeleine Arnot (1995), have applied Bernstein's theories to gender inequalities in other contexts or other professions. However, at the same time, I have questioned the extent to which I should use the work of others as a direct template for my own. To do so would contradict the purpose of my doctoral research which, to my mind, is to add something new, to be original. I also acknowledge that perhaps one reason that I didn't quite succeed in finalising a research proposal was because I *was* looking for a 'ready-made' theoretical framing and nothing that I came across quite fitted. On reflection, this perhaps came down to confidence but I now feel far more comfortable to acknowledge that building upon, adapting, reapplying the work of others is acceptable. Similarly, the prospect of applying a theoretical framing in a novel way seems far less daunting than it once did now that I have a greater understanding and sense of the aforementioned 'whole'.

### **Positivism vs social-construction**

This engagement with the theories of Wertheim and Bernstein led me into the second module on methodology which was a watershed in many ways and provided the backdrop to my third area of significant learning - being able to consider and accept a widening number of 'truths' as social-constructions. In the written assignment for the second module on methodology I undertook a largely historical exploration of the ontological, epistemological and methodological nature of physical science and social science and, essentially, provided a reflexive account of my own struggle to reconcile the two. This was incredibly insightful and useful and has had a profound effect on my own understanding of the nature of science itself.

Although I was clearly already flirting with the social construction of both gender and curriculum / pedagogy through my exploration of an appropriate theoretical frame, I had not made an explicit connection between the framing and philosophy and, even less so, methodological approaches. It has taken me quite a while to understand the link between theory and methodology in a social context.

It was another of my identified significant texts that moved me on in my philosophical thinking and acted as a bridge between the physical and social sciences. The book was Kuhn's *The Structure of Scientific Revolutions* (1996). In this seminal work, Kuhn explores, and offers a thesis, about the characteristics which (physical) scientific revolutions must have in order to be deemed as such. With *this* subject matter and context I was on very familiar ground but had yet to appreciate the implications of Kuhn's ideas to my own development as an *educational* researcher.

Throughout my own learning journey, I have always found it important not just to understand a person's work but also to have a connection with the person themselves. In the case of Kuhn, I made this connection immediately. Kuhn received a PhD in physics early in his academic career but became a science historian and philosopher. As I discussed earlier, I do not necessarily identify as a physicist. However, what particularly interests me in physics are: the fundamental concepts and ideas; the big picture of interconnected ideas; the interplay between theoretical physics and practical physics and some of the history of the development of our understanding of the physical world. I have also always been very interested in the human story; behind every theory and every discovery is a theorist or empiricist with a story to tell. Perhaps, in reality, I am a frustrated or thwarted historian! Having studied and taught physics, I was able to read *The Structure of Scientific Revolutions* and have a robust understanding of Kuhn's ideas and how they apply to physical science. Kuhn divides the historical process of science into three stages: 'normal', 'crisis' and 'revolutionary'. When science is operating in the normal stage, there is strong consensus among scientists about scientific practice and problems that require solutions. Rees (2012) explains what constitutes a crisis:

*"A crisis occurs when existing theories involve so many unsolved puzzles or "anomalies," that its explanatory ability becomes questionable. Scientists begin to consider entirely new ways of examining the data, and there is a lack of consensus on which questions are important scientifically" (p73).*

The emergence of a new solution, ‘incommensurable’ with the original, results in a new ‘paradigm’ (Kuhn, 2009) which is the revolution that instigates a new period of ‘normal’ science.

Kuhn’s book is also considered to be an important work in the field of social science and that, I initially, found more challenging. Perhaps I was not understanding the role of theory and theorists in social science in the same way as in physics, was not able to accept that social science has ‘revolutions’ and if it does, what the implications are for our understanding of society. To help with exploring this, I find it comfortable to use an example from my physical science background as the basis for a comparison in the social sciences.

The quantisation of energy is the scientific revolution which Kuhn himself quoted as the ‘ideal’ in terms of its structure. At the turn of the 19<sup>th</sup> century, the phenomenon of blackbody radiation was a significant feature of ‘normal science’ – well understood empirically and with a consensus in the scientific community about the need for a physical explanation. All attempts to apply existing, classical theories to the problem resulted in failure – a crisis loomed. Max Planck offered a new solution in which the central tenet of the model was that energy was quantised – such a revolution in thinking that even he did not believe his own theory at first. A new, normal stage, of ‘puzzle solving’ (Kuhn, 2009) resumed in which Einstein successfully applied the same theory to a different problem (the photoelectric effect) further cementing the theory. Nevertheless, the quantisation of energy became *the* new paradigm.

Rees (2012) interprets Kuhn’s premise by stating that “competing paradigms in physics never co-exist for very long, and that progress in normal science occurs precisely when scientists work within only *one* paradigm.” (p78, my italics). What Rees (2012) then goes on to do is explore the issues that arise when attempting to apply Kuhn’s structure in the social sciences. Here multiple, possibly contradictory, paradigms co-exist because the social sciences are grounded in competing views of the world and society. New paradigms may be established but they become *a* paradigm, rather than *the* paradigm. Equally, there are no precise definitions drawn from consensus. As a result, Rees concludes that there will be limits to what social science can achieve because this “inevitably means that arguments turn on *questions* of theory rather than the application of theory” (Rees, 2012 p79, my italics).

It is therefore possibly not surprising that reprogramming myself to move from viewing scientific consensus about theory and the physical world to the co-existence of multiple

models and theories proved difficult. It still feels to me, at times, that in social science, anything goes, provided it is well constructed, argued and justified and that there are as many ideas, permutations and combinations as there are people. Perhaps that is the point. However, it is clear that by the end of this second module I felt compelled (rightly or wrongly) to “nail my colours to the mast” of one particular paradigm, one particular way of seeing and understanding the world (Wain 2014) – and I never quite got there. I was, perhaps, rather enjoying the exploration of the philosophical questions of the nature of truth, and how we know come to know it, for its own sake. Or perhaps I was looking for an emotional connection or a ‘home’ for what I think, what I believe and who I am – and that never really came. This was, and remains, problematic perhaps because I am not good at making decisions in life in general! However, it appeared to be the case that peers on the doctoral programme who were able to identify with a particular paradigm, framing or methodology or perhaps just make a decision and ‘go with it’ at an early stage, made faster and more successful progress on their doctoral journeys. Should I just pick something and go with it, justifying and possibly adapting my approach along the way, or do I continue searching and re-searching, seeking the opinions of others, to find the perfect fit before setting out? This is an issue that, to some extent, remains unresolved and is discussed later.

And so, despite some unresolved issues, my theoretical thinking *was* developing and I was beginning to explore and understand and, to some extent, reconcile the dichotomy of an extreme positivist, empirical physicist’s view of the world and a growing awareness and acceptance of the reach of social-constructivism. This was certainly seeded in the theories of gender which I had begun to explore but, moreover, my understanding of gender theory has had a profound effect on my beliefs about the nature of physics itself. This is particularly the case in the educational sphere, as discussed in relation to Bernstein. In the second assignment (Wain 2013), I adapted and applied a test initially suggested by Hacking (1999) for considering the basic thrust of social constructionism (Table 1) and applied it to both extreme positivism and social constructivism. I continue to find this a very useful tool to move my thinking on.

I still, perhaps, consider myself as a positivist / social constructivist hybrid in that, in terms of the physical world, it is difficult to move from an ontological position of a physical universe in which truth exists and in which, epistemologically, the ways of knowing these truths are by empirical observation and measurement. If, for example, I replace X with the word ‘atom’, I

still find myself giving the positivist responses albeit with a degree of doubt or, at least, an awareness of alternatives that would once not have existed!

**Table 1: A test for social constructionism**

<b>Steps</b>	<b>Positivism</b>	<b>Social Constructivism</b>
<i>There are other ways that X could be*</i>	<b>NO</b>	<b>YES</b>
<i>In the present state of affairs X is taken for granted; X appears as inevitable</i>	<b>YES</b>	<b>YES</b>
<i>X need not be at all as it is. X, or X as it is at present, is not determined by the nature of things it is not inevitable.</i>	<b>NO</b>	<b>YES</b>
<i>X is quite bad as it is</i>	<b>NO</b>	<b>YES</b>
<i>We would be much better off if X were done away with, or at least radically transformed</i>	<b>NO</b>	<b>YES</b>

(adapted from Hacking 1999, p6) \*initial step added by me

As discussed earlier, Wertheim’s book *Pythagoras’ Trousers* (1995) was a catalyst in my thinking of ‘physics’ as a social construct through her feminist exploration of the overt exclusion of women from its “priestly” cultural practices. Its very creation and development has been almost entirely from a masculine perspective (Wertheim 1995). However, putting the gender argument aside (for now, at least), the fundamental realisation around my own theoretical thinking - that physics could be construed as a ‘construction’ - was key to further insights throughout the remainder of the cohort stage. Using Hacking’s test, I have realised that, perhaps, physical truth only “*appears as inevitable*”. Perhaps even atoms could be another way, or certainly modelled or described differently. Even the mathematical models used to describe the atom are surely a construction. Certainly, it now seems conceivable that it is insufficient to consider that the idea of physics as a body of knowledge, a curriculum entity, or Bernsteinian ‘singular’, as ‘fixed’. Or to put it another way, inconceivable that it should be “*considered as truth*” or “*inevitable*” or that “*there is no other way that it could be*”. If so, ‘physics’ even more so the pedagogies that have been constructed alongside. It is, perhaps, this kind of doubt that Murphy and Whitelegg were referring to when they urge teachers to present physics as “complex, diverse and tenuous” (2006b, p296)

And so, significantly, I no longer feel these tensions of positivism vs social construction at least in relation to physics in the educational context. I am happy with a socio-constructivist view of physics as a Bernsteinian curriculum singular with strong classification and framing, as well as the social construction of beliefs and practices around the teaching of physics.

To summarise, by applying Hacking's test when X = how physics is taught, I am able to formulate my own position from which future research might emerge:

*In the current school curriculum, the way physics is taught is taken for granted. We teach as we were taught and we teach in a way that reinforces what we imagine physics to be; how we teach it appears to be inevitable. However, there are other ways that physics could be portrayed; pedagogies adopted need not be as they are and are not inevitable.*

And if we specifically extend this to the engagement of girls in physics:

*There is an acute shortage of girls and the engagement of those with a feminine gender identity remains stubbornly low. The situation is very bad as it is. We would be better off if we thought very differently and physics education was radically transformed.*

### **Identifying a gap**

The fourth and final area of significant learning that I have identified emerged during the third module, the literature review. What this revealed was a deeper understanding of the means by which gaps in knowledge and, with it, a narrowing of focus, emerges out of the literature. The structure of the cohort phase resulted in a review of the literature which came after I had felt compelled (unsatisfactorily) to pin my theoretical and methodological colours to the mast. I wonder whether reviewing the literature earlier would have helped with making decisions about both and moved me more quickly to the achievement of a coherent whole. However, crucially, it was because of this review that I was able to identify the gap in knowledge that had the potential to refocus and reframe my theoretical and methodological thinking.

Whitelegg and Murphy's (2006) own review of the literature around girls and physics demonstrated that there was sufficient evidence from the literature to support the view that *teachers'* behaviours and attitudes are a key influence on students' attitudes, motivation and

continuing participation (e.g. Labudde, 2000) but they also identified that there had been no recent UK empirical studies specifically and further, into teacher effects and gender in physics.

*“The evidence from research suggests that it is likely that most UK physics teachers are aware of the issue of gender and classroom interactions but are not aware of how classroom interactions are mediated by their own and students’ beliefs about gender-appropriate behaviours in relation to physics.”*

(Murphy and Whitelegg 2006, p26).

And so, what began to emerge was the importance of teacher beliefs about gender and physics which, in turn, became the focus of an additional body of literature to review. I found a compelling study by Bailey et al. (1997) who suggest that teachers’ unconscious acceptance of gender role may influence their behaviours and teaching practices. What was particularly interesting in this study is the way in which Bailey et al. presented their findings in the form of a story about a fictitious trainee teacher, Hank, who is created out of a composite of 70 hours of observations of 17 student teachers and formal and informal conversations with student teachers and their school mentors. I found the methods and ways of reporting adopted in this study to be novel and interesting. I have since adopted this fictitious case study approach as a ‘think-piece’ in a blog for the Sheffield Institute of Education entitled “*An alternative view on the physics teacher shortage.*” (Wain, 2015).

Bailey et al.’s concluding recommendations implore teacher-educators to recognise and address gender-related issues in their courses and allow their trainees to examine, not only the knowledge- base in relation to this, but also their personal gendered histories and their beliefs about gender. They cite Kennedy (1990) who asserts that in-service professional development programmes should force teachers to question their beliefs and experiences in relation to these issues. What I took from this was that, even if *knowledge* about the issue is disseminated effectively, research suggests that it is not considered important enough by teachers to change practice. Either there is a cultural reluctance or pedagogical inability to enact change, or teachers of physics (un)consciously accept the gendered nature of the subject.

This area of teacher beliefs provided the area of focus for my pilot study in the final module. It is interesting to note that, despite my key learning to this point, my new-found acceptance of social-construction and the possibilities of qualitative methodologies, I returned to my comfort zone for this study with a predominantly quantitative methodology using a questionnaire!

### **Summary of significant learning and theoretical thinking**

Undertaking this doctoral study has done far more than provide me with a ticket to academic credibility. It has enabled me to situate, connect, interweave and understand these aspects of 'me'; physicist, physics teacher, physics educator, feminist and, of course, researcher and how I see the world and my place in it. My understanding of science is deeper and richer and, thus, my teaching of science and my teaching of the teaching science is more critical and insightful. I have unearthed an inner philosopher and have been able to unleash a historical and sociological perspective of the nature of knowledge. On the low uptake of girls in physics - what has developed is an argument that began in relatively simplistic 'equality' terms and a call to adopt 'girl friendly' pedagogical approaches to one which finishes with more sophisticated and philosophical arguments around social construction, gendering, emancipation and the beliefs and practices of physicists and physics educators. A deeper understanding of feminist and gender theory and an understanding that an emancipatory motivation, legitimised by this reading, has given me a confidence to approach my research within a feminist framing and ask questions that overtly challenge gender assumptions within physics and physics education.

### **Collaborative learning in the cohort phase**

The collaborative learning during the cohort phase was crucial to my development as a researcher. Of course, I am not able to compare my cohort experience with other forms of doctoral study that I have not experienced. I imagine, though, that there are far more lonely research journeys. Our group, by definition, was made up of educators but, beyond that, we were a very diverse group from Early Years practitioners to secondary school leaders, further education lecturers to business marketing experts. My education and practice to that point had been narrow - strongly classified in physics and secondary education. This diverse group



opened my eyes to a wide range of possibilities, of viewing the world, of finding out about the world.

I was one of a small group with a physical / natural science background and I think we all found entering the world of social science philosophically invigorating but methodologically challenging. I recently put one of these colleagues on the spot to ask whether, and in what ways, I had contributed to *her* learning. She immediately identified our shared exploration of critical realism during the time of the second assignment. Whilst she didn't go on to pursue this line in her final research, epistemologically and methodologically, this proved to be a key turning point in her research design. I have always been happy to contribute to group discussions and I would like to think that some of my contributions in which I offered a more positivist perspective may have, at least, offered others an insight into a more realist perspective.

Webb (2009, p2) reminds us that “a number of theoretical perspectives describe mechanisms by which collaboration with others may foster learning” and discusses the ideas of cognitive elaboration (O'Donnell, 2006), in which “interacting with others encourages students to engage in cognitive restructuring, through which they restructure their own knowledge and understanding.” This became particularly important and prevalent during the times when we were attempting to formulate the structure and framing of our ideas. It was often the case that by, quite literally, ‘giving voice’ to how we were thinking at the time resulted in a clarity that was able to inform the next logical step.

### **Issues that remain unresolved**

It is difficult to write retrospectively about issues that remain unresolved. In many ways, the writing of this dissertation has served to resolve some of my unresolved issues. That is how I would want it – having undertaken this level of reflection, I should expect to feel in a better position to proceed with my research. In summary, though, issues that remained unresolved at the end of the taught phase fall into two main categories:

- Methodological approaches and methods commensurate with a feminist framing
- The scope, ambition and practicalities of successful research

## **Methodology and methods**

Having shifted and grown in my understanding of philosophical, ontological and epistemological issues, there remain some lingering tensions. What is now required is to address the question of how this theoretical thinking around gender, feminism and pedagogy can frame an approach to a research methodology that is able to make meaningful claims and be a catalyst for change. This has prompted a new challenge given my background in physical science, perhaps even greater than that which I worked through ontologically and epistemologically. In order to edge towards a design for my research, it is necessary to explore methodology from a theoretical perspective before actually determining what it is that I want to know (meaningful questions) and therefore, *how* I can find out what I wanted to know (commensurate methods).

My initial reflection of the taught phase led me to thinking that I lacked an understanding of the importance of methodological issues because of the fragmented and piecemeal approach to the overall structure of the modules and my developing research proposal. However on further reflection it is, perhaps, more the case that it was *because* I lacked an understanding of methodological issues, that my proposal was fragmented. As stated previously, my peers who moved more quickly and successfully into the research phase had, or appeared to have, a coherent idea about the interconnectedness of framing, methodology and methods from an early stage. My journey, as already described, was fraught with much more uncertainty and challenge. In these final stages, moving towards actual action, I had to be clear of the distinction between methodology and method. Clough and Nutbrown (2012) provide a useful analogy. They identify the methods as being the ingredients used in a recipe and the methodology as the reasons and justification for using these ingredients in a particular way to achieve the stated goals. This works for both physical science and social science and so to this point, conceptually, at least, I am on comfortable ground.

In the second module on research methodologies, I explored the ever-present dualism of quantitative and qualitative methods (Wain 2013). Ultimately, I concluded that a mixed methods methodology would provide the richest sources of evidence. Perhaps this was inevitable given that I have already identified as a positivist / social constructivist hybrid. However, for my pilot study in the final module, I turned to a quantitative analysis using a belief based questionnaire. I couldn't quite give it up! My quantitative analysis of limited data told me very little, in truth. However, in analysing the data, I quickly realised that I

acquired a far more powerful insight into teacher beliefs about girls and physics from the few sections where I invited a qualitative response, in comparison to the more closed questions. Of course, it made me realise that what questions you ask, and how, to get at what you want is a real skill, but it was much more than this; the written responses revealed a depth and honesty and provided me with an insight which prompted me to want to ask more, look deeper, make connections. I finished my analysis with a strong desire to have a conversation with the participants, observe their practice and try to unpick what was behind their beliefs about girls and physics – and yes, perhaps challenge them and see how they responded. I could therefore begin to see how qualitative approaches could provide real insight but the pressing question for me was; how could this be used to facilitate change, how was it going to make a difference?

My principal motivation throughout the whole process has been that there is sufficient evidence from practice, derived from theoretical ideas, that we should do things differently in physics education, and that by doing things differently, we will level the playing field in terms of the numbers of males and females participating in physics and related subjects. I still had the drive that what I wanted from this research project was to ‘prove’ that to be the case. I had already acquired knowledge, in part from my own practice, but also supported by evidence from my reading, about what changes in pedagogical practice could work. In addition, as a result of my literature review, I also held a view that, by addressing the beliefs of teachers about gender and the social construction of ‘physics’ and physics pedagogy, change would be more likely to take place, thereby having an emancipatory impact on the girls in physics classrooms. To my mind, I had a hypothesis and my research design needed to prove or disprove it. I recognise now that this is a very positivist approach to research and that any methods adopted to provide this proof would take me down a positivist methodological route – at odds with my growing confidence in framing my research in feminism. However, at the research design stage I was not quite thinking in these terms.

In order to transition to the research phase of the EdD, I was required to present my research proposal at a transition event. At the time, my proposal consisted of a quasi-experiment. The intention was to work with 2 groups of teachers on their pedagogical approaches to teaching physics. Both groups would engage in professional development activities on pedagogies that have been shown to have been successful in engaging girls in physics, but only one of the two groups would engage in additional exploration of their beliefs around gender and social

construction. Perhaps my use of the word ‘quasi’ served to soften the positivist undertones in my thinking!

I had been leading professional development over several years and based my approaches mainly on ideas from the Institute of Physics, but also from some eminent physics educators in the USA where Physics Education Research is recognised and well established as a discrete academic discipline. I have also drawn heavily on physics educators such as Knight (2004) and Mortimer and Scott (2003) for my subject pedagogy. Whilst these approaches were not necessarily specifically about girls and physics, many of the key approaches espoused by these educators have distinctive features also supported in the girls in physics literature. In particular, approaches such as the importance of developing a conceptual understanding before the use of mathematical representations and the use of context-based approaches.

However, my reading on teacher beliefs for my literature review had led me to recognise the importance of working with teachers on their beliefs during the course of any intervention. For example, Lumpe, Haney and Czerniak (2000) found that when a new curriculum or teaching initiative is introduced it is essential that teachers’ beliefs should not be ignored if the recommendations are to result in sustained changes in practice. Tobin, Tippins and Gallard (1994) assert that “many of the reform attempts of the past have ignored the role of the teacher beliefs in sustaining the status quo.” (1994, p64). Murphy and Whitelegg (2006a) also highlight the importance of teacher beliefs:

*“The evidence from research suggests that it is likely that most UK physics teachers are aware of the issue of gender and classroom interactions but are not aware of how classroom interactions are mediated by their own and students’ beliefs about gender-appropriate behaviours in relation to physics.” (Murphy and Whitelegg 2006a, p26).*

And so returning to my quasi-experiment design where two groups of teachers would receive the same pedagogical training with only one of the groups undertaking some activity that provided additional knowledge about gender, the nature of physics and teacher beliefs. Reflexively I recognise in this what is, essentially, a potted version of the key moments of enlightenment in my own journey. (I wonder whether, had I been thinking more openly about methodology at this stage, an autoethnographic study may have revealed as much as

the somewhat more complex, logistically difficult quasi-experiment?) A comparison between the two groups would establish whether any interventions had impact on their own teaching but, more importantly, whether those whose beliefs were challenged and who had an input on theoretical and social issues, were better able to sustain their own practice and influence that of others. In effect, be a catalyst for cultural change.

Having presented this approach at the transition event, one of the key questions that came back from a rapporteur was how this proposed method could possibly fit with a feminist framing and a feminist methodology. This was a question I was unable to answer. I have therefore needed to undertake further exploration and reading in order to try and either reconcile this contradiction and explore ‘feminist methods’ or, instead, justify as acceptable, a quasi-experimental approach within a feminist framing.

First, then, to address a fundamental question. Is there such a thing as a feminist methodology and, if so, what defines it? It seems that this is a well explored question. For example, Sandra Harding (1987) asked exactly this question in response to a growing recognition over a decade or so that both academic and popular knowledge, and much social and scientific research, was grounded in men’s lives and male ways of thinking (Doucet and Mautner 2007). Sarantokos (2013) paraphrasing Stanley and Wise (1983) puts it rather more strongly. There were *“taken-for-granted sexist practices and the gender-blindness of government and community practices ..... that displaced, ignored or silenced women, led to an unequal and discriminating social order, and held them captive for millennia.”* (Sarantokos 2013, p54). In reality, the question that required exploration was whether there *needed* to be a distinctive feminist methodology or feminist methods. Doucet and Mautner (2007) point out that by the late 1980s many feminists opposed the idea of a uniquely feminist methodology recognising, instead, that feminist research should simply be “good” research. And so, perhaps a more fruitful approach would be to look into the characteristics of the research of feminist scholars. Drawing upon a number of sources (Doucet and Mautner 2007, Sarantokos 2013) my understanding of the key characteristics of feminist research can be summarised thus:

Feminist research:

- has a strong commitment to changing the status of women in modern societies (Sarantokos, 2013)
- is *for* women and usually by and on, or with women
- is based upon the assumption that the world is socially constructed and tends to the rejection of positivist empiricism
- is guided by sound and often innovative methodologies - often qualitative, but (increasingly) not bound to be such
- is concerned with issues of broader social change and social justice

In relation to my own quasi-experimental research design, so far, so good. Without doubt, my intentions were to change the status of girls in relation to physics. It is therefore *for* women, albeit through research with teachers who may be either men or women. At the heart is my strengthening acknowledgement that physics, as a discipline, and the way we teach it, is socially constructed. As innovation in methodology is permissible or even desirable, why not a quasi-experiment? Is this really at such odds?

Postmodernist feminism takes up the issue of ‘power’ relations within the research process and the central importance of reflexivity – to quote Denzin (1997, p27) the ways in which “our subjectivity becomes entangled in the lives of others”. Here, then, may lie the root of the tension between a feminist approach and the proposed quasi-experiment. Given that I was already starting from a position of being the ‘knower’ in terms of both the pedagogy and my own feminist standpoint, perhaps this presents somewhat of a problem. This may also be exacerbated because I had elected to work with physics teachers rather than girls themselves as participants. What I have learned is that a key feature of feminist research is to acknowledge as inevitable both power relations and reflexive positioning and then to explicitly address both in the research process.

Whilst it is clear that feminist methodology has some key characteristics and guiding principles, there is much less consensus on feminist research methods. I was intrigued during the cohort phase by one of the sessions in which eminent feminist, Ann Oakley, was discussed, not in terms of her feminism, but as a proponent of randomised control trials (RCTs) in educational research. Taking RCTs as the ultimate in positivist methodology, how did Ann Oakley justify this position? In answer to this, she suggests that methods come from

qualitative or quantitative research adjusted to meet feminist principles (Oakley 1998 in Sarantokos 2013). And so, rather than looking down a list of permissible feminist methods and designing my research around it, it was imperative that I think about what I wanted to find out, the most appropriate method for answering my questions and then look at the proposed method to ensure that the feminist principles are not only considered but are integral to the design. Here, then, is the opportunity or, even, the requirement for innovation. Here also, the point to which I reached during the cohort phase and shortly after the transfer event. It is also, arguably, the significant point at which I stalled in terms of seeing my research proposal through.

### **Scope, ambition and design**

The second unresolved issue is one that is rather more pragmatic. Cohen et al. (2012) suggest that orienting decisions made when planning research are *strategic* decisions and decisions around research design and methodology are *tactical*. I would also add that there are *practical* decisions such as, in my case, the ease with which I would be able to engage participants in the research given the time constraints of part-time study whilst in a full-time job. The research proposal I ultimately submitted was a comparative case study, with ambitious plans to spend significant amounts of time in two schools collecting field data, including through semi-structured interviews and observations. I now believe I over-reached in terms of what was practically possible. I have subsequently learned that, in terms of developing my skills as a researcher and even in the acquisition of a doctorate, I could have scaled back this ambition without compromising on the quality of the research process, the data obtained and my own development as a researcher. Furthermore, by initially planning to work with teachers this perhaps brings me back to the issue of my own identity and reflexivity in relation to my academic identity. I was still, perhaps, most closely identifying as and with ‘physics teachers’ rather than ‘initial teacher educator of physics’ or even as ‘researcher’.

It is now evident that a more appropriate group with whom to work on my research might have been my own students either as trainees or as newly or recently qualified teachers. Whilst there would, inevitably, be ethical issues related to this, this would have enabled me to integrate my research and my day to day teaching more efficiently and, potentially, have a greater impact on my own practice during, and subsequent to, my research.

## **Impact on Professional Practice**

Completion of the taught phase of the EdD has had a significant impact on all aspects of my own professional practice. To return to my auto-biographical notes, I explain that I embarked upon my doctoral studies to acquire legitimacy for my developing identity as a physics educator. Without question, even without a qualification, my engagement with theory, philosophy, methodology and research methods has reached new depths and has provided a solid foundation to my undergraduate teaching and the masters level work which I assess.

A general theme across all these aspects of my practice, however, has been an ever-deepening awareness of how theory and research links with the professional practice of teaching and how, through an undergraduate degree programme into masters level, this link between theory and practice, through critical engagement with a range of literature, progresses. It has enabled me to question my own teaching as well as providing students with a deeper learning experience by having a better understanding of the academic attributes that we should be building across the degree course. I am better able to direct the students in their thinking and in their reading. I question the 'taken for granted' more and encourage the students to do so too.

There are five main aspects of my teaching upon which my doctoral studies have had a significant impact:

- i. my teaching of physics pedagogy
- ii. my teaching of the nature and history of science
- iii. my teaching of learning theories
- iv. my assessment of undergraduate and post-graduate work.
- v. my teaching of gender issues in both science and education

Firstly, the physics modules that I teach on the undergraduate ITE programme are at levels 4, 5 and 6. What we aim to do, however, through these modules, is prepare the students to teach physics up to GCSE level. We have often questioned the content of these modules because, essentially, the physics content is at secondary school level. I have been fortunate to have worked with physics educators who were already engaged in critical thinking about, and undertook research in, physics pedagogy. This has enabled me to move from the teaching of physics to the teaching of how to teach physics. This in itself elevates the content of my KS3



and 4 modules to degree level. However, my doctoral study has taken this even further – the breadth and depth of my reading around curriculum, physics pedagogy, gender issues in physics and teacher beliefs has also enabled me to give a deeper theoretical or research informed underpinning. A key areas of physics teaching that underpins this approach is the importance of a conceptual understanding of physics over the more traditional procedural and mathematical approaches. Even those of my students who have been successful in the current education system and achieved an A level in physics find this requirement for a solid conceptual understanding challenging. These alternative approaches are well explored by Mulhall and Gunstone (2006) whose research findings suggest that teachers who are more open to conceptual change approaches are also more open to a social-constructivist view of physics. It is through engagement with this type of literature that my teaching has become much more research informed rather than what, otherwise, would be drawing upon tacit knowledge or simply dissemination of my own and others' good practice.

This leads to the second area of my practice upon which my doctoral studies have had a significant impact. Over the past three years, I have devised a level 6 module in our undergraduate science with QTS degree entitled 'Turning Points in Physics' in which we explore some of the key theories and empirical evidence that resulted in major breakthroughs in our understanding of the physical world. Although the 'physics' content of this module remains just above secondary school level, my teaching has been much enriched by my own learning. The paradigm shift from classical physics to quantum physics discussed earlier in relation to Kuhn's (1996) Structure of Scientific Revolutions is a central pillar of this module and students are expected to understand the history and structure of this, amongst other 'revolutions'. I have also found my teaching of the nature of science to have been elevated as a result of the ontological and epistemological challenges that I have wrestled with during this doctoral study. In turn, this has raised my expectations of my students, at an appropriate undergraduate level, of the importance of a critical awareness of the nature and process of science.

Thirdly, and more broadly; in the past couple of years, I have developed three education modules which are common across all the undergraduate ITE courses at my institution. Although I had been a teacher for 18 years and leading CPD in physics education for some time, the development of these modules was a little daunting, largely because I had, by now, realised that it was not sufficient to draw only upon my practice and knowledge of the

secondary curriculum in developing the academic attributes of my students. I recall one of the EdD sessions where we looked at how social scientists might frame their studies in either the psychological or the sociological. Here I can draw upon two key examples of each of these from the level 5 education modules; learning theories and the history of the curriculum. Through my deeper understanding of the role of theory and theorists I have gained a better understanding of what theorists actually do as well as a broader appreciation of the *structure* of the development of learning from theory, to application, to research based on the theory and, ultimately, professional or pedagogical practice based upon these theories (Pritchard 2014). Having gained this understanding of the overall structure, I have been able to give greater clarity to my students about the bigger picture which has, in turn, enabled me, and them, to structure our reading and writing and understanding of practice. In terms of the history of the curriculum, I no longer think of, and present this, as a historical account but rather discuss the social construction of the curriculum and the school system and the social and political influences that have been, and continue to be, at play.

In the final year of the undergraduate course, the level 6 education modules require the students to undertake a small-scale enquiry project while on their school placement. Although this is a very common type of assessment at level 6 in teacher education, my new understanding of the research process enabled me design and write the assessment criteria with confidence and insight. I have also recognised the importance of preparing the students for the nature and style of an inquiry of this type as a result of my own journey through the process, albeit at a higher level. An integral part of the teaching of this module is to teach the process and nature of a small-scale research inquiry as well as key aspects of content.

Finally, I would like to return to Bailey et al.'s (1997) concluding recommendations in their study into teacher beliefs and gender which implores teacher-educators to recognise and address gender-related issues in their courses. I have always done in my physics sessions both in order to raise my students' awareness of the 'facts' but also as an explicit justification for some of the pedagogical approaches I espouse. Bailey et al. also advocate that we allow our trainees to examine, not only the knowledge base in relation to this, but also their personal gendered histories and their beliefs about gender. I have now included a session in the final year professional studies module that discusses and challenges students to become critically aware of the issue of, and their own, unconscious bias - not just in relation to gender. What perhaps held me back from this in the past is something that I would define as

the ‘feminist stigma’. I often find myself being somewhat apologetic when challenging or encouraging others, particularly my students, to think about the issue of gender and equality both factually, theoretically, and in relation to their own attitudes. This ‘feminist stigma’ appears to be a much discussed but less so researched issue. A simple internet search of the term returns many thousands of articles and opinion pieces but a very limited number of journal articles that specifically explore this phenomenon (Anastosopoulos and Desmarais, 2016). If I can reconcile this, the question I have of myself is whether what I currently include in my modules is sufficient and, if not, what the potential impact of a deeper exploration of personal gendered histories and beliefs about gender. If this is a question of myself, then perhaps this is where my next step comes from.

### **Plans for continued exploration**

And so, to return to the question of academic legitimacy and credibility. I recall my surprise and discomfort when I first took up employment in the university and realised that I was titled an ‘academic’. Whilst this label is essentially used to broadly categorise staff I still felt a little fraudulent being labelled as such. This comes back to identity and I certainly did not *identify* with the term academic. However, I do now feel that I can make this claim as a result of this doctoral journey having engaged with literature and academic thinking and writing at doctoral level. And so, what is my academic field, what is it that colleagues might turn to me to provide expertise in? Furthermore, how can I sustain this scholarly activity, remain an expert in my field, and perhaps raise my academic credibility?

As I have outlined, during the taught phase of the EdD I have made significant advancements in my understanding of educational research. However, the writing of this dissertation has helped me to crystallise some thoughts in a number of key areas which may not necessarily lead to undertaking my own primary research but, from which, could emerge a number of papers or scholarly articles. During the taught phase, my engagement with the theories of Basil Bernstein were fleeting and not pursued throughout the remainder of the modules. However, in revisiting this for this dissertation, I would be very interested in writing a paper that links Bernstein’s theory to physics pedagogy and in relation to the perpetuation of gender inequality rather than social and class divisions. I have not found any other such paper in the education field.

With the legitimacy of a Masters behind me I would seek to engage in Master's level teaching and supervising for which there are a number of opportunities within my own institution. Of particular interest here would be to teach on a professional Masters course for newly and recently qualified teachers for whom the principle focus for their Masters' work would be to reflect and develop their own professional practice.

There is a growing interest in the idea of explicitly teaching 'Epistemic Insight' in secondary school science. For example, Billingsley and Hardman (2017) have recently launched an international research and education initiative which aims to "identify and foster strategies that can raise students' appreciation of the nature of science in a broader and academic real-world frame." (p57). A recent edition of School Science Review (ASE 2017) is devoted to Epistemic Insight and the range of topics discussed in relation to this include 'entrenched compartmentalisation' of science (Billingsley and Arias, 2017 and Chappell, 2017) and girls' enthusiasm for science (Billingsley, Nassaji and Abedin, 2017). This is all entirely commensurate with my own theoretical thinking and leaves open the possibility of introducing these ideas with my own students as well as scope for some scholarly activity of my own around these themes.

This leaves a tantalising question. If I was now to undertake my own doctoral level research, what would it look like? I believe a much more coherent structure is beginning to emerge. I would frame my research in the theories of Basil Bernstein and feminist and gender theories, acknowledging a social-constructivist epistemology in order to explore the (un)conscious beliefs about the "current state of affairs" in physics and physics teaching of trainee teachers, NQTs and RQTs (newly and recently qualified teachers). My methodology would be a participatory action research methodology commensurate with a feminist framing, based within my own teaching but using appropriate tools to allow for reflection on the participants' own gendered histories and beliefs about gender, in order to evaluate the impact on the pedagogic practice of my participants and the impact on the girls in their classes.

### **Final reflections**

Throughout this reflective piece I have explored the impact of the cohort phase on me both personally and professionally. The writing of this final piece has enabled me to recognise the inter-connectedness of philosophy, theory and methodology and the means by which each informs and influences the other, and the importance of a coherent 'whole' in successful

research. I have mapped my development and identity as an academic in the field of physics education, with a particular interest in physics teacher beliefs around curriculum, pedagogy and gender. I have identified significant achievements in my development as a professional education researcher, charting especially my journey from the naive positivism of the physical scientist to that of the complex and tenuous world of social science. My long-held inner feminism has enabled me to embrace theories of the social-construction of gender which, in turn, and more surprisingly, has led to a philosophical awakening into the socio-historical construction of both physics itself and accepted and perpetuated physics pedagogy. Significant issues remain unresolved not least identifying which research methods to adopt to make meaningful claims whilst adapting these methods to ensure they fit within a feminist methodology.

Underlying everything is a drive for emancipatory change in physics teaching. However, my journey has allowed me to gain credibility as an academic with expertise in the field, equipped to make a significant contribution to current professional practice and poised, at some point, maybe in the not-too-distant future, to make a significant and novel contribution to the field.

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